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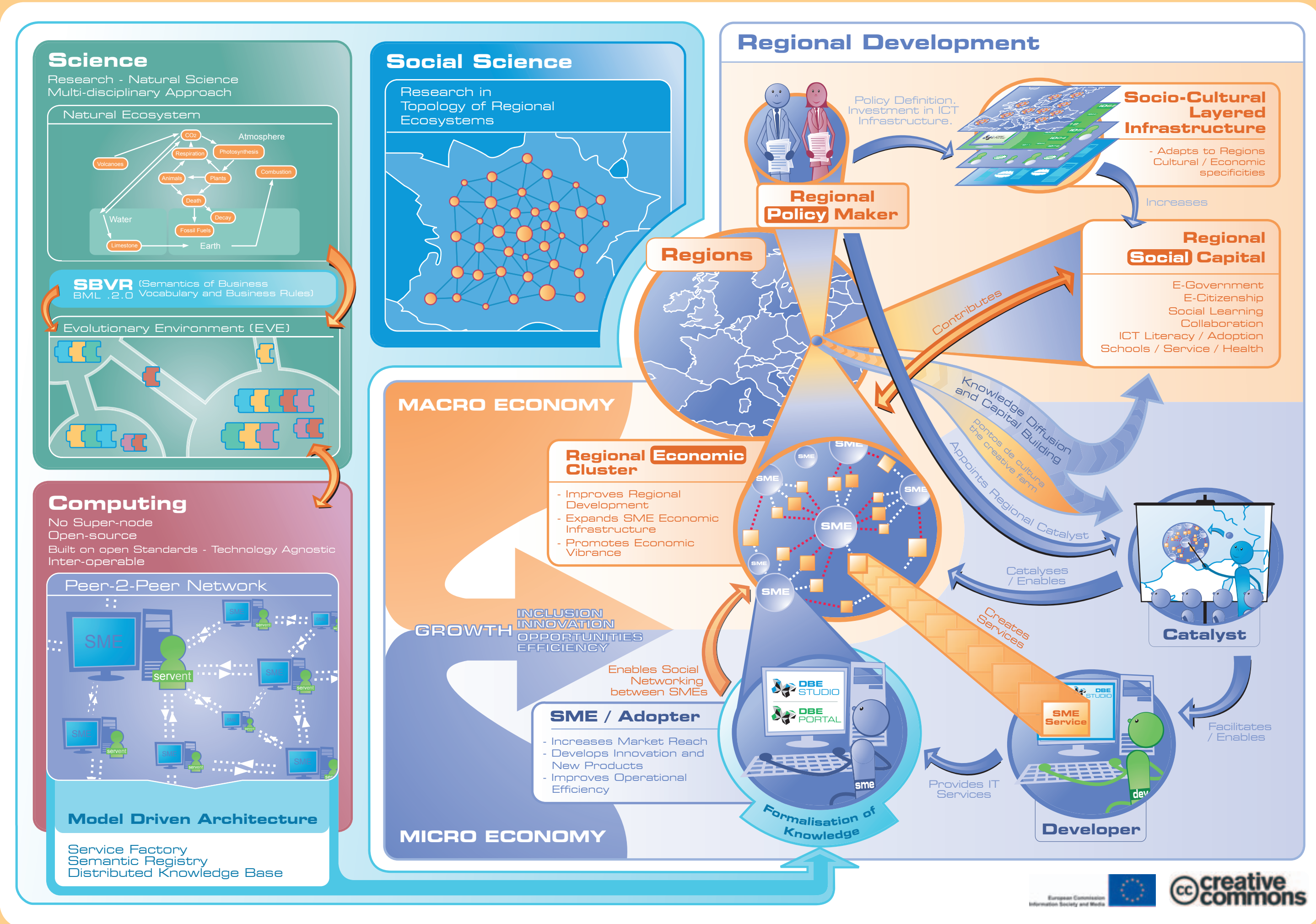

Digital Business Ecosystems

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Publications Office
Publications.europa.eu

ISBN 92-79-01817-5

European Commission
Information Society and Media

Digital Business Ecosystems

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Luxembourg: Office for Official Publications of the European Communities
2007 – 232 pp. 21 x 29.7 cm

ISBN 92-79-01817-5

The picture of the cover page is the tag-cloud which represents the folksonomy of the concepts related to the Digital Business Ecosystem as emerged from the collective of the authors

European Commission
Directorate General Information Society and Media
B-1049 Bruxelles
More information on the European Union is available on the Internet at http://europa.eu

More information about Digital Business Ecosystems is available at http://www.digital-ecosystems.org

Cataloguing data can be found at the end of this publication

Luxembourg: Office for Official Publications of the European Communities, 2007
ISBN 92-79-01817-5

Produced in association with DBE and OPAALS.
Graphic Editing by Paolo Antinori

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Digital Business Ecosystems

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European Commission
Information Society and Media

Foreword

At the Lisbon European Council of March 2000, the European Union representatives set the goal of making Europe the world's most dynamic and competitive knowledge-based economy with the need to promote an "Information Society for All". One year later, the Gothenburg European Council of June 2001 agreed a strategy for sustainable development which completes the European Union's political commitment to economic and social renewal by adding a third, environmental dimension to the Lisbon strategy.

A new approach to policy making was therefore promoted to ensure that the economic, social and environmental effects of all policies would be considered in a coordinated way. Both the Lisbon and Gothenburg strategies placed competitiveness firmly at the centre of political attention, and underlined the importance of creating a climate favourable to SMEs and the need to stimulate entrepreneurial initiative in order to achieve economic growth and sustainable development.

The "Networked Enterprise and Radio Frequency Identification (RFID)" unit of the European Commission's Information Society and Media Directorate-General aims at facilitating the emergence of future business forms designed to exploit the opportunities and manage the challenges posed by the socio-economic and technical developments of the 21st century. It recognises that businesses require new technologies, applications and services to enable them to work as networked knowledge-based enterprises.

One of the characteristics in the knowledge-based economy is the increasing collaboration among enterprises and economic and social agents, in order to offer innovative services and products, but also to engage in R&D activities. Cooperation has proved to be an endogenous feature of Europe, and one of its biggest strengths in global competition. Collaborative and innovative research has built in Europe a new sense of community and commitment to cooperate towards shaping the future "ubiquitous information society". This community spirit has been particularly well understood and respected by all stakeholders in the field of the Networked Enterprise, which sees industry, academia, research centres, governmental bodies and agencies at all territorial levels, and end-user associations singing to the same tune. Inevitably, technological challenges will have to be paired with societal challenges. The new standard set by this collaborative spirit calls for a new course of action as it recognises that the technologies and the economic and social aspects of development must be intertwined in order to achieve a sustainable economic and social impact.

The Digital Business Ecosystems (DBE) Initiative responds ideally to this challenge of creating ICT instruments together with collaborative practices and paradigms that support economic growth and include all the societal and economic actors in the process. It has been commonly recognised as a new frontier for RTD in the knowledge-based economy. Indeed, SMEs and local clusters are now competing in a global and dynamic market where they need more interrelations, more specialised resources, more research and innovation as well as access to global value chains and knowledge. The research driven within the DBE Initiative supports all these necessities by offering an open infrastructure that combines human capital, knowledge and practices, technical infrastructure, and the business and financial conditions - all modelled within the European industrial policy agenda.

The present book is therefore the result of extensive research driven by the DBE research community within the projects funded by the 6^{th} Framework Programme of the European Commission. It brings together researchers from major European institutions and stakeholders involved in the projects of the cluster "Technologies for Digital Ecosystems". It presents the projects' main research and empirical achievements. Consequently, it also discusses the future perspectives and directions of the European DBE.

This work shows that in a few years – the concept of Digital Business Ecosystems was coined initially in the context of the implementation of the *e*Europe 2002 action plan – a new science was born; a scientific community was established; RTD projects have delivered results that start now to be transferred to the market; and a network of regional digital ecosystems was established.

This book aspires to be ambitious, focussed, and forward-looking. As a consolidated result of the contributions of the large number of stakeholders involved in its conception, this book is a renewed commitment of those stakeholders engaged in the realisation of the long-term vision of the research surrounding the Digital Business Ecosystems initiative.

We have heard of the business opportunities and challenges that ICT research would bring. The time has come to realise this promise of fostering the development of those technologies, systems, applications and services that are critical to achieving higher growth, more and better jobs, and greater social inclusion.

Gérald Santucci,
European Commission, DG-Information Society and Media
Head of Unit "Networked Enterprise and RFID"

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Preface

At the end of 2002, among the EC initiatives aiming to build a favourable environment for economic growth and social cohesion, support for the adoption of Information and Communication Technologies (ICTs) was identified as playing a key role in driving the transformation of the European economy. Specific research and development efforts were directed at fostering ICT adoption on the part of enterprises and at increasing their use of ICT-based services, leading to improved business networking and greater competitiveness. However, the emergence of a 'digital divide' between large and small to medium-sized enterprises (SMEs) in the adoption of ICT technologies and ICT services caused concern. Thus, strategies for a greater inclusion of SMEs in economic and value-creation processes through greater exploitation of ICT became more urgent.

The question was widened to how ICTs can become an instrument of economic inclusion in the knowledge economy while strengthening the democratic processes upon which we are building the knowledge society. This means developing ICT-based solutions and models that support a participative society in which public and private organisations, professionals and individuals compete, interact, and collaborate for their own benefit and for the benefit of the organisations, teams, ecosystems and/or communities they belong to, in order to enable the participation of all players in the knowledge economy and in the information society.

In a cycle of online and offline consultations and workshops it was gradually recognised that the value of ICT went far beyond ICT services and the pure streamlining of production processes. A large part of the value of ICT adoption derives from its potential to exploit and integrate technological networking, knowledge networking, and socio-economic networking, enabling the dynamic creation of new connections, processes and cooperation between economic actors. It also became clear that a system enabling these multiple kinds of networking cannot be reduced to a technological platform of interoperable services, but should evolve into a process-oriented architecture that can support a knowledge-rich environment which is representative of the users and of their social and economic behaviour.

By extending the networking paradigm to the knowledge and social layers, the knowledge, the processes, and the economic activities working in cooperation and competition could be conceptualised as the organisms of an ecosystem by applying the ecosystem metaphor to their digital representation. It was through this experience of mutual discovery between the technical and the socio-economic spheres of research that the concept of digital ecosystem was born and coupled with the concept of business ecosystem to create the Digital Business Ecosystem.

Digital business ecosystems are designed to evolve under the pressure of economic forces and to adapt to local conditions. Adaptation and evolution are partly achieved by embedding specifically designed evolutionary mechanisms into their architecture and their structure, and partly through the participation of local stakeholders in the process of their development. In other words, digital ecosystems assume that the dynamic and self-organising properties can only go so far; technology is also constructed through the continuous formalisation of the knowledge and the processes that the socio-economic and cultural systems to which it is coupled express. When the technology, being constructed, becomes the medium that facilitates the formalisation and distribution of the knowledge from which the same technology emerged, the pace of transformation from the material to the knowledge economy accelerates, justifying the characterisation of ICT as a catalyst for growth. The Digital Ecosystems research initiative claims that a further acceleration can be obtained when the ICT is further designed to favour certain processes, such as shared knowledge production and openness, and to deter others, such as the formation of monopolies. Knocking down the barriers to distributed cooperative work and shared knowledge production allows the synchronisation of dynamic social and communication networks over ever-shorter time scales, pushing the ecosystem metaphor towards a distributed cognitive system and a collective intelligence.

The intersubjective processes of knowledge formalisation and the necessity to include social behaviour and economic interactions in the ecosystem highlighted the limitations of several default assumptions that tend to be made in technical fields, such as the existence of an objective reality and the neutrality of the technology and architectural principles. The acceptance that social and power relations cannot be reduced to an objective logic, but are socially constructed, had led to research that intertwined ICT research with epistemology and social science. This analysis, in fact, anticipated precisely what we are starting to observe in recent phenomena such as those encompassed under "Web 2.0" or the Web Science Research Initiative.

The ability to participate in the shaping of knowledge and in technology production motivates a greater sense of ownership of the means of socio-economic development, leading to a more active and creative participation of smaller actors in social and economic processes, with corresponding greater autonomy and empowerment. Where the accumulation of power and control becomes concentrated into monopolies, the distributed P2P architecture of digital ecosystems enables them to self-correct by diffusing it again, in this manner preserving the socio-economic structure that made this emergence possible. In parallel, the processes of governance of the digital ecosystem infrastructures that are currently being studied and defined around principles of accountability, transparency, identity, and trust increase our awareness of a shared responsibility toward the common good that can be variously referred to as *res publica*, open source, or shared vision. These concepts point to a comprehensive and holistic strategy of socio-economic development catalysed by ICTs that balances self-organisation with self-awareness, and that relies on fundamentally democratic processes as an insurance to preserve the results to be accrued from research in the form of innovation, employment, and market exploitation.

The multidisciplinarity of Digital Ecosystems research

A vision of digital ecosystems able to evolve into distributed cognitive systems, engineered to embed mechanisms of evolution and adaptation to local needs and cultures, whose content is democratically and socially constructed, and that enable the economic participation of small producers of knowledge and services, is however extremely complex and ambitious. Intertwined research in ICT technologies and social science is required to improve the processes and operations of public and private organisations and to catalyse dynamic and remote collaboration and interaction between human and digital entities and systems in various structured and unstructured organisational settings, such as distributed information systems and collaborative environments composed of complex dynamic heterogeneous networks of human and digital systems. Multidisciplinary research will enable the sharing of knowledge and practices and the modelling of micro- and macro-economic contexts, which will drive productivity, sustainability, quality and effectiveness in structured environments while unleashing creativity, innovation, dynamic networking, and participation in unstructured settings, taking advantage of diversity and multidisciplinarity, and fostering the participation of all in processes of social construction and economic development.

The Digital Business Ecosystems research initiative, thus, requires the engagement of a research community composed of computer scientists, social scientists, linguists, epistemologists, economists, political scientists, system theorists, cognitive scientists, biologists, physicists, and mathematicians in a joint enterprise finalised to define collectively technologies, practices, paradigms, and policies that can produce tangible results as the basis for a gradual deployment of a network of digital ecosystems. The implication is that there is need to create working practises of interaction and feedback among scientists, decision makers and the entrepreneurial world; there is need to implement, demonstrate, deploy, and verify the impact of pilot implementations; and there is need to deal with issues related to governance and sustainability at the regional and global scales.

The ecosystem approach facilitates the operationalisation of regional policies in support of SMEs that are not based on direct subsidies in favour of individual SMEs but are directed towards the establishment of environmental and structural conditions that empower SMEs, communities, and individuals to participate in dynamic networked global co-operative business and value chains. Such SME development policies exploit the synergy between the Cohesion policy, the 7th Framework Programme for RTD, and the Competitiveness and Innovation Programme. *"Cohesion policies reinforce each other at regional level by providing national and regional development strategies showing how this will be achieved"*, as indicated within the EC Community Strategic Guidelines 2007-2013.

Achievements

In less than 5 years from the initial ideas, we can see that the initial vision is starting to become a reality and the first tangible effects can be perceived. Ideas that seemed odd in 2002 have now started to be accepted worldwide, and to be adopted by different research communities and in different policy initiatives. A thriving interdisciplinary research community is emerging in Europe, with research and academic institutions participating from India, Africa, South America and Australia. A new "science" of digital ecosystems is being formed, and a long-term vision and research agenda has been defined. The initial research results have been implemented and engineered within the first digital ecosystem platform implementations. The first regional digital business ecosystems have been activated. A large number of SMEs of such pilot regions are exploiting the ecosystem, increasing their competitiveness, proposing new services and forming new aggregations. An increasing number of European regions are including the Digital Business Ecosystems within their Regional Operative Plans as operational policy instruments for supporting SMEs and local development. A large network of regions aiming at implementing regional digital business ecosystems (REDEN, http://reden.opaals.org) has been established to create synergies within their local business ecosystems, i.e. networking their enterprise value chains, sharing solutions, applications, ideas and practices.

But, to a casual reader, due to its irreducible complexity and unusual assumptions, the Digital Business Ecosystem concept and strategy still looks exotic and unfamiliar. This book was therefore partly motivated by the desire to provide a comprehensive presentation of the DBE concepts by researchers, engineers, business people, regional development actors and European Commission officers from the many disciplinary viewpoints, characterising this emerging field of research and development.

Research Areas

Initiating a research area in Digital Business Ecosystems implied several courageous assumptions, which enabled a change of perspective. However, this also opened up a series of research questions, some of which are quite 'out of the box'. We will list and describe them briefly here.

New Value Systems and Business Models. The research, necessarily interdisciplinary, includes policy and social science, in addition to technology. This decision has been validated by the recent trends in Internet market innovation, driven by applications that are based on the interactions between people and between companies rather than only on technological advances: solutions based on network effects and their formalisation created by an architecture of participation. This suggests the potential for new business models at the intersection between the gift and the exchange economy. The open source phenomenon is an example of this. More broadly, what is the notion of public goods in the Knowledge Economy? How does openness compare to patents in stimulating innovation? How can we couple innovation to social dynamics? How can we amplify the synergies between social development and economic growth?

Evolutionary and Adaptive Software Systems. Complementing the coupling of social dynamics to the creation of economic value, the latter can also be increased through the optimisation of the digital technologies that permeate all facets of human experience. Why do applications and operating systems become intractably complex as they scale in size? How can we develop systems that learn from the behaviour of their users; systems that are adaptive, self-organising, and self-healing? How can we design system and socio-technical architectures that reflect a network of technical and economic processes and operations, and that have the ability to reproduce themselves recursively, creating, destroying, or reorganising themselves in response to external inputs and perturbations? Genetic algorithms have progressed to the level of distributed evolutionary architectures coupled to service-oriented architectures, but there is a snag. The definition of the fitness function is context-dependent. If applied to business models or service descriptions we run into the problem of semantic matching between offers and requests. In other words, evolutionary computing applied to business computing and service oriented architectures has been solved only in part. What remains to be solved is strongly related to the life of abstract entities in a digital environment and to their ability to represent business knowledge and services, i.e. to formal and natural languages.

Natural and Formal Languages. It is difficult for ICT services to support the firm in the presence of quickly shifting business goals because software development struggles to keep up with the pace of change of the business environment. More importantly, the greatest challenge remains to ensure that the formalisation of requirements effected by the software engineers corresponds to the requirements as understood by business users. A current problem in software engineering is how to operationalise the connection between business knowledge and requirements, expressed in natural language, with the software services that express such knowledge and satisfy such requirements, through the development of appropriate design-time and run-time software tools based on formal languages. Once this first hurdle is solved, in order to make the service descriptions and specifications sensitive to the context in which they will be instantiated we will need to understand how the formalisation of the services and of the business knowledge can benefit from a formalisation of the context that could be likened to biological organisms and the ecosystems they inhabit sharing the same Periodic Table of the Elements. The progression toward common standards, itself a social process, is a simple practical example of this idea. In order to progress from software engineering as a social process to the self-organisation of digital organisms, and to integrate automatic generation of services from business process and workflow specifications with the evolution of service species under the same theoretical framework, we will need to dig deeper.

The Mathematical Structure of Logic as a Bridge between Biology and Software. In order for the virtual life of digital entities to emerge from the formalisation of the socially constructed business ecosystems, we need to understand, and ultimately operationalise along the time dimension, the deep connections between the algebraic structure of biological systems and the algebraic structure of logic. The same DNA molecule that carries hereditary information down the philogenetic tree is also responsible for the abstract specification of the cell metabolism, including all its proteins and regulatory cycles. There is strong evidence that the DNA code is related to the theory of Galois fields, the same theory that underpins Boolean algebras and quantifier algebras. The former is the mathematical expression of propositional logic, whereas the latter explains first-order logic (FOL). FOL, in turn, is the backbone of some of the new languages being developed by the OMG. Business rules and business processes can be related to specifications, which interface to transaction models for the run-time management and orchestration of service execution. One of the next challenges in computer science seems to point to the integration of the concurrent systems point of view with abstract algebra and temporal logics toward the definition of a new form of computing based on the concept of the Interaction Machine as the archetypical abstraction of a digital ecosystem.

Dynamic P2P Architectures and Autopoietic Networks. There are many fascinating open questions about how fully distributed and P2P networks can support local autonomy whilst guaranteeing consistency of coordinated distributed transactions in the execution of dynamically composed service workflows. How can we integrate business activities with an evolutionary environment that can support a distributed transaction model formalised through temporal logics to guarantee self-preserving and autopoietic networks? How can we plug in virtual vendors that can offer the same quality of service as the large enterprise retailers? How can we overcome the technological challenges for providing a large collaborative environment with a fully distributed architecture? How can we design the networks of the future to cope with heavy traffic, delegate, self-recover, and ensure consistency in the presence of millions of client-side events whilst avoiding centralised control? How can a distributed transaction model support the recoverability and consistency of asynchronous and long-lived transactions mediated by P2P networks?

The Evolution of Digital Ecosystems towards Distributed Cognitive Systems. The emergent web phenomena leverage user participation, but their ownership and governance is still centralised, for instance in YouTube, FaceBook, Second Life, BlogSphere, Google. Is this a transition phase or a long-term trend? Can fully distributed technological and 'power' architectures emerge? Does intelligence have to be distributed? Are these Web 2.0 phenomena a reflection of a new consciousness of collective intelligence, or collective identity? If the applications and infrastructures that support these Web phenomena based on social networking learn from the behaviour of their users, at what point will the collective intelligence of the users start interacting with the intelligence of the network? What do we mean by collective intelligence and what does it have to do with regional socio-economic development? How can we foster the participation of new actors? How can we operationalise the processes of formalisation of knowledge through social tagging, i.e. how can we go beyond simple tagging? Where do new forms of knowledge meet new forms of language to create new forms of cognitive processes? How can we develop languages that express the economic activities and capabilities of economic and social actors as well as aspects of socio-economic and micro-economic interactions (licenses, business and revenue models, reputation frameworks, organisational structures and aims)? How can these new formal structures and social processes enable dynamic, networked, and cooperative business processes, crowdsourcing and global cooperation? How can we develop ICT instruments and formalisms that enable the description and identification of products, services, human talent, technologies, ideas, and that incorporate business relations and knowledge through formal and/or social semantics, supporting dynamic, distributed, social, and business networking construction processes and economic development? How can we integrate technologies and economic models that support innovation ecosystems that mediate the interactions between the human and digital dimensions in a context of dynamic self-organisation of socio-technical and economic systems, integrating research efforts in ICT with social and economic sciences?

Who Will Run the Digital Business Ecosystems? Who are the stakeholders? What is the power balance? What are the rules? Who sets the rules? How can the local rules of the digital ecosystems vary between ecosystems, while still allowing global interaction among ecosystems? How can we build trust? Who is accountable? How do we go about developing a governance framework? How do we bootstrap and then preserve the autopoietic properties of digital ecosystems? Can we define structural features of the digital ecosystems that will make the emergence of oligopolies naturally difficult while fostering an inclusive economic dynamic, without having to make recourse to top-down regulatory policy? It is clear from the foregoing that Digital Business Ecosystems research is not just about software services and technology platforms, but reflects the richness and the complexity of social and economic relations. In the rest of this book this integrative point of view is elaborated from many different disciplinary perspectives, as follows.

The Sections of the Book

In Section 1: "Science: New Paradigms", the authors look at the more theoretical aspects of Digital Ecosystems research. Following a broad-sweeping discussion of the scientific foundations of Digital Ecosystems, the main concepts of biological ecosystems are presented in the second article of the section, together with their applicability to evolutionary and agent-based architectures. The third article then looks at ecosystems from the point of view of language and linguistics. The fourth and final article of the section looks at business ecosystems and organisations.

Section 2: "Economic and Social aspects" begins with an article on business and technology clusters of small firms and their increasingly dynamic role in the globalising economy. The second article addresses the challenge of developing a governance framework for Digital Ecosystems that can sustain the plurality of decision processes surrounding their social, technological and regulatory aspects. The third article is more economic in flavour and discusses a cost-benefit analysis framework for Digital Ecosystems, partly based on initial results from the participating regions. The fourth article focuses on knowledge, sustainability and scalability in open source Digital Ecosystems. The fifth and last article of the section discusses a regulatory framework for Digital Ecosystems organised around the concept of trust.

Section 3: "Digital Ecosystem Technology" is almost entirely focussed on architectural aspects. From distributed information and ecosystem-oriented architecture the section includes articles on DBE services, on Business modelling languages, on the dynamic and scale-free topology of the run-time environment, on distributed infrastructural services, on a negotiation environment, and finally on a simulation framework that can equally visualise the Evolutionary Environment and SME networks.

Section 4: "Case Studies of Technology Transfer and Digital Ecosystem Adoption" is focussed on DBE adoption. The first two articles discuss regional development. The third and fourth articles are case studies from the Regional Catalysts of the DBE Integrated Project. The final three articles are new and emerging regional experiences of direct or indirect relevance to Digital Ecosystems from India, Ireland and Brazil, respectively.

The final section, Section 5: "Digital Ecosystem Projects Cluster", gives an overview of the Digital Ecosystems Cluster of research projects funded by the European Commission.

Acknowledgements

The *DBE book team* wishes to express their recognition to Ramon O'Callagan, Miguel Vidal, Jesús Gabaldón and Antonella Passani for their hard work in writing the introductions to different sections.

The following persons also provided valuable background material, critical feedback, or stimulating discussions for specific chapters of this book: Evangelia Berdou, Alan Hooper, Paul Krause, Robin Mansell, Daniel Schreckling, Frauke Zeller.

The book is the result of extensive research driven by the DBE research community within the projects funded by the 6th Framework Programme of the European Union. It benefited from inputs and feedback provided by researchers under the cluster "Technologies for Digital Ecosystems", presented and developed in Section 5. The book also benefited from collaboration with the following institutions: Instituto Tecnológico de Aragón, University of Central England, London School of Economics and Political Science, Imperial College London, Heriot-Watt University, University of Kassel, University of Tennessee, Monash University, Technical University Ilmenau, University of Lecce, University of Surrey, Tilburg University, IESE Business School, Waterford Institute of Technology, Fachhochschule Salzburg, Indian Institute of Technology Kanpur, T6, CENSIS, TechIDEAS, Soluta, Intel Ireland, CREATE-NET, and the Regions for Digital Ecosystems Network (REDEN).

The tag cloud that is on the cover of the book was designed collectively by the DBE community by the definition of the tags and their relevance. The Picture on the back cover page was designed by Bertrand Dory and Anne English, Intel Ireland. The overall layout, graphics and desktop publishing were done by Paolo Antinori.

This book would not have been possible without the knowledge, the research, and the previous work of hundreds of scientists. Among them we would like to mention the project CYBERSYN and the FP5 project FETISH. We would like to express a special tribute to some persons whose ideas have been fundamental for building the vision expressed in this book: H Maturana, F Varela, F Flores, S Beer, G Bateson, L Lessig.

The DBE project provided part of the financial support for the editing of the book, as part of the project dissemination activites. The DBE and OPAALS projects are gratefully acknowledged.

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A **Network** of Digital Business **Ecosystems** for **Europe:** Roots, Processes and Perspectives

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Introduction

This introductory paper summarises the needs and the processes that have led to the concept of digital business ecosystem (DBE), the impact that this area of research aims to achieve, and the scientific and conceptual perspectives that have been uncovered by this approach. This area of research and policy development is still in its infancy. With the progressive coupling of the different areas of knowledge that are related to DBEs and the construction of a multidisciplinary community, the objectives have evolved since the first paper of 2002, and we now have a better understanding of the process and the scientific and conceptual challenges ahead. Although the link between learning, or knowledge transfer, and economic development is by no means a straightforward one, by leveraging an evolutionary and open knowledge approach we have been able to engage diverse communities of small and medium-sized enterprises (SMEs) in several regions of Europe in the adoption of state-of-the-art business modelling, software development, and run-time environments.

The DBE ecosystem community realised that to bring into existence information and communication technologies (ICTs) that help in the achievement of the challenges identified by the objectives of the Council of Lisbon (higher growth, more and better jobs, and greater social inclusion (COM 2004)) we needed to widen our horizons with a more holistic and systemic approach. In addition to ICT, this new approach should consider socio-economic aspects and the human perception, communication and representation dimensions in one single research domain. This approach, applied to social and economic processes and their digital representation, is consistent with the changes in the production processes brought by networks of users/producers (Benkler, 2006), which have clarified the processes of technological and social innovation and have helped us imagine the development of (post-) industrial policy (O'Callagan, 2004).

The interaction between research strands in philosophy of science, epistemology,[1] cybernetics, information theory, linguistics, and communication theory brought to a revolution in the studies of human behaviour, interaction, and communications, led by the Palo Alto school (Watzlawick et al., 1967; Bateson, 1972). We do not know whether the DBE research effort will lead to a new science of the interaction and communications between economic and digital actors. For a new science similar to the development of the general systems theory (Bertalanffy, 1969), the path still has to be forged.[2] But the vastness of the scientific challenges and of the research we are beginning to discern does not imply that the findings will be transferable to the market only after several years and that such endeavour will produce a tangible social and economic impact only in the long-term. It has been verified in the field that the evolutionary mechanisms grounding this research area, even in their initial rudimentary implementation, could be successfully applied and transferred,[3] activating services and mechanisms capable of becoming more intelligent and effective over time.

The different areas of science, but also the actors involved in the process, have just started to communicate and express themselves using common languages and models. This is also reflected by the division of the book in four sections: Science, Economic and Social Aspects, Technology, and Adoption, expressed with different disciplinary languages whose integration is not always visible. It is also reflected by this introduction written in common by people from academia, public administration and business. Nowotny et al. (2001) argue that knowledge in contemporary societies is increasingly produced in new, more complex contexts and by an increasing number of participants. This they term mode-2 knowledge, as opposed to mode-1 knowledge which characterises the more clear divisions of the institutions of knowledge of modernity. This book presents the state of the art today, the findings so far, and the initial achievements of the process towards a common understanding; it presents the first applications to the economy of a few regions, but also the future perspectives. We would also like to give an idea of the new areas of research that have been uncovered, and a sense of the amount of research still to be done. A book is not the best medium, it is only meant to provide some teasers to stimulate the curiosity and the willingness to contribute to a shared enterprise.

In this introductory chapter we will give a high-level overview of the conceptual foundations, assumptions, and principles from which a rationale is emerging for the Digital Ecosystems methodology for sustainable socio-economic development at the regional scale. Whereas 'sustainable development' usually carries environmental connotations, in

1) In Latin countries epistemology is associated with philosophy of science. In Anglo-Saxon countries it means the study of knowledge, or the analytical apparatus by which one can distinguish true from false knowledge relative to a set of beliefs. In this paper we mean the latter, which necessarily carries a connotation of knowledge creation—e.g. "epistemic community" (Latour and Wolgar, 1979; Knorr-Cetina, 1999).

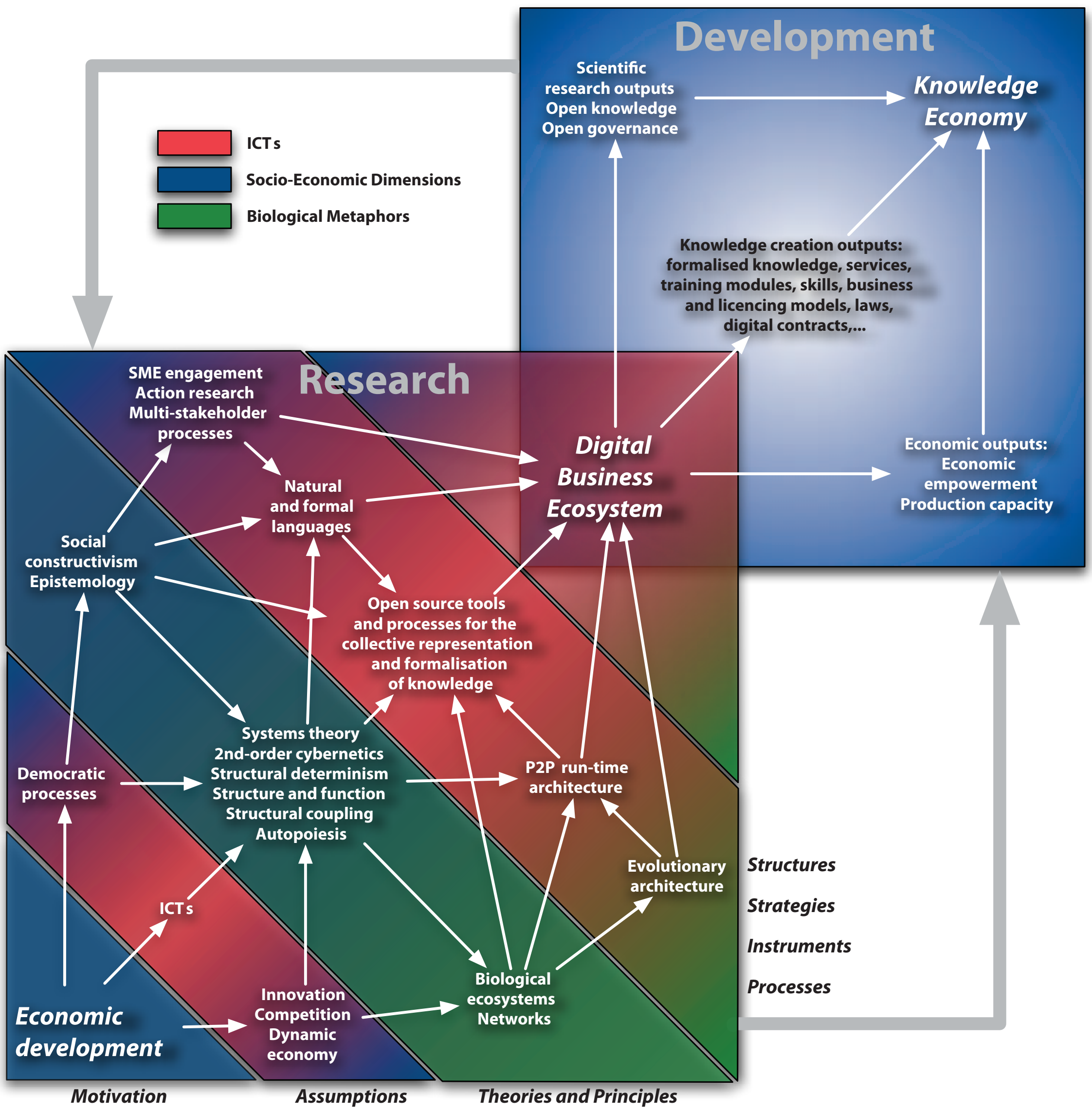
2) "Caminante, no hay camino, se hace camino al andar" ("Travellers, there is no path, paths are made by walking") (Machado, 1912).

3) As illustrated in Section 4 of this book "Case studies Technology Transfer and Digital Ecosystems Adoption"

Digital Ecosystems research it refers to the balancing effect that a greater level of integration of the social and cultural context with the economic life of a region is assumed to have on its long-term economic viability. As shown in Fig. 1, starting from an agreed overarching goal of economic development and from basic assumptions of democratic processes and fair competition, several principles, theories, and processes are summoned to understand which ICTs and which organisations and processes can foster innovation and dense communities of users, leading to a vibrant Knowledge Economy. The original digital business ecosystem vision (Nachira, 2002) is therefore revisited here on the strength of the outputs of four years of research by traversing most of the topics shown in this figure. This article and the rest of the book will visit some of the concepts shown on this map, sometimes following a recognisable path, sometimes jumping around to satisfy other presentation rationales, such as chronology. This figure, which purposefully juxtaposes the concepts of 'Research' and 'Development' to highlight their dual role, is necessarily a radical oversimplification of the many ideas and concepts discussed in this book. Given the very significant complexity of the interdisciplinary field of Digital Ecosystems research, and its frequent forays into very theoretical research as well as very applied and action-oriented research (Lewin, 1946) through direct engagement with the software industry and socio-economic stakeholders, we hope this simplified map will help the readers keep their bearings as they make their way through the maze of this book.

Fig. 1

Research and Development in Digital Ecosystems



Origins

The research area related to Digital Business Ecosystems was triggered by the initiative Go Digital (EC, 2001a)[4] aimed at boosting ICT adoption by European SMEs. It is generally thought that ICT is one of the major contributors to economic growth and economic efficiency: "The decline in EU labour productivity growth rates in the mid-1990s was attributed equally to a lower investment per employee and to a slowdown in the rate of technological progress" (Kok, 2004).

In the presence of roughly 20 million small and medium-sized enterprises (SMEs) in the EU25, which make up more than 99% of all European companies by number and approximately 50% of European GDP, the Lisbon Strategy's call (COM, 2004) for "…the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social inclusion" by 2010, was interpreted as a need to boost the SME sector in Europe. Furthermore, statement like "ICTs are central to boosting productivity and improving competitiveness"; "Public and private information and communication technologies contributed nearly 50% of EU productivity growth between 2000 and 2004" (EC, 2007); and "European productivity growth could be significantly accelerated if organisations made more and better use of ICT in their organisations and production processes" (Price Waterhouse Cooper, 2004) indicated that the general policy consensus was oriented towards the achievement of the Lisbon objectives through greater ICT adoption on the part of SMEs.

ICT is also an economic sector in itself. Indeed in 2006, the ICT sector added 5.3% value to EU GDP and 3.6% of EU employment. It also accounted for 25% of total EU research in business (EC, 2006). ICT increasingly forms an integral part of all industrial and service markets through the integration of ICT in goods or service offers. Crucial for the economic development is not only the adoption of ICT, but also the diffused capacity to master ICT technologies. Local ICT industry and skill, in addition to the related employment, is an instrument of autonomy and sovereignty and provides the capacity to develop and adapt ICT to local needs.

It is difficult to characterise SMEs and their behaviour since they are involved in all industry sectors and business domains, having developed along all possible organisational forms and company structures, and continually inventing new ones. Like all companies, however, SMEs are heavily networked in a web of business and social links with their suppliers, clients, and business partners distributed at all geographical scales. These networks can be physical and logistical or virtual, they can be local or global, or a combination of all of the above. As discussed in the literature of industrial districts, technology clusters, and growth nodes (O'Callagan, 2004), it has been clear for many years that companies of all sizes benefit from network effects, which can be defined as the greater-than-linear increase in utility derived by a network node with the increase in the total number of nodes of the network.

The European Commission, in recent years, has invested in programmes in support of SMEs, providing grants and support to single SMEs. Such direct investments—in a necessarily limited number of individual SMEs—can achieve only limited results. This is especially true when favourable conditions for business are not present, e.g. appropriate legislative framework; human capital, diffused knowledge and skills; technical infrastructures; entrepreneurial culture; and critical mass of available services. Such programmes should rather become focused on creating favourable environmental conditions and ecosystems of innovation: "Like individual plants or animals, individual businesses cannot thrive alone—they must develop in clusters or economic ecosystems" (Moore, 2003).

Thus, the Digital Ecosystem initiative was based on the assumption that public sector intervention should be aimed at creating favourable conditions for business. The optimum scale of intervention was judged to be at the regional level, where a multi-stakeholder process of policy development and implementation was likely to be more effective. The policy to support SMEs shifted from an individual approach to an approach focused on the context, aimed at building environments favourable to SMEs' business and their networking, compatibly with the EC policy for "Helping SMEs to go digital" (EC, 2001a), which set three priorities:

1. promote a favourable environment and framework conditions for electronic business and entrepreneurship
2. facilitate the take-up of electronic business
3. contribute to providing Information and Communication Technology (ICT) skills.

It is worthwhile to note the integrated approach which stresses the creation of an environment, a business ecosystem, and the need for IT skills.

4) http://ec.europa.eu/information_society/topics/ebusiness/godigital/index_en.htm

The Digital Business Ecosystem

The synthesis of the concept of Digital Business Ecosystem emerged in 2002 by adding "digital" in front of Moore's (1996) "business ecosystem" in the Unit ICT for Business[5] of the Directorate General Information Society of the European Commission (Nachira, 2002). In truth, Moore (2003) himself used the term Digital Business Ecosystem in 2003, but with a focus exclusively on developing countries. The generalisation of the term to refer to a new interpretation of what "socio-economic development catalysed by ICTs" means was new, emphasising the coevolution between the business ecosystem and its partial digital representation: the digital ecosystem. The term Digital Business Ecosystem can be "unpacked" as follows (Fig. 2):

Digital (ecosystem): the technical infrastructure, based on a P2P distributed software technology that transports, finds, and connects services and information over Internet links enabling networked transactions, and the distribution of all the digital 'objects' present within the infrastructure. Such 'organisms of the digital world' encompass any useful digital representations expressed by languages (formal or natural) that can be interpreted and processed (by computer software and/or humans), e.g. software applications, services, knowledge, taxonomies, folksonomies, ontologies, descriptions of skills, reputation and trust relationships, training modules, contractual frameworks, laws.

Business (ecosystem): "An economic community supported by a foundation of interacting organizations and individuals—the 'organisms of the business world'. This economic community produces goods and services of value to customers, who themselves are members of the ecosystem". (Moore, 1996) A wealthy ecosystem sees a balance between cooperation and competition in a dynamic free market.

Ecosystem: a biological metaphor that highlights the interdependence of all actors in the business environment, who "coevolve their capabilities and roles" (Moore, 1996). Also, in the case of Digital Business Ecosystem, an isomorphic model between biological behaviour and the behaviour of the software, based on theoretical computer science implications and leading to an evolutionary, self-organising, and self-optimising environment (Evolutionary Environemnt or EvE).

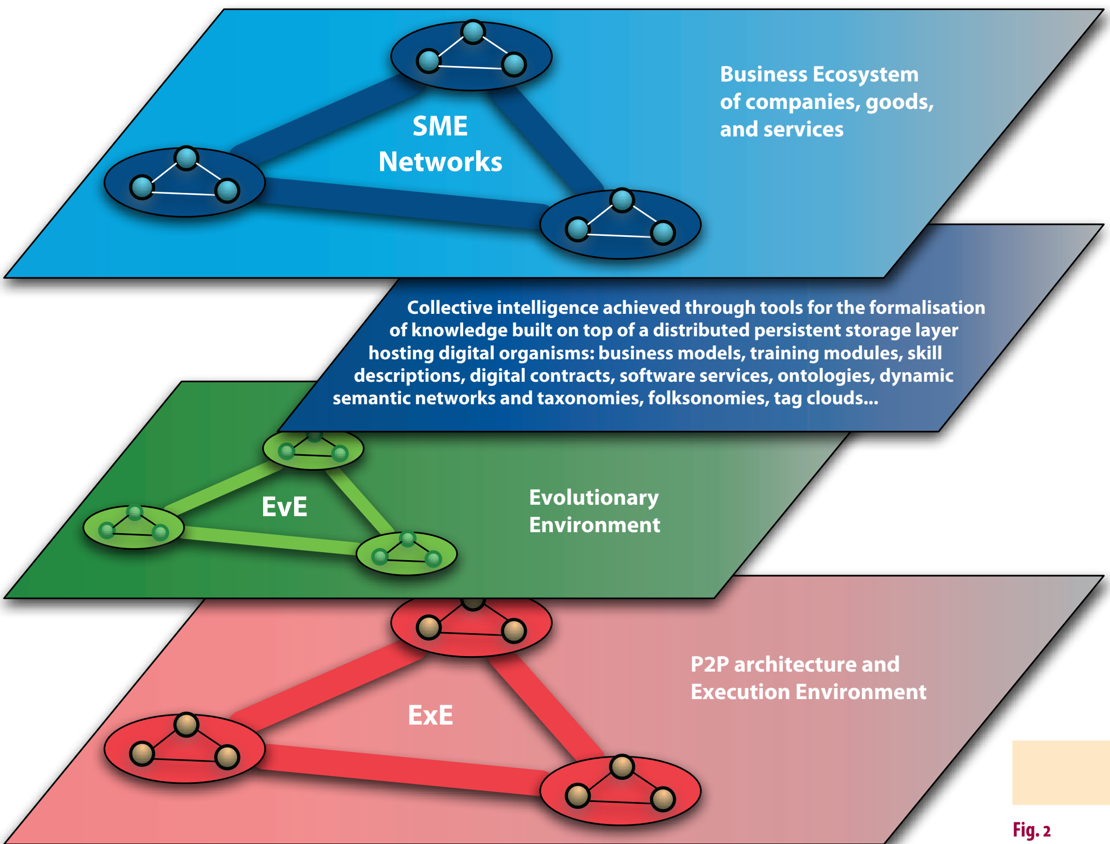


Fig. 2
The stack view of the Digital Business Ecosystem [6]

5) Now Networked Enterprise and RFID Unit, Directorate General Information Society and Media.
6) Inspired by work of Thomas Kurz, Salzburg University of Applied Sciences

Bringing these three terms together has been effective in broadening the appeal of the approach to a wide range of stakeholders from academia, industry, business, and policy-making. However, it has also rendered a clear explanation of what the three terms mean *when used together* very difficult. It is especially challenging to show how these three terms necessarily imply some characteristics of the technology and not others, or how they imply some policy and governance choices and not others. The understanding of the term 'digital ecosystem' and of the stakeholders that populate it has developed during the course of the research over the last few years. For example, research conducted in the context of the DBE IP has highlighted the importance of Regional Catalysts and other intermediary actors such as professional associations or volunteer open source communities. This has led to the broadening of the conceptualisation of the term 'business'. This book could therefore be seen as a sort of "state of the art" of the Digital Business Ecosystem concept and research in 2007, partly based on the experiences of the FP6[7] projects of the Technologies for Digital Ecosystems Cluster, with specific relevance to the Digital Business Ecosystem Integrated Project (DBE) that ran from November 2003 to January 2007. The purpose of this introduction, in turn, is to provide a high-level map within which the book's contributions can be located more easily as part of an integrated vision.

Networks

Digital Ecosystems were made possible by the convergence of three networks: ICT networks, social networks, and knowledge networks. The networked connections enabled by the Internet and the World Wide Web grew along the links of the pre-existing and underlying social, professional, collaboration, and business networks between governments, researchers, businesses, companies, and friends. Computing environments likewise spilled over from the single computer to the local area network (LAN) at first, and eventually to the global Internet. Networked computers motivated the development of distributed architectures and shared resources, culminating in the peer-to-peer (P2P) model. The faster and more pervasive communications enabled by the technology reinforced the already existing trend from a material economy based on manufacturing toward a service economy based on knowledge production and distributed value chains.

If limited to these aspects, Digital Ecosystems are not very original: in information and communication technologies often a group of applications complementing a specific product or platform is considered to form a "digital ecosystem"[8]; the ICT and media companies form a "digital ecosystem community".[9] In order for "large-scale" concepts such a Information Society to make sense in the context of economic development, however, they needed to be operationalised in terms of concepts meaningful and useful to the many facets of the economic life of the individual economic players experiencing this historic transition chiefly (and often painfully) through their yearly variation in turnover This led to the extremely difficult challenge of invoking increasingly theoretical principles and ideas in order to understand how we could succeed in developing practical software technologies that reflect the social and economic relationships between people and economic actors, that could be easily adopted and mastered by European SMEs, and that would bring measurable economic gains. The answer has been, in part, to identify ICT adoption and social networking with a ***process*** rather than an ***event***. This required the integration of the technological approach with a social science perspective, and the introduction of a holistic view of the resulting techno-social and economic system inspired by the multi-scalar biological ecosystem metaphor.

Scale and Topology

Empirical observation and the historical record in many different cultures and parts of the world indicate that economic development, industrial districts, and more recently technology clusters tend to be co-located geographically. The explanation for such a phenomenon uses a mixture of efficiency and cultural/social arguments. The interpretation favoured in the Digital Ecosystems initiative acknowledges the efficiency gains brought by shared physical infrastructures, lower transportation costs, etc, but also regards social constructivist processes as an important factor in strengthening this dynamic. In other words, it also sees the phenomenon as a natural consequence of the interpretation of technology production as an extension of the language spoken by a particular community: common language leads to a shared understanding of reality, which leads to shared means of expression and therefore similar

7) The EU 6th Framework Programme for Research and Technological Development 2002-2006 (6th FP). It started in 2003, nearly all the supported projects will finish by 2010.

8) E.g. several authors describe the SAP platform and the surrounding applications and services as a "digital ecosystem".

9) The "Digital Ecosystem" project launched by the World Economic Forum established a Digital Ecosystem community (http://www.decommunity.net/)

and interdependent technologies. This is one of the reasons why digital ecosystems are seen as even more effective at the regional rather than at the national or international scale.

The Digital Ecosystems initiative aims at helping local economic actors become active players in globalisation, 'valorising' their local culture and vocations and enabling them to interact and create value networks at the global level. Increasingly this approach, dubbed "glocalization", is being considered a successful strategy of globalisation that preserves regional growth and identity (Khondker, 2004), and has been embraced by the mayors of thousands of municipalities and by decision-makers and intellectuals joined in the Glocal Forum (2004). Similarly, Castells (2000) has written extensively on ICTs and the tension between globalisation and localisation.

The premium placed on a local production and development context represents a constraint on the architecture of globalisation that is ultimately important for its sustainability: through its integration with the many societies and economies of the world a more constructive dynamic of interaction between the local and the global scales can be achieved. Interestingly, this architecture was indicated in the very title of Nachira's original paper, as a reference to a "*network* of digital business ecosystems" (emphasis added), distributed over different geographical regions *and* over different business domains/industry sectors.

Regarding a particular business ecosystem, two main different interpretations of its structure have been discussed in the literature. The "keystone" model was assumed by Moore (1996) and has been further developed by Iansiti (Iansiti and Levien, 2004); in this model the ecosystem is dominated by a large firm that is surrounded by a large number of small suppliers. This model works well when the central firm is healthy, but represents a significant weakness for the economy of the region when when the dominant economic actor experiences economic difficulties. This model also matches the economic structure of the USA where there is a predominant number of large enterprises at the center of large value networks of suppliers (Eurostat, 2006).The model of business ecosystem developed in Europe, on the other hand, is less structured and more dynamic; it is composed of mainly small and medium firms but can accommodate also large firms; all actors complement one another, leading to a more dynamic version of the division of labour and organised along one-dimensional value chains and two-dimensional value networks (Corallo, 2007). This model is particularly well-adapted for the service and the knowledge industries, where it is easier for small firms to reinvent themselves than, for instance, in the automotive industry.

Innovation, Openness, and Creative Destruction

Compatibly with the principles it espouses, the conceptualisation of digital ecosystems is itself emergent. It tries to find a balance between "old" theories of stagnation brought by oligopolies (Steindl, 1990) on the one hand and Open Innovation (Chesbrough, 2003) and "Crowdsourcing" [10] on the other. It asks questions about Open Source and the Linux phenomenon in the same breath as Schumpeter's (1942) oversubscribed creative destruction from IBM to Microsoft to Google. It looks at new institutional and transaction costs economics (Coase, 1937; Williamson, 1975; Benkler, 2002) as well as at the economics of sharing (Benkler, 2004) and community currencies.[11] Perhaps most importantly, it strives to remain open to new ideas coming from research and academia as well as from business and development experience. It is a body of knowledge on innovation that constantly innovates itself with new ideas and new points of view.

A greater openness[12] and a multi-stakeholder approach between academia, business, and local government implies a greater emphasis on a collaborative "sense-making" process for analysing the priorities of a particular region and for devising appropriate development strategies. For example, in the Spanish region of Aragon the Instituto Tecnológico de Aragón, partly owned by the local government, is the main actor responsible for innovative regional development. By partnering with the more advanced ICT companies based in the region a successful ICT adoption and dissemination process has been set up that is able to reach hundreds of SMEs in several sectors (tourism, manufacturing, etc.) throughout the region. In the UK, by contrast, the Midlands are characterised by more than 50 public and private entities that are in one way or another concerned with development and ICT adoption. A completely different strategy for innovation is hence being devised there,

10) Crowdsourcing is defined as new business model in which a company or institution takes a job traditionally performed by a designated agent (usually an employee) and outsources it to an undefined, generally large group of people in the form of an open call over the Internet. Crowdsourcing has been used the first time by (Howe 2006).

11) http://www.openmoney.org. Work currently being done in the OPAALS project: www.opaals.org.

12) In the private sector this refers to fewer IPR restrictions, in adademia it refers to initiatives such as Open Access Publishing or Creative Commons.

based on the business school of the University of Central England acting as the Regional Catalyst, but partly delegating that role to a number of companies that offer a range of SME networking services, from meeting and conference space to ISP services.

Four years since the emergence of the Digital Ecosystem concept, we still believe that socio-economic growth depends on innovation, and that innovation is largely dependent on an open flow of ideas (Lessig 2002). Openness in the Knowledge Economy is not so different from encouraging spending to stimulate the dynamism of the Exchange Economy. However, we recognise that "spending" ideas are easier to implement in research environments than in business environments. Therefore, the balance that seems to work in business environments is based on a layered approach: combining an open source shared middleware infrastructure with software services, models and information that compete on the revenue models (which can vary from proprietary to shared or free). An open source ecosystem-oriented architecture provides, indeed, a distributed middleware that acts as a new ICT commons, or as a public road that lowers the cost of ICT adoption and maximises the reuse of models. It is important to build such an infrastructure in such a way as to preserve its intrinsic characteristic as a commons, that is, "a resource that anyone within a relevant community can use without seeking the permission of anyone else" (Lessig, 2006). The Digital Ecosystem could represent a new innovation commons tailored on the needs of SMEs, enabling business networking, cooperation, knowledge flows, and fostering creativity and growth.

Relativism and Reflexivity

Several statements in the above paragraphs are organised by a mixture of beliefs and interpretations of research results,[13] leading to temporary but fairly confident conclusions regarding the Digital Ecosystems approach (principles of openness, multi-stakeholder approach, and the tactic of using Regional Catalysts) as an effective methodology to achieve sustainable socio-economic development at the regional scale. Parallel research efforts starting from different assumptions and relying on different theories in Europe and elsewhere could have reached different conclusions. For example, Game Theory sees "atomised" economic agents in competition to maximise their own utilities as offering a better explanation, or even prescription, for a healthy dynamic equilibrium of economic systems. We do not consider Game Theory a good framework for explaining what has happened in the regions that have adopted the Digital Ecosystems approach primarily because it fails to take into account the complex institutional and cultural setting in which Digital Ecosystems are embedded. Evolutionary Game Theory (Maynard-Smith, 1982) offers an interesting alternative to the ecosystem metaphor preferred as a reference concept in this book. As another example, Schumpeter's creative destruction long ago offered a clean and "self-correcting" solution to the problem of the emergence of monopolies in free markets.

These (and others) alternative viewpoints should be acknowledged. However, there is not enough room here to do them justice with a thorough comparative analysis. In this article we prefer to offer some more background on the conceptual and theoretical foundations that have informed the interpretations and insights that have so far been reached in the Digital Ecosystems research area. The principal characteristic shared by the theories to be discussed in this article and in this book upon which the Digital Ecosystems approach is being built is variously referred to as relativism, subjectivity, or intersubjectivity, is connected to phenomenology and to cognition, and in general strives to expose the fallacy of assumptions of an objective reality external to ourselves. One of its consequences, in social science, has been the development of the useful tool of reflexive analysis, or reflexivity for short, through which we become better able to see ourselves through the eyes of others, reaching surprising conclusions such as, 'Software engineering is a social process'.

Systems Theory, Second-Order Cybernetics, and Radical Constructivism

Epistemology is the branch of philosophy that studies knowledge. It attempts to answer the basic question about how knowledge is built and what distinguishes true (adequate) knowledge from false (inadequate) knowledge. In practice, these questions translate into issues of scientific methodology: how can one develop theories or models that are better than competing theories?

13) www.digital-ecosystem.org

In 1936 the biologist Ludwig von Bertalanffy proposed Systems Theory (Bertalanffy, 1936) as a reaction against the reductionism inherent in the classical scientific analytical approach to isolate an external objective reality, separate it into its constituent parts or elements, and study and analyse it through correspondingly different disciplines. Such an approach is unable to uncover and highlight the interrelations between the parts that connect them into a whole and prevents the perception and understanding of systemic phenomena. In subsequent years Systems Theory's view grew in importance. Many of the concepts used by systems scientists led to the closely related approach of cybernetics. The systems scientists and cyberneticists felt the need to separate themselves from the more mechanistic analytic approaches, and they gradually came to emphasise autonomy, self-organisation, cognition, and the role of the observer in modelling a system. In the early 1970s this movement became known as second-order cybernetics, which studies how observers construct models of the systems with which they interact (Heyligen, 2001a). The movement culminated with the Principia Cybernetica Project, which developed a cybernetic philosophy based on the concept of the "meta-system transition" with implications for human evolution, political systems, and the foundations of mathematics.

The epistemology of (second-order) cybernetics and of the Principia Cybernetica Project has a radical constructivist basis. Ernst von Glasersfeld defines radical constructivism by the following two basic principles built on the ideas of Jean Piaget, who applied the biological concept of adaptation to epistemology:

- Knowledge is not passively received either through the senses or by way of communication, but is actively built up by the cognising subject.
- The function of cognition is adaptive (in the biological sense of the term), tending towards fit or viability) and serves the subject's organisation of the experiential world, not the discovery of an objective ontological reality. (von Glaserfeld, 1988, 1996)

The importance of constructivism and its relation to cognitive science is best understood by comparing it with the opposite, more traditional, approach in epistemology or cognitive science, which sees knowledge as a passive reflection of an external, objective reality. This implies a process of "instruction": in order to get such an image of reality, the subject must somehow receive the information from the environment, i.e. it must be "instructed". Cybernetics began with the recognition that all our knowledge of systems is mediated by our simplified representations—or models. Thus, first-order cybernetics studies a system as if it were a passive, objectively given "thing", that can be freely observed, manipulated, and for which we have to provide the "true" representation. A second-order cyberneticist working with an organism or social system, on the other hand, recognises that system as an agent in its own right, interacting with another agent, the observer (Heyligen, 2001b).

The following chapters will show the role that these considerations play in the practical realisation of Digital Business Ecosystems and in the implementation of policies for socio-economic development catalysed by ICTs. It is helpful to recount briefly the origins of these ideas, which have always been interdisciplinary. These philosophies were fundamentally important for analysing and designing systems that represent and mediate socio-economic interactions between enterprises and people.

Autopoiesis and Dynamic Conservatism

Maturana and Varela (1973) invented the concept of autopoiesis as a model that generalises the structure and function of a biological cell, and defines the characteristic of a living system. But, as noted by Maturana (1997), autopoiesis is an epistemological option, which goes beyond the cell and the nervous systems, becoming a fundamental instrument for the investigation of reality. The concept has long surpassed the realm of biology and has been used to explain human communication and social systems impacting on sociology, psychotherapy, management, anthropology, organisational science, and law.

An autopoietic system can be described briefly as a self-producing machine, or a self-generating system with the ability to reproduce itself recursively. An autopoietic system exhibits a network of processes and operations, which could create, destroy, or reorganise themselves in response to external inputs and perturbations. Since autopoietic systems are simultaneously producers and products, it could also be said that they are circular systems, that is, they work in terms of productive circularity. The reference to a "system" carries a specific meaning in the theory, namely the ability of an autopoietic system to delimit itself spatially through a physical boundary (the membrane for the cell, the interface with the "real word" for the digital ecosystem) in order for the autopoietic process to be able to discriminate the "inside" to which autopoiesis applies, from the "outside", to which it does not. In Digital Ecosystems research autopoiesis is used as the ultimate model of interactive computation, but it is also used as a metaphor for a generalised form of organisation. Specifically, "organisational closure" is defined as the stability of the organisational structure of the system, even when the system is open to a flow of energy and mass, such as a cell, whereby each element or sub-process of the system conspires to maintain the organisation of the system that makes it autopoietic.[14]

Very interestingly, an almost identical concept was arrived at roughly at the same time by the American sociologist and philosopher Donald Schön (1973), who dubbed it "dynamic conservatism". Schon did not have a biological point of view, he operated entirely within the disciplinary boundaries of sociology, but in his opinion his findings applied equally well to any social system, "…whether a naval ship, an industrial firm, or a community":

The system as a whole has the property of resistance to change. I would not call this property 'inertia', a metaphor drawn from physics—the tendency of objects to move steadily along their present courses unless a contrary force is exerted on them. The resistance to change exhibited by social systems is much more nearly a form of 'dynamic conservatism'— that is to say, a tendency to fight to remain the same. (p 31)

Structural Determinism

Autopoietic systems are structure-determined systems. The potential behaviour of the system depends on its structure. Maturana calls this concept structural determinism, i.e. a process of change of an organism that, at any point in time, is determined by the organism's previous structure but is triggered by the environment. Thus, the structure of a given system is not static; it is one of many ways in which its components can interconnect whilst retaining a recognisable organisation:

Living systems have a plastic structure, and the course that their structural changes follows while they stay alive is contingent on their own internal dynamics of structural change modulated by the structural changes triggered in them by their interactions in the medium in which they exist as such (Maturana, 1997).

Thus, the organisation determines the identity of a system and the structure determines how its parts are physically articulated. Such principles apply to all the complex digital autopoietic systems, and therefore also to the Internet and its applications/services. It was remarked by Lessig when he observed that "the code is the law of cyberspace" (1999). The Internet's structure determines how the Internet is regulated. The Internet's role in innovation, based on the 'spontaneous' creation and implementation of new protocols and services, would not be possible with a different structure characterised by a centralised instead of an end-to-end and layered 'intelligence'. The change of basic structural principles "could fundamentally alter the fabulously successful end-to-end Internet":

"The remarkable social impact and economic success of the Internet is in many ways directly attributable to the architectural characteristics that were part of its design. The Internet was designed with no gatekeepers over new content or services. The Internet is based on a layered, end-to-end model that allows people at each level of the network to innovate free of any central control. By placing intelligence at the edges rather than control in the middle of the network, the Internet has created a platform for innovation. (Cerf, 2005)

In a similar way, the effort in developing the architectural principles upon which to base the digital ecosystem were to regulate indirectly its functionalities by defining a structure that determines some behaviours and prevents others. These are the same values and behaviours that were at the base of the Internet's growth and evolution.This is best understood through the concept of structural coupling.

Structural Coupling between the Business and Digital Ecosystems

An important aspect of autopoiesis is its radical relativism, which is inescapable and manifests itself as structural coupling: a form of mutual and symmetrical interdependence between two entities that, at any point in time, is determined by each entity's previous structure whilst being triggered by the other. In other words, structural coupling is a form of interdependence between two actors or entities that satisfies the criterion of structural determinism mutually and symmetrically (conceptually similar to non-linear coupling in physics). Nothing in biology exists by itself; everything interacts with everything else. By extrapolating this concept from the physical level to the neuronal

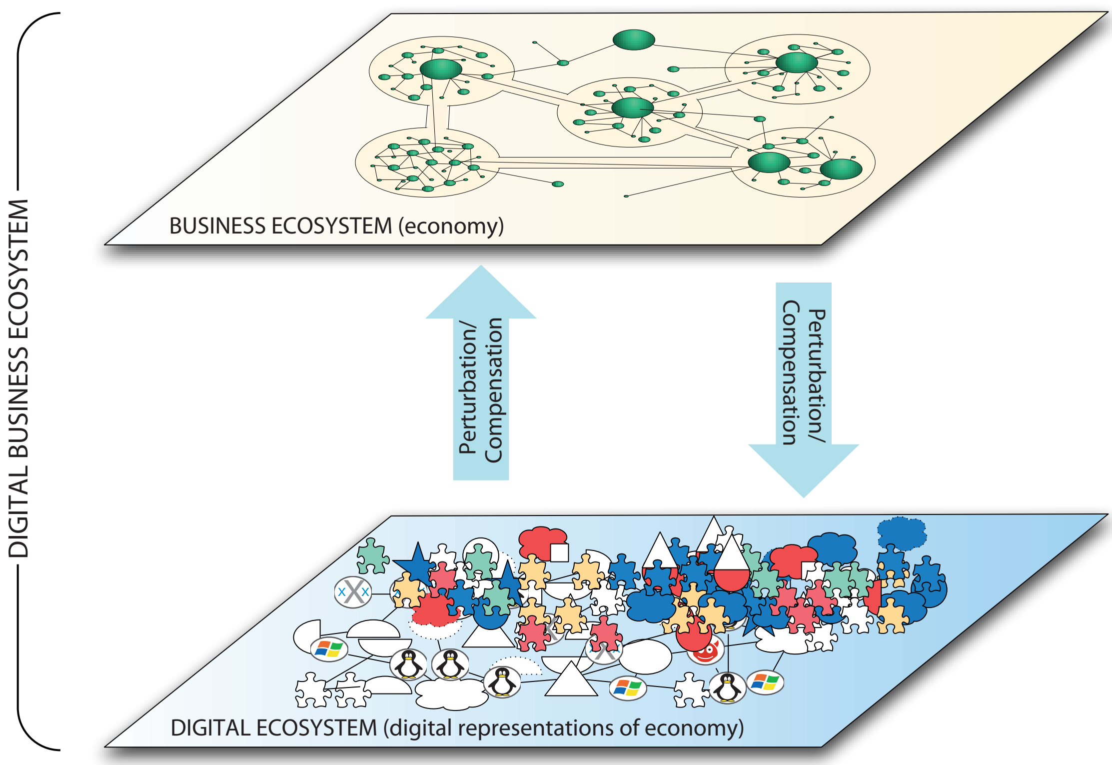
14) See the OPAALS Network of Excellence "Open Philosophies for Associative Autopoietic Digital Ecosystems" (www.opaals.org), which also studies the dynamic processes of knowledge creation and self-organisation in support of innovation.

and cognitive levels Maturana and Varela (1998) made an explicit connection with the process of "languaging" between two or more entities. This is surprisingly well aligned with the social constructivism understanding of the intersubjective construction of reality through language.

These ideas acquire greater relevance when we consider that Digital Ecosystems include digital computable representations of both the micro-economic and the macro-economic aspects of the business ecosystem.[15] The digital ecosystem provides representations of the business ecosystem, which are used for search and discovery, for aggregating and recommending services, for reorganising value chains, and for recommending potentially cooperating business partners. The digital ecosystem influences the structure of the enterprises and of their social and business networks, whilst the business ecosystem modifies the structure of the "organisms" of the digital ecosystem. The digital ecosystem and the business ecosystem, when they are viable, are structurally coupled and co-evolve forming a dynamic innovation ecosystem, as shown in Fig. 3.

The concepts of autopoiesis and of structural coupling together with a rethinking of knowledge representation and linguistics in a social context were applied to the design of a nation-wide system, the Cybersyn project (Beer, 1980), and provided the foundations for a new way to design (Winograd and Flores, 1986).

Fig. 3
Structural coupling between Business Ecosystem and Digital Ecosystem



Structural Coupling between Business Ecosystem and Digital Ecosystem

15) This includes any useful digital representation expressed in a language (formal or natural) that can be interpreted and processed (by computer software and/or humans); potentially any description of the economic and social actors, their capacities, skills and the relationships between them (EC 2005a).

Structural Principles of Digital Ecosystems

Since the digital ecosystem is structurally coupled to the socio-economic system of its users, its architectural design depends on the socio-economic properties to be facilitated or enabled. This choice is about how the world will be ordered and about which values will be given precedence (Lessig, 1999). The initial general objective of economic development was refined through online consultations and two cycles of workshops in 2002 and in 2005. It was articulated as:

Technologies and paradigms that enable the participation of SMEs and innovators in the knowledge-based economy, integrating them within local/regional/global socio-economic ecosystems and that enact unstructured dynamic business clustering to achieve greater competitiveness in the global economy.

In the course of the subsequent debates the concept was further developed into the peer production of a 'digital nervous system' that supports a participative society in which public and private organisations, professionals and individuals compete, interact, and collaborate for their own benefit and for the benefit of the organisations, teams, ecosystems and/or communities they belong to, in order to enable the participation of all players in the knowledge economy and in the knowledge society, and that empowers the creativity, the potentialities, the capacity, and the dynamic interactions (the relationships and the cooperation/competition) between all the economic players.

The public consultation process produced a research agenda (Dini et al., 2005) that is kept regularly updated[16] and a set of initial principles (EC 2005b)[17] that have to be translated and embedded within the ecosystem architecture. Some principles are general, whilst others depend on the policy aims or are specific to the structure of the local economy. In this paper we present only a few of these interrelated keystone principles, showing how they have influenced the architectural design but have also opened the need for further research. We do not explore in detail the technical and socio-economic implications or the practical implementations, which will be presented in the next sections of the book.

- *No single point of failure or control*
- *Digital ecosystems should not be dependent upon any single instance or actor*
- *Equal opportunity of access for all*
- *Scalability and robustness*

These principles imply a fully decentralised architecture; the design of a P2P structure that is robust, scalable, self-organising and self-balancing and that embeds scale-free networks and mesh topology dynamics. The open source initial implementation is freely available (http://swallow.sourceforge.net/, http://dbestudio.sourceforege.net, http://evenet.sourceforge.net) and has been adopted by SMEs in pilot regions.[18] Such networks do resemble the behaviours of social networks where node formation and dispersion is a function of activity and feedback The architecture runs over any IP network and supports the same principles also for a mesh of wireless nodes. From the information distribution perspective, it is worthwhile to note that the application of these principles means that a single node cannot access all the information in the network. By design, there is no central repository or database and there is no node/actor that has a privileged or full view of the ecosystem. However, the evolutionary architecture and distributed intelligence enable the "migration" of the (references to the) formalised knowledge and the software services where there is a greater probability of their use. From the organisational perspective these principles imply the need for balanced and decentralised governance models. The fully distributed information structures are essential for keeping the plasticity of the system[19] and for supporting the dynamic connections and re-organisation between the social, technical and knowledge networks.

- *Ability to evolve, differentiate, and self-organise constantly*
- *Activate and support self-reinforcing production and process networks*

The above are the basic mechanisms of an autopoietic system,[20] exhibited by living organisms and in natural ecosystems, but also by economic ecosystems. The objective is to produce a dynamic ecosystem of innovation; that

16) Specific EC support projects (e.g. EFFORT) include activities devoted to ensure the evolution of the research agenda and the updating of the roadmap.

17) Also aiming at defining governance models (see the following sections) and a Bill of Rights or a Constitution of the Digital Ecosystems

18) E.g. the information about the SMEs of Aragon exploiting the digital ecosystem can be found at http://www.ita.es/dbe/?ID=223

19) The holistic distribution of the information structures and the plasticity of the network replicate how information is stored in the brain and how it is constantly reorganised and elaborated through changes in the connections of the brain's neuronal network.

20) "Network of processes of production components which through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them" (Maturana, 1980)

is, to catalyse dynamic and remote collaboration and interaction between human and digital entities and systems in various structured and unstructured organisational settings, such as collaborative working environments composed of complex heterogeneous human and digital devices and systems. The ability to implement the production and the reorganisation mechanisms is crucial. Enabling the digital organisms, their networks and the whole system to exhibit mechanisms like self-organisation, selection, mutation, adaptation, and evolution brings the concept of ecosystem beyond a simple metaphor.

- *Capability to enable global solutions that adapt to local or domain specific needs*
- *Global solutions that emerge from local and sectoral inputs*
- *Local autonomy*

Economic activities cannot help but be related to local cultures and regulations. The ability to produce solutions which operate in a global market, but are adapted to the local needs and to the local business and culture, is a competitive advantage. This structure should be able to adapt to different societal environments, which are constantly changing. Therefore, it must embed mechanisms that enable adaptation and evolution. The above mechanisms imply that we do not have a single ecosystem, but several local ecosystems produced by the adaptation to local conditions. Just considering the services or the business models, this means that in some ecosystems new services will appear, in others the same services will be modified to be adapted to local conditions, regulations, business models, in yet others the services will disappear from lack of use. Solutions that need to be developed on a European scale could have sector-specific implementations that can be adapted and tuned according to local customs. Local SMEs could provide a local support infrastructure to implement these solutions in their business operations.

The Representations that "Populate" Digital Ecosystems

The digital ecosystem is the ICT infrastructure designed to support economic activities, which contains the socially-constructed representations of the business ecosystem[21]; it is essentially composed by:

- the knowledge that expresses different socially-constructed partial interpretations and views of the economy and which is represented through a variety of continuously evolving (natural and formal) languages and protocols.
- the architectural infrastructure that enables the desired "autopoietic" mechanisms and manages the distributed and pervasive storage of such knowledge, as well as the tools enacting the formalisation and the "processing" of this persistent knowledge

We can see that digital ecosystems are similar to natural ecosystems, but instead of being populated by biological organism they are populated by fragments of knowledge: these are analogous to memes (Wilkins, 1998) that could be computed, expressed in formal or natural languages, digitised and "living" and propagating through the network. Thus, the ecosystem is an environment with a 'life support' architecture designed to enable the 'life' of its 'digital organisms'. The mechanisms[22] embedded within the digital ecosystem, like a (collective) brain, operate on such languages and protocols. The digital ecosystem in its evolution will acquire more services and will be able to include more mechanisms of interpretation of knowledge ('introspection'), becoming more intelligent and providing more support to the business ecosystem. The digital ecosystem embeds evolutionary mechanisms that support the evolution and the adaptation of the languages that populate it (in both intentional an extensional representations). This approach is fundamentally an extension and a conceptualisation of the evolution of the Internet and of the Web.

Computer Science is concerned with the construction of new languages and algorithms in order to produce novel desired computer behaviours. The Web is an engineered space created through formally specified languages and protocols (Berners-Lee, 2006).

Formal Languages that Evolve and Proliferate

The issue of how distributed knowledge should be represented - and created - is one of the main research topics related to semantics of today.

21) The business ecosystem includes the socio-economic players, the material transactions, as well as the legal and institutional framework

22) Implemented through processes that could be any type of agents with intelligence, whether computer processes, humans, or a mixture thereof.

In the Web, due to the pressure of user needs, we see a continuous evolution of the protocols and artificial languages. The evolution operates at the level of the specific languages/protocols: some languages are initially rudimental, but evolve, expanding their expressive power and increasing the processing they can support, (e.g. HTML/XHTML; URL/URI). New languages and protocols keep emerging, allowing the representation of other facets of the world. The focus of many scientists in recent years has in fact been to develop formal languages that have the expressive power to define more abstracts aspects of reality, as shown by the rapid growth of the complexity and of the layers of the semantic web stack of W3C.[23] In the ecosystem metaphor this research activity can be described as the phylogenetic tree[24] of formal languages: new and more complex languages appear in the digital ecosystem, whilst the older ones continue to be present in the ecosystem as long as someone still uses them. Thus, the languages of the ecosystem continuously evolve in response to external stimuli and are not necessarily organised, e.g. in a stack. Also, these multiple representations cannot necessarily be reconciled. The cathedral of the Semantic Web is replaced by a bazaar of descriptions and formalisms. The Digital Ecosystem can support such a bazaar of fragments of knowledge at different levels of formalisation and abstraction.

A good example of this evolution could be illustrated by the recent debate about the integration of the rules in the Semantic Web Stack and how to express business definitions for business use (to represent policies, practices and procedures) whose business rule statements are executable and could be used in rule-driven systems (Kifer, 2005; Horrocks, 2005). Different schools, depending on the main business objectives, have developed different languages that express different semantics and rules. For example, SWRL and RDF_MATCH were developed by the W3C community to express the semantic rules of language, in contrast to SBVR that was developed in OMG circles to express business rules.

In addition to the complexity arising from the need to reconcile different formalisms, also the phenomena that are represented, when described by different observers, are not necessarily the same and may need to be reconciled. When we consider that in a digital ecosystem we can also represent subjective elements of knowledge (reputations, skills…) that have economic and power-relationship implications, the question arises: 'Who has the authority to populate the ecosystem with descriptions?' or, better, 'Who has the authority to say what these descriptions mean, i.e. to provide an interpretation of reality?'. Since the digital ecosystem is fully distributed, cannot be dependent upon any single instance or actor, and cannot have any single point of failure or control, it makes it more difficult for any actor to achieve a "knowledge monopoly".

However, architectural principles can only go so far. The long-term sustainability of the digital ecosystem approach requires a deeper integration between the technology that mediates social and economic interactions and the social processes that create and shape the technology. Here is where the social constructivist approach helps to define a philosophical framework for the solution.

Social Constructivism

In the past, the definition of Truth was provided by institutions that had this authority.[25] The social constructivist (or constructionist) approach, on the other hand, affirms:

It is through the daily interactions between people in the course of social life that our versions of the knowledge become fabricated. Therefore social interaction of all kinds, and particularly language, is of great interest to social constructionists. The goings-on between people in the course of their everyday lives are seen as the practices during which our shared versions of knowledge are constructed. What is considered as truth may be thought of as our current accepted ways of understanding the world. These are product not of objective observation of the world, but of the social processes and interactions in which people are constantly engaged with each other. Descriptions or constructions of the world therefore sustain some patterns of social action and exclude others. (Burr, 2003)

Concepts and categories are developed through language, which provides a framework of meaning. Languages are the necessary precondition for thought as we know it. The ways we understand the world, and the concept and the categories we use are historically and culturally determined, and do not necessarily refer to real divisions. Not only are they specific to particular cultures and periods of history, but are dependent upon the particular social and economic arrangements prevailing in that culture at that time (Burr, 2003). With the advent of the Information Society what we

23) http://www.w3.org/2006/07/layerCake-4.png

24) In biology, phylogeny is defined as 'a succession of organic forms sequentially generated by reproductive relationships'.

25) E.g. in the Middle Ages the Church was the organisation certifying the Truth.

perceive to exist is mostly what exists in the media or on the Internet. The information, or the digital representations of the ecosystem, shapes the user perception of the business ecosystem. The more rich and more 'populated' a digital ecosystem is, the more aspects of the economy can be described and mediated. Thus, when we abandon the mirage of an objective reality and accept that reality is a collectively built and shared perception resulting from a social process mediated by languages, and we apply these insights to the digital world and to formal languages, we gain powerful instruments for development.

Digital Ecosystems research faces similar issues. The problem of regional development cannot be posed as the optimisation of an external and objective "system" within which an equally objective technology can be deployed. Not only is the problem of development fundamentally endogenous, and therefore to be negotiated between the regional stakeholders, but the technology itself needs to grow out of the languages and interactions between these stakeholders (Vaca, 2005). In other words, having embraced a holistic approach that highlights the dependence of the business models and interactions and of their formalisation into software services on their socio-economic and cultural context, no assumptions can be made by external actors about what constitutes an optimum technology for a particular business domain. Technology here is meant in a wider sense that encompasses the distributed infrastructure and middleware, the software services and applications, all the attendant web technologies, and all the software development, requirements capture, and business modelling tools up to the boundary with natural language. Clearly, the closer one approaches natural language, the easier it is to see the relevance of an intersubjective viewpoint.

One of the main methodological points and, at the same time, research objectives of the Digital Ecosystems approach, therefore, is to enable the actors that belong to a region, business domain, or industry sector to describe their businesses and their services from their locally and socially constructed point of view, automating the generation of the software to interface to the underlying mediating technology through appropriate transformations.

Multiple and Subjective Descriptions

The software engineering approach and the Semantic Web approach are based on the description of some aspect of reality through formal ontologies and imposed by experts mediating on behalf of the users. The formal languages used have a high expressive power, but due to their complexity the codification requires mediation by experts. As a consequence, due to the scarcity of human resources, very limited aspects of the 'real world' have been described. Furthermore, the key unconfessed assumption of the first computational ontologists was that the knowledge described is based upon an objective description of the world, although simplified and focussed on the elements that are relevant to the context, as all domain models are. This could be a reasonable assumption in the description of a mechanical system or a business transaction. But it becomes difficult to defend this thesis when defining, for example, the reputation of a company. It is clearly unreasonable to regard the description of the competences, capacity, abilities and talent of organisations or individuals as objective.

This limitation has led to the emergence of a broad range of simpler codifications, less structured and with less expressive power, without predefined categories, but where one does not have to agree on a detailed taxonomy, like the codification made through simple tagging (Halpin, 2006a; 2007). The emergence of collaborative tagging is a natural evolution of the tagging concept itself. Collaborative tagging, social bookmarking etc. do represent the user experience in organising online information, in contrast to the approach of establishing formal ontologies by domain experts. Loose associations of concepts and a greater flexibility and adaptability in organising information links are based on a minimum level of shared meaning that allows the emergence of cooperation among users. Through collaborative tagging users do not need to rely on intermediaries to describe their business, activities, needs, they can participate directly in the modelling of reality. The descriptions made by the users through collaborative tagging are less expressive and detailed than the descriptions made with formal languages; however, being much easier to write, they are effectively made by the users, and the ecosystems are populated (Halpin, 2007).

The point of view of social constructivism, which until a few years ago would have seemed radical or simply strange in most technological fields, is actually rather obviously the basis of the Web 2.0 phenomenon. In fact, we can now say more confidently that most of the evolutions in the Information Society do not depend on the advances in technology, but on exploiting the power of social interactions (Halpin, 2006b).

The translation of this power into a mode of economic production is the central question of open source research.

Open Source in Digital Ecosystems

Two of the three[26] deep trends due to which, according to Dalle et al. (2005), FLOSS[27] has commanded the attention of social scientists are:

- The movement of information goods to centre stage as drivers of economic growth
- The ever more widespread use of the peer-to-peer modes of conducting the distribution and utilisation of information, including its re-use in creating new information goods

These two trends are bound together and reinforced by the growing recognition that the "open" (and co-operative) process of knowledge production offers economic efficiencies that in general surpass those of other institutional arrangements, namely those that address the resource allocation problems posed by 'public goods' by protecting secretive practices, or creating and enforcing intellectual property monopolies (Dalle et al., 2005).

The Digital Ecosystem realises a public good that expands the space of the digital public domain by creating an intangible 'digital commons', a digital resource that anyone within the relevant community can use under content-neutral terms (Lessig, 2002:19-22). The access to the infosphere created by the digital ecosystem commons represents one of the most promising strategies to reduce the digital divide between SMEs and large enterprises. Although there is no consensus yet, many believe that lowering the barriers to entry, reducing cost and investment, and working at the centre of a peer knowledge production process allows small enterprises to overcome the activation threshold needed to use ICT in a novel and productive way.

The Open Source approach has thus been the only possible choice for the Digital Ecosystem infrastructure, not only for the intrinsic behaviours and knowledge sharing needed for the ecosystems to flourish, which would not be possible in a proprietary schema, but also because code, and its access, is not only the law of cyberspace, but also its DNA, its genotype, and its architecture.

Access to code allows the growth of social networks able to build and transform their business/economic environment according to their shared description of the world. However, access to the code does not solve everything. There are many factors that influence the uptake of open source by companies, such as their connections in the open source community, or the know-how of the way the open source process works and the implications of different types of licences. Digital Ecosystems can then be seen as the structure that connects and mobilises such knowledge and that facilitates such processes. Furthermore, if we understand code either as Lessig reads it—the performative law of cyberspace—or as Baudrillard reads it—the hegemonic law of the symbolic and hence of real space—then open source systems become capable of alleviating some of the fears that arise when we deal and rely on closed systems: fears of monopoly, tyranny, and unjust use of power (David, work in progress). Finally, the Digital Ecosystem FLOSS approach is a public good envisaged to be co-produced and maintained by volunteers, and counters the common economic belief that private agents, without property rights, will not invest sufficient effort in the development of public goods because of free-rider externalities (Bessen, 2002).

Open source communities are epistemic communities[28] (Edwards, 2001) organised as a distributed network of agents that are not just based on altruism, reputation or hacker ethics. The key actors in the development of an open source product are the individual contributors companies (for profit and non-profit) and researchers. All sets of actors respond to the legal incentives embodied in open source production.

Up to now economic theory suggests that long-term incentives are stronger under three conditions:
1) more visible performance to the relevant audience (peers, labour market, and venture capital community);
2) higher impact of effort on performance;
3) more informative performance about talent. The first condition gives rise to what economists call 'strategic complementarities'. To have an 'audience', programmers will want to work on software projects that will attract a large number of other programmers". (Lerner, 2006)

26) The third reason is simply the very large amount of empirical data on open source communities and software production, which is certainly important for social scientists but less relevant to this discussion.

27) The acronym FLOSS stands for "Free/Libre/Open-Source Software"

28) An 'epistemic community' is a network of knowledge-based experts or groups with an authoritative claim to policy-relevant knowledge within the domain of their expertise. Members hold a common set of causal beliefs and share notions of validity based on internally defined criteria for evaluation, common policy projects, and shared normative commitments (Edwards, 2001).

The Digital Ecosystems initiative faces such a challenge to build strategic complementarities. Digital Ecosystems surely require a variety of business models to be viable and sustainable in the long run. Some of these models will be based mainly on a new Exchange Economy characterised by peer production behaviour to become integrated with the Gift Economy.[29] In the gift economy a immediate remuneration is not sought, and in many cases it is not expected. Reciprocity is believed to work eventually to provide a 'return on investment' that may in any case be difficult to monetise, such as one's reputation among peers. In other words, an "exchange rate" is required by the companies and the people who straddle both economies.

Social constructivism takes a further step to what we have discussed so far in its recognition of language as a medium of power relationships. We therefore begin to notice that by following a rather tortuous interdisciplinary route we are gradually building a comprehensive structural and process view of a Digital Ecosystem that is compatible with the latest software and web technologies, with social systems and social processes, and with the construction of a shared reality through language—but that we have not quite tackled yet the most difficult problem of all: the governance framework required to arrive at a healthy relationship between knowledge and community.

Open Knowledge, Open Governance and Community

In Digital Ecosystems research we make an explicit claim that knowledge creation and community building processes are inextricably linked. A 'knowledge model' will always also implicitly be a 'knowledge process'. A knowledge creation process, in turn, will also always imply an organisational structure.

The emergence of an organisational structure can be understood as a universal process of institutionalisation that characterises the dynamics of all social groups. From a social constructivist point of view this phenomenon is associated with the formalisation *through* language of power relationships mediated *by* language. If allowed to develop spontaneously and unhindered, therefore, such a process can become an obstacle for democratic processes or knowledge production. It is useful to invoke a natural science metaphor, namely the balance between crystallisation (order, equilibrium) and randomised reconfiguration (chaos, constant variation) that biological organisms are able to strike as a fundamental requirement to remain alive. The 'biological condition' can thus be characterised by its ability to harness its perpetual 'falling' toward equilibrium as an 'engine' that drives order construction processes in the presence, however, of a constant flow of energy, mass, and information that maintains the organism perpetually far from equilibrium and able to adapt to changing environmental conditions.

From our social constructivist viewpoint the constraints on the knowledge production processes brought about by spontaneous institutionalisation processes could then imply a constraint on the social dynamics, and therefore a possible erosion of the democratic processes themselves upon which the community is based. It is therefore important (1) to acknowledge the emergence of power relationships and hierarchies as a direct consequence of the mediation of social interactions by language and communications; and (2) to devise a governance process that can maintain the dynamics of the community "far from equilibrium". In other words, an open community will allow a constant flow of members and ideas to influence its internal knowledge production and decision-making processes. Such a constant flow of 'new blood' will counteract the encroachment of incumbents and the formation of monopolies on any aspect of the knowledge or the community. The mechanisms by which the 'counteraction' is achieved depend on transparency and accountability. The former depends upon and reinforces trust, the latter implies a process of formalisation of behaviour and its comparison with a shared memory of agreed principles of behaviour. Such a shared memory implies a rudimentary form of collective intelligence. We therefore see how the processes of formalisation of knowledge necessarily must begin with a fundamentally reflexive activity of formalisation of community through a transparent and open governance process. In a sustainable community, the dependence of knowledge production on the formalisation of governance hints at the possibility to apply the same reasoning recursively as a general requirement of epistemic communities. The next step in this line of argument would then be to attempt to extend the metaphor to autopoietic systems.

Fig. 4 is a simple schematic that attempts to show the interdependencies between several concepts that have been discussed in this introductory paper. The figure indicates the dependencies between concepts with arrows that

29) "Those who have been waiting for a new and economically viable free-standing business model for free and open source software, one uncoupled to any complementary commercial activity, may justifiably wonder whether they, too, are 'waiting for Godot'. But, instead of any such miraculous business plan, something else has emerged: the apparent willingness of profit-seeking producers of complementary goods and services to source software" (Dalle 2005).

also express a process. In other words, Language leads to Power, which leads to Organisational Structure. Adding Transparency, Accountability, Identity, and Trust leads to an Open Governance and Institutional Innovation process, which breathes new air in the OKS Community. The consequence of community renewal is to keep it open to the production of new knowledge. In the absence of Open Governance, the spontaneous (Self-Organisation) processes of institutionalisation would cause the Digital Ecosystem Community to "fossilise", making self-renewal more difficult and leading to rigid and hierarchical command & control structures. On the right of the figure a similar flow can be seen between more technical concepts and components, also depicted with thicker arrows. This second process is also important for the enablement of the self-renewal of the Digital Ecosystem Community.

It is with this framework in mind that Digital Ecosystems research looks to the future, to arrive at a participatory socio-economic development process that can bootstrap the Knowledge Economy in any regional context to construct a sustainable, global, pluralistic, and democratic Knowledge Society.

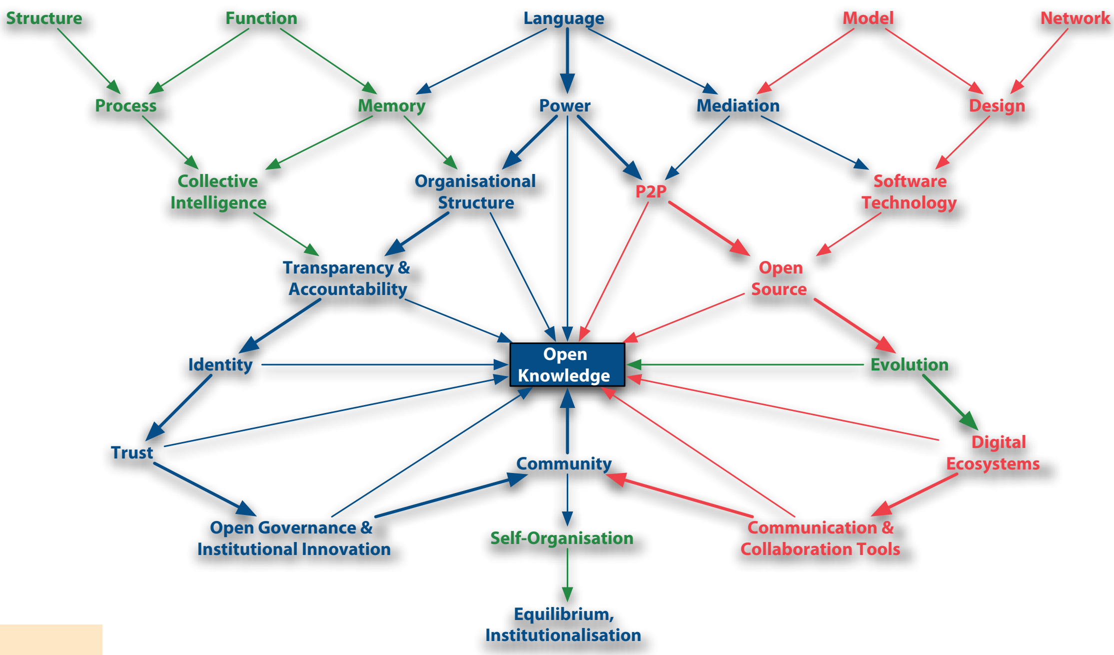


Fig. 4

Flow of innovation through community to sustain open knowledge productio

Over the last four years a path for a new science of the Digital Business Ecosystem has been opened, a community has emerged, the first technological solutions and implementations have been built, the first pilot business ecosystems have been launched, and a network of regional digital ecosystems has been established[30]. The articles in this book will go deeper in the discussion of the achievements of these first years in research (in Section 1 and Section 2), in technology and implementation (Section 3), and in deployment and adoption (Section 4).

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30) REDEN: Regional Digital Ecosystem Network, http://reden.opaals.org

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1

Section One

Science

NEW PARADIGMS

European Commission
Information Society and Media

1 A Scientific Foundation for Digital Ecosystems

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Preamble

One of the most theoretically challenging hypotheses of digital ecosystems research is that biological metaphors and isomorphic models can bring significant advantages to the e-Business software development process, to the self-optimising and self-healing properties of distributed run-time environments and service-oriented architectures, and to ICT adoption in general through greater adaptability of the software to user needs. While the concept of business ecosystem is not new (Moore, 1996) and the application of biological concepts and models to software has inspired whole fields of research, such as Artificial Life, their application to software in an e-Business context is quite innovative. Similarly, whereas the complementary roles companies play in value chains is reminiscent of the interdependence between species in biological ecosystems, using the ecosystem metaphor to conceptualise all the business, economic, and social relationships between all the private and public sector players and the academic/research institutions in a whole region is rather more ambitious. Less contentious, but still far from clear, is the role of Open Source (and more generally of a "Commons") in lowering the barrier of ICT adoption for small and medium-sized enterprises (SMEs), the role all these factors play in catalysing sustainable socio-economic development, and what regional policies can be derived from the research and engagement experience with SMEs. Further, the language-based and collaborative processes through which social networks of SMEs can influence their own sustainability in regional economies are not well understood, but ICTs are widely believed to offer the potential to amplify this social constructivist dynamic.

Overview

The paper will start with a brief discussion of the challenges posed by interdisciplinary research and will show how they largely originate from a dichotomy in how technology can be viewed from the points of view of social science and natural science. Following the social science perspective the paper will argue that the connections between language and technology lead to a recursively self-generating dynamic that is at the basis of the power of self-determination afforded by digital ecosystems. From this view informed by the connections between power and language this paper will *not* venture into an economics analysis beyond making cursory references to the interactions between the exchange economy and the gift economy (Berdou and Dini, 2005). The integration of these different accounts of social and economic action within a digital ecosystem theory is just now beginning to appear possible, but will undoubtedly require several more years of research to achieve an operational consensus supported by empirical evidence. The paper will instead use the inter-subjective view of the world common in some areas of social science, partly inspired by Heidegger's phenomenology, to follow Minger's characterisation of Maturana and Varela's work on autopoiesis as strongly relativist. This provides nothing as grand as a unification between social science and natural science (which is generally undesirable in any case) but, rather, an opportunity to recognise communications as a more modest "hinge" that connects these two rather incompatible disciplinary domains: regardless of how much the two individual domains will grow and evolve, in fact, it will always be possible to claim a strong overlap around concepts of inter-subjectivity and context-dependence of meaning, which characterise both social and biological systems.

Because a science of digital ecosystems promises at least a taxonomy of the fundamental concepts and principles, if not their integration, before surrendering to the allure of biology the line of argument will try to be reflexive and question the assumption that biology has anything at all to teach to computer science. In other words the paper will probe what the term "fundamental" could mean in the context of computer science and will fall back on biology only after a struggle that will hopefully appear convincing. This will finally bring us to the mathematically overwhelming but for some of us more familiar territory of the construction of order in biological and physical systems, of the current debates around possible explanatory theories thereof, and of the possible mappings of such mathematical theories to computer science and software engineering, which might lend some credence to the ambitious claims of adaptability and evolvability made in the Preamble.

Social Science

Interdisciplinarity and reflexivity

The deeply interdisciplinary character of the digital ecosystems paradigm (that is, a body of theory combined with a community of practice and a set of research methodologies (Kuhn, 1996)) forces a recognition of the importance of the role played by the community or communities of research, if only because the barriers in communication across disciplinary domains cannot easily be ignored. Acknowledging the presence of the researchers amplifies the perception of the nature of knowledge as subjective, relativist and pluralistic. As a consequence, if the practitioners in the different fields are to establish a productive dialogue they cannot rely on unspoken assumptions, default scripts, and routine modes of interaction. They need to question themselves and their disciplines to find new contact points, which could be either theoretical or pragmatic. They cannot take themselves and the others for granted. In other words, they need to become reflexive.

As shown in Table 1.1, a simple example of the challenges involved is provided by the very definition of a digital ecosystem. Depending on the disciplinary domain, a rather different answer to the question "What is a digital ecosystem?" is assumed.

Table 1.1

A Digital Ecosystem is…		
Social Science	**Computer Science**	**Natural Science**
• A community of users • A shared set of languages • A set of regulatory norms and guidelines to foster trust • A population of services • An open-source service-oriented infrastructure	• Several categories of users • A set of formal languages • A security and identity infrastructure • A service-oriented architecture • A service development environment • A distributed P2P run-time environment • A distributed persistent storage layer	• A population of interacting agents/ apps • A distributed evolutionary environment • A dynamic, adaptive, learning, and scale-free network infrastructure

The computer science definition is half-way between these two extremes. In fact, computer science has emerged relatively recently, as a lenticular image[1] posing an intriguing puzzle in its shifting identity between the world of technology and the world of people.

1) http://www.shortcourses.com/how/lenticular/lenticular.htm

Cooperation and competition

To ensure the success of the digital ecosystems agenda as a catalyst of sustainable socio-economic development, it is not sufficient to study and support the formation of communities of SMEs around open-source development activities or the creation of new business models, which form the core of the action within digital ecosystems (in the broad, social science sense). We must also develop a consciously and explicitly reflexive methodology of research that can stimulate and inspire a continuous process of self-renewal and innovation in the SMEs and support their participation in the broader scientific community. One of the fundamental assumptions of the digital ecosystems vision is that such a process is strongly dependent on finding the right balance between cooperation and competition. In particular, whereas competition works well in many market contexts, cooperation can amplify the positive network effects around the formalisation and codification of knowledge within industry sectors, business domains, or geographical regions, for instance in the form of shared business modelling languages and of the open source infrastructure of a service-oriented architecture. How this process works in detail for communities of practice and how it could be leveraged within the digital ecosystems vision, however, is not well understood yet. The working assumption so far has been that combining 1) a greater openness to innovation, 2) a community building process that maximises network effects, and 3) an enabling open source digital ecosystem infrastructure should lead to an environment where knowledge is constantly created and shared, flowing freely and dynamically where it is needed. This optimistic view has however run into significant practical obstacles that appear to be grounded in deeper philosophical tensions.

Philosophical tensions

As discussed in Dini and Nachira (2007), the ecosystem approach has brought to the fore the deep ontological and epistemological differences between technological research borne out of the philosophical tradition aimed at designing and building "machines" operating in a well-defined, if reductive, objective reality, on the one hand; and social science research, which is more analytical and interpretative ("hermeneutic") in character and aims to account for the interaction between human action and socio-economic and technical structures and processes in the context of policy development, on the other hand. For example, looking at the intersection between social science and Internet technology, it is far from clear whether principles such as decentralised architectures or P2P networks were derived from a particular social theory, or whether instead the converse applies. In general, it seems more accurate to state that socio-economic and technical systems are interdependent and tightly intertwined, that socio-technical and socio-economic phenomena appear to emerge spontaneously from their interaction, and that social theory then tries to explain them. This state of affairs can be interpreted as evidence that it is not so easy to make a clean separation between the "objective" technology we build and our "subjective" or "intersubjective" human experience (Ciborra and Hanseth, 1998).

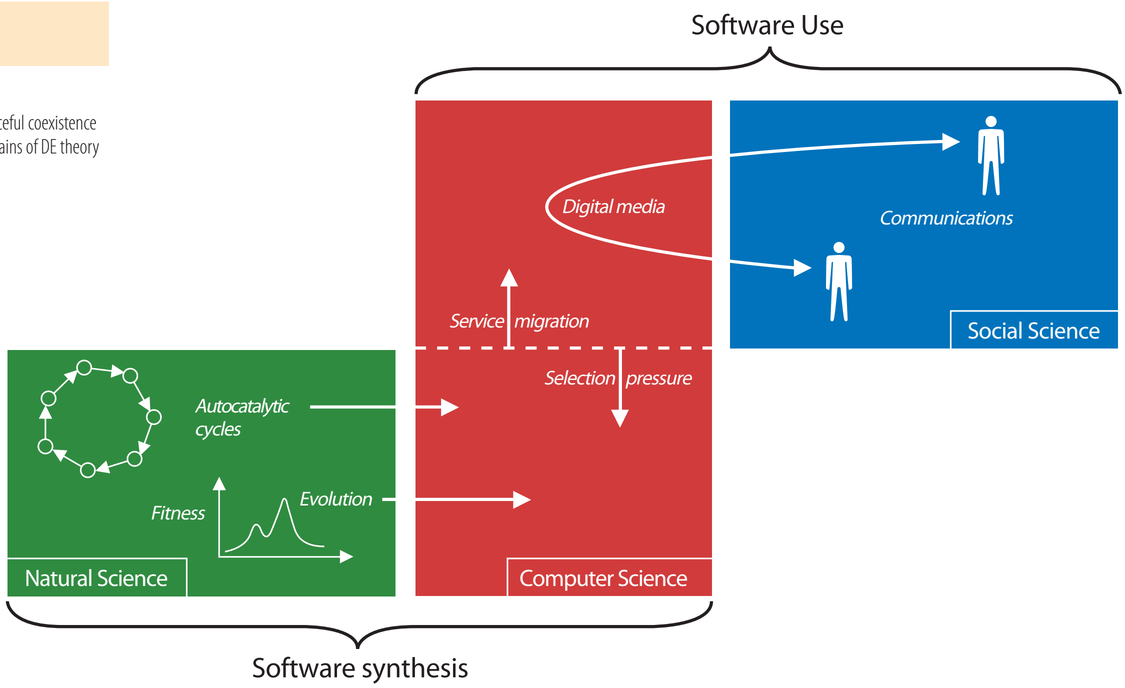


Fig. 1.1

A framework for the peaceful coexistence of the 3 disciplinary domains of DE theory

Fig. 1.1 shows how computer science can play a double role that can be rationalised in a useful practical way from these different points of view, even if they may remain problematic at the philosophical level. From the point of view of social science, the products of computer science are most visible in the form of ICTs whose primary role is to mediate communications between users. From the point of view of natural science, computer science appears to be concerned with the construction of abstract machines whose performance, self-optimisation, and self-healing capabilities could be drastically improved if only we could understand how to emulate biological behaviour in software. By recognising the dual nature of ICT as both communication channel and machine, the figure solves a few problems but leaves a gaping hole: it addresses, even if summarily, software ***use*** and software ***synthesis***, but says nothing at all of software ***design***. Rather than attempting to fit all three aspects of software technology in the same picture, our thread starts again from social science and strikes a new course in the direction of design.

Language

In digital ecosystems research language is seen as the driver and enabler of the construction of social and economic spaces, ICT as a catalyst of this process, and our role to understand how the constructive power of language can be harnessed by ICTs to realise sustainable socio-economic growth at the regional scale. The importance of language as medium of power relationships (with the attendant challenges in the management of scarce resources and in the governance of democratic institutions) is one of the fundamental assumptions of social constructivism. The introduction of technology into the mix, however, adds another level of complexity.

As discussed in Feenberg (2005), in Heidegger's early writings "Aristotle's conception of being in general is derived from the Greek practice of technical making, from τηχνέ". τηχνέ realises the inherent potentialities of things rather than violating them as does modern technology. Compatibly with this position, according to Marcuse the task of a post-Heideggerian philosophy is to conceive a technology based on respect for nature and incorporating life-affirming values in its very structure, the machines themselves. This utopian demand can be understood as "an implicit recovery of Aristotle's idea of τηχνέ in a modern context, freed from the limitations of ancient Greek thought and available as a basis for a reconstructed modernity". Making things (i.e. engineering) can then be recovered as a life-affirming, deeply human activity, as long as we are not blinded by the myth of the neutrality of technology in an objective world. Feenberg's critical theory of technology shows how technology embodies our cultural values and is in fact an extension of our human languages that necessarily generalises the concept of symbol. The language-technology continuum then contributes to the construction of our understanding of reality and in particular of our social reality.

In this panorama of technology recast as an extension of human cultures and languages ICTs play a unique role because, not only do they share with other kinds of technology this cultural and expressive valence, they *mediate* the very communications that construct the social and cultural systems that created them. It is not clear what the effect of this tight feedback loop might be, but it is pretty clear that it is likely to be a strong one, and perhaps not so easy to control. When looked at through a social science "lens", therefore, the hybrid role of computer science is perhaps best captured by Winograd and Flores' view of computers as communication media (Winograd and Flores, 1987). Because communications, in turn, carry commitments (Austin, 1962; Searle, 1979; Flores and Spinosa, 1998), it becomes easier to accept that ICT has the potential to become a catalyst of social constructivist processes.

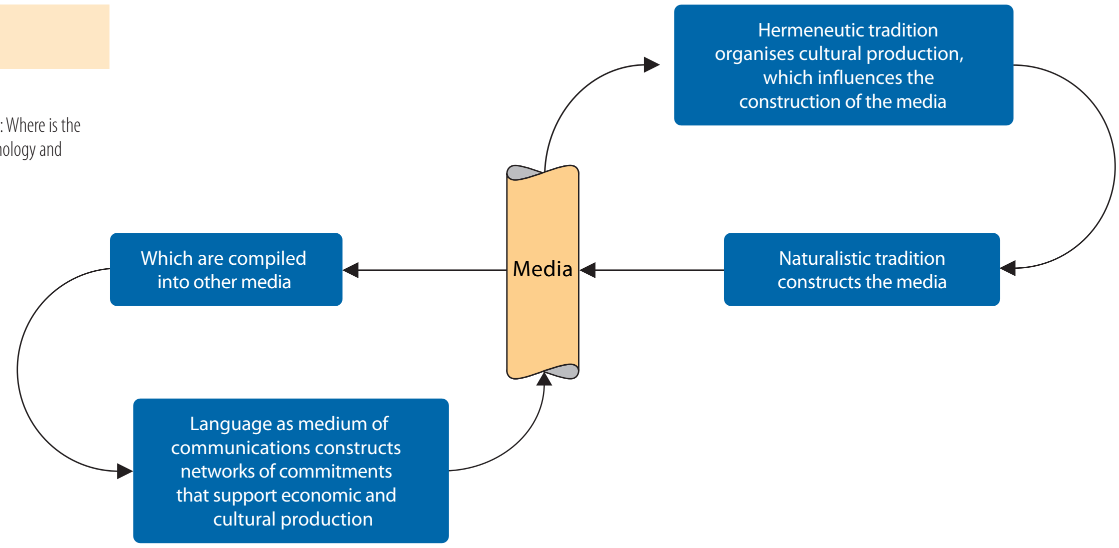
The thread that begins with language, therefore, can be seen to account for software ***design*** and software ***use***, but not software ***synthesis*** in the biologically-inspired sense of the previous figure. As argued at the beginning of the paper, software use or more generally ***communications*** do seem to provide an overlap between these very different perspectives. If we examine the finer-grained structure of language we notice that it can be further divided into a more mechanical and objective syntax, and more intersubjective and context-dependent semantics and pragmatics. The levels are in fact many more than two or three (as maintained in intertextual analysis, cultural studies, literary theory, etc). Communications, therefore, appear to span the whole spectrum of media, from machines to poetry. The discussion so far indicates that such a "media stack" is not linear but loops back on itself in a self-reinforcing dynamic. Fig. 1.2 gives an Escher-like graphical rendition of the feedback loops generated by the interaction of ICTs and media content, which could be described through the metaphor of autopoiesis.

Associative and autopoietic systems

Social science and natural science make uncomfortable neighbours. This should not stop us looking for contact points. Fig. 1.1 shows a pragmatic contact point in the ability of computer science to mediate between the two; Fig. 1.2 represents a theoretical contact point in the use of autopoiesis as a metaphor for a self-reinforcing, recursive, and self-generating process that involves only socio-economic and technical systems. A third contact point can be recognised

Fig. 1.2

The autopoiesis of media: Where is the boundary between technology and people?



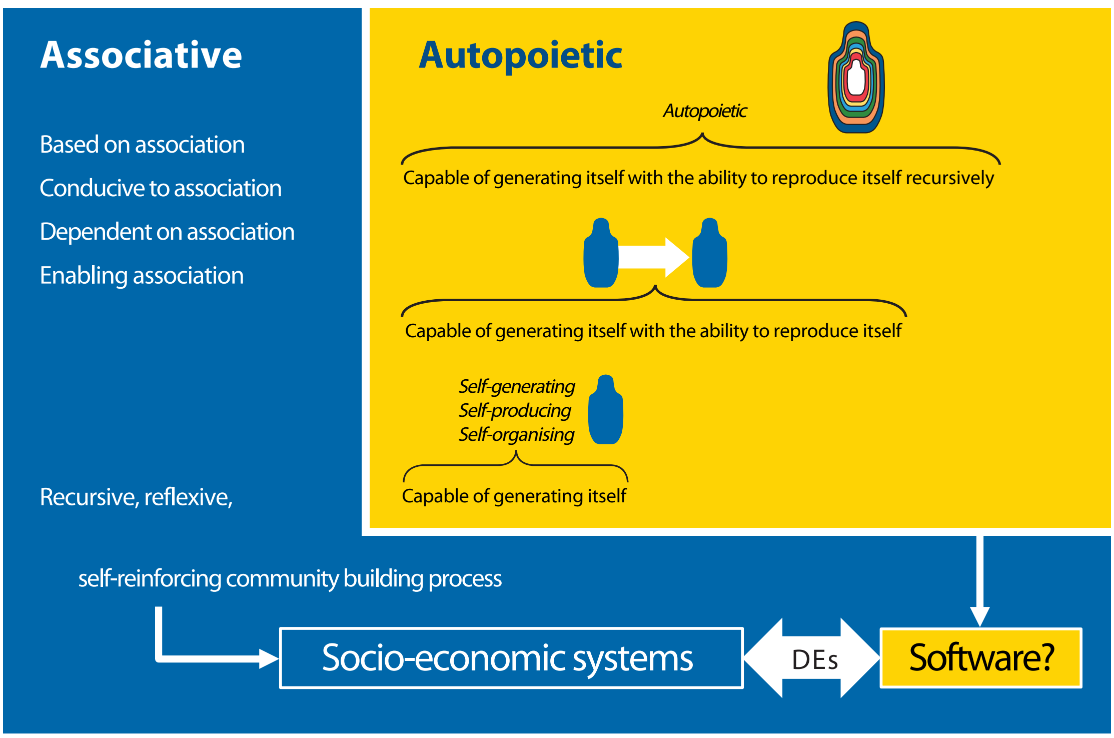
in the resonance between the intersubjectivity of language and the relativist basis of autopoiesis. More generally, digital ecosystems research aims to reconcile the associative (social science) and the autopoietic (natural science) perspectives on socio-economic, technical and natural systems.

Since Maturana and Varela's first publications on autopoiesis (1980, 1998), this theory has stimulated significant interest in a number of fields such as biology, sociology, law and family therapy. Although this theory has been criticised at least as often as it has been acclaimed, its most appealing characteristic in the context of digital ecosystems research is its strongly relativist position, which makes it stand out among most of the other objectivist theories of natural and physical systems. This is well summarised by Mingers (1995):

…I think that in a particular respect Maturana's work represents a distinct advance on classical phenomenology, a major criticism of which is that it is essentially individualist and has great difficulty in generating the intersubjective nature of social reality. Here Maturana begins from an intersubjective position. We are (as self-conscious beings) constituted

Fig. 1.3

Digital ecosystems enframe socio-economic and biologically-inspired software systems



through our language, and language is inevitably an intersubjective phenomenon. As Wittgenstein also argued, there can be no such thing as a private language. Thus language is essentially a consensual domain of agreements, of structural coupling that permits the operations of observers (p. 110).

Even if we acknowledge that autopoiesis has not been able yet to make the transition from a descriptive to an explanatory theory, Minger's words reinforce the impression that it can provide a useful conceptual framework upon which to base a productive dialogue between natural and social science. There remain big methodological differences, but autopoiesis can provide a common epistemological and ontological ground, i.e. how knowledge and a shared reality are constructed through an intersubjective process in both biological and social systems. In particular, the common philosophical problem at the core of a theory of self-organising digital ecosystems, regardless of the disciplinary viewpoint, is how associations and interactions between individual agents or actors can give rise to supra-individual or systemic behaviour, and how global and associative behaviour can in turn influence and constrain—or enable—individual action.

In the physical and biological sciences such interdependence between scales is not in question, although different theories have been developed to account for the observed emergent phenomena in different contexts. In the social sciences, on the other hand, a debate has been raging for centuries around how best to explain and understand social and economic action. Although digital ecosystems research does not pretend to be able to provide final answers to these long-standing questions, it does address challenges of a social, technical, economic, and biological nature through a pluralistic methodology that aims to find a balance between systems and individuals; between context-free models and social processes borne out of diverse cultural and economic contexts; and between optimistic accounts of intelligent and evolutionary technological infrastructure and qualitative empirical data that documents the conflicts and barriers SMEs face daily to make ends meet.

Fig. 1.3 summarises the systemic interpretation of associative and autopoietic systems and the claim that digital ecosystems can provide an environment of constructive interdisciplinary interdisciplinary interaction at the theoretical and applied levels.

Computer Science

Fundamental considerations

Touching on some of the philosophical underpinnings of socio-economic and socio-technical systems is uncovering that concepts of power, language, value, and trust play recognisably fundamental roles, based on which the development of a theoretical framework for digital ecosystems is beginning to appear as a plausible possibility from the point of view of social science. Correspondingly fundamental concepts in computer science have been slower in coming, undoubtedly due to the relatively young history of the discipline.

But, what does "fundamental" mean in computer science? There is no limit to the level of abstraction at which data structures or algorithms can be defined in computer science. Everything and anything is fair game. Therefore "fundamental" characteristics or rules of computing systems in a physics or biology sense can only imply the introduction of constraints on the universe of possibilities. How can this possibly be a good thing?[2]

If we look at computer science as a formal system defined in an abstract and objective space of possibilities, similar to "pure" mathematics and divorced from common human experience, then the argument for leaving it unhindered seems legitimate. If instead we accept computing in its many forms as a vast formal system of languages and technologies that acquires meaning through its interactions with its users, then a relativist epistemology becomes immediately relevant. Whether we wish to treat it as a closed and deterministic system (the "top-down" software engineering process: requirements, specification, modelling, implementation, testing, iterate) or as an open and emergent system (the increasingly popular evolutionary computing "paradigm": mutate, cross-over, implement, select, iterate), the meaning of the software remains entirely dependent on the existence of its users. Take the users away and you are left with arbitrary binary strings.

Or perhaps not? There is the concept of time, or the clock. There is the concept of interaction. There is the concept of state and of state transition. There is the concept of computation as an arithmetic operation on binary strings. Even if we do not force any particular way (architecture) to connect these concepts, there does seem to be some "fundamental"

2) Based on a conversation with Professor Vinny Cahill, Department of Computer Science, Trinity College Dublin (2003).

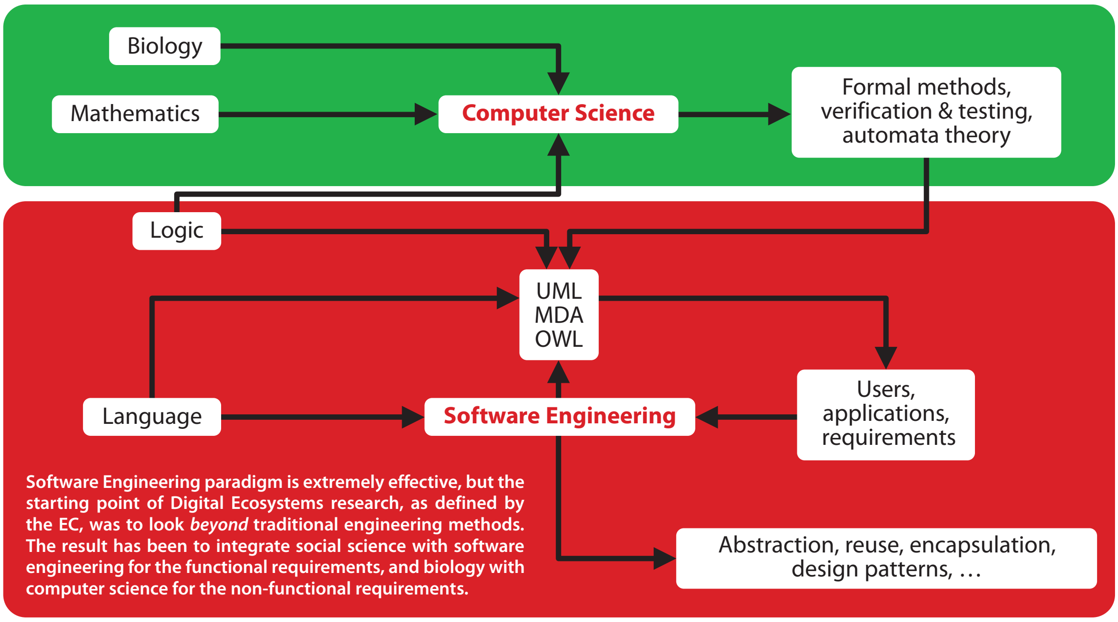


Fig. 1.4
Looking for a useful framework

structure after all, a structure that has much in common with the mathematical structure of the physical universe—which we could allow ourselves to endow with some degree of objectivity. These two views could be reconciled by recognising that the theoretical foundations of software engineering and computer science are different, even if they do overlap on many points. In addition, software engineering is strongly biased toward the functional requirements of software applications, whereas computer science is more concerned with the non-functional requirements. We do not pretend to resolve such a complex set of issues for the huge and growing discipline of computing so easily, but Fig. 1.4 proposes such an oversimplification that could serve as a starting point for discussion.

Assuming that the above is a plausible initial approximation at a framework that can reconcile the different tensions experienced by software engineering and computer science, and by the corresponding communities of practitioners, this figure shows how biocomputing needs to focus on mathematics, biology, and automata theory before it can usefully address software engineering concerns. The rest of this chapter is structured according to this view.

Beyond Turing Machines

As discussed by Golding and Wegner (2005), computer science has in fact been constrained for a long time, specifically since the emergence of the mathematical perspective of computing that identifies algorithms with the evaluation of mathematical functions and that culminates with the Turing Machine "dogma". In the mid-60s Milner started to realise that deterministic finite automata (DFAs) were not quite adequate to model interaction between processes, and he started wondering why automata theory did not allow automata to interact.[3] Perhaps something closer to Mealy automata, which generate an output for every state change triggered by an input, could be harnessed? Fifteen years later Milner and his collaborators (in parallel with Hoare who developed CSP, the calculus of Communicating Sequential Processes) had developed the Calculus of Communicating Systems, which models processes exchanging data along channels that connect them in a fixed topology. Ten years after that he published the π-calculus (Milner, 1999), in which also channel names can be passed along channels, thereby achieving the ability to model variable topology, which is equivalent to mobility.

Hoare, Milner and others have long realized that TMs do not model all of computation. However, when their theory of concurrent computation was first developed in the late '70s, it was premature to openly challenge TMs as a complete model of computation. Concurrency theory positions interaction as orthogonal to computation, rather than a part of it. By separating interaction from computation, the question whether the models for CCS and the π-calculus went beyond Turing machines and algorithms was avoided. (Golding and Wegner, 2005)

3) Interview with Robin Milner conducted by Martin Berger (2003). http://www.dcs.qmul.ac.uk/~martinb/interviews/milner/

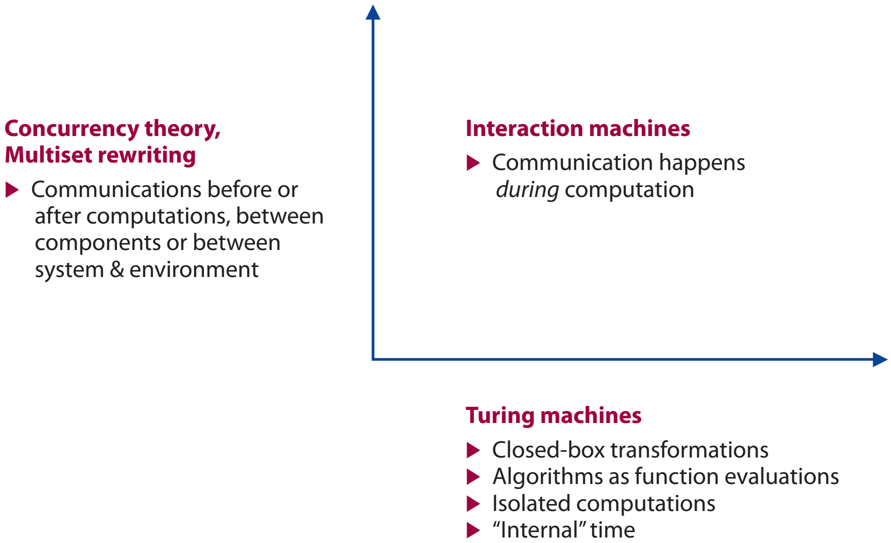


Fig. 1.5
The three main models of computation

Fig. 1.5 shows graphically where interaction fits relative to algorithms and concurrency. Golding and Wegner's paper represents the culmination of a 10-year research effort initiated by Peter Wegner where he addresses the foundations of computer science in order to develop a self-consistent theoretical framework for distributed and interactive computing. He shows how Turing Machines (TMs) were never intended to provide a model of computation for distributed and interactive computing, but were ascribed that role through a series of conceptual adjustments (misinterpretations) of the original theory motivated by practical concerns. This has led to a divergence between computer science and software engineering. Recognising the legitimacy of an extension of the concept of computation and exposing the historical reasons due to which the misconceptions developed, Golding and Wegner provide a clear explanation of the limits of TMs and lay the groundwork for the development of a theory of interaction machines.

Indeed, Turing himself was very clear about the scope of his formal result. In his 1936 paper (Turing, 1936) he spoke of different kinds of computation, including interactive computation. The technological limits of the first computers that were built in the 1940s and 50s, however, highlighted the single-processor von Neumann architecture and hid the other possibilities. As Golding and Wegner explain, computer science textbooks from the 60s were not uniformly precise in their definitions of algorithm, facilitating the emergence of the perception that all computable problems can be described by an algorithm and that TMs can model any computation. This was partly motivated by the need for software and telecommunications engineering to address practical problems that initially led and soon outstripped the much slower theoretical developments of computer science. They conclude their article recounting the claims that have emerged since the 1936 Church-Turing thesis was published and that make up its common but faulty intepretation. They then provide amended versions of these claims to reflect the original intended meaning of the Church-Turing thesis (Golding and Wegner, 2005):

Claim 1.	(Mathematical worldview) All computable problems are function-based.
Claim 2.	(Focus on algorithms) All computable problems can be described by an algorithm.
Claim 3.	(Practical approach) Algorithms are what computers do.
Claim 4.	(Nature of computers) TMs serve as a general model for computers.
Claim 5.	(Universality corollary) TMs can simulate any computer.
Corrected Claim 1.	All algorithmic problems are function-based.
Corrected Claim 2.	All function-based problems can be described by an algorithm.
Corrected Claim 3.	Algorithms are what early computers used to do.
Corrected Claim 4.	TMs serve as a general model for early computers.
Corrected Claim 5.	TMs can simulate any algorithmic computing device.

Furthermore, the following claim is also correct:

Corrected Claim 6.	TMs cannot compute all problems, nor can they do everything real computers can do.

The view that TMs cannot cope with interactive computing continues to be categorically rejected by most practicing computer scientists. Clearly any algorithm, even in the context of interactive computing, can be represented *a posteriori* by a Turing Machine. The problem arises when one does not know who or what might interrupt an algorithm through an unpredictable and independent external input, when that might happen, and what an appropriate response might be. It is true that we design and implement applications that wait for events before proceeding, or that easily handle being interrupted by unpredictable events, but achieving an appropriate response that has not in some way been programmed in advance seems beyond the range of present possibilities. Whether or not such scenarios are computable by Turing Machines may take a long time to prove in a definitive way to everyone's satisfaction. In the meantime it is probably a matter of personal choice which point of view one chooses to adopt, since such viewpoints do not prevent us from *building* new conceptions and new architectures of software systems. This discussion is still relevant, however, because we need to develop a rationale for attempting a radically different approach at computer science and software engineering. In the absence of mathematical or logical proofs we are limited to relying on "circumstantial evidence" and intuition. If we achieve something useful or interesting we will leave the statement and proof of any corresponding theorems to a later phase of the research.

In Digital Ecosystems research we are examining a further conceptual extension that can be referred to generally as a "distributed algorithm", a term that is increasingly gaining currency in the literature (Babaoglou et al., 2006). In the present discussion we mean an algorithm in a particular software module that is incomplete and can only be completed through interaction with another module or through its "environment". The motivation for such a concept arises from the increasing need for software to adapt automatically to its context, and to continue adapting as its context changes. An architecture capable of handling such a generic and ill-defined requirement differentiates between repeatable, general, and reusable properties of the software and customisable, context-specific properties. Software engineering has evolved precisely in this direction, through its reliance on design patterns for the former and parametric or case-based adaptation for the latter. Rendering the adaptation process autonomous, i.e. not internally pre-programmed, necessarily requires the software to acquire relevant information externally, from its environment. The only way such information can be aquired is through some kind of interaction.

As the number, scope, and recursion levels of such hypothetical algorithm construction steps through interactions increase, it becomes increasingly difficult to see an infinite linear tape and tape head as an adequate conceptual model of the corresponding computation. Be that as it may, while the search for the most appropriate theoretical model of computation continues it will hopefully not seem too implausible to claim that interactions are as fundamental to the brand of computer science that underpins digital ecosystems in the narrow sense as power, language, value, and trust underpin digital ecosystems in the broad sense.

Do we need more structure?

The introduction of interactions has not constrained computer science, it has actually enlarged it. This is easily seen by the fact that the π-calculus (which is Turing-complete) can represent any computation expressed in λ-calculus (the Turing-complete theoretical archetype of all functional programming languages), but the converse is not true, i.e. not every π-calculus computation can be represented in λ-calculus. Such a strong claim is actually not easy to find stated so starkly in the literature. The sense given here, however, can be extracted from a few quotations taken from the current reference text on π-calculus (Sangiorgi and Walker, 2001), written by two close collaborators of Milner's:

…the π-calculus can actually do the old job which the λ-calculus does in underpinning conventional programming (R Milner, in the Foreword) … The π-calculus has two aspects. First, it is a theory of mobile systems. … Second, the π-calculus is a general model of computation, which takes interaction as primitive (p. 3). … The λ-calculus, in its untyped or typed versions, cannot describe functions whose algorithmic definition requires that some arguments be run in parallel. … In contrast, the π-calculus naturally describes parallel computations. The π-calculus 'world' is that of processes, rather than functions. Since functions can be seen as special kinds of processes, parallel functions like Por ['parallel or'] can be described in the π-calculus (p. 427). … the class of π-calculus contexts is much richer than the class of λ-calculus contexts … In the π-calculus one can express parallelism and non-determinism, which … are not expressible in the λ-calculus (p. 480).

Faced with the ability to represent and describe the behaviour of an arbitrary number of concurrent processes interacting in arbitrarily complex ways, the response of the formal testing, verification, and simulation methods of computer science (including the π-calculus creators) has been to limit the space of possibilities to formal systems that could be completely defined (the actual number of states for such systems might still be combinatorially large). It is not clear whether we have explicitly limited the expressive power of the calculi of concurrent systems (also known as process algebras) to deterministic systems or whether such calculi are intrinsically limited in this manner. A broader question that seems "fundamental" and worth asking is whether formal systems can be emergent. A linguist would probably reply "Yes". The related more applied question that lies at the heart of digital ecosystems theory (in the narrow sense) is whether computable, or computing, systems can be emergent.

The relevance of emergent structure and behaviour in software is justified by the need to develop software frameworks that can support the adaptation to new and unforeseeable circumstances and requirements. Given the present state of the art, if we relax the deterministic constraints in the formal system that is supposed to model such a software framework, we are left with a ship without a rudder. We are hard-pressed imagining how an incomplete specification of a software system can result into a useful and functioning piece of technology, or how an incomplete formal model can verify anything at all. In such conditions the need for more structure appears evident. The response from the connectionist "camp" of Artificial Intelligence has been the incremental and iterative construction of structure based on the information provided by the target behaviour. Incremental construction implies the presence of a memory mechanism to store intermediate representations, thus making it increasingly difficult to ignore the relevance of biological systems to the discussion.

Whereas on the short time-scale of the individual organism memory is associated with learning, biological evolution generalises the concept of memory to act across generations and over time-scales of the same order as the age of the Earth. In both cases the emergence of structure happens through a passive order construction process that we could equate to a form of pattern replication. In biological systems the pattern is given by sensory inputs or by the selection pressure on a given species arising from the ecosystem within which that species is living. In computer science much simpler frameworks have been developed in the form of neural networks and genetic algorithms, both of which blindly reproduce a desired behaviour or meet a particular set of requirements through many iterations and incremental adjustments that coarsely reflect, respectively, our current limited understanding of neural and evolutionary mechanisms.

This cannot be the final answer. If we assume no relationship between external behaviour and internal structure, then desired external behaviour can only be achieved by a random trial-and-error process of incremental structure formation and rearrangement coupled with a notion of "fitness" and a selection mechanism until the structure finally exhibits the desired target behaviour. If, however, we assume that desired external behaviour is related in some way to internal structure, we might start thinking of other questions. If for example we notice that internal structure is more often than not modular and nested, then we might wonder whether external behaviour might not be somehow related to internal interactions between modules at different scales and between different scales.

Granted that this can be seen as nothing more than the description of any one of the hundreds of thousands of software applications running on the millions of processors and computers in the world today. But how were such applications constructed? Does the fact that they were constructed by relying on the logical relationships between representations at different levels of abstraction, otherwise known as "design", mean that design is the only way to achieve such structures and behaviours? The widespread use of design patterns in software engineering has not led us to wonder if there might be underlying "laws" that give rise to similar patterns in similar situations. We appear to be content to apply the same logical deduction process every time we design an application, a process that starts with user requirements and ends with a class diagram. The class diagram together with other UML views can be seen as a modularisation of code with well-defined interfaces between the modules, so that the writing of functional code within these boundaries can again be deduced logically from the "boundary conditions" themselves. Reuse of patterns cuts down drastically on design time, which is good. But where do these patterns come from?

In physics we can explain the shape of a soap bubble through the local relationships between individual soap and water molecules; but we can also invoke the deeper principle of minimisation of potential energy to arrive at the same geometry with less effort. In the design of complex mechanisms we can likewise invoke global principles and conservation laws that greatly simplify the process relative to what a deterministic Newtonian approach could afford. The reliance on a relatively small number of "fundamental"[4] principles in physics to explain a practically infinite number of observable phenomena is compatible with causal logic over a significant range of length scales, but not over *all* length and time scales. For example, conservation of energy (if we allow for the mass-energy of relativity) applies everywhere and at every scale, whereas deterministic Newtonian mechanics is rather more limited.

Is logic the only framework we can rely upon to construct order? Are there alternative organising principles and frameworks? Logical frameworks are being continually developed, extended, and refined, with corresponding improvements in their expressive power. They help us describe and verify the behaviour of systems defined through formal specifications. This is impressive, but is it enough to achieve open, adaptive, and emergent software systems?

4) Richard Feynman, one of the foremost physicists of the 20th Century, says in (Feynman, 1965), "I think I can safely say that nobody understands Quantum Mechanics", and in Volume 1 of (Feyman et al., 1965b), " It is important to realise that in physics today we do not know what energy is (p. 4-2)" [emphasis in the original]. In other words, more often than not the fundamental concepts of physics remain slippery and mysterious axioms or tautologies, even if they can in fact explain a large number of observable phenomena.

Can we formalise, or specify, useful design patterns within a framework of non-deterministic and emergent interactive computing? The answer to the question at the top of this section appears to be that we need less structure than that afforded by deterministic formal frameworks, but more structure than what evolutionary computation embodies. A mathematical theory that might do just that is the theory of groups, which can equivalently be regarded as a theory of symmetry (Armstrong, 1988) and which lies at the foundations of physics and of much of mathematics.

If we have succeeded in arguing for the need for a theory of emergent computation based on interactions and symmetries, perhaps it may seem justified to bring in biology at this point.

Natural Science

Biological development as metaphor for the construction of order [5]

In 1993 Stuart Kauffman, a theoretical biologist, argued in a long and complex book that in his opinion evolution by natural selection was not a sufficiently powerful order construction process (Kauffman, 1993):

… Darwin's answer to the sources of the order we see all around us is overwhelmingly an appeal to a single singular force: natural selection. It is this single-force view which I believe to be inadequate, for it fails to notice, fails to stress, fails to incorporate the possibility that simple and complex systems exhibit order spontaneously (p. XIII, Preface).

In other words, something more has been at play to explain the infinite variety of life forms that we observe around us and that are organised in a recursive nested hierarchy of form and function over 10 spatial orders of magnitude from the periodic table to the Blue Whale. The growing general consensus is that morphogenesis and gene expression embody additional "machinery" that adds a "turbo-charger" to the evolutionary order construction process. For example, in a recent collection of papers exploring the boundary between biology and computer science Kumar and Bentley (2003) say,

Natural evolution has evolved countless organisms of varied morphologies. But before this astonishing diversity of life could evolve, evolution had to create the process of development. … Central to development is construction and self-organisation (p 2) … The main goal of developmental and evolutionary biologists is to understand construction (p 9) … In technological fields, the dream of complex technology that can design itself requires a new way of thinking. We cannot go on building knowledge-rich systems where human designers dictate what should and should not be possible. Instead, we need systems capable of building up complexity from a set of low-level components. Such systems need to be able to learn and adapt in order to discover the most effective ways of assembling components into novel solutions. And this is exactly what developmental processes in biology do, to great effect. (p 10).

Kumar and Bentley go on to ask why we should bother with development when evolutionary algorithms (EAs) can evolve solutions to our problems. The answer lies in the fact that

…for traditional EAs … typically there is a one-to-one relationship between the genotype and the correspoding solution description. … As solutions become more complex, the length of the genome encoding the solution typically increases. … Instead, evolution by natural selection evolved a highly intricate, non-linear method of mapping genotype to phenotype: development. … Development has enabled evolution to learn how to create complexity. (p 10)

Even though genetic programming operates at a higher level of abstraction, and is therefore correspondingly more powerful in terms of expression of functionality and closer to a non-linear mapping, it relies on the same genetic operators (mutation, cross-over and selection) as genetic algorithms as the basis of the order construction process.

In fact, evolution is not very creative at all. It relies on sexual reproduction and on mutation to recombine existing traits and to create new traits, respectively. This is the constructive part. Natural selection is the "subtractive" part, i.e. most mutations perish, only the best-adapted survive and reproduce. We are looking for additional principle(s) that can bolster the constructive part. As mentioned above, a potential candidate is the field of mathematical symmetries.

5) See Dini (2006) for a more extensive discussion.

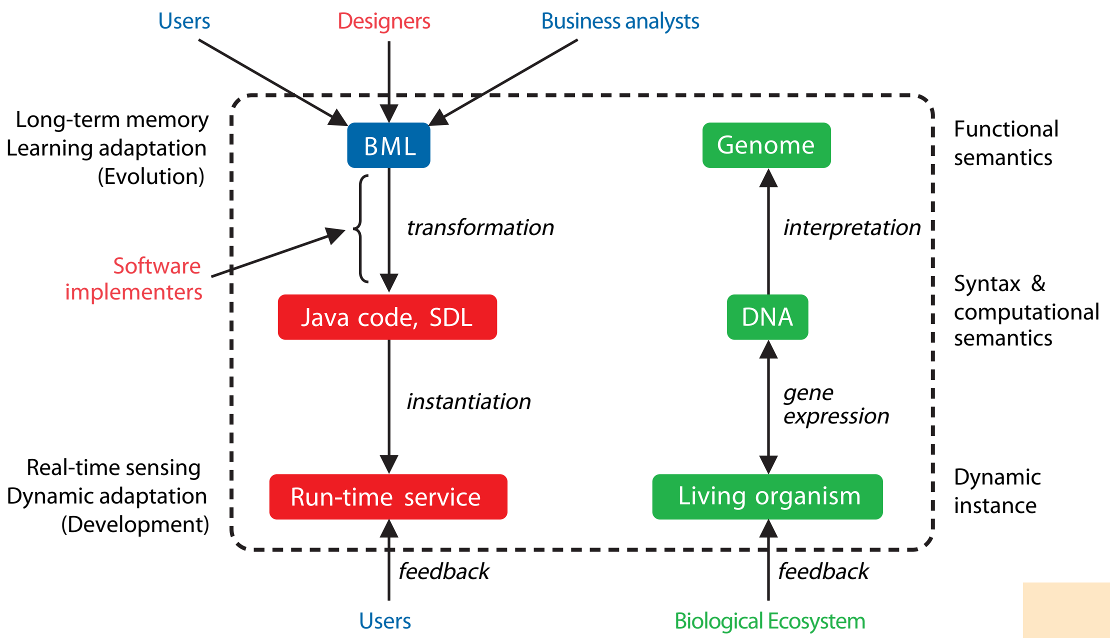


Fig. 1.6
High-level analogy between software engineering and gene expression workflows

Within biology (as a discipline) symmetry has been pioneered as an organising concept by D'Arcy Thompson (1992). How do we make symmetry understandable and, more importantly, how do we connect it to software in a useful way? Let's contextualise the discussion to digital ecosystems before developing this question further.

Whether we call it "non-linear mapping", "distributed algorithm", or some kind of generalised run-time context sensing, it seems pretty clear that we are still looking for an autonomous and stable process framework that is able to construct complex software structures and behaviours from high-level specifications, in response to run-time needs and to specific and information-rich contexts. Fig. 1.6 shows the most recent understanding[6] of how the concepts discussed here may be brought together to provide a starting point for the challenging problem of "software development".

DNA can be considered a high-level specification of the organism, and expression of the DNA into a living organism is fundamentally dependent on the interactions between the DNA and its environment. In addition to carrying information on morphological and behavioural traits between generations (evolution), and in addition to serving as the blueprint of the organism (morphogenesis), the DNA also "runs" the body metabolism. Gene expression covers the latter two functions. The interactive character of gene expression and the complementarity of DNA and its environment imply that biological processes are characterised by a distributed, parallel, and collaborative form of "computing", where by computing we mean the breathtakingly fast and hierarchically nested succession of interconnected states and signals from molecular to macroscopic scales.

Whereas gene expression could be associated with automatic code generation (here labelled "transformation"), it seems to map better to run-time instantiation or just-in-time execution. The implication is that BML (Business Modelling Language) models are not anymore regarded as equivalent to "the DNA of the services". This is actually not as big a shift as it might appear at first. In fact, a common interpretation of DNA lumps together its syntactical aspect (code) with its *functional* semantics whereas, strictly speaking, in biology DNA is just a pattern of organic molecules obeying a precise syntax and *computational* semantics.[7] The functional semantics (which gene is correlated to which behavioural or structural trait) are arbitrarily imposed by us and are collectively referred to as the genome of the individual (or the species).

6) I am grateful to Gerard Briscoe and Giulio Marcon for their contributions to this diagram.
7) I made up the terms "functional semantics" and "computational semantics", which in the present context seem to make sense. I believe the latter is actually called "operational semantics", but the mapping is not immediate. For example, Wynskel (1993) breaks down formal semantics into operational semantics, denotational (or mathematical) semantics, and axiomatic semantics. All three categories are much closer to the computational machine than to the "business semantics" or "functional semantics" discussed here. See D18.4 and other DBE deliverables (e.g. from WP9) for further discussion.

Another point this figure highlights is that whereas in biology species evolve by balancing development with natural selection by the ecosystem, in the context of digital ecosystems we have an opportunity, and a requirement, to enable the "design" or at least the specification of the characteristics of the digital species. The two opposing streams of information that this implies (design-time formalisation and run-time feedback) were recognised from the very beginning of this research. Also in the figure above they can be reconciled by emphasising their different granularities and the adaptive nature of the bottom-up process.

The left column is more problematic. Even if we assume that the UML or BML functional specification can be translated into Java automatically, it is not necessarily obvious or correct to equate Java to DNA. None-the-less, the instantiation of a software entity into RAM does have something in common with gene expression and morphogenesis (although it happens much more quickly), for example in the sensing of available RAM, necessary APIs, and so forth. So the stage between BML and Run-Time Service is labelled as "code" only for the sake of clarity. Our expectation is that in the long term the meaning of "code" and of "code generation" will change. With the continued fragmentation of monolithic applications into declarative/structural code and reusable functional modules, as basic functionality is encapsulated into ever-smaller reusable modules and atomic components, and as these modules are increasingly "shed" by applications and are absorbed by the distributed computational environment, we are not far from being able to jump from BML directly to run-time behaviour.

In the remainder of this chapter we will analyse in greater depth the relationships between the boxes shown in Fig. 1.6, in an attempt ot develop a theoretical framework for the science that is emerging at the boundary between biology and computer science.

From metaphors to isomorphic models

The flip-side of biologically-inspired computing is the new field of computational biology. We should be careful to differentiate between bioinformatics, which is concerned with all of the computer science and software engineering tools, frameworks, algorithms, architectures, and data structures that *support* biological research (for instance the Genome Project), and computational biology, which seeks to utilise computer science concepts and frameworks to *model* biological systems, in particular the biochemistry of the cell. In digital ecosystems research we are concerned with the latter and not at all with the former, other than as one of the many manifestations of "knowledge" that can be mediated by and shared through digital ecosystems and that is therefore relevant to the first half of this article. The convergence between biocomputing and computational biology is very exciting because it is making it possible for biologists and computer scientists to work on the same modelling frameworks even if they are then applied to radically different systems.

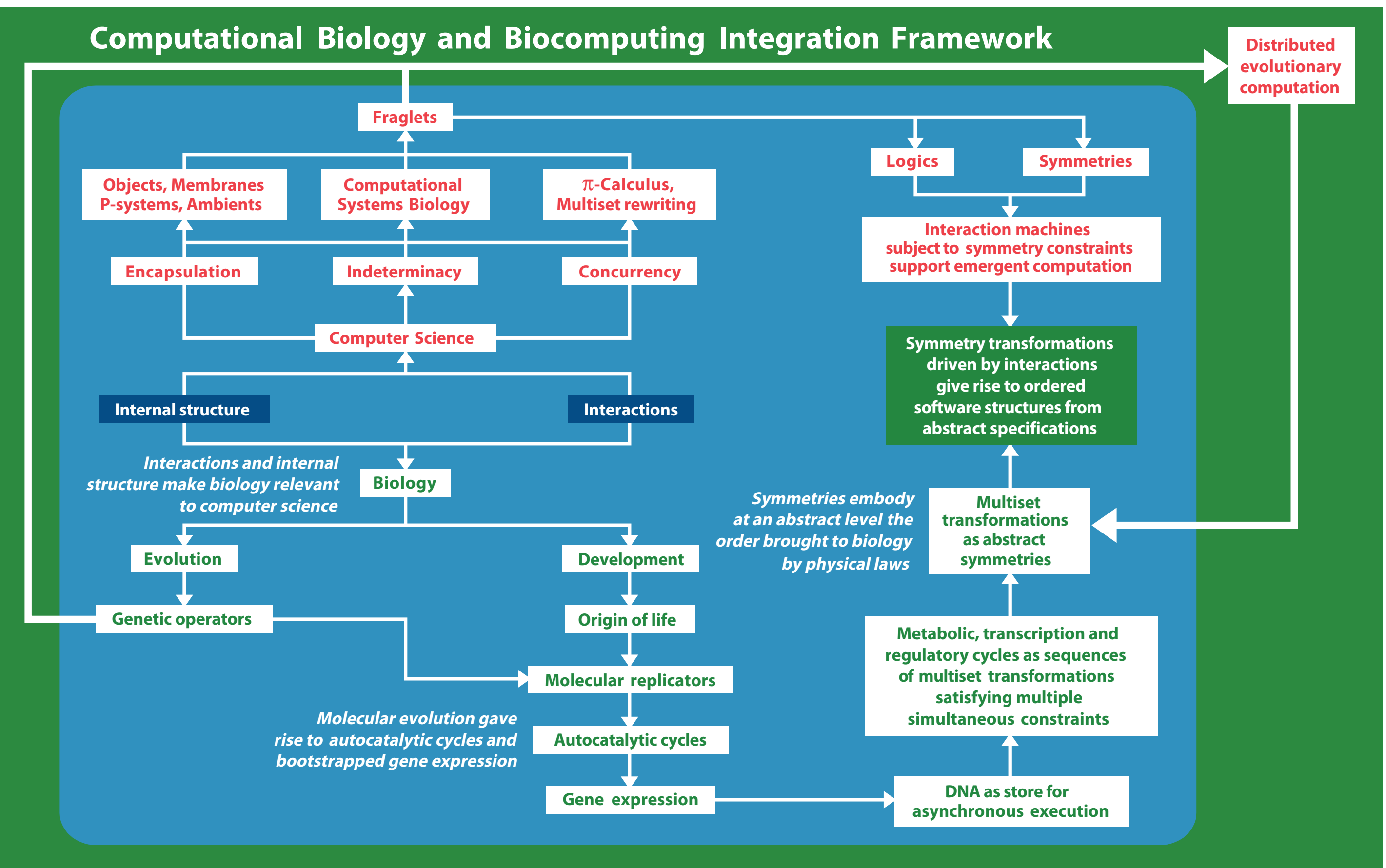


Fig. 1.6

Toward a common mathematical framework for biology and computer science

Fig. 1.7 is an attempt at an integrating conceptual framework between these two increasingly complementary and interdependent sub-disciplines. The figure relies on the familiar metaphor of the organism (blue rounded box) embedded in an environment or ecosystem (green background), implying an analogy with a software service embedded in a digital ecosystem (in the narrow sense). The text-boxes shown, however, are not the components of such an organism/service or ecosystem/digital ecosystem. Rather, they are those areas of research in computer science, biology, and mathematics that are relevant to the different parts of the metaphor and that have already been accepted as central (most of the lower half of the figure), that are gaining acceptance (top-left quadrant), or that are far from proven and are currently being assessed in digital ecosystems research (all the references to symmetries).

The figure starts with the concepts of interactions and internal structure and presents those aspects of computer science that, by chance or by design, are giving rise to an increasingly "biological" conception of computing. Digital ecosystems research so far has mainly been concerned with the mapping of all the boxes shown on the left, associated with biology and computer science, and with the development of a distributed architecture that can support evolutionary computing, shown on the outside as a feedback. The same concepts of interactions and internal structure are central also for a rationalisation of biological systems through the processes of evolution and development, whose interdependence has led to increasingly complex organisms and processes, such as gene expression. It is helpful to recount very briefly how this might have happened.

Evolution has evolved gene expression. Thus, evolution is indeed the starting point. At some point, by chance, some of the molecular species populating the primordial soup acquired the ability to make copies of themselves. The first replicators were born. The competition between replicator species in the race for the absorption of sunlight and loose nutrients (sugars or whatever else) in some cases turned into cooperation, where two or more interdependent species acquired an evolutionary advantage over species acting on their own. These were the early "value chains" of the primordial soup. In the case where the chain of interdependencies between replicators closed back on itself an "autocatalytic cycle" formed. This cursory reference could never do justice to the large bibliography on replicator dynamics (Eigen and Schuster, 1977-78; Stadler and Stadler, 2003; Stephan-Otto Attolini, 2005) that, over the past several decades, has pieced together a plausible scenario for how the initial molecular replicators gradually bootstrapped themselves into RNA and slowly into families of interdependent structures. When one such structure, the membrane, closed around such a family in a symbiotic (i.e. mutually beneficial or synergistic) relationship the first cell was born.

The cell is composed of parts that conspired to reproduce themselves at each step of their evolution. It is a super-structure that organises sub-structures, that are themselves nested hierarchies of structures. The behaviour of such structures is also nested and recursive. Thus evolution favoured those replicators whose replicating ability depended upon, and reinforced, the replicating ability of their partners. Furthermore, evolution favoured those replicators whose behaviour enabled the group of replicators to replicate as a unit. This is how autopoiesis came about. A stem cell is the best example we have of an autopoietic system.

In this paper I argue that to reach the chimera of self-organising software systems we need to understand how to model the order construction processes of biology through symmetry groups. In biology symmetries are symptoms of universal physical laws that, by acting upon a stable alphabet of chemical elements, are responsible for all the order construction that we see in the organic and inorganic worlds. Because software systems are abstract and do not rely on underlying physical laws, the role of symmetries as symptoms of underlying order can be inverted to become mathematically formalised constraints that make possible the construction of an equivalent order out of the range of possible structures and behaviours of software. To clarify, in the software engineering methodology called Programming by Contract certain preconditions and post-conditions are specified and enforced when a call is made on a module. These are clearly constraints. In this discussion the constraints we are referring to apply to the software that needs to be created *between* the preconditions and the postconditions, to enable the highest possible level of automatic generation of code (or behaviour, as mentioned above).

The constraints need to act on something, and that something is a large number of interacting components over a wide range of scales. The presence of interactions driven either by the "external" environment (users, other components, network messages, RPCs, etc) or by pre-programmed internal random "mixing" processes is analogous to a non-zero temperature in a physical system. Thus the conceptual basis of this picture is clearly inspired by statistical physics: the global state of the system results from a balance between the tendency toward order that is observed as the temperature approaches zero and that manifests itself in the solid state, as regular and symmetric crystals, and the tendency toward chaos that is observed as the temperature increases without bound and that manifests itself in the gaseous state, as a structureless collection of randomly colliding components. Biological systems, in fact, are able to strike this balance and depend mainly on the liquid state, although they involve all three phases of matter.

Because for pragmatic purposes we need to accelerate the evolutionary dynamics of digital ecosystems and, equivalently, we have a further requirement for the software to reflect directly the needs of the users, we need to meet an additional challenge. Digital ecosystems are immensely complex and many-dimensional, but in a sense they are semi-infinite media since by definition they will always present one interface to the users. Thus the order construction processes and the interaction frameworks discussed here will always need to be compatible with one "boundary condition": the specification of the services and the behaviour of the users that the software needs to adapt to. Whereas the latter can be usefully harnessed through the sub-symbolic learning approaches of Connectionism, the former points to the need for the interaction-driven and symmetry-based order construction framework outlined here to "grow" out of abstract specifications. In other words, it would appear that we also need to find a connection between group theory and formal logics.

The argument developed in the DBE Science Vision report, already cited, led to the "fundamental dychotomy of the DBE" which, following Varela (Varela et al, 1991), pits symbols against behaviours in both biology and cognitive science as opposite perspectives on order construction. The discussion in this article could be summarised with the claim that the group-theoretic approach has the potential to reconcile this dichotomy, as shown in Table 1.2.

Table 1.2

The fundamental dichotomy of the DBE: A possible reconciliation?

	Evolutionary Biology	Group Theory	Cognitive Science
Symbols	GENETIC DETERMINISM [8]		COGNITIVISM
Symmetries		EMERGENT SYSTEMS	
Behaviours	AUTOPOIESIS		CONNECTIONISM

The connections between logic and groups are a current area of research and will not be discussed further in this article. The article will instead review briefly existing modelling frameworks from physics, chemistry and computer science. This will lead to a very innovative model of computation borne out of the practical concerns of communication protocols, the Fraglets. The discussion will end with a simple example of how symmetries can connect biology to computer science.

In search of the right model

The dialogue between the wide range of modelling frameworks that have been developed over the past hundred years in physics, biology, and chemistry and computer science began about twenty years ago. In digital ecosystems research this kind of analysis was begun in Deliverable D18.1 and is on-going.[9] Some such frameworks have tended to be based on assumptions of continuity or on the validity of averaging simply because this affords a huge dimensional reduction in the number of variables needed to be accounted for. Unfortunately, however, such assumptions work well only for systems that are very large (Avogadro's number of particles) or in equilibrium, or both. The cell is much smaller (10^3 – 10^9 particles as opposed to 10^{23}) and can only function by virtue of a flow of energy and nutrients maintaining it *away* from equilibrium. The motor force that drives self-organising processes in fact comes from the cell's continuous "fall" toward equilibrium, which it never reaches as long as the organism remains alive.

Although the non-linear coupling of dynamical systems theory is undoubtedly relevant to this discussion, differential equations do not seem to be "granular" enough. They model the time evolution of average concentrations of reactants and products, thereby making it difficult to resolve the spatial variations within a particular cell compartment (such as the nucleus) or the overall topology of the cell. Reaction-diffusion systems based on partial differential equations do better in resolving spatial variations (by definition), but remain limited in the number of variables they are able to model simultaneously.

The study of non-equilibrium statistical mechanics and critical phenomena could be seen as attempting to strike a compromise between equilibrium statistical methods (applicable to large systems in equilibrium) and dynamical systems theory (applicable to small unstable systems). One of the appealing aspects of such approaches is their ability to model the communication between different scales of the system. However, although phase transitions and critical phenomena are a direct consequence of the presence of interaction forces between the system's components, which sounds close in concept to interactive computing, it is difficult to imagine how an interaction potential energy function of very limited expressiveness could usefully encode arbitrary information exchange between software modules.

8) See, for instance Dawkins (1989).

9) See Dini and Berdou (2004).

In the absence of a direct link between physical interaction forces and order construction processes, we are left with no choice but seek a rationale for self-organisation at higher levels of abstraction. It seems better to focus on the state changes that result from interactions rather than on the modelling of the coupling mechanism itself. A significant amount of work in this direction has come from modelling frameworks inspired from chemistry, generally referred to as multiset rewriting (Banatre and Metayer, 1993; Giavitto et al., 2004; Stanley and Mikkulainen, 2003). Multiset are sets where more than one copy of each element can be present, and "rewriting" refers to the rewriting of chemical reactants into chemical products as a result of a chemical reaction.

A conceptually similar approach has extended the π-calculus into the Stochastic π-Calculus by assigning reaction probabilities between different processes, which then become relevant to the modelling of biochemical systems and have given rise to the field of Computational Systems Biology (Priami, 2005). The stochastic π-calculus has been used with interesting results by Shapiro and co-workers (Regev and Shapiro, 2002). A wealth of detail and some very interesting examples can be found in Regev's PhD thesis (2002). In essence these approaches rely on associating a π-calculus process with a bio-molecule such as a protein or enzyme. Communications between processes become physical interactions or chemical reactions between molecules. Regev shows how this approach can reproduce phenomena such as the cell circadian clock[10] as long as the relevant chemical species and their concentrations are set up correctly at the beginning of the simulation.

Regev also explores a more recent example of computer science-based biochemical modelling, Cardelli's Ambient Calculus (Regev et al, 2004). Ambients, as an alternative approach called P-Systems (Paun and Rozenberg, 2002), are a form of membrane computing. Both approaches are concerned with a model of computation that uses a membrane as a primitive and is therefore implicitly capable of resolving the topology of the biochemical environment of the cell.

As a final point in this extremely brief review it is worth noting that the π-calculus has also served as one of the theoretical reference frameworks in the development of BPEL (Business Process Execution Language) (Havey, 2005). BPEL is the syntactical language being used in the DBE project to specify the interfaces between the service modules of a complex service and their order of execution, and therefore underpins service composition.

As we survey the rather wide field of possible modelling approaches that have the potential to achieve the challenge of self-organisation of software, we reach two high-level requirements:

1. from the point of view of biology, the model must be able to reproduce ordered patterns and behaviour of open biochemical systems to an appropriate level of granularity. In addition, the model must be able to resolve the topology of the biochemical environment.
2. from the point of view of computer science, the model must combine expressiveness with the ability to support interactions and real-time non-preprogrammed adaptation to unforeseen events and situations. As a special case, it must also be able to support the generation of a running instance of a service or application based on a high-level symbolic specification of its functional behaviour.

These are tall orders, but a model that, although in its early stages, seems to hold the potential eventually to satisfy these requirements is the Fraglets.

Fraglets: a new way of computing?

It seems fair to say that Fraglets (Tschudin, 2003)[11] represent a radically different approach at computing. Fraglets are based on theoretical computer science frameworks that are centred on the concept of interaction, such as process algebras (π-calculus) and multiset rewriting (artificial chemistry). They are sufficiently versatile to support the encoding of deterministic algorithms, but can just as well support multiple levels of non-determinism, as explained below. They intrinsically embody interactions and can *only* be implemented as a distributed algorithm. Because they were first developed to implement communication protocols they can also very easily model different topologies that can equally well represent network nodes or cell compartments.

Other aspects of Fraglets that are not immediately relevant to this discussion, but that are important for biocomputing in general and digital ecosystems in particular, concern their extension toward genetic programming (Yamamoto and Tschudin, 2005), membranes (i.e. nested containers), Java APIs for atomic function implementation and reuse

10) Wikipedia: a roughly-24-hour cycle in the physiological processes of living beings
11) See www.fraglets.org for a copy of this paper and the open source (GPL) downloadable execution environment

in engineering contexts, and variable topology (i.e. mobility). Aspects that are relevant to this discussion and that are currently very much the focus of research include a store to model asynchronous DNA function and a prototypical autocatalytic cycle as the atomic or archetypal autopoietic system. These topics are all work in progress or possibilities under evaluation, for instance in the OPAALS and the BIONETS EU projects.[12]

Fraglets are strings of instructions and/or data, or arbitrary length. Their syntax is very simple:

A [keyword1 : keyword2: ...] N

where "A" is the name of the node in which the fraglet is located and "N" is the number of identical fraglets of a particular type being defined at the beginning of the run. Each keyword can be either an instruction or data. Data can be a "payload" that needs to be transmitted between nodes or a token (essentially a pattern) that e.g. can be matched with another fraglet's keyword to allow the reaction between them to proceed. Only the first keyword or the first two keywords are "active" in each fraglet at any one time, which means that execution proceeds by header processing. Each fraglet is thus equivalent to a sequential process. However no fraglet is (usually) self-sufficient. For a meaningful action to be executed several fraglets need to interact to activate the required sequence of instructions. Thus the algorithm that needs to be executed is actually distributed over a set of fraglets.

Fraglets do not just interact, they can also be executed on their own, depending on the instruction being executed. Fraglet semantics can be summarised as only seven instructions, as shown in the table.

Table 1.3

Fraglets instructions (reaction and transformation rules)

Reaction	Input	Output	Semantics
match	[match : s : tail1], [s : tail2]	[tail1 : tail2]	concatenates 2 fraglets with matching tags
matchp	[matchp : s : tail1], [s : tail2]	[matchp : s : tail1],[tail1 : tail2]	Persistent match (works as an enzyme, i.e. it is not consumed)
Transformation			
dup	[dup : t : u : tail]	[t : u : u : tail]	duplicates a symbol
exch	[exch : t : u : v : tail]	[t : v : u : tail]	swaps two symbols
split	[split : t : . . . : * : tail]	[t : . . .], [tail]	breaks fraglet at position *
send	A[send : B : tail]	B[tail] (unreliably)	sends fraglet from A to B
wait	[wait : tail]	[tail] (after interval)	waits a predefined interval
nul	[nul : tail]	[ ]	fraglet is removed

Fig. 1.8 (in the next double page) shows an example of a communication protocol that is explained in detail in Tschudin's 2003 paper already cited. Here we will focus only on a few points relevant to the present discussion. The two coloured boxes represent two nodes of a network. All the fraglets in the yellow box should start with an "A" and all those in the cyan box should start with a "B". In this figure, however, the intent was to emphasise the difference between the initial set of fraglets in each node and the fraglets that are generated at run-time, through interactions and transformations. The initial set is recognisable by the starting letter and boldface type; all the other fraglets are generated at run-time. This example is also helpful for showing how, for example, the yellow node could be the cytoplasm and the cyan node could be the nucleus of the cell. In other words, the same computing model can be used for biocomputing applications and for computational biology simulations.

Clearly the initial set makes no sense by itself. When displayed together with the fraglets it generates, on the other hand, an execution path can be recognised. The execution of a multiset of fraglets proceeds by emulation of chemical reactions. In other words, at each time-step the whole set is examined and a fraglet (or two interacting ones) is picked from the subset of actions that are possible at that point. Even though the current Fraglets execution environment uses interleaving to simulate parallelism, the execution could be parallelised over multiple processors without loss of semantics.

This particular example is deterministic in spite of the forks in the execution path, in the sense that it will perform the protocol function that was specified. It may activate or generate intermediate fraglets in a slightly different order each

12) www.opaals.org (Contract number FP6-034824); www.bionets.org (Contract number FP6-027748)

time it is run (if a true random number generator is used), but the effect will be the same. Therefore, this particular example is equivalent to the same protocol written in a standard language such as C. The implication is that the initial set of fraglets could be seen as a "compressed" form of the full algorithm shown in the figure. The forks in the execution path, however, point to the possibility of programming the multiset to do different and mutually exclusive things depending on which path is chosen at a fork. Since at each time-step the next action is chosen randomly from the set of allowable actions, a Fraglets program could be designed to be non-deterministic at one or more forks. This is the first level of non-determinism mentioned above.

The current emphasis of digital ecosystems research in the construction of order, however, is concerned with the next level of non-determinism. In particular, is it possible to devise a multiset of fraglets that is incomplete, i.e. that does *not* correspond to a unique and complete program even when expanded, and that is still capable of executing a useful or meaningful function? Based on the concepts discussed so far in this article the answer is "Maybe". It appears that the missing information would need to be acquired from the environment the Fraglets program is interacting with. And that it might be possible to derive the structuring of such information by relying on symmetry properties of the fraglets. This hypothesis is inspired by the tight interdependence between structure and function in biology. We can say little more at this point about whether this line or enquiry might be successful or not. We close the article with a reductionist look at the connections between symmetries, biology, and computer science.

Toward a simplistic model of digital enzymes

The following facts are surprising to the non-initiated and somewhat mind-boggling (Alberts et al., 2002):

A typical enzyme will catalyze the reaction of about a thousand substrate molecules every second. … Rapid binding is possible because the motions caused by heat energy are enormously fast at the molecular level. … a large globular protein is constantly tumbling, rotating about its axis about a million times per second. … Since enzymes move more slowly than substrates in cells, we can think of them as sitting still. The rate of encounter of each enzyme with its substrate will depend on the concentration of the substrate molecule. [In a typical case,] the active site on an enzyme molecule will be bombarded by about 500,000 random collisions with the substrate molecule per second (pp 77-78).

When faced with the task of modelling biological processes, upon encountering descriptions such as the above it is difficult not to think of the cell biomolecular system as an immensely powerful digital finite state machine. The cell "computes" in the sense that interactions between molecules change their states, and these state transitions correspond to the execution of some function, just like an algorithm. Such functions are called metabolic, catabolic, transcription, or regulatory cycles, and are themselves components of higher-level functions inside and outside the cell, which could be said to culminate with the mind. What makes the cell machinery so powerful is its parallelism. Even though the 1 KHz rate of interaction of an enzyme with its substrate is very slow compared to the Mac upon which I am writing this article (2.33 GHz dual core), which is 4.66 million times faster, in a typical cell there are many millions such interactions happening in parallel every second, performing hundreds of metabolic cycles simultaneously, thus making each cell significantly more powerful.

Having argued in a hopefully convincing way about the fundamental importance of interactions in biocomputing, we have identified the Fraglets as the most promising model that starts with a "foot" in engineering but that could be expanded in many ways toward biology thanks to its theoretical basis in process algebras and multisets. Now we are looking at the other side, starting with biology and developing a theoretical framework that is compatible with digital systems. In this article we will not be able to find the meeting point of these two tunnels under the mountain that currently divides the valley of deterministic computing systems from the valley of emergent biological systems. We only mean to show what could be a plausible starting point and direction for the second tunnel.

Because this article is not the place for a diversion into group theory and symmetries, a certain level of familiarity with the basic concepts must unfortunately be assumed. It may help to realise that mathematical symmetries can be seen as generalisations of the more familiar and commonplace concept of symmetry. If a symmetry is defined as a transformation that leaves something invariant, then the common interpretation of the term could be stated as "invariance of shape with respect to 180-degree rotations about the vertical axis". In examining a typical Fraglets program such as the one shown in Fig. 1.8 it does not take long to realise that some patterns of execution tend to repeat themselves when similar tasks are being performed. This recurrence is an example of a simple form of invariance and is one of the observations, along with D'Arcy Thompson's symmetries, that is motivating this line of enquiry.

Because the active site(s) of enzymes occur at discrete angular intervals and because enzymes rotate to look for a match with their substrate, it seems worthwhile to investigate the rotational symmetries of the regular solids.

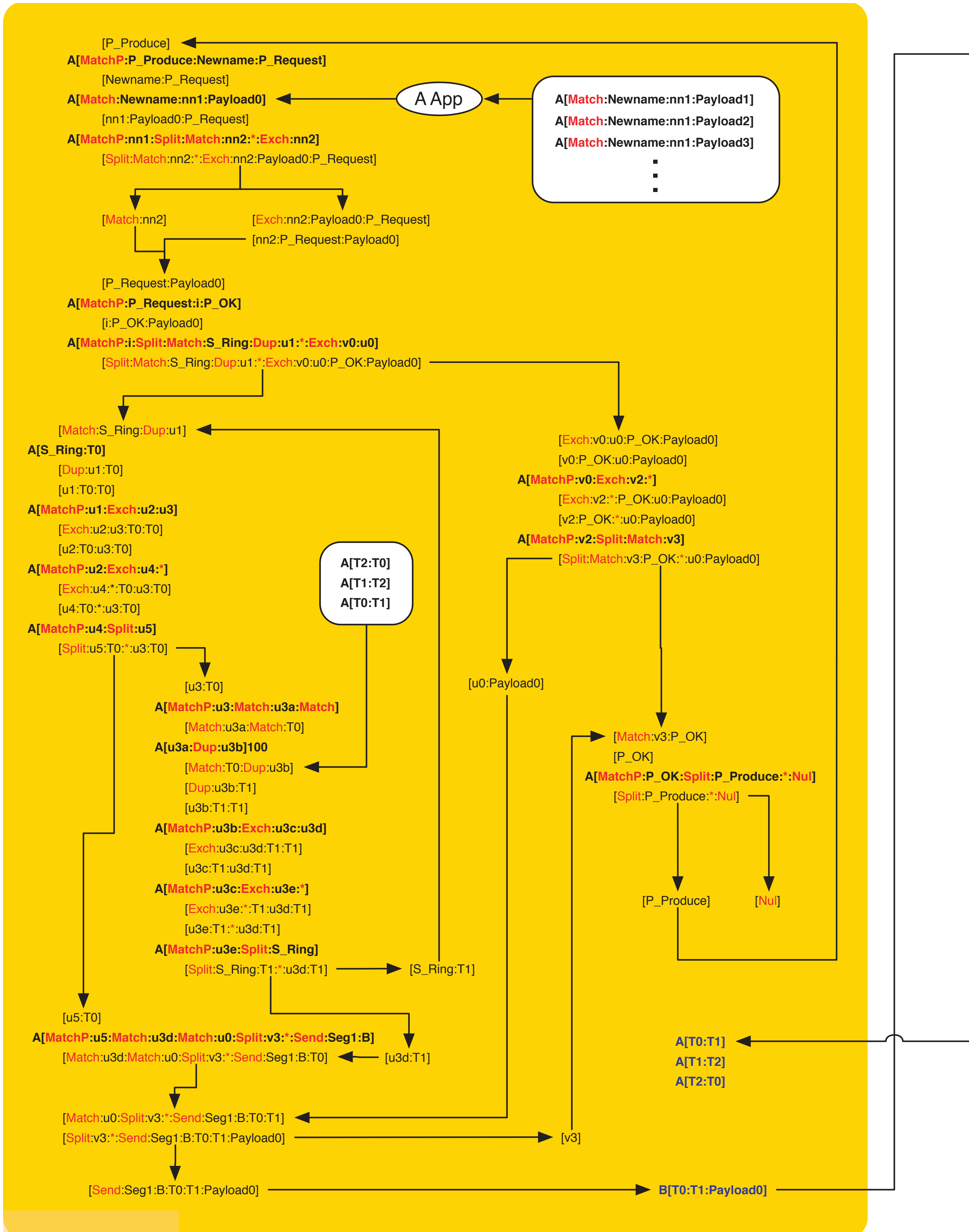
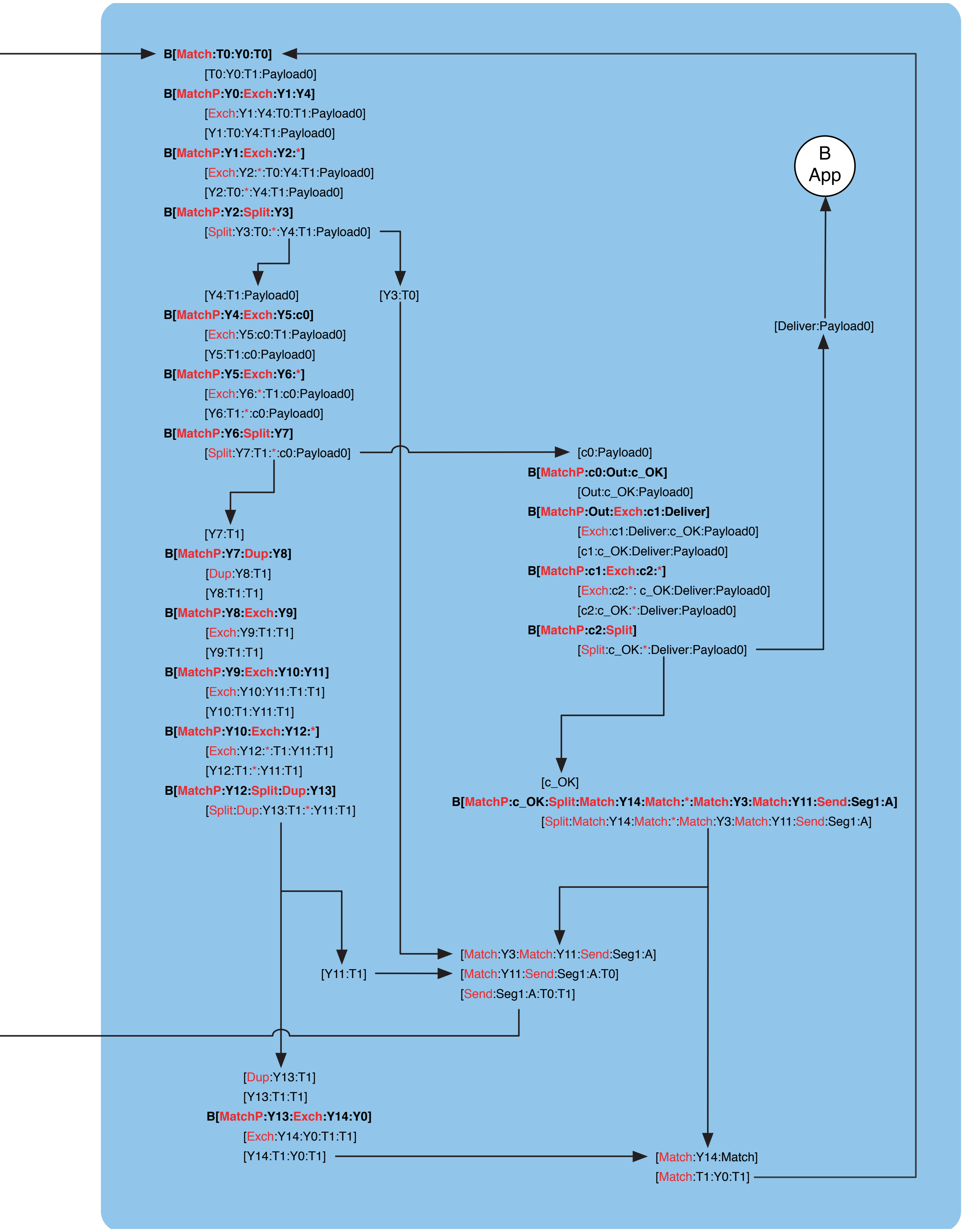


Fig. 1.8

Fraglets example showing the explicit algorithm (regular font) along with the implicit initial fraglet multiset (bold)



Credit-based flow control with reordering (C. Tschudin & L. Yamamoto, UBASEL; visualisation by P. Dini, LSE)

Fig. 1.9

The five Platonic solids[13]

Fig. 1.10 shows the 12 rotational symmetries of the tetrahedron, where "*e*" stands for the Identity transformation.[14] Interestingly, these can be expressed as combinations of the two rotations "*r*", 120 deg rotation about the vertical axis, and "*s*", 180 deg about an axis bisecting two opposite edges. When the tetrahedron is rotated by either *r* or *s* its shape relative to a stationary observer does not change. Furthermore, when it is rotated by any combination of *r*'s and *s*'s, its shape will also remain invariant. The figure shows 12 different (but non-unique) combinations of *r*'s and *s*'s that give all 12 symmetries. If these combinations of rotations are viewed as a binary alphabet, it is straightforward to define a deterministic finite automaton (DFA) that will accept any string of *r*'s and *s*'s, Fig. 1.11. Clearly one needs to define the accepting state(s), and depending on which such state(s) is/are chosen a different regular language will be recognised by the automaton. Figs. 1.12 and 1.13 show the equivalent analysis for the cube, which turns out to be isomorphic to the octahedron.

This suggests that a possible strategy to "translate" metabolic behaviour into a stream of digital symbols—and back. The former is conceptually related to a monitoring or analytic function of cell metabolism, whereas the latter is related to a modelling or synthetic function. There are huge challenges still to be overcome, clearly. Furthermore, rotations are suggestive but are only an example of transformations (state transitions) that could be useful or semantically meaningful for biological computation. It is not clear what other kinds of transformations might be useful.

If we take the rotations not as absolute but as relative rotations between an enzyme and its substrate, it may be possible to imagine a stream of bits issuing from their interaction. Each interaction, however, may produce a very short stream indeed, since its result is generally the formation of a new compound whose geometry is different. Each time a new compound is generated only a few state transitions are effected. How are the millions of fragmented digital streams being generated in parallel to be integrated into a coherent high-level description of functional behaviour? Interestingly, this is qualitatively not unlike the behaviour of the Fraglets.

It may appear that this approach is too low-level. However, another fundamental aspect of biological systems is their recursive structural and functional organisation. This means that higher-level structure and behaviour is built with

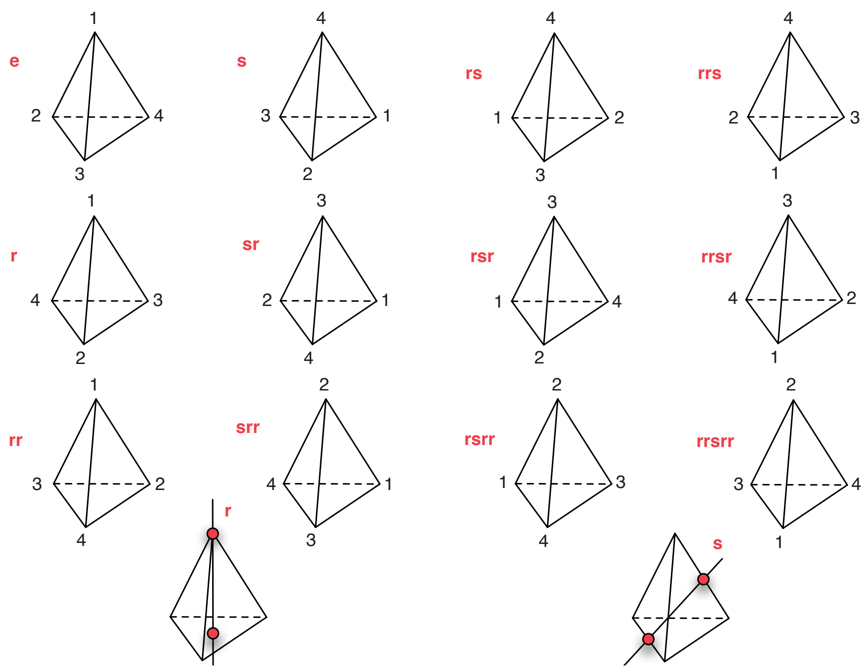


Fig. 1.10

The 12 rotational symmetries of the tetrahedron, generated by 2 rotation axes (Alternating Group A 4)

13) http://www.3quarks.com/GIF-Animations/PlatonicSolids/

14) A complete discussion of the symmetries of the Platonic solids can be found in Armstrong (1988).

nested lower-level structure and behaviour that in many cases replicates the higher-level characteristics at a smaller physical scale and faster time scale. The mathematical objects that model scale invariance are Mandelbrodt's Fractals, which are symmetric in yet another way and that have been used to model countless biological (and physical) structures.

Clearly the Platonic solids are not realistic models of real enzymes. The more important point is to build a modelling framework that replicates, however crudely, the main aspects of the mathematical structure that underpins biological computation. It is entirely possible that some abstraction of the solids, similar to the Fraglets, will be able to achieve the required expressiveness and recursion capability. The Platonic solids in this case could simply serve as an intermediate conceptualisation tool, to aid our intuition in building a bridge from proteins to bit streams, and possibly to help us visualise distributed interactive computation in the future. The next step might therefore be to construct "atomic" DFAs that correspond to Fraglets state transitions and that could be combined into larger finite state machines whilst retaining certain structural characteristics that correspond to particular behaviour.

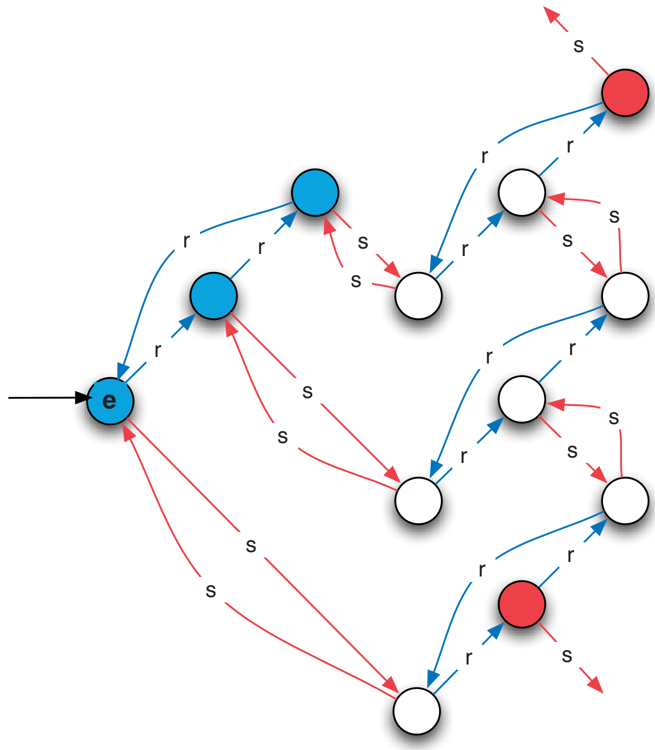


Fig. 1.11

The 12 rotational symmetries of the tetrahedron as the 12 states of a Finite Deterministic Automaton whose language is given by any string of "r" and "s" symbols (Alternating Group A4)

As a final contextual point it is helpful to remind ourselves of the Chomsky (1957) hierarchy of languages:

- **(Type 0)** Turing Machines (TMs) are the most general and recognise anything (although not necessarily in finite time)
- **(Type 1)** Bounded-tape Turing Machines are more complex and recognise context-sensitive languages
- **(Type 2)** Pushdown Automata (PDA) have a stack and recognise context-free languages
- **(Type 3)** Deterministic Finite Automata (DFA) recognise Regular Languages (simple commands like "ls" in Unix to list directory files)

Java falls somewhere between Type 2 and Type 1, but is closer to Type 2. The extremely simple examples we are discussing here belong to the lowest level of the hierarchy (Type 3). There is no proof yet that Fraglets are Turing-complete (Type 0) but it is suspected that they are. If what we have argued in this article is correct, the credit-based flow control with reordering protocol of Fig. 1.8 would be an example of a deterministic algorithm not unlike Java. The interesting fundamental and still open question is whether by relaxing the determinism of Fraglets programs in the manner suggested here we might be climbing the hierarchy to the top, perhaps going beyond Turing Machines themselves.

Acknowledgement

In addition to the names already included in the footnotes, I am happy to acknowledge many conversations, suggestions, and references that have all helped the development of the ideas contained in this paper and that have been offered by Gordon Gow, Robin Mansell, Mary Darking, Edgar Whitley, Frauke Zeller, Christian Tschudin, Lidia Yamamoto, and Francesco Nachira.

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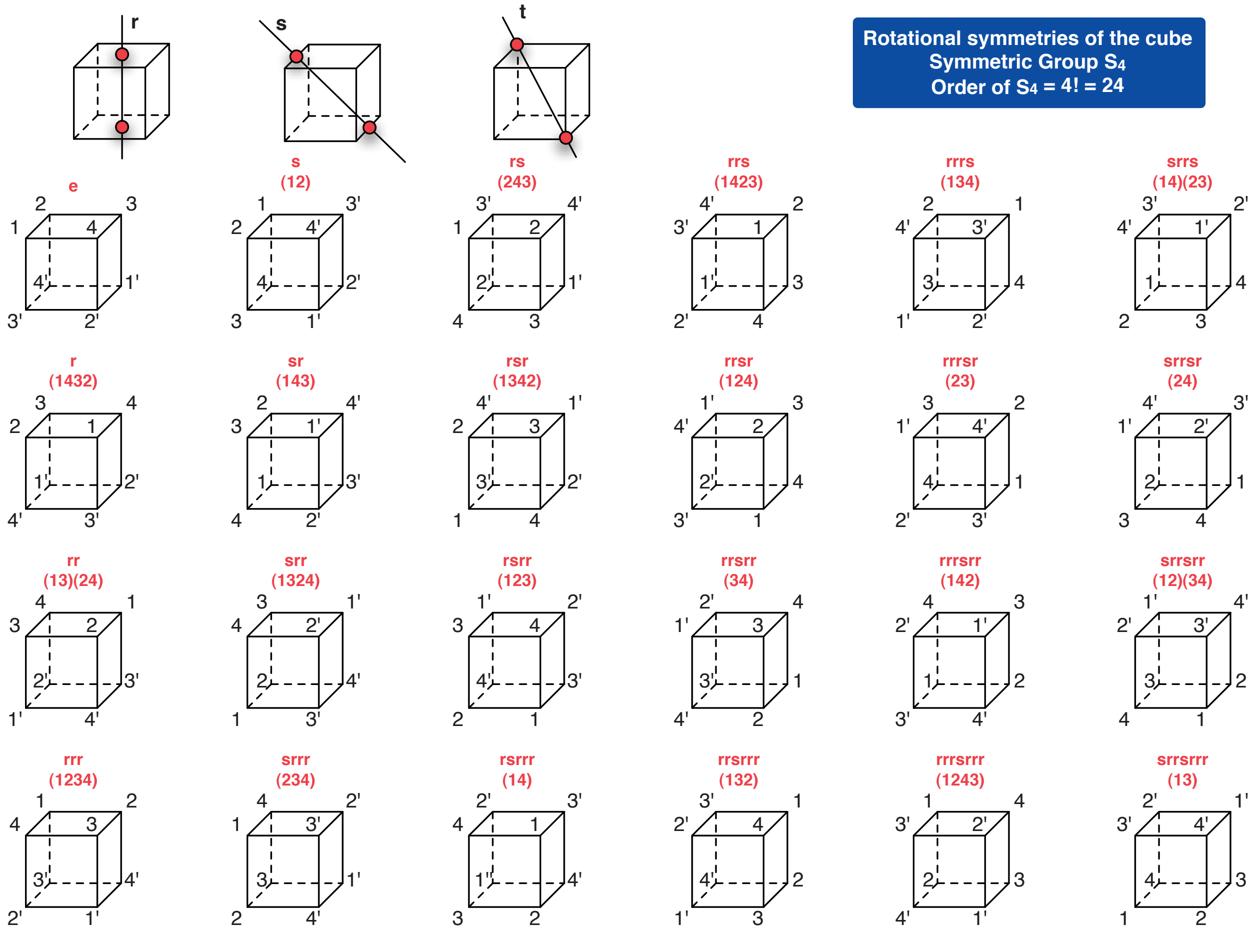
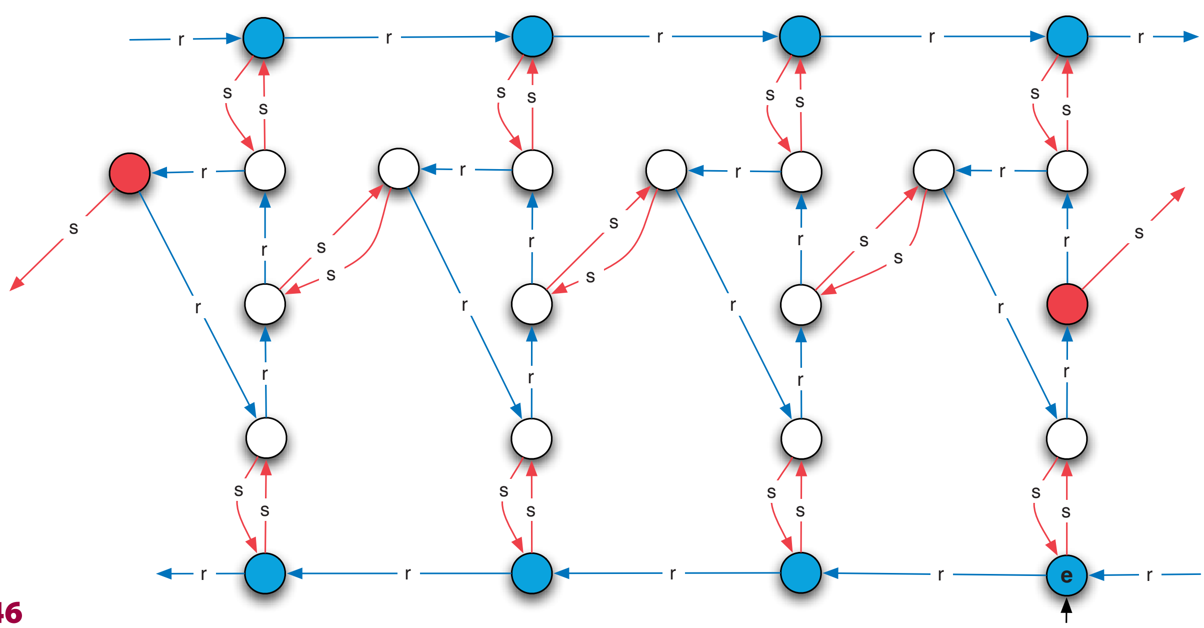


Fig. 1.12

The 24 rotational symmetries of the cube, generated by 2 rotation axes (Symmetric Group S4)

Fig. 1.13

DFA isomorphic to the symmetries of the cube



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2 Natural Science Paradigms

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A primary motivation for research in Digital Ecosystems is the desire to exploit the self-organising properties of natural ecosystems. Ecosystems are thought to be robust, scalable architectures that can automatically solve complex, dynamic problems. However, the biological processes that contribute to these properties have not been made explicit in Digital Ecosystem research. Here, we introduce how biological properties contribute to the self-organising features of natural ecosystems. These properties include populations of evolving agents, a complex dynamic environment, and spatial distributions which generate local interactions. The potential for exploiting these properties in artificial systems is then considered.

Introduction

Natural science is the study of the universe via rules or laws of natural order. The term natural science is also used to differentiate those fields using scientific method in the study of nature, in contrast with social sciences which use the scientific method applied to human behaviour. The fields of natural science are diverse, ranging from soil science to astronomy. We are by no means claiming that all these fields of study will provide paradigms for Digital Ecosystems. So, a brief summary of the relevant fields are shown below:

- Physics, the study of the fundamental constituents of the universe, the forces and interactions they exert on one another, and the results produced by these forces.
- Biology, the study of life
  - Ecology and Environmental science, the studies of the interrelationships of life and the environment.
- Chemistry, the study of the composition, chemical reactivity, structure, and properties of matter and with the (physical and chemical) transformations that they undergo.

The further one wishes to take the analogy of the word ecosystem in Digital Ecosystems, the more one has to consider the relevance of the fields of natural science, because our focus is in creating the digital counterpart of biological ecosystems.

The Biology of Digital Ecosystems [7]

Is mimicking nature the future for information systems? A key challenge in modern computing is to develop systems that address complex, dynamic problems in a scalable and effcient way. One approach to this challenge is to develop Digital Ecosystems, artificial systems that aim to harness the dynamics that underlie the complex and diverse adaptations of living organisms. However, the connections between Digital Ecosystems and their biological counterparts have not been closely examined. Here, we consider how properties of natural ecosystems influence functions that are relevant to developing Digital Ecosystems to solve practical problems. This leads us to suggest ways in which concepts from ecology can be used to combine biologically inspired techniques to create an applied Digital Ecosystem.

The increasing complexity of software [17] makes designing and maintaining effcient and flexible systems a growing challenge. Many authors argue that software development has hit a complexity wall which can only be overcome by automating the search for new algorithms [23]. Natural ecosystems possess several properties that may be useful in such automated systems. These properties include self-organisation, self-management, scalability, the ability to provide complex solutions, and automated composition of these complex solutions.

A natural ecosystem consists of a community of interacting organisms in their physical environment. Several fundamental properties influence the structure and function of natural ecosystems. These include agent population dynamics, spatial interactions, evolution, and complex, changing environments. We examine these properties, and the role they may play in an applied Digital Ecosystem. We suggest that several key features of natural ecosystems have not been fully explored in existing Digital Ecosystems, and discuss how mimicking these feature may assist in developing robust, scalable self-organising architectures.

Arguably the most fundamental differences between biological and Digital Ecosystems lie in the motivation and approach of researchers. Biological ecosystems are ubiquitous natural phenomena, whose maintenance is crucial to our survival. The performance of natural ecosystems is often measured in terms of their stability, complexity and diversity. In contrast, Digital Ecosystems as defined here are technology engineered to serve specific human purposes. The performance of a Digital Ecosystem, then, can be judged relative to the function it is designed to perform. In many cases, the purpose of a Digital Ecosystem is to solve dynamic problems in parallel with high effciency. This criterion may be related only indirectly to complexity, diversity and stability, an issue we shall examine further.

Genetic algorithms are the subset of evolutionary computation that uses natural selection to evolve solutions. Starting with a set of arbitrarily chosen possible solutions, selection, replication, recombination and mutation are applied iteratively. Selection is based on conformation to a fitness function which is determined by the specific problem of interest. Over time, better solutions to the problem can thus evolve. Because they are intended to solve problems by evolving solutions, applied Digital Ecosystems are likely to incorporate some form of genetic algorithm. However, we suggest that a Digital Ecosystem should also incorporate additional features which give it a closer resemblance to natural ecosystems. Such features might include complex, dynamic fitness functions, a distributed or network environment, and self-organisation arising from interactions among agents and their environment. These properties are discussed further below.

Fitness Landscapes and Agents

As described above, an ecosystem comprises both an environment and a set of interacting, reproducing entities (or agents) in that environment. In biological ecosystems, the environment acts as a set of physical and chemical constraints on reproduction and survival. These constraints can be considered in abstract using the metaphor of the fitness landscape [26]. Individuals are represented in the fitness landscape as solutions to the problem of survival and reproduction.

All possible solutions are distributed in a space whose dimensions are the possible properties of individuals. An additional dimension, height, indicates the relative fitness (in terms of survival and reproduction) of each solution. The fitness landscape is envisaged as a rugged, multidimensional landscape of hills, mountains and valleys, because individuals with certain sets of properties are fitter than others.

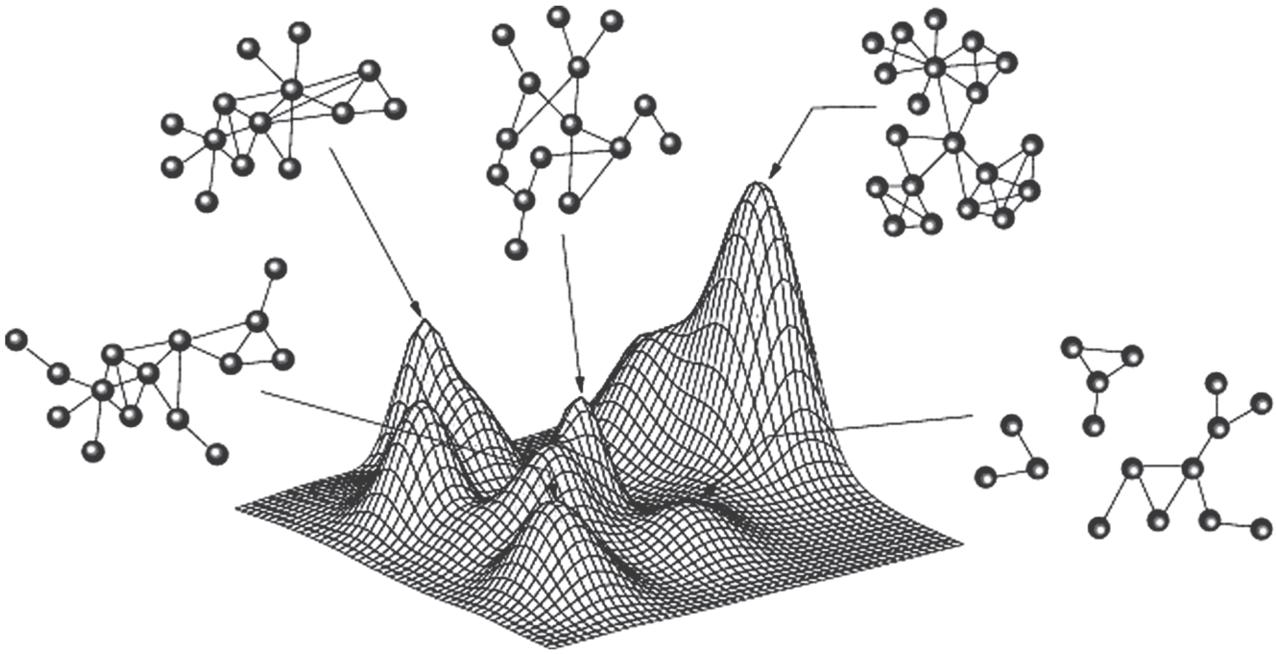


Fig. 1

A hypothetical software fitness landscape. Peaks correspond to sub-optimal solutions. We can represent software development as a walk through the landscape towards these peaks. The roughness of the landscape indicates how diffcult is to reach an optimal software design. [24]

In biological ecosystems, fitness landscapes are virtually impossible to identify. This is both because there are large numbers of possible traits that can influence individual fitness, and because the environment changes over time and space. In contrast, within a digital environment, it is normally possible to specify explicitly the constraints that act on individuals in order to evolve solutions that perform better within these constraints.

Within genetic algorithms, exact specification of a fitness landscape or function is common practice. However, within a Digital Ecosystem, the ideal constraints are those that allow solution populations to evolve to meet user needs with maximum effciency. User needs will change from place to place and time to time. In this sense the Digital Ecosystem fitness landscape is complex and dynamic, and more like that of a biological ecosystem than like that of a traditional genetic algorithm. The designer of a Digital Ecosystem therefore faces a double challenge: firstly, to specify rules that govern the shape of the fitness landscape in a way that meaningfully maps landscape dynamics to user requests, and secondly, to evolve solution populations within this space that are diverse enough to solve disparate problems, complex enough to meet user needs, and effcient enough to be superior to those generated by other means.

The agents within a Digital Ecosystem are like biological individuals in the sense that they reproduce, vary, interact, move and die. Each of these properties contributes to the dynamics of the ecosystem. However, the way in which these individual properties are encoded may vary substantially depending on the purpose of the system.

Networks and Spatial Dynamics

A key factor in the maintenance of diversity in natural ecosystems is spatial interactions. Several modelling systems have been used to represent spatial interactions. These include metapopulations, diffusion models, cellular automata and agent-based models (termed individual-based models in ecology). The broad predictions of these diverse models are in good agreement. At local scales, spatial interactions favor relatively abundant species disproportionately. However, at a wider scale, this effect can preserve diversity, because different species will be locally abundant in different places. The result is that even in homogeneous environments, population distributions tend to form discrete, long-lasting patches that can resist invasion by superior competitors [11]. Population distributions can also be influenced by environmental variations such as barriers, gradients and patches. The possible behavior of spatially distributed ecosystems is so diverse that scenario-specific modelling is necessary to understand any real system [9]. Nonetheless, certain robust patterns are observed. These include the relative abundance of species (which consistently follows a roughly log-normal relationship) [3] and the relationship between geographic area and the number of species present (which follows a power law) [1]. The reasons for these patterns are disputed: both spatial extensions of simple Lotka-Volterra competition models [14], and more complex ecosystem models [22], are capable of generating them.

Landscape connectivity plays an important part in ecosystems. When the density of habitat within an environment falls below a critical threshold, widespread species may fragment into isolated populations. Fragmentation can have several consequences. Within populations, these effects include loss of genetic diversity and harmful inbreeding [10]. At a broader scale, isolated populations may diverge genetically, leading to speciation. From an information theory perspective, this phase change in landscape connectivity can mediate global and local search strategies [13]. In a well-connected landscape, selection favors the globally superior, and pursuit of different evolutionary paths is discouraged, potentially leading to premature convergence. When the landscape is fragmented, populations may diverge, solving the same problems in different ways. Recently, it has been suggested that the evolution of complexity in nature involves repeated landscape phase changes allowing selection to alternate between local and global search [12].

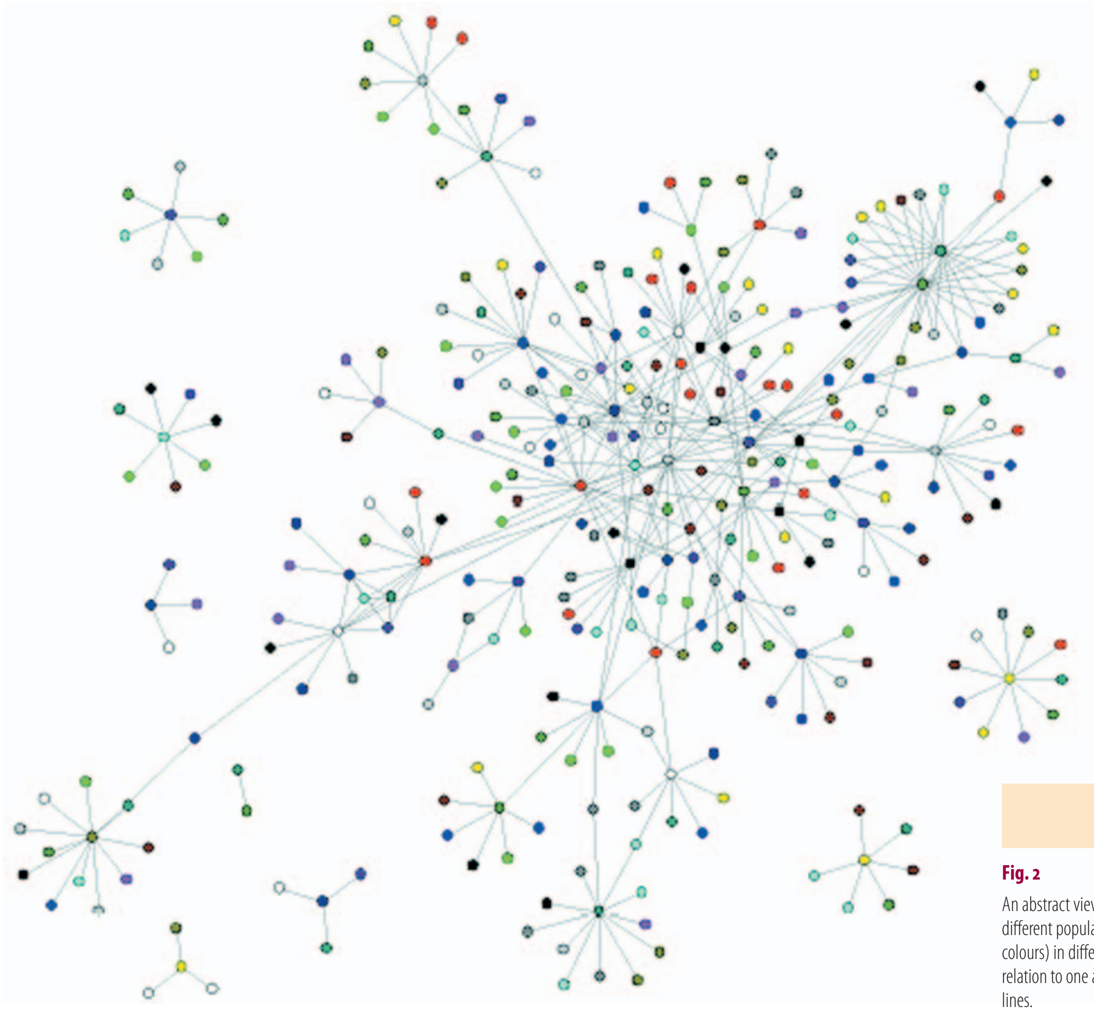


Fig. 2

An abstract view of an ecosystem, showing different populations (by the different colours) in different spatial areas, and their relation to one another by the connecting lines.

In a digital context, we can simulate spatial interactions by creating a distributed system that consists of a set of interconnected locations. Agents can migrate between connected locations with low probability. Depending on the how the connections between locations were organised, such Digital Ecosystems might have dynamics closely parallel to spatially explicit models, diffusion models, or metapopulations [9]. In all of these systems, the spatial dynamics are relatively simple compared with those seen in real ecosystems, which incorporate barriers, gradients and patchy environments at multiple scales in continuous space. Another alternative in a Digital Ecosystem is to apply a spatial system that has no geometric equivalent. These could include, for example, small world networks and geographic systems that evolve by Hebbian learninonig. We will discuss an example of a non-geometric spatial network, and some possible reasons for using this approach, in a later section.

Selection and Self-Organisation

The major hypothetical advantage of Digital Ecosystems over other complex organisational models is their potential for dynamic adaptive self-organisation. However, for the solutions evolving in Digital Ecosystems to be useful, they must not only be effcient in a computational sense, they must also solve meaningful problems. That is, the fitness of agents must translate in some sense to real-world usefulness as demanded by users.

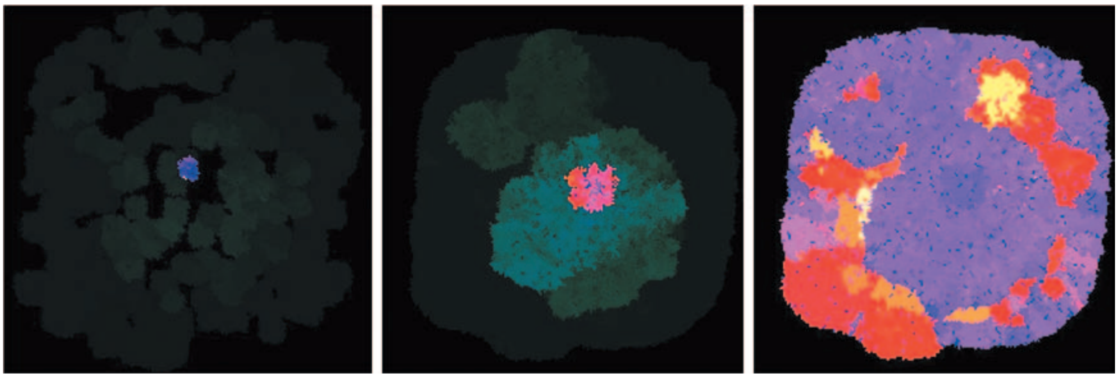


Fig. 3

An evolving population of digital organisms in a virtual petri dish at three time steps, showing the self-organistion of the population undergoing selection. The colour shows the genetic variability of the digital organisms, with the genetically identical being the same colour. [20]

Constructing a useful Digital Ecosystem therefore requires a balance between freedom of the system to self-organise, and constraint of the system to generate useful solutions. These factors must be balanced because the more the system's behavior is dictated by internal dynamics of the system, the less it may respond to fitness criteria imposed by users. At one extreme, when system dynamics are mainly internal, agents may evolve that are good at survival and reproduction within the digital environment, but useless in the real world. At the other extreme, where the users' fitness criteria overwhelmingly dictate function, we suggest that dynamic exploration of solution space and complexity are likely to be limited.

The reasoning behind this argument is as follows. Consider a multidimensional solution space which maps to a rugged fitness landscape. In this landscape, competing solution lineages will gradually become extinct through chance processes. Consequently, the solution space explored becomes smaller over time as the population adapts and diversity of solutions decreases. Ultimately, all solutions may be confined to a small region of solution space. In a static fitness landscape, this situation is not undesirable because the surviving solution lineages will usually be clustered around an optimum. However, if the fitness landscape is dynamic, the location of optima varies over time. Should lineages become confined to a small area of solution space, subsequent selection will locate only optima that are near this area. This is undesirable if new, higher optima arise that are far from pre-existing ones. A related issue is that complex solutions are less likely to be found by chance than simple ones. Complex solutions can be visualised as sharp, isolated peaks on the fitness landscape. Especially in the case of a dynamic landscape, these peaks are most likely to be found when the system explores solution space widely. Consequently, a self-organising mechanism other than the fitness criteria of users is required to maintain diversity among competing solutions in the Digital Ecosystem.

Stability and Diversity in Complex Adaptive Systems

Ecosystems are often described as complex adaptive systems (CAS). That is, they are systems comprised of diverse, locally interacting components that are subject to selection. Other complex adaptive systems include brains, individuals, economies, and the biosphere. All are characterised by hierarchical organisation, continual adaptation and novelty, and non-equilibrium dynamics. These properties lead to behavior that is non-linear, historically contingent, subject to thresholds, and contains multiple basins of attraction [15].

In the above sections we have advocated Digital Ecosystems that include agent populations evolving by natural selection in distributed environments. Like real ecosystems, digital systems designed in this way fit the definition of complex adaptive systems. The features of these systems, especially non-linearity and non-equilibrium dynamics, offer both advantages and hazards for adaptive problem-solving. The major hazard is that the dynamics of complex adaptive systems are intrinsically hard to predict due to self-organisation. This observation implies that designing a useful Digital Ecosystem will be partly a matter of trial and error. The occurrence of multiple basins of attraction in complex adaptive systems suggests that even a system that functions well for a long period may at some point suddenly transition to a less desirable state. For example, in some types of system self-organising mass extinctions might result from interactions among populations, leading to temporary unavailability of diverse solutions. This concern may be addressed by incorporating negative feedback mechanisms at the global scale.

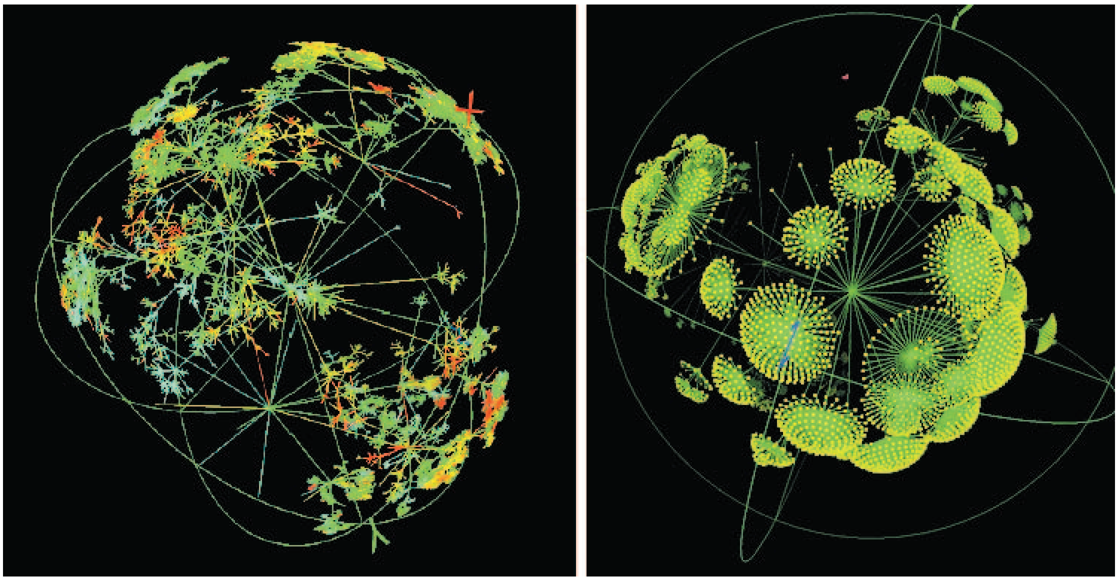
The challenges in designing an effective Digital Ecosystem are mirrored by the system's potential strengths. Nonlinear behavior provides the opportunity for scalable organisation and the evolution of complex hierarchical solutions. Rapid state transitions potentially allow the system to adapt to sudden environmental changes with minimal loss of functionality.

A key question for designers of Digital Ecosystems is how the stability and diversity properties of natural ecosystems map to performance measures in digital systems. For a Digital Ecosystem, the ultimate performance measure is user satisfaction, a system-specific property. However, assuming that the motivation for engineering a Digital Ecosystem is the development of scalable, adaptive solutions to complex dynamic problems, certain generalisations can be made. Sustained diversity, as discussed above, is a key requirement for dynamic adaptation. In the Digital Ecosystem, diversity must be balanced against adaptive effciency because maintaining large numbers of poorly-adapted solutions is costly.The exact form of this tradeoff will be guided by the specific requirements of the system in question. Stability, as discussed above, is likewise a tradeoff: we want the system to respond to environmental change with rapid adaptation, but not to be so responsive that mass extinctions deplete diversity or sudden state changes prevent control.

Fig. 4

Left: An abstract view of an ecosystem, showing the diversity of different populations by the different colours.

Right: An abstract view of population diversity within a single habitat, with space between points showing genetic diversity.



Evolutionary Environment (EvE) Digital Ecosystem

The Digital Business Ecosystem (DBE) [21] is a proposed methodology for economic and technological innovation. Specifically, the DBE has a Digital Ecosystem software infrastructure for supporting a large number of interacting business users and services, called the EvE [4, 6, 5]. The individuals of a EvE are software agents that represent business services. These agents interact, evolve and adapt to a dynamic digital environment, thereby serving the ever-changing business requirements imposed by the economy.

The EvE is a two-level optimisation scheme inspired by natural ecosystems. A decentralised peer-to-peer network forms an underlying tier of distributed services. These services feed a second optimisation level based on genetic algorithms that operates locally on single peers (habitats) and is aimed at finding solutions satisfying locally relevant constraints. Through this twofold process, the local search is sped up and yields better local optima as the distributed optimisation provides prior sampling of the search space by making use of computations already performed in other peers with similar constraints.

The EvE is a Digital Ecosystem in which autonomous mobile agents represent various services (or compositions of services) offered by participating businesses. The abiotic environment is represented by a network of interconnected habitats nodes. Each connected enterprise has a dedicated habitat. Enterprises search for, and deploy, services in local habitats. Continuous and varying user requests for services provide a dynamic evolutionary pressure on the agents, which have to evolve to better satisfy those requests.

In natural ecosystems geography defines the connectivity between habitats. Nodes in the EvE do not have a default geographical topology to define connectivity. A re-configurable network topology is used instead, which is dynamically adapted on the basis of observed migration paths of the individuals within the EvE habitat network. Following the idea of Hebbian learning, the habitats which succesfully exchange individuals more often obtain stronger connections and habitats which do not succesfully exchange individuals will become less strongly connected. This way, a network topology is discovered with time, which reflects the structure of the business-sectors within the user base. The resulting

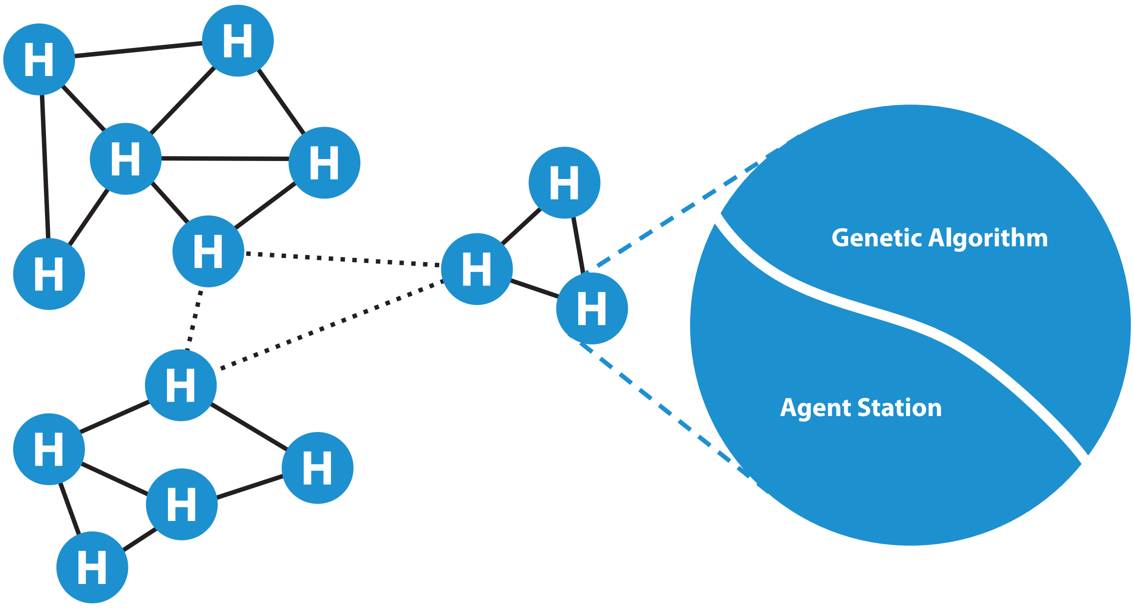


Fig. 5

Optimisation architecture: agents travel along the peer-to-peer connections that have the topology of a small-world network; in each node local optimisation is performed through a genetic algorithm, where the search space is defined by the agents contained in the node.

network will resemble the connectivity of the businesses within the user base, typically a small-world network in the case of Small & Medium Enterprises (SMEs) [27, 8, 19]. Such a network has many strongly connected clusters called sub-networks (quasi complete graphs) and a few connections between these clusters. Graphs with this topology have a very high clustering coeffcient and small characteristic path lengths [25, 18], as shown in Figure 5.

In simulation we compared some of the EvE's dynamics to those of natural ecosystems, and the experimental results indicated that under simulation conditions the EvE behaves in some ways like a natural ecosystem. This suggests that incorporating ideas from theoretical ecology can contribute to useful self-organising properties in Digital Ecosystems. [7]

Conclusions

By comparing and contrasting theoretical ecology with the anticipated requirements of Digital Ecosystems, we have examined how ecological features may emerge in some systems designed for adaptive problem solving. Specifically, we suggested that a Digital Ecosystem, like a real ecosystem, will usually consist of self-replicating agents that interact both with one another and with an external environment. Agent population dynamics and evolution, spatial and network interactions, and complex dynamic fitness landscapes will all influence the behaviour of these systems. Many of these properties can be understood via well-known ecological models [16, 14].

A further body of theory treats ecosystems as complex adaptive systems [15]. These models provide a theoretical basis for the occurrence of self-organisation in both digital and real ecosystems. Self-organisation results when interactions among agents and their environment giving rise to complex non-linear behavior. It is this property that provides the underlying potential for scalable problem-solving in a digital environment.

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3 Digital Ecosystem and Language

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Introduction

This chapter introduces to the role of language and communication in digital ecosystems research and application. It will highlight the potential of linguistics (and communication studies) as a binding theoretical framework for the intrinsically interdisciplinary field of digital ecosystems. Key aspects of language and communication will be discussed firstly on a macro-level in order to sketch the demarcation lines of the theoretical framework, and secondly, on a micro-level, depicting some examples for the application of methodologies and theories from linguistics and communication studies. The key approach of this chapter is to regard language (diversity) as predominant and challenging feature of digital ecosystems.

Digital Ecosystems and Language Concepts

The scientific field of ecolinguistics combines several sciences such as anthropology, ethology, or social science and is concerned with the inter-relationship of language users with their environment. It focuses for example on dialects, language varieties, and technical languages. One example is the analysis of language as a tool to establish communities or even to solve conflicts between different communities. Ecolinguistics thus regards language as a system which inherits the potential to create as well as define a specific notion of Umwelt (environment).

Any digital environment can be defined as an abstract concept which is not part of our real world in a strict sense of interpretation. This means that we define digital environments by ourselves, including its components, rules, and social aspects. The act of defining is based on language, and the words we use in order to depict certain concepts of a digital environment. Reflecting on linguistic determinism which claims that language shapes thoughts, most certainly provides a point of departure with strong restrictions if we would refer exclusively to Wittgenstein (1981): “The limits of my language mean the limits of my world” (proposition 5.6), or “Whereof one cannot speak, thereof one must be silent.” (proposition 7). Sapir and Whorf however propose a different starting point by claiming that individuals experienced the world based on the words they possess (Kay & Kempton, 1984). This hypothesis implies that:

a. the world is perceived differently by each individual,

b. a socio-cultural dimension plays an important role because natural languages as arbitrary systems are also shaped by socio-cultural backgrounds,
c. an abstract concept such as digital environment inherits a multitude of different "worlds" according to the definitory "words" which are used by a group of individuals in order to depict that abstract concept.

Switching to a Gramscian mode and asking what kind of "intellettuale organico" (Gipper, 1992) we would have to imagine as participants or inhabitants of digital environments, we can state that all participants are 'always already' linguists as they all (may it be computer scientists, natural scientistis, organisational designers, or social scientists) shape and form environment(s) (Umwelten) by means of their linguistic abilities.

At this point, it should be emphasized that this chapter does not head towards another debate on the reliability of linguistic determinism and its accompanying hypotheses and paradigms (however, it should be noted that recent studies of Peter Gordon (2004) investigating the language of a tribe of hunter-gatherers in Brazil, Pirahã, provide favourable input for the hypothesis of linguistic determinism), but rather reflect upon the conceptual and linguistic diversity of digital ecosystems and introduce different corresponding methodologies.

Language Diversity

The foregoing part discussed language as predominant tool to define abstract concepts such as digital ecosystems. It also discussed the diversity of defining concepts based on each individual's language register/potential and usage. Focussing on the key approach of this chapter ("language diversity as predominant and challenging feature of digital ecosystems") we will now touch on language diversity from a socio-cultural and evolutionary point of view.

Socio-Cultural Language Diversity

Digital ecosystems, particularly the European digital ecosystems' concept[1] that supports SMEs and regional development, focuses on four key principle groups of stakeholders in the European Knowledge Economy: Small and medium-sized enterprises (SMEs) represented by their associations, the European software and knowledge-based service industry, the research community participating in currently funded FP6 projects, and regional/local decision makers represented by their catalysts and agencies (Dini et alii, 2005). In order to analyse and discuss socio-cultural language diversity, we will emphasize on the two groups 'SMEs' and the 'research community'. Language and communication is intrinsically interwoven with our beliefs, desires, and intentions (BDI) of and about the world. The BDI structure of our two examples differs strongly when it comes to define desired potentials of the Digital Ecosystem and services to be provided by one particular framework. SMEs face distinct economic, legal, and social circumstances than researchers employed at universities (for example) which is catalysed in their specific BDI structures. This in turn influences the primary associations and approaches when participating in the Digital Ecosystem. Therefore, we cannot simply speak of a value chain 'researcher to end-user' when there is no common ground in terms of BDI for the digital ecosystem.

However, 'diversity' can be seen as a fruitful component for any ecosystem, as it is claimed to enhance and foster the robustness of a system towards environmental stress and influence[2]. Language diversity (and correspondingly the multiple BDI structures) then has to be preserved in the Digital Ecosystem instead of finding a common language for all actors. This includes the diversity of the different socio-cultural backgrounds, being for example domain specific languages (different expertise and focal interests), cultural beliefs and etiquette (collaboration and interdisciplinary work), economic and legal contexts (infrastructure and organisational issues), which are all expressed in specific communication practices and acts.

Evolutionary Language (and) Diversity

The mere preservation of the aforementioned language diversity in the Digital Ecosystem could jeopardize the collaborative processes within the ecosystem, as the different "communication practices" and BDI structures hamper the interdisciplinary understanding and collaboration. Collaboration represents another vital variable for the Digital Ecosystem regarding the vision and concept of a European Knowledge Economy (Dini et alii, 2005).

1) Hereinafter called Digital Ecosystem.

2) As the term „digital ecosystem" was inspired by biological ecosystems, the authors refer in this argument to the field of biodiversity.

Another factor which contributes to the communication diversity is added by the tools we use when collaborating in the Digital Ecosystem. Information and communication technology, or computers as the most common interface to digital environments, are symbol processing machines based on a binary system i.e. formal languages (algorithms) in order to process natural languages. The computer as a formal language entity allows us to juxtapose the language diversity "dilemma" for a short glimpse by concentrating on a common formal language approach. This is being realized by the Digital Business Ecosystem (DBE) Integrated Project (IP) in terms of intensive work on a Business Modelling Language (BML) for integrated services, or by the Opaals Network of Excellence (NoE) which deals with the development of a formal language called Semantics of Business Vocabulary and Rules (SBVR). However, this juxtaposition cannot be dealt with as a successful solution, as the development of formal languages for knowledge creation, processing and consecutive services within the Digital Ecosystem has a strong evolutionary character due to the underlying concepts and paradigms of the Ecosystem. Thus, the evolutionary formal language approach has to take into account the underlying socio-cultural factors in order to be successful in terms of collaboratively developing the formal language and in terms of acceptance of the new language including the resulting service potentials and applications.

More precisely, on the back-end level of our formal language production we are faced with collaboration issues and community building challenges. Both DBE and Opaals consist of a dispersed multicultural network of researchers which have to collaborate on the given task. Additionally, based on experience from prior work within DBE, Opaals aims to integrate interdisciplinary findings into the overall development process, which means that the dispersed multicultural network consists of researchers from different domains, each carrying its own set of domain specific language, communication practice and BDI structure.

On the front-end level we have the SMEs and regional/local decision makers represented by their catalysts and agencies. One key conclusion which derived from a Digital Ecosystems Cluster workshop in 2005 is the demand for global solutions with a local input and sector approach. This means that the socio-cultural (including socio-economic) diversity factor must be taken into consideration regarding the end users. It also refers to linguistic characteristics of the front-end and interface design, as language is a key denominator for group and community building.

An evolutionary language approach in terms of an advanced linguistic theory framework has to encompass both, the engines of formal languages and the gestalts and geometries of situated meaning. 'Evolutionary' also in terms of the inherent variable of dynamics and process, reflecting ongoing work in Opaals where communities of knowledge creation and processing are about to arise, constitute, and re-constitute themselves in an recurrent, autopoietic process.

Approaches

In the foregoing parts of this chapter we have tried to emphasise the dominant and vital role of language and communication within the Digital Ecosystem. We will now introduce social science approaches to research and application within the Digital Ecosystem Cluster.

Community Building

In order to build a 'new' community inside the Digital Ecosystem we have to understand the communities which are meant to participate. As mentioned before, these communities bring their own BDI structures, communication and work practices, and experience/expert knowledge which should be regarded as an important asset within the new Digital Ecosystem. In order to understand them and to build a new cooperative network, we have to analyse these inherent and inherited characteristics, which can be carried out by means of social network analysis. We can focus then on social relationships regarding language/communication usage when collaborating.

The language focus enables us to understand better :
a. organisational structures in terms of hierarchies, relationships, etc. (this would refer to the field of Critical Discourse Analysis);
b. hermeneutics which in this case aims to account for the interaction between human action and socio-economic and technical structures;
c. the different register of each community, i.e. establishing a first and tentative lexicon (database) of domain specific key terminology which can serve as an important input for formal language development (e.g. SBVR).

Knowledge Structures

Actor network theory (ANT) provides the necessary tools in order to analyse (among other aspects) knowledge and knowledge structures, which represent an important part of the Digital Ecosystem. ANT provides the necessary methodological framework to analyse such abstract and at the same time socially situated conceptual artefact as 'knowledge' in its relation to technology and community networks.

'Knowledge' can be considered as being highly embedded in a complex web of relationships and dependencies, it is inseparable from our working practices. According to Hanseth, who suggests a community-of-practice approach to knowledge: "[P]ractices are based on specific tools and technologies, organizing structures, various kinds of institutions, and other important factors. Knowledge is also dependent upon, and tied to, the context within which its epistemic culture and machinery is produced [...]" (Hanseth, 2004: 110). Understanding communities thus is a key to understand knowledge structures and production processes.

Advanced Automaton Approach

To conclude this chapter, we would like to shift our focus from language diversity as predominant and challenging feature of digital ecosystems to language as productive automaton within the Digital Ecosystem. An advanced automaton approach does not only state the constitutive role of language and communication practices in (digital) communities, but also propagates a practical, output-driven focus on language. Regarding the various communicative actions inside our Digital Ecosystem, we should analyse how we can manufacture those actions into any kind of communicative output (i.e. text, audio, video). Discussions on different tools for collaborative work are a necessary point of departure. However, addressing language itself as an automaton provides an additional and useful perspective. Language as automaton means that we can define the recurrent and constituting structures of different text genres across different disciplines or scientific domains, such as scientific article, deliverable, report, etc. This analytic mode can be stretched from a macro-level (overall text structure) to a micro-level, i.e. considering domain specific key terminology. Integrated into a manufacturing process inside the Digital Ecosystem this can help to increase the visible knowledge output (naturally, focussing on qualitative aspects) of the ecosystem and to foster the interdisciplinary community development inside the ecosystem by means of developing an analytic approach to cross-disciplinary publishing.

The advanced automaton approach certainly reflects an ambitious goal that combines a wide range of scientific domains, such as textlinguistics, sociolinguistics, computational linguistics, and computer science. However, research activities in the DBE cluster provide both expertise and associated research foci for a seedbed of an advanced and holistic notion of language and communication.

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4 Business Networks and Ecosystems: rethinking the biological metaphor

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Introduction

Driven by technological and market changes organizations compete and cooperate, and bring firms to experiment alternative coordination mechanisms that lead to intermediate or hybrid forms of organization. During the 90s, Powell and Castells argued that networks are distinctive form of coordinating economic activity and made sense to classify as "business network" any organizational structure adopting such a coordination mechanism.

Although research has made important contributions towards the understanding of business networks, further theoretical and empirical research is required to develop a better understanding of the processes underlying the structure and evolution of them.

Renewing the expectation of Marshall (1948) several authors look for inspiration in biological science, electing "the theory of ecosystems" and "the evolutionary theory" as the main biological research fields affecting social and economic science that provide innovative perspective and theoretical models.

In this work, we look forward to rethink the biological metaphor in order to explain the real relationship between business network and ecosystem in an evolutionary perspective.

Business Networks as Business Ecosystems

Castells (1996) proposed the concept of the networked enterprise as the organizational form that a firm would adopt to fit the conditions of uncertain and unpredictable environments. According to the same author, the strengths of the networked enterprise lie in the shift from vertical bureaucracies to horizontal enterprise enabled by the use of digital technology to connect and relate dispersed organizational nodes. In the networked enterprise, components are both independent of and dependent on the network organization and can also be part of several other networks. A network organization combines the advantage of bureaucratic organization with a structure that supports innovation.

Networks (Quinn et al. 1998) could be shaped by pointing out the nodes where knowledge is created and detained, the nodes where it is used to implement solution, and the kind of relationship that links together the different nodes. Taking into account both firm and market perspectives, the new organizational problem of the firms seems to be no longer that of granting alignment among different department objectives, but of coordinating networks of knowledge-owning firms to create added value products and services.

Inside clusters, a co-evolution process is emerging; it develops between the networks of localized knowledge and the trans-local knowledge networks (Doz et al. 2001), based on digital information exchange. These inter-organizational structures, defined as virtual clusters, are characterized by collaboration and complementarities and by the exchange of mainly digital knowledge. The concept of space is therefore crucial.

We may extend the concept of 'actor agglomeration' from industrial district to business network, as the generalization of any agglomeration structure that is represented by a set of firms, linked by some sort of spatial proximity (geographical, technological or institutional).

Economists belonging to any school of thought have discussed similarities between biological evolution and economic development for more than a century (Hodgson, 1998). Basing on the premise that "human beings exist wholly within nature as part of the natural order in every respect", Jacobs (2000) argues that the same principles underlie both ecosystems and economies. In particular, the author investigates the hypothesis according to which economic life obey the same rules as those governing the systems in nature, arguing that economic life is ruled by processes and principles that people do not invent and can not transcend.

Two serious drawbacks have always constrained the rigid application of biological metaphors to the study of economic development. The first is that evolution involves no intentionality toward a specific goal, whereas economic development is driven by the satisfaction of human wants. The second is that, with the exception of the smallest levels of complexity (such as genes and microbes), different biological species do not interbreed, while human beings produce new things by relentlessly combining artefacts, skills and ideas (Basalla, 1988; De Gregori, 1985; Mokyr, 1990). In this sense, economic development is the result of individuals trying to solve problems affecting them by combining heterogeneous facts, ideas, faculties, and skills on a scale that is unparalleled in the rest of nature (Jacobs, 2000).

Even if any comparison between economic and ecologic realms has to be careful, biological ecosystems seem to provide a powerful metaphor for understanding a business network. As biological ecosystems, business networks are communities of agents with different characteristics and interests, bound together by different mutual relationships as a collective whole. Species within ecosystems are related and interact with each other as much as firms play a specific role in a business network. The fate of each living organism in the ecosystem is related to the fate of the others; cooperation and competition, as much as in a business network, are considered ecosystem characterizing phenomena.

Tansley (1935) firstly defined an ecosystem as the whole system represented by both the biological organisms and a complex set of physical factors and he correlated the ecosystem with a network of relationships. Starting from the definition by Tansley, Lindeman (1942) developed the modern approach to the ecosystem by adopting Elton's food web model and Lotka's thermodynamic approach (Elton, 1927; Lotka, 1925) .

The first approach to business ecosystem is due to Moore (1993) who argued that a firm is not just a member of a single industry but a part of a business ecosystem that crosses a variety of industries. In a business ecosystem, firms' capabilities co-evolve around new innovations that characterise the ecosystem itself, as the locus around which species co-evolve by exploring innovative evolutionary path.

Extending Moore's biological metaphor and emphasizing the keystone metaphor, Iansiti and Levien (2004a) identified in keystone firms the leader and the centre of the ecosystem. They support two basic items: that the food web model is useful to describe systems of organizations as a network of mutual relationships, and that the new form of competition, the need for collaboration and the process of market co-evolution are simply explained as a results of the biological metaphor adoption.

Anyway we believe that biological metaphor proposed by Iansiti and Levien is hard to be used as an instrument of analysis for the business ecosystem for some reasons. First, it uses both thermodynamic and network theory in order to model interaction among populations and environment, while the business ecosystem perspective is not able to model the environmental conditions and can't leverage the thermodynamic theory to build a business ecosystem theory. Second, the concept of community, as defined in biological science, is proper to define Iansiti's own approach than the ecosystem one, since community takes care about populations relationships and evolution, and excludes environmental interaction. Third, Iansiti identifies the role of leader in keystone species that seem to have a role that is closer to the Iansiti artificial ecosystem than to the natural ones.

As a consequence, the key question is: how could we design, or at least support the creation and growth of natural business ecosystems? Although a business ecosystem may evolve toward centralized structures, moving toward what Tapscott et al. (2000) define as an aggregator model, a business ecosystem theory needs to be quite general in order to explain it as a kind of self constructed and auto organized business network. In such a context, we focus on the understanding of the rules that govern natural biological ecosystems and, as a consequence, natural business ecosystems.

The Evolutionary Perspective

Evolutionary perspective is the common ground for a theory of organizational change, capable of explaining the evolution of organizational models in terms of emergence and selection of new species.

Organisms play two roles in evolution. The first is the basis for most evolutionary theory and it consists of carrying genes; organisms survive and reproduce according to chance and natural selection pressures in their environments. However, organisms also interact with environments and modify at least some of the natural selection pressures present in their own, and in each other's, local environments. This second role for phenotypes in evolution is not been subject to a great deal of investigation: it is called "niche construction" (Odling-Smee 1988).

Niche construction should be regarded, after natural selection, as a second major participant in evolution. It is the process whereby organisms, through their activities and choices, modify their own and each other's niches. By transforming natural selection pressures, niche construction generates feedback in evolution in a manner that alters the evolutionary dynamic. Odling-Smee et al. (2003) developed a new approach to evolution that treats niche construction as a fundamental evolutionary process in its own right: it is called extended evolutionary theory.

In this new perspective, culture adds a second knowledge inheritance system to the evolutionary process through which socially learned information is accrued, stored, and transmitted between individuals. Tylor (1871) defined culture as "that complex whole which includes knowledge, belief, art, morals, custom and any other capabilities and habits acquired by man as member of a society", so how could such an inextricably interwoven complex of ideas, behaviour, and artefacts evolve?

Evolutionary Theory and Organizational Change

The first and most influential biological metaphor applied to socio economic science was Darwinian selection on the population ecology by Hannan and Freeman (1977), that takes from the biological perspective the suggestion of the emergence of new species of organizations that compete for resources. According to Hannah and Freeman, each organization is defined by its technology, structure, products or services, objective and people. These elements cause the organization's survival in the environment or make it disappear because of environmental selective pressure.

The attempt to adapt the evolutionary theory as a metaphor for explaining business perspective has a strong limitation in the lack of a unit of analysis for the evolution process, as gene for biological evolution. As a consequence it is difficult to create a model describing the emergence of organizational phenotypes in the evolution processes and their fitness respect to the environmental conditions.

Nelson and Winter (1982) suggested an evolutionary model, mainly based on the parallelism between genes and routines. The Nelson and Winter Evolutionary Theory of the Firm focuses the attention on organizational routines as unit of knowledge. They consider routines as behavioural patterns that workers use during their activities, which make different one firm from the others. Partly driven by his attempt to show that Universal Darwinism (Dawkins, 1983) provides a suitable framework for evolutionary economics (Hodgson and Knudsen 2006), also Hodgson suggests that routines are like genotypes (Hodgson 2003, Hodgson and Knudsen 2003).

The routine approach can be extended separating the perspective between behaviour and thing: according to Fontana (1998) behaviour is not a thing but it is property of a thing. As a consequence, the organizational routines could represent the functions and the dynamical principles that govern the interactions among the parts of the organization.

In this perspective Nelson and Winter routines became the phenotype of more complex genotypic elements that Padgett defines logic of identity.

According to Padgett (2001), organizations - social or biological - are developmental products of these founder logics, interacting with the inherent properties of the social or biological raw materials being assembled. In economic organization, these raw materials are in large part the social networks of business interaction partners, selected through trading and personnel flows.

Social and political networks have the two-fold roles of generation and regulation of markets. Recombination and refunctionality are the key elements through which organizational ideas and models are transposed from one domain to another. Social and political networks operate through negative feedback as a regulatory mechanism for transposition and reproduction, granting stability and equilibrium to the systems (Padgett and Powell, 2003).

Final Considerations

In the attempt to review the biological metaphor overcoming the limitations highlighted before, we considered the promising perspective come out from the studies of Fontana and Padgett.

The Fontana analysis about the relationships existing between phenotype, genotype and populations gives the opportunity for a deepeening about organizational genotype, relationship about organizational genotype and phenotype, environmental influence on the emergence of organizational population.

The Padgett analysis focuses the attention on the systematic relationship between processes of organizational birth and the surrounding social and economic contexts, out of which organizations are constructed. This perspective fits organizational emergence in respect to the surrounding social, economical and political environment.

Padgett logic of identity and multiple dynamic networks represent two key issues that enable further research on business ecosystem theoretical foundation and give a fundamental contribution in order to develop an evolutionary model for business network.

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2

Section Two

Economic and social aspects

NEW PARADIGMS

European Commission
Information Society and Media

1 Towards **Dynamic Clustering:** Capabilities and IT Enablers

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Abstract

"Industry clusters" are systemic agglomerations of enterprises with common or complementary business interests. Firms in clusters benefit from sharing the fixed costs of common resources, such as infrastructure and services, skilled labor pools, specialized suppliers, and a common knowledge base. These sources of productivity lie outside of individual firms, and economists refer to them as "external economies of scale" (Marshall, 1920). Given that these factors are geographically concentrated, the benefits of clusters are traditionally associated with spatial proximity. But in the 21st century, one can posit a new way of clustering based on networking of knowledge and competencies that goes beyond geographical proximity and that overcomes the "inward looking" nature associated with traditional clusters and Italian "industrial districts".

This paper sets forth emerging forms of "virtual" clusters that transcend location, focus on international markets, operate as ad-hoc business networks, are IT-enabled and based on dynamic aggregation of capabilities of different (often small) firms. The working hypothesis is that these new organizational arrangements, which in this paper are called "extended dynamic clustering" (EDC), can help small companies position themselves better in terms of global market access and innovation. The paper also discusses roles for information technology applications, and suggests a research agenda and potential policy implications.

Business Networks: Cluster Precursors

A decade ago, networks were the policy of choice for increasing industrial competitiveness. Major networking programs were promoted, supported, and studied by United Nations Industrial Development Organization, the World Bank, USAID, the European Union, and Organization for Economic Cooperation and Development (Rosenberg, 2005). The transition from policies to build networks to policies to build clusters—and to a large extent back to networks—is a story of evolving economic development practices.

In the 1980s, when international competition and rapid technological change forced massive restructuring across industries, Miles and Snow (1986) introduced their view of enterprise networks as a flexible, fluctuating and dynamic structure. Within the trend toward disaggregation and looser coupling, managers experimented with various organizational arrangements. Instead of using plans and schedules, and transfer prices to coordinate internal units, they turned to contracts and other exchange agreements to link together external components into various network structures. The "flexible manufacturing network" was rediscovered in western Europe –particularly in Northern Italy– where inter-firm collaboration was documented and explained by researchers (Brusco 1982, and Sabel 1989) and supported by organizations such as the National Confederation of Artisans in Emilia Romagna and the Steinbeis Foundation in Baden Wurttemburg. The idea was simple: companies would join together to achieve economic goals unattainable by an individual organization on its own. They would network to produce more complex goods, extend their market reach, acquire costly resources or services, or simply reduce costs.

In 1990, the Danish Technological Institute in Århus designed what became the standard policy model to increase networking among small and mid-sized enterprises (SMEs). It consisted by five steps: 1) publicizing the concept among SMEs; 2) training network brokers to organize and facilitate networks; 3) training "multipliers" (e.g., accountants, consultants, and lawyers) to identify potential network opportunities; 4) creating a three phase grants program as incentives for organizing networks that agreed to collaborate on hard business opportunities, developing plans, and implementation; and 5) evaluating the outcomes. The goal was to create a program that would change the behavior of SMEs and create the culture of cooperation observed in Northern Italy.

Numerous network typologies can be found in the literature (Powell, 1990). Proposals range from strategic hub-and-satellite networks as in the automotive industry (Kerwood, 1995), clan-like structures as in Japanese Keiretsus (Ouchi, 1980) and regional networks up to temporary networks and dynamic virtual organizations. Some distinguish between "soft" and "hard" networks (Williams, 1996). "Hard networks" are relatively small groups of companies that have been established to achieve concrete business objectives such as entering new markets, joint product development, co-production, or co-marketing and are likely to require formal agreements for sharing profits or resources. Hard networks are thus formed with a specific "bottom line" motivation. Firms in "soft networks" also expect to make money but not necessarily through contractual business ventures. The soft networks have open membership, tackle generic issues, and provide some general services. They depend on membership fees for part of their funding, and thus tend to be quite large. Their goals and structures are similar to trade associations.

Most research on business networks has focused on the general characteristics of organically evolved networks, and on their structure and development processes. Less attention has been paid to intentionally developed nets and their management, with the notable exceptions of the work of Jarillo (1993) and Parolini (1999) on value nets, and the emerging theory of network governance in economic sociology and strategic management (Amit and Zott 2001, Gulati et al 2000, Jones et al., 1997). The challenges involved in operating in a complex network remain fairly unarticulated. Relevant issues in this context are: the coordination of tasks and processes within networks, the allocation of orders, the measurement of surplus or utility and the distribution of profits. Future research should aim at the development of network management. Such research could integrate notions from Industrial Network Theory and the Dynamic Capabilities View (Moller et al., 2002) in order to identify the basic capabilities required in managing different types of strategic networks, and to elaborate their characteristics and interrelatedness.

Perspectives on Regional Clusters

Like networks, clusters are composed of firms that co-locate around a variety of common interests or needs[1]. But, unlike networks, neither "membership" in an organization nor cooperation is required to be "in" a cluster. "Free riders," simply by virtue of geography, are able to realize non-exclusive external economies that accrue to members of cluster associations, including access to information that flows informally.

Regional clusters are examples of external economies derived from industrial localization. They are self-reinforcing agglomerations of technical skill, venture capital, specialized suppliers, infrastructure, and spillovers of knowledge associated with proximity to universities and informal information flows (Hall and Markusen, 1985; Arthur, 1990). Porter's identification of local agglomerations, based on a large-scale empirical analysis of the internationally competitive industries for several countries, has been especially influential, and his term "industrial cluster" has

1) A cluster includes groups of companies and/or services and all of the public and private entities on which they depend, including suppliers, consultants, bankers, lawyers, education and training providers, business and professional associations, and government agencies.

become the standard concept in this field (Porter, 1998, 2001). Also, the work of Krugman (1991, 1996) has been concerned with the economic theory of the spatial localization of industry. Both authors have argued that the economic geography of a nation is key to understanding its growth and international competitiveness.

Clustering gives businesses an advantage over more isolated competitors. It provides access to more suppliers and support services, to experienced and skilled labor pools, and to the inevitable transfer of knowledge that occurs where people casually meet and talk business. Clustering enables companies to focus on what they know and do best; they need not do things they do not do well. Firms also benefit from synergy. Companies able to operate more or less as a system can use their resources more efficiently and collectively produce more than the sum of their individual outputs.

Among the advantages of clustering, none is as important as access to innovation, knowledge, and know-how. Industry-specific knowledge and know-how is created and diffused through entrepreneurial initiatives and innovative companies. Firms gain from greater access to tacit knowledge, the movement of knowledge that occurs intentionally among friends and colleagues and unintentionally when employees change jobs. This perspective suggests a social network model of clusters. A social network approach provides insights into the structure and dynamics of regional clusters by focusing on the relationships between firms and the social structures and institutions of their particular localities (Powell, 1990; Nohria and Eccles, 1992). This view has been used to explain the divergent trajectories of Silicon Valley and Boston's Route 128 economies (Saxenian, 1994).

The Challenges of Globalization: Small firms within and beyond clusters

The trend towards globalization of the economy poses a number of challenges to the smaller firms in traditional clusters. Often, due to size, scale, specialization and not least regulatory and legal impediments, SMEs lack the capacity to respond adequately to market opportunities or participate in tenders in international procurement contracts. This shortcoming is related to both the conditions that SMEs face and the operation of geographically based clusters. More specifically, one can distinguish 'internal' reasons (specific to the SMEs) and 'external' reasons (specific to clusters and insufficiently developed cross-border and cross-regional collaboration mechanisms among clusters):

- Internal reasons have to do with limited resources and competences. SMEs often do not posses all the relevant skills and competencies, and cannot afford the specialized human resources (e.g. legal, and technical expertise) required to participate in collaborative cross-border or cross-region processes for the co-creation and delivery of products and services;

- External reasons span from the perceived complexities of international contract negotiation, to trust and financial issues, as well as the perceived disadvantages in terms of size and skills (e.g. SMEs may rule themselves out when they know that some large competitors will be bidding). External reasons include also regulatory and legal gaps that create roadblocks to cross-border collaboration, contract negotiation, intra- and intercluster governance policy and institutional issues which hinder the formation and efficient operation of cross-border and cross-regional collaborative networks.

From these two perspectives, a fundamental challenge is how to facilitate linkages, not only among SMEs within a given cluster but also how to build such capacity across clusters and networks of SMEs. This challenge involves building 'internal' capabilities by enhancing the organizational, knowledge and technological capacity of SMEs to enter into cross-border and cross-regional collaborative processes for jointly producing and delivering products and services. It also involves building 'external' capacity in the environments in which SMEs and their clusters operate. In other words, if the 'internal' set of issues refers to the business challenges SMEs face, the 'external' issues concern the 'enabling framework' that will facilitate cross-border and cross-regional collaboration among SME clusters.

The Extended Dynamic Cluster: a New Paradigm

For the purposes of this paper, "extended dynamic" clusters are conceptualized as virtual clusters that transcend location, focus on interregional or international markets, are ITenabled, operate as ad-hoc business networks that can aggregate and reconfigure capabilities from different firms. "Dynamic" clusters can integrate SMEs involved in different production processes or operating in different markets. The advantage is that the resulting "extended dynamic" cluster is much more responsive and enjoys a steep learning curve.

Changes inside the cluster (e.g. changing or adding a key new partner) can bring significant changes in the ability to respond to opportunities in the market. This involves a knowledgetransfer process. Let's consider, for example, a cluster specialized in producing mechanical parts and tools for the automotive sector. They decide to respond to a tender from an aerospace company, and, because they lack some necessary skills, they decide to include in the cluster a supplier operating in the aerospace sector. The added competence of this new partner gives the cluster the possibility not only to go in the new market place, but to learn "by immersion" in a new industrial environment. This "full immersion learning" is learning not only from the new partner, but also from all the players in the aerospace environment, i.e. customers, competitors, suppliers, the regulatory agency, etc. Thus, in a short period of time, the cluster learns and evolves into a "new" type of cluster that now can operate in a new sector. Repeating this process several times improves the dynamic capabilities and thus the flexibility of the cluster to innovate, incorporate new technologies and tackle new markets.

One way to understand the notion of "extended dynamic" clustering is by positioning this new construct against traditional forms of business agglomeration, e.g. industrial clusters, and business networks. The diagram in figure 1 shows the two dimensions that characterize this evolved cluster form.

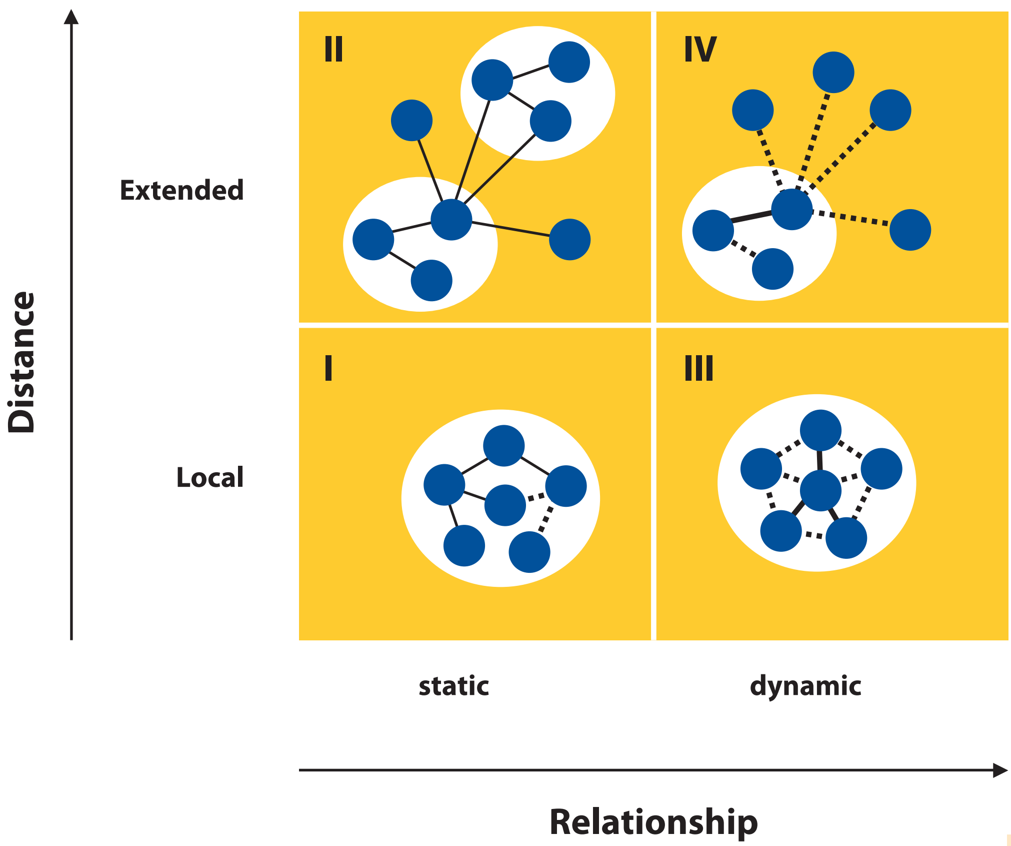

Fig. 1
Clustering typology

The horizontal dimension is based on the typology found in the literature on business networks that differentiates "dynamic" from "static" business relationships. Miles and Snow (1986) introduced their view of enterprise networks as flexible, fluctuating and dynamic structures. They point out that, while some networks bring suppliers, producers, and distributors together in long-term stable relationships (i.e. "stable networks"), other networks are much more dynamic, with components along the value chain coupled contractually for perhaps a single project or product and then decoupled and reconfigured to be part of a new value chain for the next business venture (i.e. "dynamic networks").

The vertical dimension represents the geographic reach of the network, i.e. the space in which a given (extended) cluster operates. This dimension can be operationalized essentially as the average geographic distance between the networked firms. In practice, it may be useful to differentiate between local, regional, national, and transnational domains. This differentiation may be particularly important for network governance. Both governance issues and policy recommendations are likely to differ at local, regional, national and supra-national level.

Capabilities for Dynamic Clustering

The strategic management literature has traditionally focused on analyses of firm-level strategies for sustaining and protecting extant competitive advantage, but has performed less well with respect to assisting in the understanding of how and why certain firms build competitive advantage in regimes of rapid change. To address this problem, researchers have focused on "dynamic capabilities" which are defined as the "ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece et al., 1997).

Dynamic capabilities reflect "the ability to learn new domains" (Danneels 2002). Hence, their value lies in the configurations of functional competencies they create (Eisenhardt and Martin 2000, Zott 2003). For example, by spotting market trends and accordingly revamping functional competencies, dynamic capabilities can prevent rigidities (Leonard-Barton 1992) and competency traps (March 1991). Also, by replacing outdated configurations of functional competencies and architecting more relevant ones, dynamic capabilities can create better matches between the new configurations of functional competencies and environmental conditions (Teece et al. 1997).

Reconfiguration is generally viewed as the ultimate outcome of dynamic capabilities. Most studies in the dynamic capabilities literature stress the importance of reconfiguring existing resources into new configurations of functional competencies. For example, reconfigurability refers to the timeliness and efficiency by which existing resources can be reconfigured (Galunic and Rodan 1998, Zott 2003). It refers also to the concept of 'combinative capabilities' (Kogut and Zander 1992) that describes the novel synthesis of existing resources into new applications. Eisenhardt and Brown (1999) refer to the ability to "quickly reconfigure resources into the right chunks at the right scale to address shifting market opportunities". Applied to extended clusters, the concept of "dynamic capabilities" implies that SMEs networks can re-deploy their existing competencies to build new products or services through innovative, aggregated competencies that better match emerging market and technological needs.

The dynamic capabilities and related literatures describe four processes that drive reconfiguration for innovation:

- Sensing the environment (market orientation): Sensing helps understand the environment, identify market needs, and spot new opportunities (Zahra and George 2002).
- Learning: Learning builds new thinking, generates new knowledge, and enhances existing resources (Zollo and Winter 2002).
- Coordinating Activities: Coordinating helps allocate resources, assign tasks, and synchronize activities (Teece et al. 1997).
- Integrating Resources: Structuring interactions among partners and integrating resources helps implement architectural innovations (Grant 1996, Henderson and Clark 1990).

While dynamic capabilities can reconfigure all resources (Prahalad and Ramaswamy 2004), it is important to stress the role of knowledge as an intangible resource (Galunic and Rodan 1998). Leonard-Barton (1992) argues that as resources become less tangible, but explicitly codified, they will be easier to reconfigure.

The Role of Information technology

Much has been made of the potential of ICT to enable a de-spatialization of economic activity. Cairncross (2001), among others, posits that with the introduction of the Internet and new communications technologies, distance as a relevant factor in the conduct of business is becoming irrelevant. She contends that the "death of distance" will be the single most important economic force shaping all of society over the next half century.

Indeed, the advent of the Internet and overnight delivery reduces the value of localization economies, i.e., access to the lower cost intermediary inputs to production, including parts, services, and information at a distance. Proximity still matters for critical components that are knowledge intensive and depend on interactive research and design or special expertise for assembly or utilization, but many of the sectors included in standard cluster maps are of diminishing economic advantage. Future research will thus have to look at "extended" clusters as geographically proximate complex organizational systems of learning and economic and social activity that are globally networked and enabled by the effective application of IT. These are some of the key questions:

- How will IT affect traditionally perceived needs for physical proximity and introduce "virtual" proximity as a complement to physical proximity?
- Can "virtual" clusters be expected to emerge and/or develop, in part, as a result of the widespread application of IT?

- What combinations of physically proximate and "virtual" arrangements best augment the social and economic performance of networked clusters?

One way to address these questions is by focusing on the processes that enable "extended" and "dynamic" clustering as identified above and envisioning different ways in which IT can play a relevant role. The following sections discuss potential roles of information technology to enable clustering capabilities along the two dimensions identified earlier, i.e. virtual proximity capabilities and dynamic clustering capabilities.

IT and Virtual Proximity

In traditional clusters, the need for physical proximity has led to regional agglomerations. The geographic boundaries of these clusters are set by the distances that those in firms and entrepreneurs are willing to travel for informal face to-face meetings and by how far employees are willing to travel to work. But relying exclusively on physical proximity limits the available talent pool and the access to specialized facilities. So there is a strong case for taking advantage of IT to link to remote professionals and resources, and to other organizations through ties such as alliances, partnerships, and information-exchanges. The underlying assumption here is that geographical proximity, collegiality, and group membership does not bound communication. Indeed, employees rely increasingly on information from outside their group and outside their organization for accomplishing their tasks, (Wellman 2001, Hargadon and Sutton 1997).

These boundary-spanning links make organizations more open systems whose boundaries are more permeable to information from the outside. They function as interconnectors between multiple networks, providing access to new information and more creative problem solving (Jarvenpaa and Ives 1994). For example, Robin Teigland (2000) has shown that boundaryspanning information exchanges led to higher levels of creativity, and information obtained from online communities increased workers' performance.

Some researchers argue, however, that knowledge cannot be shared or absorbed independently of the processes through which it is generated (Roberts, 2000). But, if greater stocks of knowledge can be circulated across electronic networks and used in ways that effectively support learning, then the importance of geographical clustering and physical presence may indeed be reduced.

Figure 3 shows a relationship between the degree of codification of knowledge and the speed and extent of its diffusion within a target population (O'Callaghan and Andreu, 2006). The figure highlights a tradeoff between codification and reach. The shape of the curve indicates that more people can be reached per unit of time with knowledge that is codified (explicit) than with knowledge that remains uncodified (tacit). As the size of the target population that one seeks to reach increases, the message needs to be more highly codified to reach that population quickly, and much of the contextual richness of the message must be sacrificed for the sake of communicative efficiency.

New IT applications can change the nature of this trade-off between loss of context and speed of diffusion. By increasing data processing and transmission capacities, they enable more data to reach more people, whatever the level of codification chosen, as indicated in the figure 2. This is shown by a horizontal shift in the curve.

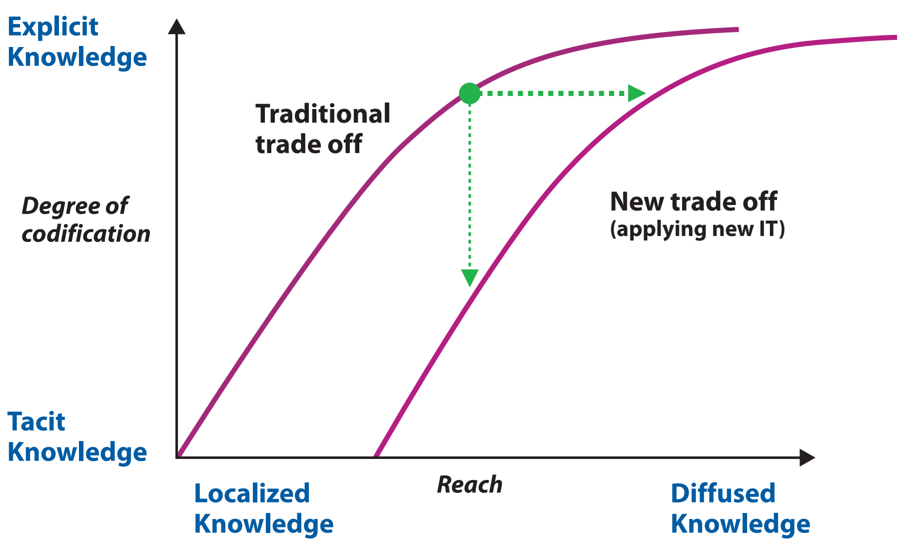

Fig. 2
Knowledge flows, distance and IT impacts

The horizontal arrow shows how at a given level of codification, the population to which a message can be diffused increases. But, the vertical, downward pointing arrow also shows something else: it suggests that, for a given size of population being targeted, a message can be sent at a lower level of codification than in the absence of IT, i.e. the message can transmit more of its context, thus restoring some of the context-specific interpersonal qualities usually sacrificed to codification.

Early generations of knowledge management solutions focused on explicit knowledge in the form of documents and databases, but as the above figure suggests, there is a need to expand the scope of the solutions to integrate technologies that can support tacit knowledge (Marwick 2001). Future applications will have to address the following needs:

- IT to assist teams share experiences: build and share tacit knowledge
- IT to help groups work effectively together: group support and collaboration
- IT for electronic meetings and trust building: e.g. high definition videoconferencing
- IT to identify individuals with the right knowledge: expertise locator
- IT to elicit help from experts and the community: forums and bulletin boards
- IT to tap the knowledge of experts: capture expert judgments via hyperlinks, citations
- IT to support the formation of new tacit knowledge from explicit knowledge: portals, taxonomies, knowledge mapping, etc.

IT and dynamic capabilities

The following paragraphs focus the potential role of IT to enable or support dynamic clustering capabilities. The discussion is structured around the four constructs identified above: market orientation, absorptive capacity, coordination, and collective mind. This is illustrated in figure 3 that depicts a model for IT applications used to overcome distance barriers, enable virtual proximity, and support dynamic capabilities.

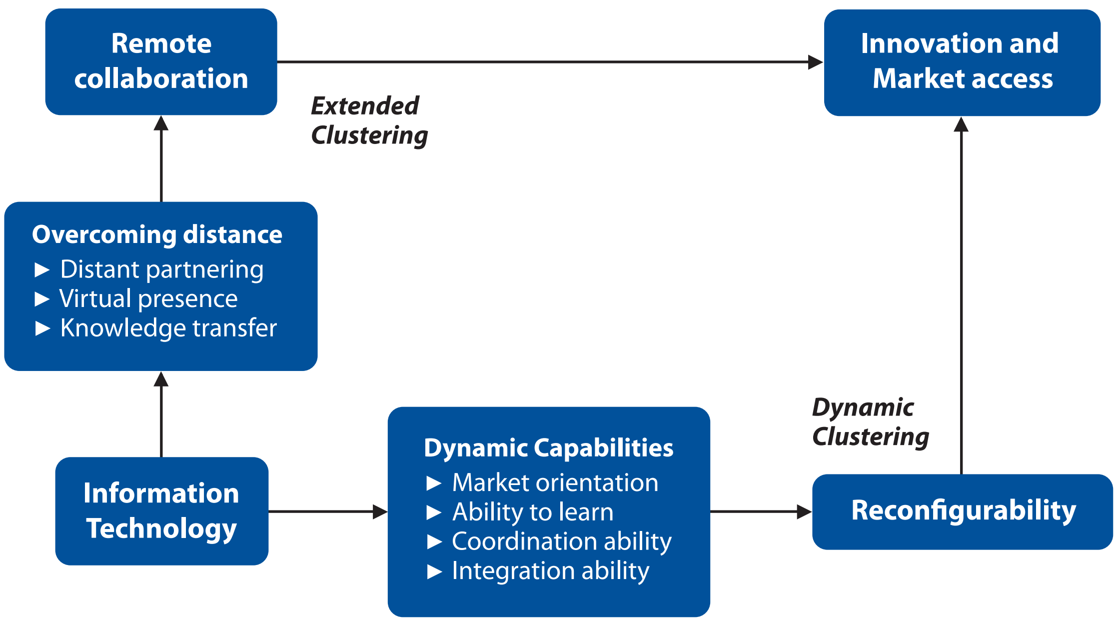

Fig. 3
Role of IT in Extended Dynamic Clustering

"*Market Orientation*" reflects the ability to sense the environment and understand customer needs and competitive dynamics. It is defined as 'the process of generating, disseminating, and responding to market intelligence about customer needs' (Kohli and Jaworski 1990). These processes can be supported with the following IT applications:

- IT for capturing market intelligence, e.g. external communication links for sensing market trends or discover new market opportunities.
- IT for disseminating market intelligence to the appropriate parties in the business network / virtual cluster
- IT for analyzing and interpreting market intelligence
- IT for responding to market trends, e.g. by enabling processes and supporting operations that capitalize on market intelligence

The literature refers to "*Absorptive Capacity*" as the *ability to learn* by identifying, assimilating, transforming and exploiting existing knowledge resources to generate new knowledge (Cohen and Levinthal 1990, Zahra and George 2002). Regarding IT, the relevant IT applications are:

- IT to help acquire or "broker" knowledge
- IT to help assimilate knowledge (e.g. knowledge articulation and codification)
- IT to help transform knowledge, (e.g. in supporting new thinking, brainstorming, experimentation, and problem-solving)
- IT to help exploit knowledge (e.g. in new projects, identifying new solutions)

Coordination capability reflects the ability to manage dependencies among resources and tasks to create new ways of performing a desired set of activities (Crowston 1997, Malone and Crowston 1994). Pertinent IT applications are:

- IT for allocating resources (including distribution of knowledge)
- IT to help assign tasks among partners
- IT for appointing the right person to the right unit or project
- IT to help synchronize activities among collaborating partners
- IT for reaching synergies among tasks and resources

The literature refers to "*Collective Mind*" as the "*ability to integrate* disparate inputs through heedful contribution, representation, and subordination into a group system" (Weick and Roberts 1993). "Collective Mind" can also be conceptualised as the *architecture* for the whole system. In this respect, it helps implement a set of complex activities by specifying the organizing principles by which individual knowledge is integrated (Grant 1996). The IT related questions are:

- IT to model and help structure the cluster/ network
- IT to monitor how partners fit in, interact, and their activities affect others
- IT to interrelate diverse inputs (including knowledge) from constituent firms to execute the collective activity of the cluster / network
- IT to help individual inputs contribute to the group outcome
- IT to support the sharing of knowledge among partners
- IT to keep network managers informed

Policy implications and future research

The research advocated in this paper calls for the development of a theoretically grounded framework for "Extended Dynamic Clustering" (EDC) in order to investigate how ICT infrastructures, collaborative systems, governance structures and other factors can influence clustering across borders and improve SMEs' ability to innovate and access global markets.

The Extended Dynamic Clustering (EDC) paradigm may provide a new perspective for policy research and practice. To apply the EDC concept to policy, instruments have to be developed to identify extended dynamic clusters (or clusters that have EDC potential), as well as tools for improving inter-organizational structures and processes that facilitate dynamic clustering. Research should identify extended dynamic clusters in some countries or regions, and establish whether the regional / national economies can be effectively examined through the EDC lens; and, if so, whether policy makers can more accurately identify market imperfections of existing clusters, and determine what interventions might have the greatest impacts. To this effect, potential research products could include:

- Conditions for an outward-looking perspective on clusters with emphasis on the traditional economic strengths of regions but also on dynamic capabilities to respond to rapid economic changes and global competition.
- Conditions for reconfiguring clusters as 'hubs' and roles of institutions in helping build regional economic capacity (in terms of dynamic capabilities, networking and international connections) to enable regional SMEs to confront the challenges of being 'hubs' between a global economy and a regional business ecosystem.
- The effects of open-source IT platforms and tools that may support new methods of collaboration, and process integration within, between and across regional networks incorporating SME's and large contracting organizations, as part of an end-to-end supply chain.
- Domains for policy intervention in terms of regulation, legal measures, technology policy at supranational, national and regional levels for the creation and facilitation of dynamic clustering.

Extended dynamic clusters differ from traditional clusters in their extra-territorial reach, dynamic capabilities and the enabling role of IT. Information technologies provide a new means of linking up local places and regions within networks of organizations. Inclusion in the network requires an adequate local technological infrastructure, a system of ancillary firms and other organizations providing support services, a specialized labor market, and a system of services required by the professional labor force. Research outcomes should include guidelines for policy makers and civil society organizations in order to facilitate the transitioning of SMEs to extended dynamic clusters as well as the adoption and usage of related ITs. Research results could also inform, for example, ways for SMEs to reconfigure themselves from being simple members of a local cluster to being important nodes of a global network of business partners.

The new industrial spaces of today are complex networks with multiple nodes. They can be seen as geographically proximate, complex organizational systems of learning and economic activity that are globally networked with other systems. The spread of global, national, regional and local IT networks and information flows may fuel an "innovation ecosystem" (cross regional and trans-national), and act as a catalyst for social learning processes that give rise to successful economic and social development. If public policy makers proactively encourage the integration of advanced information technologies through "digital ecosystems" to link geographically clustered firms with other organizations within and beyond their immediate regional surroundings, there might be opportunities for a departure from the conventional pattern of regional development and a catalyst for growth.

Social and economic aspects of ecosystems: The next chapters

The next chapters in this book develop different aspects of "digital business ecosystems" (DBE), including economic, social, regulatory and trust-related issues. Darking's chapter discusses the role of "governance" in ecosystems, and proposes six different "dimensions" of governance: 1) constitution and balance of interests, 2) culture of communication, 3) credibility, attunement and trust, 4) organization and synchronization, 5) licensing and regulation, 6) technological dimension. Cutting across organizational, regulatory and technological frameworks, these dimensions provide inter-related concepts for further research and discussion. The chapter of Rivera Leon provides a framework for assessing the cost and benefits of DBE with the aim to raise awareness among policymakers and encourage them to implement DBE in their regions. In another chapter, Berdou discusses two important characteristics of networks and communities of practice (knowledge and structural embeddedness) and indicates how they relate to the sustainability and scalability of Digital Ecosystems. Knowledge embeddedness relates to the dependency of knowledge on social context. Structural embeddedness refers to embeddedness of economic action in social relations and the way "the quality and network architecture of exchange relations influence economic activity". In the last chapter, Tsatsou and Elaluf-Calderwood summarize research on the factors contributing to trust amongst small- and medium–sized enterprises (SMEs) in Digital Business Ecosystems. They describe a regulatory framework based on three building blocks: 1) Privacy and consumer protection, 2) e-signatures and security, and 3) jurisdiction and consumer protection, and discuss the development of the "Knowledge Base of Regulatory Issues" which is important in the context of the development of Free Software/Open Source (FS/OS) for commercial use within the European Union countries.

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2 Understanding the Role of Governance in the context of Digital Ecosystems

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Abstract

In this chapter, key characteristics of digital ecosystems are described and developed as 'dimensions of governance'. Governance can have far-reaching and fundamental consequences with respect to the way relationships are constituted within a given social context. Understanding the role of governance in the context of digital ecosystems requires consideration of the social, regulatory and technological aspects of ecosystem-based technologies and social networks. It also involves understanding governance as a spectrum of working practices that include both formal and informal working arrangements. In this chapter, social science research contributions from the digital business ecosystem project are drawn upon to develop a preliminary framework for supporting discussion and further research around this topic.

Introduction

The policy vision for digital ecosystems is to use the latest developments in technology infrastructure design, to create a framework for innovation that will enable small and medium-sized enterprises (SMEs) to cross the digital divide, thus stimulating regional development. The innovation and diversity inherent in the business models and practices of SMEs has the potential to provide Europe with a groundswell of new products, ideas and services. However, for this source of innovation to be fully mobilised, the right regulatory, technological and social conditions need to be created. However, in seeking out the 'right' regulatory, technological and social conditions, a central paradox is opened up. Diversity is contextual in that environments that are themselves varied and distinct nurture it. In this respect, what constitutes 'ideal conditions' for growth in one environment may prove obstructive in another. Therefore, formulating a template for governance that puts in place the 'right' conditions for ecosystem-based innovation and which also supports the diversity inherent in the business practices of European SMEs constitutes a significant challenge.

In this paper, the role of governance is considered in the context of digital ecosystems and a preliminary framework for supporting discussion and further research around this topic is outlined. Social science research carried out as part of the Digital Business Ecosystems (DBE) project is drawn upon to elicit insights into regulatory, constitutional and technological aspects of digital ecosystems governance. From this, a number of different 'dimensions' are proposed according to which the topic of ecosystems governance can be understood. The significance of these dimensions can only be touched on here, but in developing them, a basis for thinking about and analysing issues of digital ecosystems governance is provided and can be further developed in future research.

Understanding the role of governance

Governance refers to the constitution of relationships between different social groups and the processes of decision-making through which rights and responsibilities are established and defined. Traditionally, the term 'governance' has been used to describe the relationship between a government and its people or alternatively, the relationship between a company and its shareholders - the latter known as 'corporate governance' (Coyle 2003; Benn and Durphy, 2006). Over time, the meaning of governance has been extended to include all aspects of civil society, not simply those pertaining to central government or large companies (Ostrom, 1983). More recently, as understanding has grown of the choices inherent in the design of new technologies, governance is also used to describe technology procurement and the way key technological relationships and dependencies are established between technological products and systems purchased by an organisation (Thomas and Ranganathan, 2005).

One of the analytical challenges of understanding the role of governance is that it is comprised of characteristics that are deeply context specific, yet it focuses attention on principles and dimensions that have a generic or universal quality, such as duties, rights and responsibilities. In addition, the spectrum of decision-making structures, events and routines to which it can refer are far-reaching; from formal voting mechanisms to informal consensus building, governance can be understood to be comprised of a range of different practices and 'working rules' (Mansell, 2006). Together these rules and practices constitute a basis for coordination and an associated culture of meetings and communication (Darking, 2006). At the formal end of the spectrum, legally constituted entities and relationships bind and characterise relationships. However, the significance of informal means of coordination should not be underestimated. Informal environments afford flexibility with reduced organisational overhead and less reliance on formal contracts. In a business context, this flexibility can allow smaller companies to respond to customer needs in an agile and timely way. It can also create conditions of trust that facilitate the transfer of knowledge between companies and co-workers (Gow, Elaluf-Calderwood and Tsatsou, 2005).

Another analytical challenge is that, from a governance perspective, regulatory, technological and organisational frameworks cannot be studied in isolation from one another. Each of these frameworks can alter the basis according to which interactions take place; therefore alterations to one can have consequences for each of the other. It is therefore necessary to consider regulatory, organisational and technological dimensions both respectively and relative to one another, when considering questions of governance.

The digital ecosystems context

There are several key characteristics that have an important bearing on the underlying logics that shape the governance and coordination requirements of digital ecosystems. The most significant characteristic is the policy vision and focus of digital ecosystems, which is firmly centred on SMEs and regional development (Nachira, 2002). This emphasis acts as an organising principle in all decision-making processes relating to the DBE infrastructure. Similarly, the distributed and open source philosophies that are characteristic of DBE technology design and infrastructure development also play a significant role in the ecosystem vision. A further constitutional aspect of the DBE is the membership and participation conditions applied to stakeholders, each of whom have clear yet diverse interests in ensuring the sustainability of the DBE. Guaranteeing a balance of interest amongst diverse stakeholders – especially where those stakeholders are of varying size (i.e. a small company and a large corporation) - is of critical importance if digital ecosystems are to maintain their orientation towards supporting SMEs. For stakeholders to understand themselves as having a voice within governance and decision-making processes, an open, inclusive and transparent culture of meetings and communication needs to be established. Internet technologies and open communication forums offer an important vehicle for achieving such transparency (WGIG, 2005).

Aligning interests around common goals and ensuring that infrastructure development remains attuned to the needs of SMEs and regional development will have a fundamental impact on the level of trust and credibility associated with digital ecosystems. Trust, credibility and attunement were identified as fundamental to the specific e-business practices involved in using the DBE and in the continuing engagement of SMEs (Darking & Whitley, 2005; Gow, Elaluf-Calderwood and Tsatsou, 2005). These attributes are particularly relevant given that use of the DBE involves a high degree of knowledge sharing with respect to business models and in terms of engagement in open source development. In establishing credibility and ensuring that engagement strategies were attuned to the needs of regions and SMEs, results from DBE regional analysis highlighted the diversity that exists between regions. Identifying relevant sectors, communities and organisations with which to engage was a region-specific task from which individual strategies could be derived, but from which no single model for leadership could be defined (Passani, 2005).

In addition to the coordination of regional engagement, the developer community who are responsible for maintaining and developing the DBE code base also require a basic framework for carrying out their responsibilities. At present, the developers act as a distributed group working under the leadership of two individual 'synchronisers'. This lightweight level of coordination and integration was designed in order to keep organisational overheads to a minimum, thus enabling the sustained, voluntary engagement of developers beyond the end of the project (Darking 2006). The code base also requires the protection offered by licensing, in this case, the General Public and Creative Commons licensing that currently dictates the use of DBE knowledge and code. As well as licensing arrangements relating specifically to the code base, the DBE project also developed a regulatory framework, which aimed to provide basic legal resources necessary to enable SMEs to carry out business via the DBE infrastructure and included an automated process for contract generation. The significance of this framework in acting as a resource to support SME e-business interactions was such that its coordination and design constituted an area of governance research in and of itself.

The de-centralised, distributed design philosophy that underlies the way in which the DBE infrastructure is maintained and developed constitutes another defining characteristic. This 'meta' approach to infrastructure development is designed to reduce lock-in and dependency, pushing choice and decision-making power away from the centre. The role of open source development methodologies and modes of organisation is a central requirement with respect to attaining this end. Finally, one of the most innovative characteristics of digital ecosystems is its use of biologically-inspired algorithms to support the distribution and composition of business services

Dimensions of digital ecosystems governance

Drawing on the key characteristics of the digital ecosystems context outlined in the previous section and the observation that governance involves a spectrum of processes, rules and interactions made in the introductory section, six 'dimensions of digital ecosystem governance' are outlined. Integrating key findings from social science research carried out as part of the DBE project, the table below links characteristics of the digital ecosystem context together with dimensions of governance. Cutting across organisational, regulatory and technological frameworks, these dimensions should be considered as inter-related and at times over-lapping concepts for organising further research and discussion on the topic of digital ecosystems governance.

Characteristic of digital ecosystems	Dimension of digital ecosystem governance
Shared values, common vision, participation and membership expressed in constitutional documents such as manifesto, bill of rights, code of practice	Constitution and balance of interests
Transparency, inclusion, due process, policy, procedure and accountability	Culture of communication
Alliance forming and regional coordination, allowing for diverse governance models and diverse membership	Credibility, attunement and trust
Distributed template, lightweight organisation and synchronisation for aligning codebase infrastructure development; association and alliance forming	Organisation and synchronisation
Knowledge and technology licensing, regulatory framework for digital ecosystems e-business interactions and legal definitions relevant to DBE entity	Licensing and regulation
Choice of software development methodologies, technological directions and infrastructural standards; association and alliance forming	Technological dimension

In order to set in place the policy vision for digital ecosystems, the values and priorities encapsulated by that vision need to be embedded in constitutional documents such as a manifesto, bill of rights or other statement of common purpose. Defining the constituency to whom the bill or rights or common values apply is another important aspect of constitution building.

In terms of ensuring the operational viability of the infrastructure, there are a number of tangible areas toward which questions of governance can be applied. Questions surrounding the maintenance and development of the DBE code base constitutes one such area. Another tangible area is security; the extent to which identities can be trusted and data securely shared via the DBE infrastructure. Sharing business models is also a significant tangible area that requires constitutional support in the form of a code of practice for SMEs to ensure interests are protected. In addition to these operational questions, governance of the DBE regulatory framework is an extremely influential area of the ecosystems environment, which brings with it specific governance requirements. As a set of processes that involves consequences for the infrastructure as a whole, the evolutionary environment denotes another area that will require some form of governance or coordination.

Conclusion

The purpose of identifying the characteristics and dimensions above is to formulate the outline of a framework for considering issues associated with digital ecosystems governance. As more fully developed in deliverable D32.7, these characteristics and dimensions can be applied to tangible areas that arise as relevant to digital governance and coordination efforts. From a research perspective, this framework could act as a basis for formulating a taxonomical approach to exploring, setting the boundaries and assessing the relevance of issues associated with digital ecosystems governance.

The policy vision for digital ecosystems places specific demands on the creation of a template for governance. Creating organisational channels for participation and collaboration that allow SMEs to define a technological infrastructure and regulatory environment that serves their needs above all others is not straightforward. The diversity inherent in SME requirements and the regional variations as to what constitutes a credible framework for participation indicate that a distributed, de-centralised template would offer the highest degree of flexibility and attunement to local needs. Preserving the diversity of local needs and contexts has the potential to support and inspire innovation offering significant advantages to SMEs, regions and Europe as a whole.

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3 A Cost-Benefit Analysis Framework for Assessing the Net Benefits of Digital Business Ecosystem implementation in Europe

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Introduction

Knowledge is central for economic development (World Bank, 1998). The movement of ideas within a country or a region and the capacity on which knowledge can produce positive impacts on economic development depends on the effectiveness of its knowledge communication system. The Digital Business Ecosystems (DBE) has the capacity to provide every business entity in Europe with a powerful opportunity to efficiently use knowledge. The ability to be connected and to share and acquire knowledge is a contributor to reduce the information gaps and to lower power asymmetries between Large Enterprises (LEs) and Small and Medium Enterprises (SMEs). DBE infrastructure can be conceived as a corrective action to solve the lack of access to information among enterprises. Business connectivity allow SMEs to increase their opportunities to integrate themselves into global value chains and provide them with more upgrading opportunities that create further positive impacts on regional development.

DBE implementation has the potentiality to produce positive effects on productivity as knowledge (access and dissemination) enhances the productivity of capital (Stiglitz, 1999)[1]. It also has a potential in inducing regional development through competitiveness enhancement among business. New growth theories consider that the more resources devoted to technical progress (activities that produce innovations), the higher the growth rates (De Castro, 1998). DBE has the potentiality to endogenously impact production, as productivity increases are endogenous to production (Cooke et.al., 2005). Investing in DBE implementation is a long-term investment in knowledge creation and dissemination.

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1) It allows access to information and knowledge through business connectivity.

Although the scientific research on the potentialities of DBE has been extensively developing over the last years, there is still a lack of awareness among policymakers and general public on the socioeconomic impacts of DBE implementation. This paper explores these potentialities while proposing a Multiple-Account Cost-Benefit Analysis (CBA) framework to assess them.

This study has two main objectives:

1. to provide an efficiency analysis of the existing pilot projects
2. to promote among policymakers the benefits of DBE implementation.

CBA is a systematic framework to analyse the efficiency of projects, programmes, policies or regulations (Munford et.al., 2000). We believe that by giving monetary values to benefits and costs of DBE implementation we will be able to provide policymakers with valuable information to encourage them to implement DBE in their regions.

Four different accounts are proposed for the CBA for DBE implementation: financial, user/consumer, economic development and social.

The first two accounts (financial and user/consumer accounts) present the actual data of two selected regions that have implemented DBE pilot projects: the region of Aragon in Spain and West Midlands in the United Kingdom (UK). The economic development and social accounts are presented in the form of guidelines, as they are region-specific[2]. The main indicators that should be analyzed by any interested region on DBE are presented. Because current pilot projects are still at an early stage of development we cannot provide concrete impacts on these accounts. Economic theory will provide us with the bases of the likely impacts of DBE implementation.

An ideal business structure for DBE development

DBE can be used by every business entity in Europe, irrespective of the size of the concerned enterprise and its sector of activity. According to the Industry, Trade and Services Statistics of Eurostat (2006)[3] there are more than 17 million SMEs in the European Union 25 (EU-25). SMEs have a main role in the business structure of Europe. In 2003, 99.8% of total enterprises in EU-25 non-financial business economy were SMEs. Micro enterprises are predominant, representing the 91.4% of total enterprises, followed by small enterprises with 7.3% of total and medium enterprises with 1.1%. LEs are only 0.2% of the total[4]. As DBE is especially oriented to support SMEs connectivity[5] it is necessary to study European business characteristics focusing on SMEs.

More than 65% of all SMEs in EU-25 are concentrated in 5 countries: Italy (22% of total), Spain (14%), France (13%), Germany (10%) and the United Kingdom (9%). Italy and Spain together have more SMEs than 20 other countries in the EU-25. In average, in 2003 there were 38 SMEs per 1,000 population in the EU-25. Countries above this average are Italy, Spain, the Czech Republic, Portugal, Hungary, Slovenia, Cyprus and Luxembourg. Some of these countries are different from the countries that concentrate most of SMEs mentioned above, indicating that the industrial structure of a country is determinant for SME proliferation. We expect that DBE implementation will be largely beneficial for countries whose sectors and economic structure are dominated by small firms.

Data from the Observatory of European SMEs[6] shows that the countries with the largest concentration of SMEs have seen their number of SMEs decrease considerably over the last 10 years, evidencing a large SME mortality rate. DBE also would help SMEs to reduce their vulnerability by creating networks among them.

2) "Region-specific" in the sense that the social context and the economic (and institutional framework) setting vary from region to region

3) Although otherwise stated, all the indicators presented in this section are built from data of the Industry, Trade and Services Statistics of Eurostat. Raw statistical data can be found on the Eurostat website.

4) A micro enterprise is an enterprise that has 1 to 9 employees. Small enterprises have between 10 and 49 employees. Medium enterprises employ between 50 and 249 persons and large enterprises employ more than 250 persons.

5) SMEs could be connected with other SMEs but also with large enterprises around Europe.

6) This data is taken from the CD-ROM of the Observatory of European SMEs. It gathers data from SME statistics from Eurostat and from the ENSR Enterprise Surveys. The online version is accessible at: http://www.eim.nl/Observatory_Seven_and_Eight/start.htm

European SMEs serve a variety of different sectors. They are mainly concentrated in two sectors: services and trade. Service SMEs[7] are mainly located in Germany, the UK and Italy, while trade SMEs[8] are dominant in Italy, Germany and Spain. Manufacturing industry SMEs are less important in number but are very relevant in terms of value added and employment. Manufacturing industry SMEs are mainly located in Italy, the UK and Germany[9]. Construction SMEs are mainly located in the United Kingdom, while most of the wholesale and retail trade SMEs are located in Italy. Hotels and catering SMEs are widely present in France, Italy and Spain; while the majority of business services SMEs are located in Italy, Germany and the United Kingdom. On analyzing the economic impact of DBE implementation it is important to understand that different outputs can be expected according to the "weighted importance" that the concerned sector has on the regional economy. It is necessary to underline that expected outcomes are region-specific, but they could be also sector specific according to the deployment strategy and the approach to DBE[10] adopted by each region.

An important facilitator for DBE implementation is SME's engagement in e-business. The European Commission E-business survey 2006 shows that there are big differentials in the use of e-business applications between large enterprises and SMEs (EC, 2006). The overall e-business Index[11] (based on firm-weighted data[12]) in 2006 reveals that there are approximately 50 SMEs engaged in e-business for every 100 LEs. The European Commission (2005) underlines that ICT and e-business offer SMEs an improved access to market information at low cost. Nevertheless, as fixed costs for technology implementation tend to be relatively higher for small companies, there is still a weak use of internal applications and supply-side e-business activities among SMEs.

In contrast, there are no differences between small and large enterprises when receiving orders from customers online[13]. The sectors connecting and receiving orders from customers online more frequently for small enterprises are tourism, Telecommunications and the Pulp and Paper sector. This reveals that connectivity with customers and cooperation networks with other SMEs is crucial for them while competing in the marketplace. Nevertheless, there is a gap between the percentage of SMEs receiving at least some orders online (26%) and those that have special software for doing so (11%). This confirms that SMEs use rather "simple" forms of e-commerce: receiving orders by e-mail without any system integration of the related information and document flow.

Benchmarking ICT adoption and e-business by country is a complex exercise, since results could reflect other factors such as the industrial structure. However, Nordic countries are in general the most active users of e-business among SMEs. Differences are not pronounced and not clear among countries like France, Germany, Italy, Spain and the UK.

The results of the benchmarking suggest a pronounced digital divide between small and large firms. For example, in Italy, sectors dominated by small firms are much more prevalent than in other countries. This structure is reflected in the score of Italy in the benchmark. The DBE, as a 'non-traditional' application of ICT for business, could help the sectors (and SMEs) of these countries to overcome the digital divide.

The Digital Ecosystem has a big potentiality in helping SMEs to connect with potential customers both in Business-to-Business (B2B) transactions and in Business-to-Customers (B2C) transactions. In average, only about 11% of SMEs use software solutions or internet-based services for e-procurement. There is also a massive gap between the percentage of SMEs placing at least some orders online (53%) and those that use special software for this (11%). Companies without a special software place orders mainly through websites or extranets of suppliers, revealing that the digital back-office integration of procurement related processes is not advanced in these cases.

7) Actvities performed by service SMEs are: Hotels and catering; transport and communications; banking, finance or insurance; business services and other service industries.

8) Trade SMEs include wholesale trade and retail trade SMEs.

9) Manufacturing industry SMEs located in Italy produced the largest value added in the EU in 2000 (European Communities, 2003). DBE implementation in this industry could create large impacts on Italian economy.

10) See Shelton (2006) and section 3.

11) The e-business Index is drawn under a Balanced Scoreboard approach. It consists of 16 component indicators which are aggregated into 4 sub-indices that represent major application areas of e-business: Access to ICT networks, e-process integration, Supply-side activity, and Marketing and sales. The four sub-indices can be aggregated into an overall e-Business Index.

12) Firm-weighted data expresses e-business adoption as "% of firms within a size-band with a certain activity".

13) 26% of both, small and large enterprises receive orders from customers online.

Cost-Benefit Analysis and Digital Business Ecosystems: a Multiple-Account Analysis[14]

Decision-makers at the regional level are most of the time devoted to the economic development of their region, and are interested in those projects whose implementation produce society gains. Economic efficiency is at the core of CBA. Its aim is to address the question on what the net balance would be between economic and social benefits of projects implementation (Shaffer et.al., 2003). It gives monetary values to benefits and costs in order to express the aggregate change in individual well-being from policies or projects (Munford et.al., 2000). In this effort, we are interested in measuring incremental benefits and costs (our baseline will be "no-adoption" of DBE). In CBA, economists value benefits and costs by comparing "willingness to pay" (WTP) to "opportunity costs" (OC). WTP is defined as the maximum amount SMEs or large enterprises (DBE's users/consumers) are prepared to pay for DBE implementation. OC are the costs to the region of implementing DBE instead of implementing any other project (the next best alternative that is foregone whenever a decision-maker decides to adopt DBE). It would be also really useful for some regions, policymakers and users to analyse WTP and OC using the baseline 'DBE adoption'. In this case, OC are the costs to the region/policymakers/users of implementing any other project instead of implementing DBE. In both cases, the aim is to analyse what are the net benefits of DBE implementation and/or what are the net costs of no implementing DBE.

A Multiple Account CBA is proposed. Four evaluation accounts are being designed to provide an overall assessment (Shaffer et.al., 2003). The use of different accounts is done in order to present a clear description on what the consequences and trade-offs from DBE implementation will be. This methodology recognizes that it is very difficult to assign a Euro-value to all different impacts and to aggregate them into a measure of net benefits[15]. The lack of any precedent on DBE implementation (apart from the pilot projects) makes us recognize the uncertainty of the outcomes. A wide range of outcomes may occur due to the regional and sector-specificity of projects. This specificity might contribute to greater (or lower) success from DBE implementation. The accounts developed in the next sections are an overview on how the analysis should be developed[16]. They will provide interested regions with an initial screening of the net benefits from DBE implementation.

The four evaluation accounts are[17]:

- **Financial account.** This account looks at the expected revenues and expenditures from DBE implementation. Its aim is to explain the financial cost of DBE, in order to determine if the project is efficient from a private market perspective[18] (Campbell et.al., 2003). It also looks at the OC of the projects funding.
- **User/Consumer account.** The account describes the net benefits to users and direct beneficiaries from DBE implementation. It values the user's maximum WTP for DBE in comparison to the baseline of DBE "no-adoption". It is meant to evaluate net impacts in terms of productivity, competitiveness, efficiency, business connectivity and innovation.
- **Economic Development account.** Two key questions are addressed in the economic development account. First, it looks at the amount of income and employment (incremental effects) that is likely to be generated from DBE implementation. Second, and more important for CBA, it analyzes the significance that these effects have on the regional economy.
- **Social account.** The account looks at significant community and social impacts (externalities) from DBE implementation. The aim is to understand the positive legacies to societies on using DBE. We are particularly concerned on how DBE contributes to reduce income inequality between the concerned region and the country and between the country and the rest of Europe.

The final overall assessment is not meant to answer whether DBE should or should not be implemented in a particular region. It is to policymakers (and general public to some extent) to make the final decision (Shaffer et.al., 2003).

14) I would like to thank Dr Marvin Shaffer, former Senior Lecturer at the University of British Columbia in Canada that provided me with general guidance in developing the methodology for the CBA framework on DBE implementation.

15) This difficulty has been specially recognized by the research team, the project managers of pilot projects and the current users.

16) Time and data constraints preclude a more detailed analysis.

17) Further development on the accounts is presented in the sections that follow.

18) The future streams of benefits and costs are converted into equivalent values today using a discount rate (net present value).

Cost efficiency of DBE projects: the financial account[19]

Regional authorities and institutions are frequently dealing with budgetary restrictions. One of their main concerns is the financial cost of projects. This section includes the main results from an empirical exercise done with the project managers of two selected regions running DBE pilot projects: Aragón and the West Midlands. We believe that presenting the results of an *ex-post* analysis on this account will be useful for every policymaker interested in DBE[20]. Three types of costs have been identified and analyzed[21]. Fixed costs (1) include the costs of the digital ecosystems infrastructure; research and development costs; and other fixed costs. Variable costs (2) include training costs, training travel, research costs and other variable costs. Operating costs (3) include human resources costs, infrastructure maintenance costs and SMEs service integration costs (deployment). Table 1 summarizes the financial costs for both regions.

Table 1

Total financial costs for pilot implementation of digital ecosystems in the West Midlands and Aragón (November 2003 – January 2007)

Cost Type	West Midlands		Aragón	
	thousand Euros	% of total costs	thousand Euros	% of total costs
Fixed Costs				
Cost of Digital Ecosystem infrastructure	4	1	4	0
Research and developement costs	0	0	120	10
Other fixed costs	0	0	0	0
Total Fixed Costs*	***9***	***1***	***124***	***10***
Variable Costs				
Training Costs	10	2	174	15
Resesarch travel	7	2	22	2
Training travel	26	6	16	1
Other variable costs (events, conferences etc.)	0	0	32	3
Total Variable Costs	***43***	***10***	***244***	***21***
Operating Costs				
Human resosurces costs (admin, management and R&D)	277	65	110	9
Infrastructure manteinance costs	0	0	10	1
SMEs services integration costs (deployment)	100	23	700	59
Total Operating Costs	***377***	***88***	***820***	***69***
TOTALS	**429**	**100**	**1188**	**100**

* In the case of the West Midlands, total fixed costs include an audit and balancing item equal to 5K euros: this value represents 1% of total financial costs for the region

Source: DBE questionnaire to pilot project managers, 2006

Total financial costs of DBE pilot projects are very different in absolute values in both regions (429K Euros in the West Midlands and 1,188K Euros in Aragón), but are distributed in the same pattern according to cost type. The largest proportion of total costs is operating costs, followed by variable costs, and fixed costs. Pilot projects data shows that between 2.20% and 10.40% of total costs are fixed costs. Surprisingly in this distribution is the low participation of the digital ecosystems (DE) infrastructure in total costs. DE infrastructure represents only 0.90% of total costs in the West Midlands (3.88K Euros in absolute values) and 0.29% in Aragón (3.50K Euros). Scientists have expressed that there is an overall belief among policymakers that DE infrastructure is 'expensive' and in consequence "unreachable" for their regions. Evidence in our sample pilot projects does not leave place for this argument. In contrast, our analysis shows that between 10% and 21% of total costs are variable costs (mainly training costs and training travel); and more

19) I would like to thank Rod Shelton, Javier Val and Nagaraj Konda for their hard work and disposition to participate in this exercise. Paolo Dini and Francesco Nachira provided valuable inputs and comments.

20) The analysis covers the period from November 2003 to January 2007.

21) Every interested region on DBE should expect to incur in (at least) these costs for DBE implementation.

than 70% of total costs are operating costs, including human resources costs and SMEs service integration costs (deployment). Most of these costs are certainly an investment on regional development, as resources are allocated in knowledge creation and dissemination. Policymakers should compare financial costs with benefits produced in the user/consumer account and social accounts when assessing the net benefits of DBE implementation.

Important in this analysis is the role of the regional catalysts in cost allocation. We believe that costs are determined by the regional priorities and regional catalysts leadership initiatives on innovation. Shelton (2006) has identified three different approaches to DBE according to the regional catalyst organisation: the government funded approach, the local association approach and the public company approach. The DBE approach chosen by the interested region will directly affect the CBA financial account[22]. Our empirical study highlights that in the early stages of project implementation regions focus on SMEs service integration, training and dissemination of the concept of DBE among regional SMEs. Regions allocating more financial resources to these activities will see their costs on the CBA financial account increase, but this change might be more than compensated by the benefits gained under the other three accounts. For instance, the region of Aragon, following the government funded approach, has been really active in developing SMEs service integration[23]. The government funding has been accompanied by an active participation of the concerned SMEs in R&D (equal to 484K Euro in the period), creating a feeling of entrepreneurship among SMEs. This scheme could further develop into a public-and-private partnership (PPP), whose non-marketed benefits are difficult to value.

Costs projections show that an average cost reduction of 19% is expected for both of the studied regions by the end of 2007 (costs are expected to decrease by 23% in the West Midlands, and by 16% in Aragon). Benefiting from economies of scale, further costs reductions are expected as projects reach maturity.

The financial costs described above are generally financed by three different sources: European Commission (EC) funds, regional contributions (funding from the regional government), and private contributions (funds by the regional private sector, i.e. the concerned SMEs). The sources of funding and its participation in total costs will vary according to the approach to DBE chosen by the region, but also by sector and stage of project (Shelton, 2006). Figures for the West Midlands and Aragón are presented in table 2. In both of our studied regions most of the funding come from EC funds (79% of total costs in the West Midlands, and 46% in Aragon), followed by regional contributions in West Midlands (21% of total costs) and private contributions in Aragon (41% of total).

Table 2

Source of funding in the West Midlands and Aragón (November 2003 – January 2007)

Source of funding	West Midlands		Aragon	
	thousand Euros	% of total costs	thousand Euros	% of total costs
European Commission Fund	338,91	78,92	548,85	46,19
Regional contributions	90,54	21,08	155,00v	13,05
Private contributions	0	0	484,25	40,76
TOTALS	**429,45**	**100**	**1188,10**	**100**

Source: DBE questionnaire to pilot project managers, 2006

Policymakers should be careful while analysing the costs related to public funding. OC of public funds are central in a CBA. In principle, as Shaffer (et.al., 2003) states "*more spending in the (DBE) project would […] reduce the amount of regional government (institutions) spending available for other initiatives in the region*". A proper CBA must recognize that if undertaking DBE while involving a net flow of public funds, the deadweight loss (DWL) associated to the collection of these funds should be attributed as a cost of DBE implementation. In the same way, if DBE implementation involves a net inflow of public funds, the project must be credited with the DWL of raising these funds in another way (Campbell, et.al., 2003). In all cases, the fall in the CBA financial account net benefits will be matched by an equivalent (or more than equivalent) rise in the net benefits in the other three CBA accounts.

Again, higher financial costs do not imply cost-inefficiency, as evidence shows that these costs are related to the regional engagement with innovation. We would expect that if costs are incurred in the short-run (paid by the regional

22) As a consequence of the chosen approach, further indirect effects on the user/consumer account and social account might be expected.

23) The region has assigned 155K Euros from November 2003 to January 2007 for SMEs service integration, and has already committed 157K Euros for these activities after January 2007.

effort of the current generation), the benefits of investing in innovation are expected in the long-run, favouring a broader range of population due to secondary benefits and multiplier effects that innovation is expected to create on the regional economy. While analyzing this future stream of benefits we must take into account the net present value (NPV) of the benefits. NPV is also central in CBA. This concept expresses Euro values in different years in equivalent terms, recognizing that 1 Euro spent today is more costly than a Euro that will be spent in one year's time. The NPV is calculated using a discount rate. The lower the discount rate, the greater the emphasis policymakers give to long term benefits (DEAT, 2004). Regional authorities and policymakers devoted to the development of its region should easily realise that the financial costs incurred from DBE project implementation will be more than compensated by the benefits stemmed by the other CBA accounts to be analyzed below.

The net benefits to DBE "users": the user/consumer account

This account explores the net benefits to users/consumers as what DBE implementation provides them. Users/consumers are mainly SMEs, but large enterprises are not excluded[24]. There are 44 SMEs currently connected through the DBE infrastructure in the West Midlands and 35 SMEs in Aragón, serving a variety of sectors[25]. Different net benefits are expected according to the roles of SMEs in the market. Shelton (2006) has identified four types of SMEs characterized by their different roles in the market: early adopters, implementers, discoverers and users. Early adopters focus on new approaches to software development, while implementers SMEs apply the original work of the early developers in a particular sector of business. Large benefits are expected to driver SMEs (early adopters) and implementers. As these SMEs focus on software development, the formation of software communities in the regions is favoured. The West Midland's SMEs (drivers and implementers) have expressed that one of the main attractors that made them participate on DBE was to be at the forefront of research into software development with world leaders and other university partners (Shelton: 2006). This reveals a real 'entrepreneur' attitude towards innovation. Discoverer SMEs are those SMEs that are willing to adopt a service in their business (and work with the implementers) but do not wish to involve themselves in activities that require high-level technical abilities. These SMEs would be benefiting from connectivity with other SMEs. They would also experience some innovation while adopting a service in their business. 'User SMEs'[26] would be implementing aspects of DBE in their business model (without being involved in technical software issues), and then benefiting from connectivity with suppliers and customers. For them, DBE will help to connect them with potential customers in B2B and in B2C transactions. In all cases 'DBE users' will be benefiting from improvements in productivity and competitiveness of their business.

Monetary valuations for these benefits are hard to conceive. We recognize the uniqueness of DBE and in consequence the difficulty to assess its impacts. We believe that until 'critical mass' is reached the range of possible outcomes from DBE implementation will remain wide. For 'user SMEs' incremental sales (or reduced costs) could help in the effort of valuation[27]. Incremental profitability (increased producer surplus) of concerned SMEs could be used as an indicative variable to measure WTP. Until now, pilot projects have not benefited from sales increases from DBE implementation[28]. This is understandable due to the early stage of the projects. The region of Aragón has expressed that the reason for no quantifiable benefits include platform instability and DBE applications not been yet applied in real business. SMEs in West Midlands have expressed that being connected has helped them in developing new enhanced services at lower cost and with greater market reach.

Most of the benefits to DBE users/consumers described above are not traded, and in consequence, no market prices for them exist. But this does not mean that these benefits (goods) have no value. According to DEAT (2004), the values of non-marketed goods can often be inferred from economic behaviour and from the study of related markets. The study of these related markets is region-specific. Available information provided by pilot projects is limited. Generalising these effects (and benefits) to other European regions is not possible. It is for every interested region in DBE to assign

24) In the West Midlands, four large enterprises-SMEs linkages have been formed or are forming.

25) The West Midlands pilot project has been addressed to five sectors: tourism, manufacturing, business services, nanotechnology and bio-sciences. The Aragón project has been focused on the tourism sector, but other related services include taxi float management systems, ERPs, access control, e-commerce and accident management systems.

26) 'Users SMEs' should not be misunderstood with 'DBE users/consumers'. The latter includes the four types of SMEs identified by Shelton (2006), plus large enterprises.

27) The baseline is 'DBE no-adoption'.

28) One exceptional case has occurred in the West Midlands, where a transaction between a driver company and an implementer valued in 40,000 GBP has been agreed for additional services due to their relationships on DBE.

value to these benefits. If it becomes impossible to measure them, or if the measurement is subject to large errors, Campbell (et.al., 2003) suggests to summarize the net benefits in a form of Impact Statements (IE), by identifying the qualitative effects to 'DBE users' from DBE implementation. A disadvantage of this approach is that these qualitative net benefits are not comparable with the costs and benefits raised under the CBA. Nevertheless they will be effective in providing policymakers with a complete view of what the net benefits to the users/consumers will be.

Digital Business Ecosystems and economic efficiency: the economic development account[29]

Regional development is at the core of DBE. The economic development account will valuate the amount of income and employment that is likely to be generated from DBE implementation. Policymakers should first look at the business structure of their regions. They must identify the employment structure of the sectors applying DBE and should then assess what is the value added that these sectors produce on the regional economy. As we are just interested on the incremental generation of employment and in incremental income generation, we expect that net benefits on this account will be shown in the long-run. As the idea of DBE is conceived on the regional level in the first stages and on the European level further on, policymakers might want to value the impact on trade from DBE implementation in the long-run. The NPV of these impacts must be also calculated. As stated before, higher net benefits can be expected in those countries applying DBE to the sectors where the industrial structure favours SMEs proliferation.

CBA is also concerned about the economic significance of job and income generation. We are particularly interested in the "multiplier effects" of DBE implementation. Multiplier effects are the effects caused by the linkages (indirect) that the project creates with the rest of the economy (regional, national and global). Nevertheless, these effects will only appear once the scale of DBE deployment reaches 'critical mass'.

Digital Business Ecosystems and human well-being effects: the social account

The social account looks at community and social impacts produced from DBE implementation. Policymakers deciding whether or not to implement DBE should analyse all the costs on surrounding communities that DBE implementation could arise in their regions. Positive and negative externalities might appear. Positive externalities are legacies to societies. A positive externality in the social account could be the training of workers involved in DBE (knowledge acquisition) and their increased productivity while working somewhere else[30].
If the scale of DBE implementation increases, there should be an interest in knowing how DBE implementation could contribute to reducing income inequalities between the concerned region and the country, and between the country and the rest of Europe.

DBE implementation decision-making: the overall assessment

The summary of the evaluation of DBE implementation presents the welfare effects measured in monetary terms. Economic theory assumes that human well being is determined by the capacity of people to fulfil their preferences (Munford, et.al, 2000). The approach developed here should allow policymakers to take a decision on DBE implementation, as it provides all valuable information on the project in order to facilitate the decision.

As many of the benefits and costs expected to be generated by DBE are hard to measure, the regional commitment to innovation and economic development of political leaders will be crucial on the decision making. The results presented in this paper are preliminary conclusions based on the existing DBE pilot projects.

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29) The next two accounts (economic development and social) present just some general ideas to guide a deeper analysis on DBE implementation. A further study to appear in 2007 will valuate more precisely these two accounts by using an empirical analysis on the existing pilot projects. Time constrains have forced me to reduce my analysis to what is presented here.

30) Workers and SMEs receiving training financed by DBE will keep this knowledge for a long time. In case these workers apply this knowledge elsewhere, positive externalities will be generated.

Evidence showed us that financial costs will be mainly variable costs and operating costs. Regions investing in DBE are investors in knowledge creation and capacity-building. Policymakers must also realize that digital ecosystems infrastructure costs are really low as a proportion of total costs. Although, costs will be determined by regional priorities and regional catalysts leadership initiatives, evidence shows that after the implementation of a pilot project (40 months in average) costs can be expected to decrease in between 15% and 20%. Further costs reductions are expected as projects reach maturity. We encourage policymakers to compare financial costs with benefits produced in the economic development account and social account, as high financial costs do not necessarily imply cost-inefficiency.

Finally, we would like to underline that once the "critical mass" is reached, a complete range of net benefits will become available. The velocity to reach this critical mass is in the hands of policymakers.

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4 A Critical, inward and outward, View of Digital Ecosystems' open, collaborative Communities: interdisciplinarity, sustainability and scalability at the intersection of gift and exchange Economies

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Abstract

The idea of "community" represents a central notion in the body of knowledge emerging as part of the Digital Ecosystems (DEs) research and philosophy. This chapter draws from two deliverables produced for the DBE in order to highlight two important characteristics of communities and networks of practice, their knowledge and structural embeddedness. Knowledge embeddedness refers to the context specific frames of meaning and signification as indicated by the difficulties of translating knowledge across different communities. Structural embeddedness refers to the intertwining of socio-economic structures as expressed by the frequently overlapping character of digital, social, economic and professional networks. It is argued that these two aspects of embeddedness are crucial for the sustainability and scalability of Digital Ecosystems.

Introduction

Cooperation between epistemic communities is regarded as a crucial element for the realization of the DEs ambitious interdisciplinary research agenda. At the same time, the sustainability of emerging DEs largely hinges upon the cultivation of their ties with existing Free/Open source (F/OS) software communities. Within the context of the research these two types of communities along with other groups of DE stakeholders, such as Small and Medium Sized enterprises (SMEs), were examined as communities or networks of practice (CoP)/(NoP), that is, more or less tightly knit communities formed through the pursuit of a shared enterprise which act as repositories of experience and knowledge (Wenger E. and J. Lave, 1991).

The aim of this chapter is to highlight two important characteristics of networks and communities of practice: their knowledge and structural embeddedness and to indicate how they relate to the sustainability and scalability of DEs. Knowledge embeddedness relates to the dependency of knowledge on social context, which makes it difficult to translate across different CoP, domains and networks. Structural embeddedness refers to embeddedness of economic action in social relations and the way "the quality and network architecture of exchange relations influence economic activity" (Uzzi B., 2001:208). This chapter is organized as follows. After elaborating on the concepts of knowledge and structural embeddedness, the findings of two associated studies conducted for the DBE project are presented. The last section outlines why and how the two concepts are related to wider issues of scalability and sustainability of DEs.

The first study that is drawn upon is an internal report 'In the Cocoon: translating complexity across communities and networks of practice in a collaborative open source project' (Berdou E., 2005) and the second, deliverable D18.3 titled 'Report on the Socio-economics of Free/Open Source: Working together at the intersection of the gift and exchange economies: sustainability and scalability in F/OS' (Berdou E. and P. Dini, 2005). Both studies examined dynamics of collaboration between different groups of actors involved in the project and in the wider, envisioned ecosystem. In particular, the internal report focused on the dynamics of cooperation and the implicit decision making processes of three groups of stakeholders internal to the project: regional catalysts, SMEs and BML (Business Modelling Language) designers. On the other hand, deliverable D18.3 provided a framework for critically understanding the main socio-economic dynamics of F/OS from the perspective of the interrelated activities of three groups of actors involved in the, wider, F/OS process of development, deployment and adoption: volunteer communities, businesses and public institutions.

Knowledge and structural embeddedness

The concept of knowledge embeddedness is closely linked with the view of learning, working and innovation encapsulated by the CoP perspective. The community of practice (CoP) perspective was originally developed to account for forms of learning and patterns of socialisation that take place within and across the boundaries of traditional organizations.

The theory has its roots in social constructivism, a perspective that emphasizes the importance of culture and context in understanding what occurs in society. Lave and Wenger (1991), the two theorists who first elaborated the term, argued that a society's knowledge is situated in relations among practitioners, their practices, and their social organization and political economy. Communities of practice, which may include such disparate groups as a team of fire-fighters, office secretaries and hackers, arise mainly through the pursuit of a shared enterprise. The socially embedded character of knowledge, however, which makes CoP very effective in organizing and sharing knowledge among their members creates considerable difficulties when attempting to codify and communicate this knowledge across this groups boundaries. In essence, the COP perspective argues that:

- Practice is highly localized and knowledge is inextricably connected to the social processes that create and maintain it,
- knowledge exchange and communication between and across different communities and networks of practice are not straightforward. In addition to the difficulties created by the loss of context that the codification of knowledge entails, there are additional barriers that may hinder cooperation, such as that of diverging agendas.

The concept of structural embeddedness was first developed by the American Sociologist Mark Granovetter. In his seminal article on 'Economic Action and Social Structure: The problem of embeddedness' (1985) Granovetter argued that "continuing business relations often become overlaid with social content that carries strong expectations of trust and abstention of opportunism" (1985:490). Granovetter defined economic embeddedness as the: "argument that the [economic] behaviour and [economic] institutions to be analysed are so constrained by social relations that to construe them as independent is a grievous misunderstanding" (1985:482).

Granovetter developed this idea partly as an answer to what he regards as "undersocialized" and 'oversocialized' accounts of human action. The first, is consistent with the perspective of neoclassical economics that: "disallow by hypothesis any impact of social structure and social relations on production, distribution and consumption."(Gran ovetter, 1985:483). The second type of accounts is more common in some branches of sociology and emphasizes, for example, the importance of social processes, norms and values, at the expense of the political and economic structures permeating many aspects of economic life. If the concept of knowledge embeddedness argues for distinctiveness, the idea of structural embeddedness emphasizes connections that are expressed through the frequently overlapping character of digital, social, economic and professional networks. These ties need to be taken into account as they shape the landscape of Digital Ecosystems and can therefore influence their development.

Internal Report: "In the Cocoon: translating complexity across communities and networks of practice in a collaborative open source project"

In this report the points of contact and departure of the strategies of regional catalysts, early SMEs adopters (software producers) and DBE's designers at the beginning of the project were mapped and some concrete recommendations on how to improve DBE's bootstrapping process were offered. In this research 15 interviews were conducted with representatives from each group. revealing some of the difficulties that arise through the construction and translation of social complexity into business and computing models and practices.

a. In relation to regional catalysts (RC) the results indicated that: regional catalyst representatives were assigned responsibilities primarily related to DBE adoption and dissemination. Although their specific goals were clearly identified in the DBE project's Technical Annex, the way that these activities were pursued in practice was largely influenced by the specific dynamics of the region and by their networking capacity and skills make-up. The gradual elaboration of the SME recruitment strategy and the specification of the opportunity spaces helped to structure and focus the related activities. However, the initially underdeveloped business message of the project created significant challenges for RC partners who needed to translate the scientific and technical vision of the DBE into concrete business opportunities for SMEs. In addition to their primary tasks, RC representatives also had to coordinate contacts between SMEs and the various research teams in the project. Besides drawing attention to the difficulties of brokering knowledge between practitioners and researchers and of creating bridges between these two different modes of engagement, the interviewees also pointed to the moral implications of SME engagement and the way that their activities transformed them and informed their views of what being a regional catalyst meant.

b. In relation to early SME adopters, the results indicated that although the productive capacity of the DBE in terms of supporting the development of new services and applications was frequently acknowledged, the SME interviewees who were engaged during this period perceived the DBE primarily as a conduit for networking and for marketing their existing services and applications. At the same time, the technological and business aspects of the DBE were perceived and discussed nearly always in relation to each other. As their attitude to open source shows, this is characteristic of the problem-solving, hands-on engagement approach of SME representatives that focuses on the immediate opportunities and implications of the DBE technology and design for their businesses. There are several indications that this might also be their attitude in relation to the scientific aspects of the DBE, for example, the automated recommender of services. This poses some interesting challenges for the project. As the technological and scientific aspects of the DBE were translated into perceived opportunities or hindrances from the perspective of SME drivers, the DBE researchers were faced with the task of: a) clarifying their own assumptions about business and (re)aligning them with the realities of business practice b) maintaining a balance between the needs and requirements of SMEs and the scientific, technological and political vision of the DBE.

c. BML designers aimed to develop in essence a tool that would allow the integration of collaboration between software developers and software users and that would foster the creation of new value chains within and across traditionally defined business domains. In order to achieve their goals, the team of developers initiated a methodology that aimed to combine top-down and bottom-up design approaches. During the first phases of the project, however, the development of the BML was predominantly guided by the top-down design approach which involved the examination of existing standards. This involved balancing the requirements of the platform against the dynamics of the industry and networking with organizations such as OMG. The two major turns in BML development involved the decision to adopt a lighter and more abstract meta-model and to adopt an emerging standard (SBVR) that would allow business participants to specify their needs without any technical knowledge of UML modelling techniques.

The wider implications of these actors' strategies for the sustainability of the DBE were also investigated and some concrete recommendations for improving the bootstrapping process were made. The study highlighted:

a. some of the challenges involved in setting up the network of regional catalysts (RC) that, in addition to the business perspective, it is necessary to take into account:
- where the RC intermediaries are located in the economic and political-industrial spectrum of each region; and
- their technological or business orientation.

b. the importance of SME recruitment strategy for the process of bootstrapping the DBE. In particular it was argued that one of the ways of reaching out to open source communities is through the involvement of SMEs with experience in open source (OS) development community processes from the early stages of the project. It is possible that the engagement of OS communities will become increasingly difficult if the DBE is developed at the level of applications using proprietary standards.

c. The long term implications of aspects of the BML implementation, mainly:

- how the adopted and/or imported ontologies and standards used by different business communities within the same domain will scale up within the context of the project; and
- how the various vocabularies will be integrated and maintained across different

This challenge is amplified if we consider that different interpretations of domain models are not just a result of diverging viewpoints, but are often linked to competing interests associated with the use of specific standards and domain models.

Report on the Socio-economics of Free/Open Source. Working together at the intersection of the gift and exchange economies: sustainability and scalability in F/OS (D18.3)

This deliverable drew on a doctoral research study (Berdou E., Forthcoming 2007), adopting a holistic view of the F/OS process that took into account the intersecting activities of volunteer communities, businesses and policy. It was suggested that a twofold strategy for involving F/OS communities in the DBE would be an important aspect of the DBE project. More specifically, this study indicated that:

a. Volunteer communities display both mundane and unique characteristics of software development and social organization. Community managed F/OS projects are often structured in ways that remind us of traditional processes of software development in terms of use of technical tools, negotiating goals and priorities, editing and reviewing. However, they are also underlined by unique dynamics such as the intensive modularization of tasks, the parallelization of the debugging process and a highly developed sense of shared ownership and responsibility. At the same time, the social foundations of communities, such as their purely meritocratic basis, have been revised as a result of studies that develop more elaborate frameworks of membership and participation.

b. The boundaries between the gift economy, the purview of communities, and the exchange economy, where proprietary development takes place, are more permeable than was originally assumed. The interconnections between the two value systems are intensified by the progressive commercialization of F/OS. Examples include companies contributing to community development and volunteer developers exchanging their reputational benefits for higher and better paid positions or improved access to venture capital.

c. The business appropriation of F/OS raises more general issues with respect to software business models. In addition, there seems to be a considerable gap between the rhetoric about the business potential of F/OS and the barriers to formulating and implementing strategies that leverage it. Copyright concerns and lack of know-how regarding social and technical aspects of F/OS development are considerable barriers to its adoption by SMEs. Some of the most prominent business models are based on combinations of F/OS and proprietary code. However, companies that appropriate F/OS often do so without contributing back to the communities and without revealing code. The virtuous cycle between business and F/OS code that is often envisaged within the discourse is therefore rarely realized in its idealized form, that of a synergistic relationship between companies and communities.

d. The sustainability and scalability of F/OS are dependent on a wide range of policy issues that involve most prominently patents and reverse engineering legislation. At another level of policy intervention, public institutions have shown in recent years an increasing interest in F/OS and a commitment towards open standards, but lack in many cases the social, technical and legal know-how to participate fully in the F/OS process. F/OS is leveraged both as an instrument for industrial development and as an integral part of the provision of e-Government services for administration, businesses and citizens. However, the policy framework concerning public support of F/OS is considerably fragmented. This is largely due to the way the issue is framed within the policy domain. On the one side, the debate concerning the welfare benefits of F/OS software is dominated by neoliberal arguments that consider public support as having the potential to distort the basis for competition in the software market. On the other, there are those who argue that the benefits of F/OS are not strictly economic, but are connected with the opportunities it offers for improved provision of and access to products and services for businesses, administrations and citizens.

Based on the above two strategies for involving F/OS communities in the DBE were suggested.

a. The first strategy, predicated on the distinctive characteristics of community development and their knowledge embeddedness, argued that the DBE should aim to facilitate the learning process for volunteer developers in order for them to become familiarized with the project's code base and to cultivate a sense of shared ownership. Since it was impossible to involve communities from the early stages of the project, providing high quality documentation, maintaining active task lists and providing support on mailing lists and IRC channels would encourage the participation of volunteers.

b. The second strategy, following on from a recommendation in the internal report, was predicated on the embeddedness of F/OS in the commercial world. It aimed to take advantage of the overlapping networks of contacts and partnerships between companies, public organizations and volunteer communities. Given the limited timeframe of the DBE project this strategy is likely to be the most viable of the two. The involvement of companies with ties in the F/OS world would additionally create multiple entry points for communities to become involved in various aspects of the DBE's development, both at the level of the applications and at the level of the platform.

Knowledge and structural embeddedness and the question of sustainability and scalability of Digital Ecosystems

DEs encompass a large number of different public and private actors operating across different regions, industrial sectors, knowledge domains and institutional settings. These actors may have divergent agendas and the complexity of bootstrapping and establishing a functional ecosystem requires a coordinated effort on many levels of policy and intervention. Unlike emerging open collaborative communities, like F/OS or epistemic communities, which have an established framework for negotiating the requirements of the gift and exchange economies and in the light of competing notions of practice and meritocracy, DEs need to find their own balance in cultivating these relations across a complex cultural, geographical, socio-economic and institutional landscape.

As the two deliverables indicated, knowledge and structural embeddedness have multiple implications for the sustainability and scalability of DEs. For example, the difficulty of knowledge codification associated with the socially embedded character of knowledge is an important consideration:

- for understanding the opportunities and barriers associated with leveraging Information and Communication Technologies (ICTs) for improving knowledge codification (Steinmueller E. W., 2000). This is especially important for the design of Business Modelling Language.
- for understanding the difficulties involved in developing a policy framework aiming to translate the lessons learned at the level of distinct CoP to the level of institutions. This is also relevant for the development of the DE's governance framework.
- for understanding the challenges involved in the communication and coordination between widely different communities and network of practice with divergent priorities.

The issue of knowledge embeddedness is associated with the challenges involved in balancing the local characteristics, knowledge and practices of specific CoP with the global requirements of DEs. The notion of structural embeddedness is useful in mapping the socio-economic and institutional landscape which DEs will intersect with and in understanding difficulties associated with reproducing or fostering similar types of cooperative ties within the context of the ecosystem. Deliverable D32.4 'Locational Issues for the implementation of the Knowledge base' focused on the creation of a regulatory framework for building trust.

As Uzzi notes (2001), however, overembeddedness can have ambiguous implications for actors' abilities to adapt to changes in their partner network. For instance a contractor that has become highly skilled at working with a certain manufacturer's fabric, design specifications and building schedule, may be put at risk when this manufacturer moves offshore. DEs are expected to help SMEs adapt to these changes by supporting the creation of cooperative ties across geographical boundaries. The notion of structural embeddedness is therefore useful for understanding:

- How DEs are embedded in an existing socio-economic landscape and how their development is framed by existing cooperative dynamics.
- How DEs affect this landscape in their own right and, in particular, whether and how they disembed existing cooperative relations from their established networks of collaboration.

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5 Trust among SMEs in Digital Business Ecosystems: Theoretical and Methodological Foundations for Establishing Trust through a Knowledge Base of Regulatory Issues

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Abstract

The aim of this chapter is to summarise research on the factors contributing to the establishment of trust amongst small- and medium–sized enterprises (SMEs) in Digital Business Ecosystems. This chapter describes the development of a Knowledge Base of Regulatory Issues that are important in the context of the development of Free Software/Open Source (FS/OS) for commercial use within the European Union countries. The Knowledge Base of Regulatory Issues arising from SMEs' participation in Digital Business Ecosystems is discussed in the wider context of the Digital Business Ecosystems initiative to indicate the results of initial research, to highlight aspects of the change of paradigm associated with ecosystems which involve trust, and to emphasise the need to confront conceptual research on technological change with empirical examination of the real-life contexts in which these ecosystems are developing.

In order to achieve this aim, in part 1 the core theoretical issues are identified and examined in terms of the engagement and participation of SMEs in Business to Business (B2B) collaborations within ecosystems. Issues of trust were identified in the early phase of the research as having the potential to constrain SME participation in e-business initiatives. Part 1 presents a conceptual analysis of the layers of trust required for increasing SME participation. Part 2 presents an illustration of the rationale leading to the methodology used to establish a taxonomy framework for addressing the regulatory issues. In part 3 a three-dimensional taxonomy framework is presented, together with a discussion of the Knowledge Base of Regulatory Issues that emerged as being of critical importance for developing trust among SMEs involved in ecosystems, that is, privacy, e-signatures and security, jurisdiction and consumer protection.

The conceptual framework was examined empirically by interviewing SMEs with respect to their views and concerns about the Digital Business Ecosystem vision and their experiences during the DBE project. The results of the interviews were used as a means of testing the validity of the taxonomy framework and the Knowledge Base that was developed. The validity of the Knowledge Base was verified and new insights into the importance of the Knowledge Base for SME engagement with Digital Business Ecosystems in the European Union were obtained. Part 4 summarizes the main empirical findings and overall conclusions are presented in part 5.

Trust: Why Does It Matter in Digital Business Ecosystems?

The adoption of new forms of e-commerce and e-business in the European small and medium enterprise (SME) sector has been identified by policy makers as a key priority for fostering innovation and competitiveness of the European SMEs in global markets (European Commission, 2005). The aim of Digital Business Ecosystems is to overcome existing barriers and to promote innovative forms of software creation, knowledge sharing and community building, thereby enabling long-term growth and competitiveness of the European SME sector. As envisaged by Nachira (2002), the Digital Business Ecosystem is intended to foster new and flexible modes of co-operation and networking through the dynamic aggregation and self-organising evolution of organisations by means of an open-source infrastructure. The control of the infrastructure and the dialectic between Open Source infrastructure and the regulatory issues arising in the ecosystem in the light of SMEs' perceptions, attitudes and understandings and as a result of their experience of specific services offered in the ecosystem are key issues to be addressed.

The Digital Business Ecosystem vision contrasts radically with business ecosystem concepts based on proprietary software, where control over infrastructure can be tightly managed. For example, the Digital Business Ecosystem vision does not include software development hierarchical frameworks as in the case of those developed by firms such as SAP, Novell or Microsoft, in which a main controller or owner of the software code rights is clearly responsible for development. Within a proprietary model, these elements are produced, transferred, and implemented in a managed process, usually with important checks and balances in place to ensure quality of service and compliance with policy and regulatory environments within which the systems will operate.

The Digital Business Ecosystem vision does, nevertheless, present some unique challenges that are difficult to manage, insofar as the vision embraces an open source model. An open source model suggests a decentralized undertaking, open to a diverse range of participants across many locations, making quality control more difficult to achieve. Issues such as favouritism, risk of exclusion or flaming, peer review mechanisms, problems in measuring team performance, effective correction of software errors and management of human resources have all been highlighted in the literature as potentially creating difficulties in open source environments (Raymond 1999; Bezroukov 1999). The aim of achieving self-organization in Digital Business Ecosystems suggests the need for a higher order capability to reproduce components with minimum intervention of human agents, thereby creating additional challenges for quality control.

The aim of the research reported in this chapter was to take an initial step toward the understanding of the regulatory requirements of Digital Business Ecosystems through the creation of a knowledge base of relevant generic regulatory issues. In attempting to identify and assess the key regulatory domains that have implications for the Digital Business Ecosystem vision, the thematic notion of trust was chosen as the point of departure. Trust relationships are central to e-business activities because any kind of economic transaction requires a level of confidence between the parties involved in a given transaction.

The regulatory domain is central to building trust relationships. This is evident in the characterization of 'trust' as an indicator of the confidence required by two or more parties if they are to enter into economic exchange. A trust relationship may be described in the following manner:

The willingness of a party to be vulnerable to the actions of another party based on the expectations that the other party will perform a particular action important to the trustee, irrespective of the ability to monitor or control that other party (Mayer, Davis and Schoorman 1995).

Trust is understood to enable action by establishing confidence among those parties with an interest in the expected outcomes of current or future transactions (Clarke 2002; Dutton and Sheppard 2004). One important prerequisite of confidence is a degree of 'certainty' which is a core issue for SMEs operating in a complex regulatory environment. In the e-business context envisaged by the Digital Business Ecosystem, a degree of confidence or 'certainty' is relevant to trust in each of the three facets that Nachira (2002: 14) identifies as necessary attributes of a digital ecosystem:

- Trust in services and technological solutions
- Trust in business activities
- Trust in knowledge

First, trust in services and in technological solutions may be regarded as a measure of confidence expressed in terms of security and reliability. This facet of trust comes close to the notion of 'technological trust' (Rosenbaum 2003) or the 'belief that technologies will perform reliably and will not be used for untoward purposes'. For trust relationships to develop within the Digital Business Ecosystem, developers and users need to have confidence that both the basic layer of the system and supported applications provide the necessary degree of security and that risks to the reliability of services provided using the DBE platform are minimised.

Second, trust in business activities may be regarded as a measure of confidence expressed as the mutual recognition of accepted practices and procedures for specific sectors and local contexts. This aspect of trust is related to the notion of 'institutional trust' or to a collective expectation that the procedures needed for carrying out transactions successfully will be facilitated and followed (Pavlou 2002). For companies to successfully to adopt and continue using DBE services there trust relationships need to be established in relation to the expected patterns of behaviour and organisational practices adhered to within the Digital Business Ecosystem. Without a shared understanding and the existence of supporting structures to facilitate the creation of trust relationships, cultural and organisational differences are likely to inhibit the formation of business relationships within the ecosystem environment.

Third, trust in knowledge may be conceived as a measure of confidence expressed in terms of symmetric access to information. Because knowledge is a critical asset in e-business activities (Fahey et al, 2001), differences in access to knowledge and information of relevance to e-business activities can lead to unequal advantage for parties operating within the business ecosystem environment. Hence, facilitation of symmetric knowledge-sharing and equal access to information are important for establishing trust relationships between companies participating in the ecosystem.

The next part (2) presents a review of the methodology applied in developing a Knowledge Base of Regulatory Issues. This is followed by a discussion of the taxonomy framework for the Knowledge Base which was created to link the concept of trust to specific regulatory issues as viewed from different operational perspectives (s.3). Finally, part 4 presents an overview of the empirical findings on the extent to which SME interviews confirm the conceptual aspects of the research.

Methodology for Understanding Trust in Digital Business Ecosystems: A Knowledge Base of Regulatory Issues

The Rationale

The rationale adopted in building a Knowledge Base of Regulatory Issues in Digital Business Ecosystems aimed to draw on key regulatory issues linked to engagement and participation of SMEs in B2B collaboration within this ecosystem. The issues identified as being important are the domains of the regulatory environment that should be given priority when developing e-business initiatives. They are referred to as "building blocks of the regulatory framework" and are as follows:

PRIVACY AND CONSUMER PROTECTION

The regulatory building block of privacy and consumer protection refers to regulatory issues with respect to the processing, control and distribution of personal and consumer data using electronic formats, taking into account the individual rights and freedoms of the e-business users.

E-SIGNATURES AND SECURITY

This regulatory building block refers to the issues associated with the sharing of information using digital media. The concern is to ensure autonomy and cross-border interoperability through mechanisms for authentication, non-repudiation, and ensuring the integrity of data.

JURISDICTION AND CONSUMER PROTECTION

This regulatory building block refers to the issues resulting from the cross-border nature of many e-business services and the associated challenges associated with contractual relationships between goods or service providers and customers, such as jurisdictional issues and the means for resolving cross-border disputes.

Specific Issues Arising from a Trust Perspective

The foregoing regulatory domains were considered to be important for establishing trust relationships in e-business (Berkey, 2002) and were examined in the light of their implications specifically for Digital Business Ecosystems. These specific considerations are explored in greater detail below.

PRIVACY AND CONSUMER PROTECTION AS TRUST DETERMINANT

Privacy issues are closely linked to consumer rights and existing legislation comprehensively covers business to consumer (B2C) transactions, whereas in the case of B2B contracts, the existing legislation is less stringent. In the context of Digital Business Ecosystems, issues concerning the management of databases shared between members of the ecosystem are important, as these databases are likely to contain information to which privacy measures are applicable as well as information that may facilitate the process of developing inferences about commercial activity derived from commercially sensitive data patterns. Other concerns include the relevance of information and access rights to the database, accuracy in the use of data, measures to enable evaluation of data sensitivity, and, finally, the need for a policy with respect to the rights of companies to prevent or allow the transfer of sensitive data.

The data privacy and consumer protection issues raise questions about the degree of trust established among businesses. The framework of the Digital Business Ecosystem plays the role of mediator and gate-keeper between interested parties.

E-SIGNATURES AND AUTHENTICATION AS A TRUST DETERMINANT

The regulatory domain of e-signatures and authentication is closely related to security issues in the e-business context. Regulatory considerations are especially important in the areas of authentication, digital signatures, electronic invoicing and payments. Authentication mechanisms support access rights to different information resources; they provide a means for identifying malpractice; and they provide an audit trail of transactions that is necessary for resolving disputes.

In the Digital Business Ecosystem vision, relationships between participants lead to payments and various types of transactions and issues related to e-signatures and authentication are important for establishing and sustaining trust between partners. In addition, considerations with respect to the interoperability of electronic invoicing systems and the traceability of processes within these systems are important factors in ensuring successful collaboration between partners.

JURISDICTION AND CONSUMER PROTECTION AS TRUST DETERMINANT

The regulatory issues in this area arise because of the cross-border nature of many e-business transactions. In the case of the Digital Business Ecosystem the main issues in this area are concerned with cross-border online contracting. Jurisdictional issues create severe limits for digital platforms that aim to bridge geographical distance and industry sectors and to facilitate e-business at the international level.

A Regulatory Taxonomy Framework

The review of the literature concerned with regulatory issues relevant to Digital Business Ecosystems provided the basis for the development of a taxonomy framework and for an examination of the most important regulatory issues from the perspectives of the SME users of the ecosystem environment. Taxonomy provided a framework for capturing the key elements of the overall regulatory environment that is likely to be applicable to the generic layer of a Digital Business Ecosystem.

Taxonomy Framework for the Knowledge Base of Regulatory Issues in Digital Business Ecosystems

Taxonomy framework: a description

The taxonomy framework developed for identifying and classifying regulatory issues relevant to the Digital Business Ecosystem vision draws its working definition from an approach adopted by the ALIVE project on legal issues for virtual organisations (IST 2000-25459):

[A] taxonomy should be regarded as a quest, setting out the boundaries of the main research subject and providing a preliminary framework of guidelines for an in-depth analysis of the [regulatory] issues related to the [project]. The taxonomy... initiates

further research by... pointing out the most problematic legal questions, clarifying and illustrating the significance of certain [regulatory] issues. The taxonomy does not present [regulatory or legal] solutions to these issues (Schoubroeck et al 2001a).

The taxonomy framework served as a tool for directing research on e-business ecosystem regulations. The result is baseline knowledge and a common point of reference for future research on important regulatory issues. The taxonomy framework contributes by guiding 'further discussions and the distillation of findings and existing knowledge' (Schoubroeck et al 2001b). The three-dimensional taxonomy framework is graphically depicted in Figure 1.

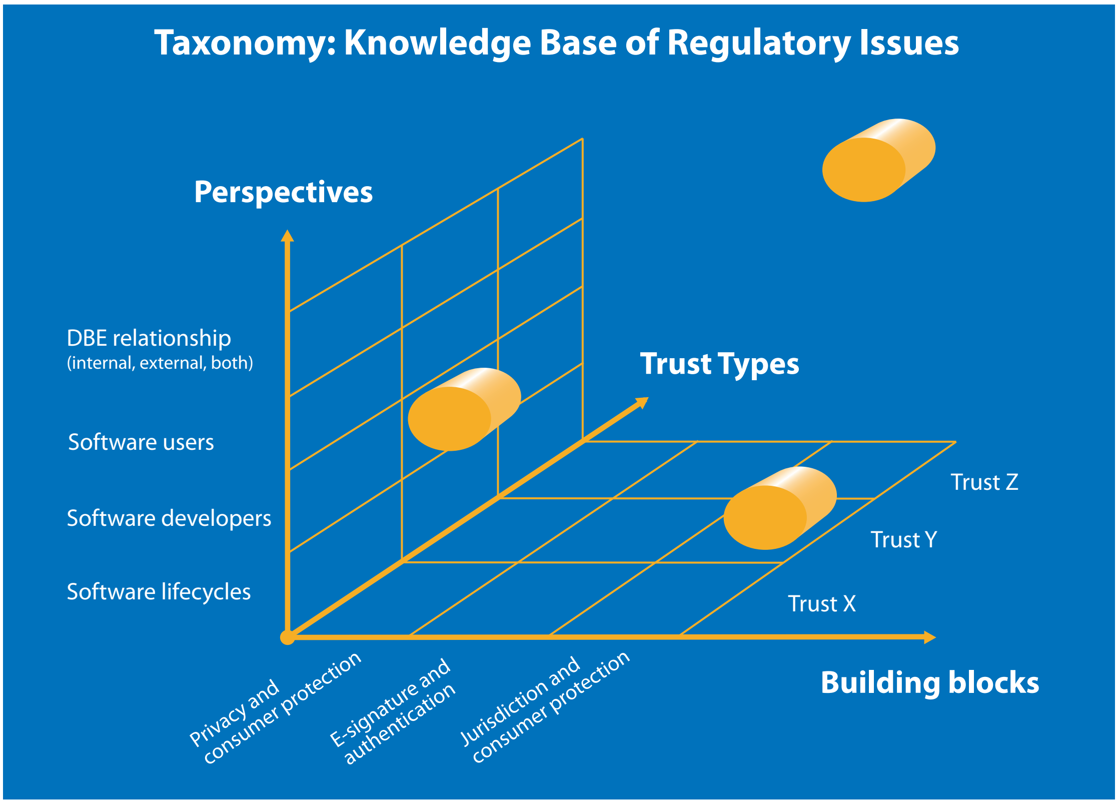

Fig. 1
A three-dimensional representation of the taxonomy

Taxonomy Framework: trust at the core

As Figure 1 shows, three types of trust were identified as initial starting points for the classification of regulatory issues, drawing on the model of trust suggested by Meents, Tan and Verhagen (2003):

TRUST TYPE X

This type of trust refers to trust with respect to the companies joining the Digital Business Ecosystem. From a regulatory perspective, the expectation is that the technical architecture and the basic services will incorporate existing e-business regulations and provide the facilities for carrying out transactions in a way that will ensure compliance with existing laws and norms.

TRUST TYPE Y

This type of trust refers to the expectations on the part of the DBE participants who are the developers of the ecosystem with respect to the companies joining the ecosystem. In order to establish trusting relationships, companies are expected to comply with existing laws and norms and to avoid creating unnecessary risks for the DBE participants.

TRUST TYPE Z

Trust type Z refers to the trust relationships between DBE participants themselves. This type of trust is indicated by confidence in the ability of existing norms and laws to govern the interactions resulting from the self-organisation and evolution of the DBE environment.

Building Blocks of Regulatory Issues and Operational Perspectives

The building blocks of regulatory trust summarised in part 2, representing the domains of the regulatory environment that are of priority concern when developing e-business initiatives are discussed in the light of the taxonomy framework together with issues that arise from an operational perspective.

BUILDING BLOCKS OF REGULATORY ISSUES

The generic building blocks of privacy and consumer protection, e-signatures and security, as well as jurisdiction and consumer protection, do not yield a complete understanding of the complexity of the regulatory environment associated with the Digital Business Ecosystem vision. The specific regulatory issues identified in each of the building blocks need to be examined and refined in the light of particular sector-specific and local settings and with respect to the aim of facilitating e-business among SMEs across Europe and in an ecosystem context.

OPERATIONAL PERSPECTIVES

The taxonomy framework outlined above can be further developed in the light of the operational perspectives of three sets of relationships or actors as indicated in Figure 1 – y axis.

DBE relationships

Regulatory issues can be classified on the basis of the degree of their relevance in the ecosystem environment. Two main types of relationships can be identified in this context:
Regulatory issues classified as internal refer to issues that either

- arise in the ecosystem environment and are specific to the ecosystem setting, or
- are directly linked to ecosystem participants and their activities in the ecosystem environment.

External issues are those that are not within the remit of the ecosystem members or governors to change – i.e. the external regulations applicable to e-business activities such as tax rules, consumer and data protection regulations, contract and competition law provisions, and so on.

In some cases, regulatory issues may be classified as both external and internal. For instance, based on an example from the ALIVE project (Schoubroeck et al 2001a), the use of digital signatures by the ecosystem members will be affected by certification mechanisms established within the project and by external certification requirements.

DBE actors

The classification of regulatory issues based on the actors helps to identify issues relevant to particular ecosystem parties and to analyse these issues from the perspectives of different actors. These are as follows[1]:

- SME Service Providers: provide digital (software component) services that use the Digital Business Ecosystem as an infrastructure platform.
- SME Users: use services provided by the Digital Business Ecosystem for their own business needs in the form of "self-consumption" or in order to undertake transactions with other users of the same or compatible services.
- Business Analysts: help users to connect and establish their BML (Business Markup Language) profiles, while helping service providers to integrate into service chains and make services compatible.

Software Lifecycles

A software lifecycle perspective highlights regulatory concerns associated with software development, deployment, upgrading, expansion and discontinuation. Although software lifecycles are not specific to Digital Business Ecosystems, their importance for business collaboration is acknowledged in the literature and their role needs to be considered in the context of B2B collaborations within ecosystems as well.

Empirical Verification

The taxonomy framework reviewed in part 3 was developed further by populating it with real life data. Empirical research was conducted with SMEs linked to the DBE project in the EU (Finland, the UK and Spain). SMEs were invited to reflect on the taxonomy framework during interviews. Interviews were conducted with seven SMEs

1) An alternative classification can be based on a technical perspective (see Ferronato 2004) which distinguishes between SME SW Developer, SME Run-time User (Service Provider or Service Consumer) and Business Analyst.

operating in important areas and that had been provided access to the Digital Business Ecosystem platform. These areas included commerce, content management and accountancy.

The results of these interviews confirmed that trust is a crucial issue. In particular interviewees confirmed that trust in the systems architecture and the business solutions that provide DBE services, trust in the institutional arrangements supporting knowledge accumulation, and trust in the context of conducting business between companies, are the most important issues. From the perspective of the SME drivers of the DBE, in any given business sector their participation is influenced by their specific concerns about issues concerning identification, security, privacy and consumer protection, as well as by contractual issues specific to a given business domain.

SMEs can contribute significantly to the identification of issues of critical importance for the establishment of trust in the Digital Business Ecosystem and their views are also helpful in identifying measures that are likely to augment the future business prospects and commercial viability of the DBE framework.

The interviews with SMEs in Finland, the UK and Spain suggested additional critical issues that are likely to affect the Digital Business Ecosystem's future development. An important unresolved issue that emerged is whether the DBE will be legally constituted under European, national or local law. An associated issue is the extent to which the members of a business domain will have a role in the adoption of the DBE legal form in the context of their everyday B2B practices. The interviewees suggested that without a clear definition of the legal aspects, the engagement of SMEs with digital business ecosystems may be affected.

A possible solution to these issues was proposed by the interviewees. It was suggested that an authority could be created that would resolve some of the regulatory issues confronting SMEs. The SME representatives who were interviewed suggested that an authoritative body might reflect on appropriate regulatory principles, drawing on the expertise of an executive committee bringing together representatives from a wide spectrum of DBE partners. The interviewees appeared to favour a means through which the advice of legal experts could be sought officially so that the business interests of the SMEs and the technical potential of the DBE platform could be respected, thereby making the goal of DBE sustainability and trust more feasible to achieve in the future. This may appear to contradict the DBE vision of self-organisation, but it also suggests the need to ensure that the concerns of SME users of the DBE with respect to regulatory issues are addressed.

Table 1 presents a list of key regulatory issues that arise in the context of an examination of trust relationships for SME users of digital business ecosystems.

Table 1

Taxonomy Description: The SME View

Perspective	Attribute	Method (example)
DBE Relationship	Internal	Concerns about DBE legal entity
	External	Integration of E-signatures
		Governance issues
DBE Actors	SME Service Provider	Identification
	SME Users	Security
	Business Analysts	Contractual issues
		Commercial incentives
Software Lifecycles	Proprietary Model	IP rights
	Open Source Model	Middleware ownership

This framework could be extended to consider regulatory issues from other vantage points in future research.

Conclusions

Further research is needed to extend the taxonomy framework presented here to other business domains and sectors. The Regulatory Issues Knowledge Base tool was developed through a multidisciplinary collaboration between social and computing scientists and it needs to be extended and validated in a working digital business ecosystems environment. The initial research reported here suggests that it will be very important to investigate the crucial regulatory issues in the context of the further development of governance mechanisms for Digital Business Ecosystems that will need to be developed to ensure their sustainability. The accumulation of a Regulatory Issues Knowledge Base that can be adapted to the specific needs of SME users of the ecosystems will need to be incorporated within future research in this area.

It is likely that issues of integration and compatibility between local, regional and national domains in which Digital Business Ecosystems become operational will need to be addressed in addition to those of trust. These issues will provide a basis for further elaboration of the Regulatory Issues Knowledge Base as a basis for developing and defining SME sector policies.

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3

Section Three

Digital Ecosystem Technology

European Commission
Information Society and Media

Section Three

1

Digital Ecosystems **Technology** and Distributed **Nature** of **Information**

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Introduction

Since the Internet (IP network) inception in 1969, it has been assumed that servers (and therefore services) are unmovable. The IP network was designed as a static network, with the ability of dynamic routing. It is precisely its ability of dynamic routing (only possible if IP nodes are fixed in place) which is the key to its success. The IP network is self-reconfigurable by construction (i.e. highly adaptable).

Thirty years later we have a great quantity of networks in which the nodes that form them (potential servers) are moving constantly (or changing its IP address by means of DHCP). In spite of this, we have tried to maintain the paradigm which gave so good results: the server and service are bound to an IP address.

If it is assumed, though, that users change their location, that devices are portable (laptops, PDAs, etc), that networks do no longer need fixed infrastructures (there are wireless networks like Bluetooth, GPRS, UMTS, 802.11a/b/g/n, WiMax, etc), why not suppose that servers can change their location (say their IP addresses) without the need to interrupt the service they provide?

Coming back to our problem: if the mobile device changes its IP address, is the service it provides the same? Obviously so. It is not so, however, at the network level. The idea must be, therefore, to get rid of the transport level, so as to add mobility to the service.

How to tackle disappearing services?

To provide usable services, in spite of the mobility of the service which supports them, we need an infrastructure that relates the service (which we perceive as fixed) with the device that provides it (which we suppose intrinsically mobile) making it appear as fixed when in fact it is moving. In this way, what remains unmovable is the service provided to the network, not the physical location from which the service is provided.

The obvious solution is to have a fixed data structure (and, therefore, known by all) that keeps the relation between the unmovable element (the service) and the mobile element (the device that supports it).

However, the use of a centralized solution generates the appearance of a weak point, a single point of failure, within the very service repository. When we want to create a system with the ability to move, we need to keep in mind that it implies failure management. Something that moves may disappear, and therefore, we need to design mechanisms that enable to detect and recover from the disappearance of the service.

If we wish to avoid a single point of failure, we have to solve the problem without the use of a central data repository that matches the binding between the IP and the service. Is it feasible?

What is clear is that we have to change paradigm in order to face this new challenges. The approach we propose in the project is just to change the point of view. Instead of looking for 100% of information with a 99.9% probability (i.e. the up time of the system) we propose to have 99.9% of the information with a 100% probability (100% of system up time). This is the way in which nature works, and in which information is stored in natural environments.

Nature of information

Information is an essentially distributed resource in nature. It is not fully contained in central units, but rather distributed across a huge number of parts or elements, which are far spread out in space and time. Consequently, natural systems can hardly ever cope with all the information available. Nevertheless, such a limitation does not prevent natural organisms and ecosystems from evolving; on the contrary, it fosters competition and the "struggle for life".

On the other hand, most computer databases and networks are still built upon a strongly centralized hierarchy. Centralized systems do work well for most purposes on a small scale. As size increases, distributed systems outperform centralized ones, but the management of decentralized networks results in new challenging difficulties that we are just beginning to address. Here we will give some hints and describe the main characteristics of the new paradigm of computer communities and network information systems, and their advantages and drawbacks in computer sciences.

Fundamentally, there is no direct exchange of information between computers in centralized networks. Therefore, all traffic passes through a server: e.g. Public Switched Telephone Networks (PSTN) are strongly centralised communication networks. This type of networks has driven human society to Internet, and will probably allow us to go much further. However, other technologies like IP Telephony, File Sharing (P2P) and its related applications have shown an unparalleled development during the last years. Indeed, since its onset, this breakthrough has been achieved by young and small, but highly skilled companies.

One of the main limitations of centralized networks is bandwidth. Since all data pass through central servers, these are under strong pressure. Consequently, providing sufficient bandwidth for millions of users would demand onerous investments in infrastructure and technological skills. However, distributed and decentralized networks (which we shall from now on name Computer Communities) do not have servers but nodes, and these can play both roles.

Computer communities assume most of the structural and functional characteristics of the natural communities and ecosystems. They include essentially: self-organizing, self-healing, self-protecting and self-optimizing. Self-healing is the capacity to recover or rebuild a functional and optimized topology after one or several node disconnections. This is a complex behaviour emerging as a side effect of the local activity of certain nodes. Nevertheless, most man-made systems like computer networks are designed to self-protect against external perturbations and internal errors.

The main goal of distributed networks is to use a large number of nodes with variable connectivity in unified form in order to minimize central organization. This is linked to four reasons:

1. to avoid having a single point of failure,
2. due to resource limitations,
3. for a more efficient use of distributed information and resources,
4. and finally, to increase the performance and stability of the system.

In addition, most of the centralized computer networks suffer from the structural and functional limitations of closed systems. They were not designed to growth indefinitely and boundlessly, therefore the growth rate of a computer network strictly follows the law of diminishing returns, which means that the scalability cost is not linear but exponential in size. On the contrary, scalability costs remain linear in distributed networks. The larger the number of nodes in the network the greater the robustness and stability, as well as the total transport rate, service performance and efficiency. There are thus strong reasons for developing such type of networks.

In practice, centralized networks cannot grow indefinitely. Bandwidth is a fundamental resource for such networks that easily becomes limiting. As such, it is not possible to ensure an infinite bandwidth supply and, therefore, growth will progressively be reduced to zero for economic or technological reasons. Actually, the growth of centralized networks can only be carried out by human intervention. This is because the growth of such networks is achieved by a physical (hardware) upgrade of the system or addition. Human action still remains fundamental in most network maintenance and upgrading services. Human intervention is, however, one of the main tasks which one seeks to minimize, or even avoid, for the future.

Technology

The following chapters address the technology developed within the Digital Business Ecosystem project in order to build a highly resilient distributed infrastructure enabling the construction of an ecosystem of digital components. This infrastructure is a self-healing and self-managed system that avoids the need for a DBE corporation which would be in charge of infrastructure maintenance.

2 Ecosystem Oriented Architecture (EOA) vs SOA

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Introduction

As James Moore [1] pointed out, a Business Ecosystem is based on a dynamic interaction of organizations which evolve over time in terms of capabilities and roles. To this extent this section will describe why the Service Oriented Architecture (SOA) is not adequate to face such challenges which are unique in the context of a Digital Ecosystem (DE). The author will highlight such differences and describe the features of a new architectural style, called the Ecosystem Oriented Architecture (EOA).

The chapter will explore the fact that an Ecosystem Oriented Architecture is not a "sort of SOA", nor is it just a "bigger SOA". A DE employ a broad set of digital components, such as: software services, business services, knowledge, representations of the economy, etc. Software services being just one of them. To explain the differences between EOA and SOA, this article will focus on software services. All the components interact together, forming a digital ecosystem. A whole set of new problems are to be addressed, namely responsive alignment with the business, decentralization, ownership of a distributed knowledge base, self-organisation and self-healing. EOA is a new mindset in decentralized architectures for Digital Ecosystems.

A Digital Ecosystem implementation needs to support a particular dynamic scenario where dynamic business service aggregations and evolutions are key. Neither are B2B market place solutions able to adequately tackle such challenges. DE has to "... exploit the dynamic interaction (with cooperation and competition) of several players in order to produce systemic results in terms of innovation and economic development"[2].

It is indeed true that the recent achievements in Business to Business (B2B) implementations are enabling enterprises to accelerate the dynamic of business, however these solutions are still limited because Service Oriented Architectures (SOA), the prime supporting architectural style of B2B, has been conceived for supporting a single value chain, in a single business domain and usually between a static set of participants; in fact it is often the implementation of a single-organization supply chain. We shall rather name the current implemented scenarios as "business to Business" (b2B) to enhance the fact that the structure is not "democratic": in these cases there is a single Master in the supply chain, which is often the company that owns the chain. This company which is usually a large organization, can impose it's standard to its suppliers and customers, and the 'small' players have to accept the specifications; it's not a peer based model, as the name B2B do inspires, the two 'b' have to be different: this is key. Such b2B environments are thought as being an example of an across enterprise implementation where interoperability is tackled and successfully implemented but -on the other hand- this is an oversimplification, since in reality supply chains do intersect and overlap.

B2B solutions are rarely applied outside the boundary of an enterprise and it is a challenging project: it is cumbersome, and especially complex to maintain. Digital Ecosystems are to be implemented applying a new perspective in Software Architecture that has to overcome the limitations of SOA: an Ecosystem Oriented Architecture (EOA). We intend to pin-point the fact that DE specific features and issues cannot be properly addressed by SOA; there is a need to define a different architectural style that specifically tackles DE requirements from both the functional and structural viewpoint. Applying SOA when dealing with DE implementations overlooks the problems.

SOA has been conceived in the context of intra enterprise systems: in essence, the assumption is that any aspect either functional or structural is managed (or manageable) via a central governance entity. The infrastructure is under control and managed via a single department unit: network appliances like routers, firewalls, cables, routing and topology are planned and managed centrally. In addition, also the functional specifications of the SOA are planned in advance either in joint meetings between parties or defined by a single central authority. The WSDL representing the common technical contract for service invocation are defined up front and are to be used by all the partners in order for the value chain implementation to be effective: this is the environment in which SOA was born and where it is actually used most of the time. SOA is an architectural style that evolved from EAI, RPC and CORBA where the focus was on Applications, Procedures, Objects; focus on services was added later but still with an "intra enterprise" mindset (Figure 1 below).

An SOA implementation is often conceived, funded and implemented by an organization with the sole goal of supporting and increasing its business, as a consequence this drives the entire environment which is single-party centred and does not follow the competition/evolution core feature of a DE.

In an enabling ICT-based infrastructure aiming at supporting the economic activity of networks of business clusters (or business ecosystems) fostering systemic synergies with special focus to SMEs. DE scenarios are changing the rules, because the focus is moving from "intra enterprise" to "across enterprises" (inter community) and soon "across communities". Using SOA for implementing a DE, that requires enlarging the participants in a broader spectrum, supporting a wider set of functional models, running over the Internet, spanning a WAN, is underestimating the problem. As a matter of fact, reading the literature[3], and from the author's experience, it is evident that dynamism and flexibility are key for running a Business.

In a digital ecosystem the value chains are overlapping, they are not partitioned but intersect each other;

- the social and business network topologies are not hierarchical [4];
- a single functional reference model cannot be implemented;
- there is no single point of management from both the business and structural viewpoints.

Taking the previous premises into account, the final goal should be the integration of the services offered by each of these SMEs, without involving extra investments in items not related to their businesses (such as information systems). Therefore, the system should be operated automatically without human intervention. In other words, the system that supports integration of the aforementioned services should have self-organising capabilities.

On the other hand, it should be decided what would be the minimum infrastructure required to allow the presence on the Internet (that is: great portals, operators, ISPs, etc) of these businesses without the need for great investments, or great resources. To reach this goal, two clear premises were identified: minimum hardware, and zero maintenance. The need for maintenance and administration should be eliminated, wiping off the greatest source of cost. This now opens the challenge of zero-administration, which requires the development of software technology that provided self-organization mechanisms. Along with these elements, the system should bring us the possibility to publish the presence of a given business (identified as a service) from the moment it's connected to the DBE network, and the ability to detect its disconnection to eliminate the service from all the contents in which it was referenced.

Functional Reference Model

Digital Ecosystems cross business domains and different value chains, for this reason they are characterized by not having a single functional reference model. Since it is not feasible to define up front all the required functional models, which are intricate, complex and continuously changing, the ecosystems participants need to be free to define, publish and use any models that they consider adequate for their business.

As an example, a book distributor or reseller might create a model that represents their application interface to allow consumers to search, browser, order and buy books. This model could be published and implemented by their service component. Other competitors in the ecosystem will probably do the same in autonomy and this will end up with a set of different APIs that would burden the effort of a bookstore when required to automate the order process; for each supplier/distributor a different technical adapter is required. This constraint would slow down the rate of adoption and lock stores on a single supplier because of the effort required to align the software again. This would represent the dead end of the ecosystem; without fast business alignment, there will be no evolution.

One rather ingenuous approach to overcome this issue is to have all the book distributors sit around a table in an association defining "The" reference model for the book store sector. From direct experience of the author(2), this is a method that does not scale for a long time and, assuming that the participants are able to converge to a suitable model, there will soon be other "competing standards" (notice the oxymoron) that would again create interoperability problems.

Also, maintaining the specification would be very time consuming and in the end it would not be possible to keep it aligned with the business requirements: new features driven by the end users or marketing would incur the risk of being left behind, waiting for the new specification to emerge or -even worse- of being implemented diverging from the standard. As a consequence, the expected well ordered mechanism would soon break.

This scenario is a gross over-simplification of the models what might be found in a DE, especially considering cross value and supply chains. The overall map of models would be so complex and articulated that managing them would be impossible. As a comparison, we can recall the Internet map(3)[5] and its topology; no-one can have full control of it. It emerges rather autonomously from complex usage mechanisms that have been investigated only in recent times. Even maintaining the functional models of a complex ERP project, with well-defined boundaries and dependencies, can be very difficult and impossible for a single party; changes and updates are often tough tasks to accomplish. In a business ecosystem this effort cannot be addressed at all, and a new mindset and approach in this sense is required, and the SOA approach is hence inadequate. In addition, assuming that an ecosystem can be managed is a contradiction in terms. The keyword is "self-regulation", "self-adaptation"[6] and the EOA has to implement the required instruments for this to happen, it is useless to fight and oppose the dynamic nature of a DE, it is better to support it.

The way to go about then assumes the inability to control the reference models; we might assert that there is no reference model at all, and take all the required architectural decisions to support it and let the ecosystem converge, dependant on time, in a model. What is fundamental to assume when defining the architecture of a DE is to recall that it is a highly dynamic environment where the IT related frictions and inertias needs to be reduced to the minimum. This is the prime condition that will allow an ecosystem to self-converge and adapt.

The architecture needs a mechanism to allow participants to:

- publish any model;
- investigate which is the most adequate to their needs;
- adopt it (and change it) in a totally free and uncontrolled space (regulatory and restrictive features shall only be added as a means to avoid hacking or spamming the environment).

A structured and highly connected repository has to manage the models, their dependencies and their association with implementing services. As an example: if the book distributor could inspect the ecosystem (specifically using a model repository), it could detect that there is a functional model for the book sector that is adopted by 75% of bookstores and another one less adopted (hence less connected) but closer to its technical needs and more straightforward to implement due to the better alignment with their back-end systems. The distributor has the chance to decide whether to adopt the most connected model, hence facilitating the migration and adoption by bookstores, or to stick to the easy way with an obvious drawback regarding the level of adoption. In this scenario it is evident that bookstores (the service consumers) on the other hand will try to reduce the number of different models in order to lower their integration efforts and favour the quality of the service offered. The balance between the symmetric aspects is the basis for competition and evolution.

Model repository

In SOA, UDDI is the catalogue of services and service models. They are mixed with binding information, there is no separation between the technical specification and the functional one, and in addition the service end-point is also written in the service specification. Such structure is a consequence of the fact that UDDI has been conceived as a static catalogue of intranet services(4); it is clearly a consequence of the fact that it descends from classical RPC approaches. UDDI is essentially a catalogue of programmatic resources.

For example: two different book distributors might use the same technical specification of the service (e.g. WSDL) but have different kinds of discount policies, different return policies, different quantity discounts or serve different regions. The WSDL is a technical specification that exposes the service protocol that in turns implements the business service. What has to be modelled and delivered is the business service rather then the mediator to the service. In an SOA the need to model the business specification is not a prime need because there is no economical transaction involved. SOA is often implemented, in the author's experience, in a context where the associated business transaction costs are null (zero). Nevertheless, the writer is aware of some SOA implementations (rather tough though) in which an invocation implies an effective business transaction, i.e. some "money exchange". But also in these cases the participants and the services involved have been defined up-front -statically- and the business models are known in advance: there is no dynamic discovery or negotiation and for this reason -under these assumptions- SOA works fine: in DE on the other hand it would not scale. Reference documentation about UDDI mentions "Companies can establish a structured and standardized way to describe and discover services"(5), but a DE is not a structured or standardized environment.

In a DE, the model repository needs to manage business models instead of programmatic specifications. OMG's XMI is the prime choice for encoding models because it is a platform-independent specification; it supports meta-modelling, model dependency, merging, inclusion, inheritance and versioning. XMI is able to represent semantically rich model specifications, where WSDL is not. Services in DE need to make use of more complex specifications, the definition of software interfaces is not sufficient: there is the need to express the underlying business model. The plain interface specification is not relevant in the context of an ecosystem where services need to be explored automatically via recommendation agents: having computable business models is essential.

In addition, the functionalities provided by the repository need to support an enormous amount of unstructured and related information. The users, either a software component or a human being, must be able to navigate the intricacy of models and their dependencies in order to identify those that are most useful and adequate. In this sense the repository needs to provide intelligent and semantically aware research and recommendation tools[7].

It is also essential is to decouple the service model catalogue from the actual service instance catalogue: "The service registry".

Service Registry

The service registry contains the references to actual services published in a DE associated with the technical and business models. Each entry includes self-contained information about the service (called Service Manifest[8]), made of:

1. service business models;
2. technical specification (i.e. Service APIs);
3. business data;
4. service end-point.

The first type is essentially the business specification (it might be a reference to an entry in the model repository, this is an implementation aspect which is not relevant in this context). The second is the technical specification of the service. The third is information specific to the service instance, for example the name of the published service or the location of the service; in general this information is associated with the business model. The fourth is programmatic information needed to actually invoke the service, for example – it is an over simplification – the IP address and the protocol used.

Whatever way this registry is implemented, the essential aspect is that is has to be extremely dynamic and bind to the actual published service. In SOA it is a great frustration to try to invoke services from information found in the UDDI just to discover that they are not available. The real issue in these cases is that the requesting service is not able to provide the reason for the failure: is it due to the fact that it has been discontinued or because there are some temporary technical issues? In an intranet SOA implementation, the architect has the ability to put all the efforts in order to have a high availability of service: in the Internet this cannot be assured. As a solution, the service entry in the registry needs to be bound with the actual remote published service so that it provides up-to-date status information; since it is too administratively intense to manually keep it aligned, a lease base mechanism is a good technical approach, like SUN's Jini(6) framework dynamic lease management or the FADA framework (7).

As for the model repository, the service registry needs to be MOF8 compliant in order to ease the issues related to model interoperability.

The model repository and service registry represent a single point of failure (SPoF) for the DE architecture and this can jeopardize the entire ecosystem. This issue is addressed via a decentralized architecture, described in section 5 "Single Point of Failure" Chapter.

Basic Services

An architecture for DE needs to consider a set of basic business services to support the ecosystems and facilitate the rapid and correct interaction between business services. A DE without a proper set of basic services is unlikely to be sustainable: the goal is to improve the level of adoption by easing the participants' effort in publishing and integrating services. It is fundamental for example to execute a negotiation process before actually consuming the service (which is not required in an SOA implementation, as mentioned above) essentially because a service invocation in a DE is a business service consumption. For the same reasons, services such are reputation and trust are as fundamental in a DE.

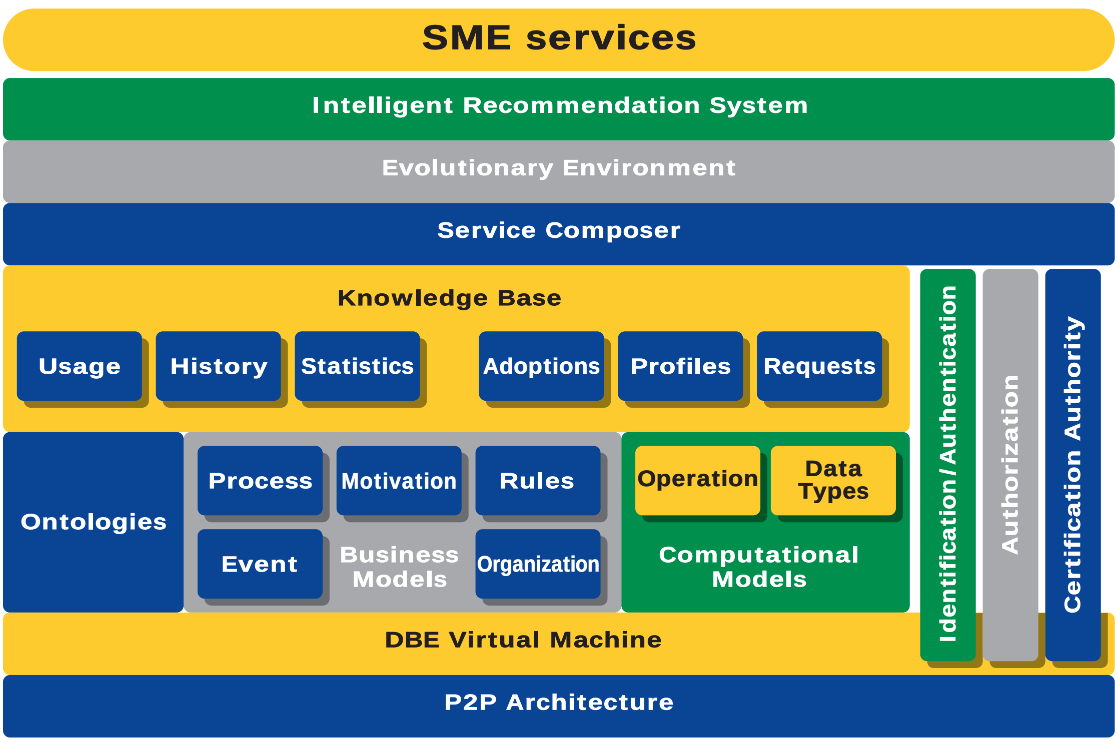
The following services are needed essential to facilitate the bootstrapping phase in a DE:

- Payment
- Business Contract & Negotiations
- Information Carriers
- Billing
- Trust
- Reputation
- Legal compatibility

It is however important to underline that all these services do not specifically need to be implemented up front. It is important to support them for example by defining their models in the repository and providing an adequate infrastructure for their implementation: it might be up to participants and organizations to implement them. But some, like the accounting service, need to be supported by the core infrastructure of a DE because it has to adequately intercept the inter services messages.

One of the most significant services required in a DE is support for negotiations. In SOA, in those rare case in which it is implemented in across-enterprise B2B environments, negotiation takes place outside of the IT systems, often through real meetings; in SOA implementations, only the service execution is supported together with a poor search mechanism. In DE, following the definition given at the beginning, the ecosystem is such only if the integration mechanisms are fast and automated. As a matter of fact DE had to replicate in an e-environment what happens in the real world environment.

Fig. 1
An example of the service stack in the Digital Business Ecosystem project (DBE)



In addition there is the need to reconsider other services, although in a different perspective:
- Service Discovery
- Reliability-guaranteed delivery
- Security
- Long running Transactions
- XML Firewall.

Single Point of Failure

The Service registry is a key element for SOA; it is used at run time for service discovery and invocation, for this reason it represents a single point of failure for the entire architecture. If the registry is not available, the services will not be reachable.

This is a key issue also in SOA, for this reason UDDI version 3 has introduced replication schema for cluster of registries that provides high availability feature[10]. It supports both clustering and mirroring, however replications are based on the complete mirroring of nodes; in addition the replication policy is to be accurately planned by an administrator and implemented beforehand. But for a DE, given the complexity and intricacy of the infrastructure, the very frequent changes and the absence of any "root" node, this solution is not adequate.

In DE, the registry is even more critical because service IP addresses change very often, while in a classical SOA all the services are published in static IPs and change quite seldom: caching IPs would not work for long[11].

Setting up a single central fail-safe and highly redundant registry server would be very expensive and would not even guarantee service continuity in case of natural disaster. The alternative solution is to exploit decentralized approaches, i.e. a topology and replication schema that does not make the DE dependant on a single node but rather on a collaborative set of peer nodes (more on this in the next section "Scale free networks"). Instead of a controlled cluster of nodes, there is the need to advocate the use of peer-to-peer networks as the routing infrastructure that improves routing resilience to node failure and attacks on service registries[16]. Such a network of nodes needs to be self healing and self adaptable to the ever changing nature of the requests and traffic: there should not be an administrator. Such kind of solutions would be resilient to node failures and would not loose information under critical circumstances. Nodes within this network interact in rich and complex ways, greatly stressing traditional approaches to name service, routing, information replication and links.

In such types of networks, data replication within nodes takes place intelligently: entries migrate automatically in relation to requests, moving data toward nodes that started the request. In this way, as in typical caching mechanisms, information is copied from the closest nodes so as to increase the probability that sequential requests get fulfilled in less time. It is relevant to notice that "close" in this context is relative to speed and not to geographical distance, since often in Internet hub nodes 100 km apart are faster to ping then local servers. Moreover, such a copying mechanism replicates redundant information among nodes so as to increase tolerance in case of nodes failure. As a matter of fact the new Italian Health Care System is adopting such a decentralized architecture for the Patient Health Record registry[12].

Avoiding having single points of failure for an EOA is essential. Beside the technical non marginal aspect of having a more reliable system, the DE will not suffer from the "big brother syndrome". With a decentralized P2P based architecture the knowledge which is held in by the model repository and the service registry is not managed by a single institution which could tamper with it at the expense of the community by imposing unwanted control. A DE is self-regulated and self adaptable by definition[13] and a central institution with the potential power to control the environment from a technical and functional point of view could hinder the entire process of adoption and sustainability. Consider for example what would happen in case the organization hosting the service registry decided to shut it down. Such possibility would impede the adoption of the DE.

DE founds its entire sustainability and existence on knowledge about models and services. Participants in the DE are providing and using models while actively participating and being part of a business community, they are hence scared about loosing models. The owners of DE knowledge need to be the community itself, to this extent a peer-to-peer network (see next section "Scale Free Network) is a good approach because it is democratic; it provides participants with the possibility to offer resources to host part of this knowledge.

The significant drawback is the implementation: such a peer-to-peer infrastructure needs to be self-healing and self-adaptable. But there are already some frameworks and tools that support the enhancement of the properties of Scale Free networks.

Scale Free Networks

Most of the solutions in SOA, like the cluster of UDDI registries, are based on hierarchical structures because this is the way humans proceed in order to deal with complexity, i.e. in order to create comprehensible models. But as a matter of fact, the social and business networks in the real world are not hierarchical at all: this is essentially the reason why information models become more and more unmanageable with the increase in complexity. The more the IT systems push in the direction of being aligned with the business, the more the IT becomes unmanageable. Below a certain degree of complexity, any model can be reduced to a hierarchy that represents a good approximation, but with the increase in complexity it becomes impossible to stick to a hierarchy because reality is not as simply structured: it is based on different models and topologies: Scale Free networks[15].

The scale free networks are well described in the literature[14], we do not intend to describe it in this paper; what we state is that since scale free networks are the topology at the basis of business and social networks[15], a proper EOA has to support it and define appropriate mechanisms in order to let it emerge in a self organized way without human intervention.

In order for a Scale Free Network to emerge, it is necessary to support connectivity, proximity and preference[16]; it is dangerous and it represents a risk in the architecture to over-impose an unnatural topology. The advantage of a Scale Free Network is well described in the literature, essentially it is tolerant to a random failure of nodes and the properties of a "small world" allow efficient searches[17][18].

The author envisages a service registry and a model repository implementation that take advantage of such kind of networks essentially because this is the way they exist in the real world and supporting this vision will help align the ecosystem with the business -as is required.

Technologies are already available and they make use of concepts like the Tuple Space or the Distributed Hash Table, for example Sun's Jini™ Network Technology[10], FADA[11], Bamboo[12], Cord[13] and others; there are also commercial implementations like GigaSpaces©[14]. P2P architecture can help, even if they can be used to infringe copyright: there is no need to be prejudiced, a technology is not bad per se, but it depends on the way it is used. The Digital Business Ecosystem (DBE)[15] has made a significant step forward in this direction.

Conclusion

Service Oriented Architectures (SOA) do not scale nor address the new challenges addressed by the architectures for Digital Ecosystems. The author envisions a new architectural style, called the Ecosystem Oriented Architecture (EOA). Three levels of service specifications are to be identified and addressed[20]:

- service models: a catalogue of business and computational models to be reused;
- service implementation: a catalogue of services descriptions (Service Manifest) implementing some models together with their data;
- service instances: service name and endpoint to actually invoke and consume a service.

In DE it is essential to have a repository of models separated from the registry of services[20]. The model repository needs a whole set of discovery features and supports XMI in order to implement model driven capabilities like dependency, versioning, merging and inheritance. Services need to be described also from the business viewpoint: the computational specification is not sufficient in DE because services are not known in advance and the discovery process needs to be smarter and based on business specifications.

The service registry needs to overcome the static limitation of UDD-like services and be dynamically bound to actual published services. In the near future a lot of mobile services are expected and these devices are going to make use of dynamic IPs, enhancing SOA based approaches is not enough. The service instances are to be resolved at run-time via a sort of DNS service.

Given the nature of a DE, the architecture needs to avoid single points of failure, the best approach envisioned is to make use of P2P technology to implement a decentralized data storage system (as opposed to the SOA centralized or distributed approach).

Basic services need to be implemented and defined up front in order to sustain the ecosystem, such as negotiation, information carriers, payments, accounting, billing and others. While SOA essentially supports only the service execution phase, a DE has to support the entire business service life-cycle including service selection (as opposed to service search), negotiation, agreement, contract specification, consumption and delivery.

In any aspect, either functional, structural or topological we have to reflect the real ecosystem in the DE: after over 40 years we realize that we are still applying the Conway[16] law that states "Organizations which design systems are constrained to produce designs which are copies of the communication structures of these organizations"[21], i.e. any piece of software reflects the organizational structure that produced it, and a DE is no different.

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3 DE Services in Ecosystem Oriented Architecture

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Introduction

This paper introduces the concept of Digital Ecosystem Services deployed in an Ecosystem Oriented Architecture (EOA). As described in Chapter 3.1, the EOA concept is based on a peer-to-peer architecture that allows the digital ecosystem to be effectively pervasive and decentralised. There is no single point of failure and the ecosystem itself is owned by participant SMEs and not by a governing body or organisation. The knowledge and services are spread across the supporting nodes through a peer-to-peer self-healing architecture. Services are described in both the technical and business point of view hence allowing semantic and business types of search and discovery.

This paper will describe the requirements of services deployed in an EOA and how the DBE project [1] have realised these requirements for SME service deployment.

Digital Ecosystem Services

A conceptual framework for DBE services emerged from the work done by Soluta.net on DBE architecture requirements. This framework is similarly applicable to DE services in an EOA. This can be seen below in Figure 1. Every DE service is specified using a set of formal languages that aims at defining the business models as well as the technical interface in a platform implementation way. Thanks to the model driven approach taken, business models can be transformed and mapped into platform specific models without specific user interventions. The family of languages adopted defines the service's DNA that fully specify the service and the ability to evolve and adapt. Each structural component is decentralised. Such an approach potentially allows the ecosystem to be self-healing and survive technical and network failures.

The technical architecture eases the entire integration and adoption process by providing an infrastructure at both sides of the pipe in a consumer-provider point of view. Services already residing in legacy systems can quickly become DE enabled, thanks to the decoupling approach provided by EOA and the MDA (Model Driven Architecture [2]).

A Service Composer allows for browsing of the collected published services and the creation of a workflow that can be executed and published as an atomic service. The chained nature of such new service will be completely transparent to the consumer application or user.

Given the meta-service and meta-modelling approach followed, there is not a single model or service that cannot be replaced or enhanced. No pre-defined or immutable behaviour is coded in an EOA. [3]

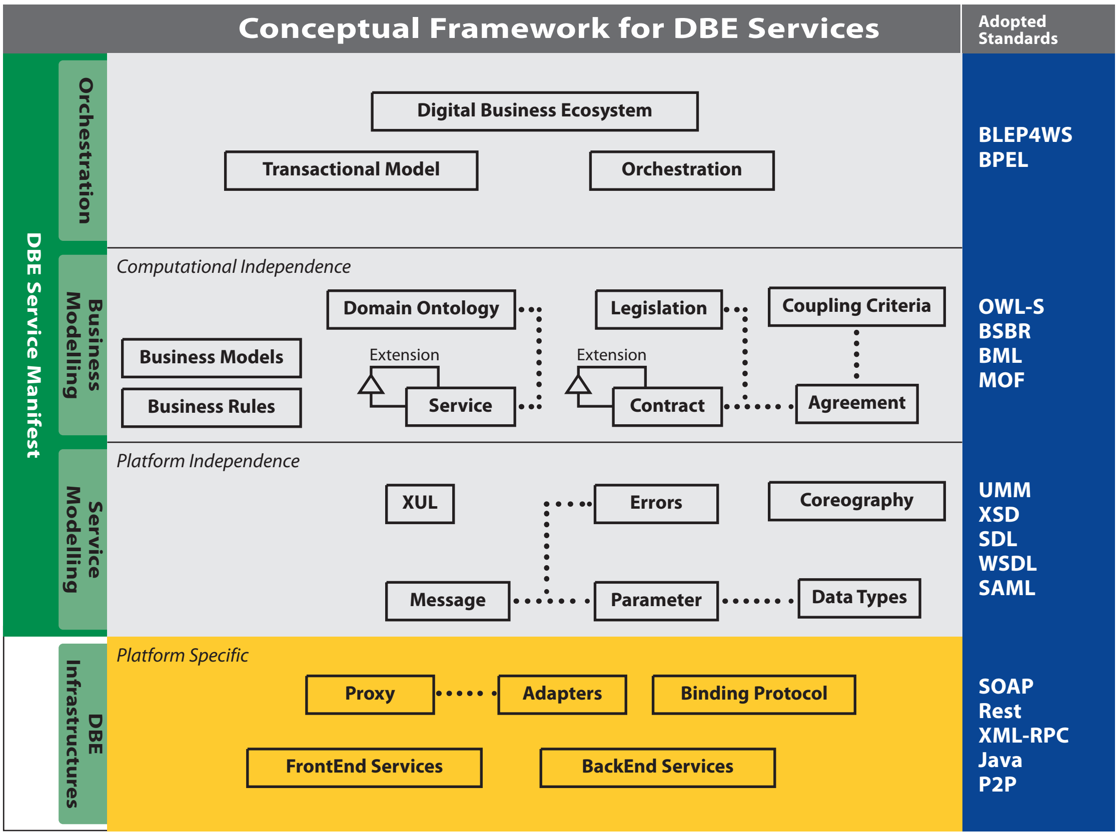

Fig. 1

DBE Services Conceptual Framework (Source [3])

The Service Factory
Creating and Maintaining the Services

The starting point for a participant in a digital ecosystem is to model and create a DE Service through a Service Factory. A Service Factory is a set of tools to aid the developer in the creation of DE Services, through the association of those services with appropriate models and deploy those services in the Execution Environment. The Service Factory was realised in DBE through the open source DBEStudio Project [4].

The DBEStudio is an Integrated Development Environment (IDE) for the Digital Business Ecosystem (DBE). It was developed using the Eclipse framework [5] and includes a set of eclipse plug-ins that allow business services to be analysed, and corresponding software services to be defined, developed and deployed. When the DBEStudio is launched it is configured by the user to connect to the core DBE Services via a URL denoting the location of a running Execution Environment.
Descriptions of the core plug-ins are provided below.

BML Editor

The BML(Business Modelling Language [6] Editor plug-in is a visual modelling tool and provides a UML-like Graphical User Interface (GUI), similar to that of well known UML editors. The tool supports the modelling tasks and stores the created models in the DBE Knowledge Base (KB) deployed in the Servent. The current version of the editor supports both the semantic description of the services offered by an SME and the business model of the particular

SME. The former provides to the user the ability to create service models according to semantic service language metamodel and the latter to create business models based on the BML metamodel. Both metamodels are described using OMG's MOF 1.4 [7].

BML Data Editor

The BML data editor takes MDA M1 level BML models (created with the BML Editor) and allows the developer to populate these in order to create M0 level instances of those models. These M0 models then represent the business data associated with actual running instances of service business models.

Ontology Analysis Tool

The Ontology Analysis Tool plug-in provides a visual environment based on a UML-like graphical user interface that enables business analysts to deploy domain specific ontologies in order to describe the business requirements of SMEs in the context of the DBE project. The ontology definitions is based on the Ontology Definition Metamodel (ODM) compatible with the OWL, can be represented using XMI (XML Metadata Interchange [8]) technologies and can be stored either locally (in the local file system) or into the DBE Knowledge Base using the JMI (Java Metadata Interface) standard.

Service Exporter

The Service Exporter plug-in enables a user to export a DBE project and deploy it as a DBE service to a Servent. Using a set of wizards the user can add/edit their deployment information. The tool creates a DBE Archive (DAR) file, which contains a particular structure for deployment within a Servent. This plug-in is also integrated with the Metering Wizard to allow users to add metering information at deployment time.

Metering Wizard

The DBE metering wizard is run as an optional element of the Service Exporter plug-in. This wizard allows for the selection of parameters upon which the filters installed in the servent can extract usage data. The SME deploying the service can select methods and parameters of those methods that require metering. This usage data can then be used by OSS (Operation Support Systems) type services installed in the Execution Environment. In DBE, open source accounting services have been implemented and deployed and make use of this usage data in applying charges for services usage as well as providing billing information.

Manual Composer Tool

BPEL Editor

The DBE Composer Tool is a BPEL (Business Process Execution Language [9]) editor to allow for the creation of composed services for execution in the DBE ExE. The design of the BPEL Manual Composer tool centres on a graphical editor and a composition wizard for this composition language. This editor is the core component as it allows the user to graphically design the composed service as a workflow process, while the wizard uses simple rules to help a user to select services and create model structures. The implementation of both the editor and the wizard fully support the BPEL meta-model. The design of the editor provides a 3-view editor where each view has a more abstracted representation of the BPEL model. The intention is to provide two levels of graphical abstraction and granularity to suit both a semi-technical user and a BPEL developer, where the wizard and the graphical editor attempt to address the needs of both user types respectively.

SDL Editor

The SDL (Service Description Language [10]) editor allows SMEs to define their services from a technical point of view. The editor provides a graphical means of defining service interfaces and expresses those interfaces via XML instances of the SDL schema

SDL2Java Compiler

This plug-in takes the XML SDL instance created by the SDL editor and generates a set of Java packages and interfaces which need to be implemented by the developer in order for the service to be deployed successfully in the SBE Execution Environment.

Service Manifest Composer

The Service Manifest composer is responsible for the creation of the Service Manifest (SM) [11]. The Service Manifest acts as an advertisement for a deployed service and contains both business and technical models of the service instance. The Service Manifest Composer is responsible for the creation of this from the models created from the other plugins. This SM is deployed with the service and inserted into the Semantic Registry (Service Registry). See the next section for details.

Execution Environment
Deploying the Services

As described in the chapter on EOA, an execution environment for DEs must provide certain functionalities; a suitable peer-to-peer network, a service container, a service composition engine, a model repository and a service registry.

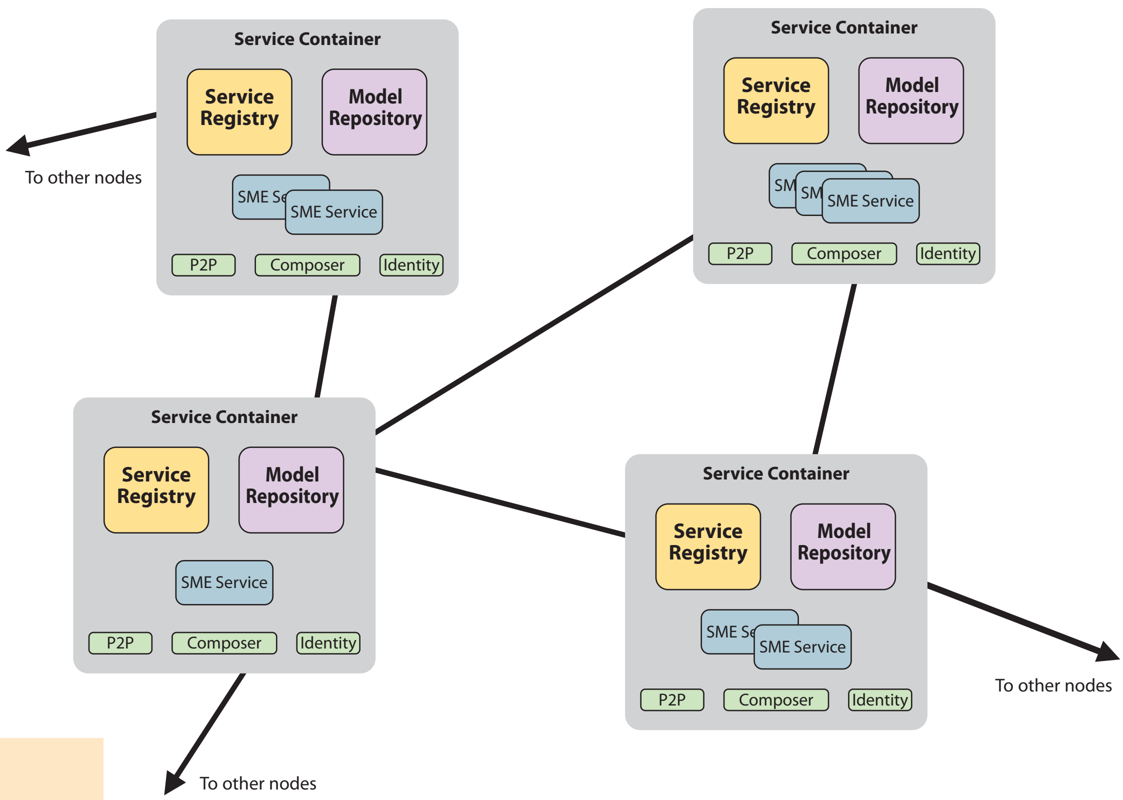

Fig. 2
Distributed Infrastructure of EOA

The distributed infrastructure of the EOA can be seen in Figure 2. The nodes are connected via the peer-to-peer overlay network. Each node contains the core functional components required for the EOA to be successful. Each node also hosts services offered by SMEs. The services have the ability to migrate, providing high availability of service provision in the event of a node failure or downtime.

Each of the supporting core components is briefly discussed below and the DBE implementations also referenced. Detailed descriptions of these implementations are available in the chapter on Distributed Infrastructural Services.

Service Composer

The composer provides the ability to orchestrate and manage the execution of composed service chains. The DBE implementation integrated the open-source workflow engine ActiveBPEL [12] and extended it with a custom invoke handler to deal with invocations. This provides the advantages of a standards-based workflow description and execution with the added bonus of DBE peer-to-peer interaction.

Model Repository

The model repository is a business model container. Services deployed in the ecosystem are associated with one or more of these models. The preferred encoding option of models in the registry is XMI (XML Metadata Interchange)[8] (see chapter on Ecosystem Oriented Architectures). The DBE implementation, developed by the Technical University of Crete, is called the Knowledge Base and provides distributed persistence satisfying the OMG MDA [2] approach taken in DBE.

Service Registry

The service registry is a repository for references to deployed services in a digital ecosystem. Each entry is associated with one deployed service and contains information on business models, technical specifications, business data and the service end point. The DBE implementation of this component, developed by the Technical University of Crete, is the Semantic Registry, which is used to store a Service Manifest [11] per deployed service.

Peer-to-Peer Overlay Network

A peer-to-peer overlay network is essential in providing a digital ecosystem with the assurance of no single point of failure and robust distributed knowledge and service provision through a distributed set of collaborative nodes. This approach improves routing resilience to node failure. A suitable implementation needs to be self healing and autonomically adaptable to the changing nature of the requests and the traffic.

FADA (Federated Autonomous Directory Architecture) [13] was the initial peer-to-peer implementation deployed in DBE. FADA emerged from the European project Fetish. Trinity College Dublin also developed a DHT (Distributed Hash Table) peer-to-peer implementation based on their peer-to-peer architecture design for DBE [14]. More details of both these implementations are available in the chapter on Distributed Infrastructural Services.

Identity

A fully distributed identity management system is essential for providing trust among the participants in digital ecosystems. Identity constitutes one of the basic building blocks for providing accountability functionality to B2B transactions. Services need to be associated with an identity of the service provider and service consumers need also to be identified for accounting and access control purposes. However creating a decentralised, robust and trustworthy identity management system with no dependencies on third party certificate authorities is a challenging proposition.

In the DBE project, Trinity College Dublin developed a core identity component overlayed on top of the DHT implementation. This contitutes a decentralised solution that provides the redundancy and management features inherent in the DHT. The system has the ability to verify keys associated with service invocations.

Conclusion

Successful digital ecosystem service deployment in EOAs requires a set of mechanisms for the definition of business and technical models, the creation of service interfaces based on these models and robust decentralised service hosting. These mechanisms have been described in this paper, together with descriptions of how these mechanisms have been realised in the DBE project.

Acknowledgements

John Kennedy, Intel Ireland. Pierfranco Ferronato, Soluta.net. Dominik Dahlem, Trinity College Dublin. Fotis Kazasis, Technical University of Crete. Juanjo Aparacio, TechIdeas.

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4 Modelling Languages, BML, SBVR

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Introduction

The fast growth and the diffusion of the World Wide Web, its effect on trade, economic transactions and communication systems, allowed and boosted the diffusion of the network society. Radical changes in the geography of costs, production and human and social capital affected the space-time of business altering the traditional business frontiers (Castells, 1996).

These phenomena allowed companies and organisations to grow globally, reacting to the climate of uncertainty through the decentralisation of production and innovation. Shifting activities to the electronic dimension allowed an increase in efficiency and the reduction of coordination costs. At the same time, organisations geographically distributed start to interact and trade globally, enhancing the growth of networks of distributed companies. Transient networks and organisations as portfolios constitute new organisational forms, which exhibit unmatched connectivity, flexibility and adaptability. Competing in this context poses a number of integration problems that enterprises have to tackle, such as the integration with customers, among suppliers or between design and manufacturing sites. As a consequence, integration ceases to be only a matter of interconnecting physical and software applications; more than this, it starts to be considered in a wider perspective, that concerns the overall business and all its aspects. This means that, in order to enable a different use of enterprise and network resources to better achieve strategic objectives, a global business integration is needed and considered as a key factor for successful enterprises.

The most interesting consideration arising from these concepts is related to modelling issues. Things to be integrated and coordinated need to be clearly defined and expressed: the more a model is effective, the easier is the definition of communication, coordination, control and exchange mechanisms. Thus, enterprise modelling is clearly a prerequisite for enterprise integration.

An *enterprise model* is a computational representation of the structure, activities, processes, information, resources, people, behaviour, goals and constraints (Vernadat, 1996) of a business, government, or other organisations. It can be both descriptive and definitional - spanning what is and what should be. The role of an enterprise model is to achieve model-driven enterprise design, analysis and operation. The finality is to make explicit facts and knowledge that add value to the enterprise or can be shared by business applications and users. Besides an effective enterprise integration, the main purposes of business modelling are to support the analysis of an enterprise and, more specifically, to represent and understand how the enterprise works, to capitalize acquired knowledge and know-how for later reuse, to design and redesign a part of the enterprise, to simulate the behaviour of the enterprise, to make better decisions or to control, coordinate and monitor some parts of the enterprise. Enterprise modelling techniques and associated visual languages are very important and useful to support new approaches to enterprise business transformation and improvement, developing smart businesses and new networked organisations.

Approaches and methodologies

Enterprise modelling was born in the United States at the beginning of the 80's and emerged through large Computer Integrated Manufacturing projects. In the mid-80's, Europe launched several projects on enterprise modelling giving birth to several enterprise modelling languages. As a result, in the 90's many commercial tools dealing with enterprise modelling or business process modelling appeared on the marketplace, as well as a myriad of workflow systems, each one with its own modelling environment. This intensive production of tools has led to a Tower of Babel situation in which the many tools, while offering powerful but different functionalities and semantics, are unable to interoperate and can hardly or not at all communicate and exchange models. Currently, enterprise modelling is a wide and complex domain containing many different methodologies, languages, tools and techniques, often developed in different context for different scope. Such languages could be roughly divided among the approaches developed mainly from a business perspective and the languages and methodologies related to design and development of IT applications.

In the stream of the knowledge modelling related to the business area, there are many languages and frameworks devote to model specific characteristics of enterprise. Among them, the *Zackman Framework* (Zachman, 1987) and the *Generalised Enterprise Reference Architecture and Methodology* (GERAM) (Bernus et al., 1997) represent the most general approaches; more operational frameworks are the *Integrated Enterprise Modelling Method* (IEM) (Spur et al., 1996), the *Integrated DEFinition methodology* (IDEF) (NIST, 1981), the *Architecture of integrated Information Systems* (ARIS) (Scheer, 1992), the *Process Specification Language* (PSL) [8], the *Workflow Process Definition Language* (WPDL) (WMC, 2002), the *Business Process Modelling Language* (BPML) (BPMI, 2002), and the *Business Rules* (BRG, 2000) approach.

Among the standards related with software design and development there are the *UN/CEFACT Modelling Methodology* (UMM) (UN/CEFACT, 2003) and the *Rosetta Net* (RosettaNetl, 1998). In the same group, there are some industry initiatives and de-facto standards, such as those promoted by the Object Management Group: the *Model Driven Architecture* (MDA) (Frankel, 2003), the *Unified Modelling Language* (UML) (OMG, 2003), the *Meta Object Facility* (MOF) (OMG, 2003a) and the *Semantic of Business Vocabulary and Business Rules* (SBVR) (OMG, 2006). Other relevant standards in metadata definition and exchange are related to the work of W3C. Among them there are the *eXtensible Markup Language* (XML) (Bray et al., 1998), the *Resource Description Framework* (RDF) (Lassila et al., 1999) and the *Ontology Web Language* (OWL) (McGuinness et al., 2004).

The Business Modelling Language

The Business Modelling Language (BML) has been created as the business language for the DBE project. Its main aim is thus to create a general framework enabling business people to represent the business knowledge related to DBE services and to the enterprise that stands behind such services, in order to allow communication mechanisms based on semantically rich information models.

One of the most interesting characteristics of BML is that it has been designed in order to bridge the gap between business and technology perspectives. If on one side BML allows to express business concepts, that is the actual concepts, actions and events that business people have to deal with as they run their businesses, independently by technological aspects, on the other side it grants a rigorous mapping to formal logics, to make business knowledge accessible to software.

Another important aspect, is related to the software production methodology and to the effort in realizing mechanisms for software development based on models. The BML framework is aimed at supporting business analysts to express in a formal and well defined way all the knowledge necessary to represent a customer company.

Defining the BML framework has implied the definition of the BML syntax (how information is expressed) and the BML semantics (how obtaining a shared meaning). In order to decouple these two fundamental issues, it has been chosen to define a general architecture based on a meta-modelling approach. In this way, the information model, that could change during the evolution of the project, is related only to the meta-model content, without implication on the general architecture of the framework.

The BML general architecture

The BML architecture has been developed applying a meta-modelling approach. Such an approach refers to the Meta-Object Facility (MOF), a standard defined by the Object Management Group (OMG, 2003a), that aims at guaranteeing a universal approach to describe modelling constructs. It is based on a multi-layered architecture, where each level is defined through the constructs defined in the upper one. This design choice has allowed to exploit many advantageous features for the semantics definition, since every item defined in whatever level could benefit from the semantics inherited from upper level models, in terms both of definition and relationships. This approach also grants coherence among different sub-domains since, once a general meta-model has been defined, it is possible to define different coherent domain models, used to provide a shared meaning to the businesses of a given industry or community. Moreover, this design choice permits to obtain interoperability and interchange capabilities through the MOF mapping technologies. As an example, MOF XMI (OMG, 2002) encoding can be used to transfer models conforming to the BML meta-model as XML documents and to transform the BML meta-model itself into an XML document, for interchange between MOF-compliant repositories. This allows to translate BML artefacts in formal language expressions that could be interpreted and processed by software. The choice of MOF is also related to the objective of supporting simple and smart software development processes. MOF is the cornerstone of the Model Driven Architecture (Frankel, 2003), one the most interesting approaches in software development methodology. Starting from this basic assumption, the BML architecture has been designed as shown in Figure 1.

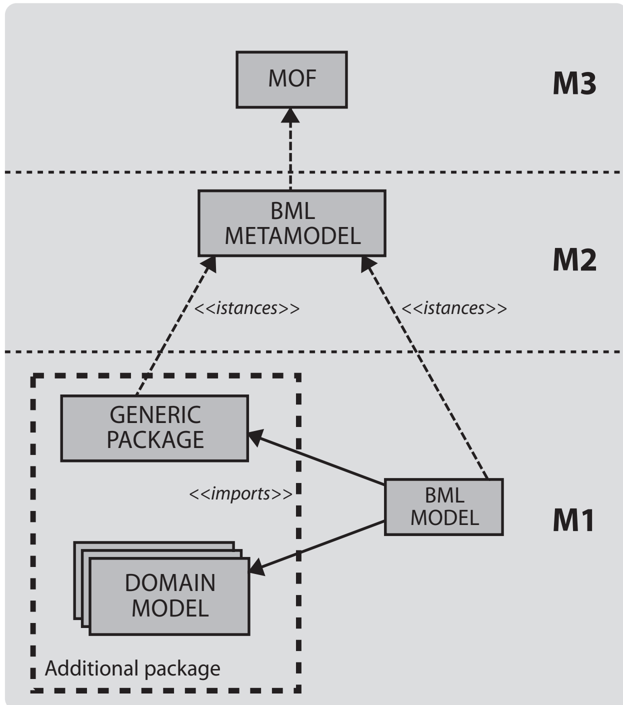


Fig. 1
The BML general architecture

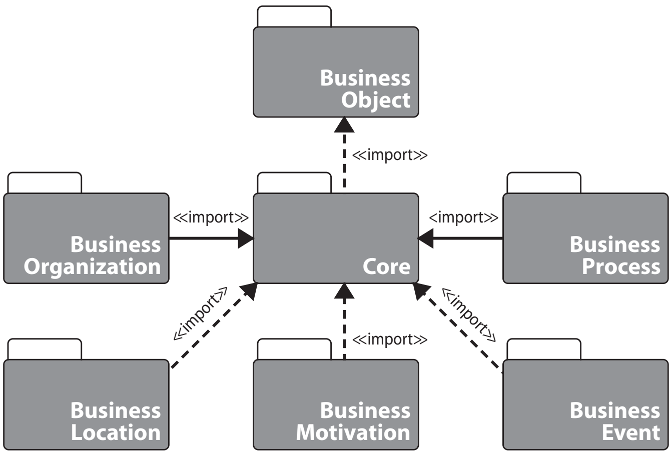
The M3 level contains the MOF constructs, which define the set of elements used to define meta models (e.g. Class, Attribute, Association). The M2 level contains the BML meta-model, that is the semantics necessary to create business and domain models in the DBE project. More specifically the BML meta-model, provides several packages that constitutes the BML information model and contains all the primitives necessary to define a business. Such primitives are abstract and independent from specific business domain, in order to be instantiated in whatever business domain. The information at M2 level is considered long lifecycle information and requires complex competencies in both business and modelling field; this implies that it can be modified only by DBE experts. This MOF-based meta model has been indicated as *BML 1.0*. In the M1 level, it has been developed a *Generic Package*, containing cross-domain concepts and constructs (e.g. the concepts of price or customer). Moreover, this level will contain several business *Domain Models*, a repository of knowledge shared within a specific business domain and developed by domain experts or a given community, and the *BML Models*, developed by SMEs to describe themselves and their services. Such models can be created instantiating concepts from a domain model, from the Generic Package and directly from the BML meta-model.

The BML Semantics

The definition of the BML semantics is based on two main key elements. From one side, it has been decided to align it with the main standards for business and e-business modelling. First of all, the BML meta-model is provided with a packages structure compliant to the OMG *Architecture of Business Modelling* framework [223]; moreover, the specific content of the packages has been developed using as input information coming from other e-business standard, such as UMM (UN/CEFACT, 2003) and ebXML (Lassila et al., 1999). On the other side, from a theoretical perspective, the meta-model has been built on the basis of the Zachman Framework for Enterprise Architecture (Zachman, 1987).

Fig. 2

The BML packages structure



The resulting meta-model is split up into seven packages, as shown in Figure 2: *Core*; *BusinessOrganization*; *BusinessProcess*; *BusinessMotivation*; *BusinessLocation*; *BusinessEvent*; *BusinessObject*. These packages are relatively independent of one another and allow to obtain the needed range of expressivity and flexibility.

In more details, the *Core* package contains the basic classes generic enough to be defined as a separate set within the BML meta-model and extended by the other six packages. Many of the element of this package are defined using the ebXML core component library. The *BusinessOrganization* package aims at describing the whole organization, specifying the entities involved in the business, their resources and how they can interact. The *BusinessProcess* package is used to define the behavioural elements of an organization. It contains all the meta-concepts needed to describe how the organization actually performs its business. One of the purpose of this package is the description of the dependencies existing between partner processes, modelling the business actions and objects that create, consume and exchange business information. The BusinessProcess package encompasses two main areas, closely related each other: an agreement area, concerning parties' engagements created by collaborative activity, and a behavioural area, related to the organizational working activities to perform a specific business. The *BusinessMotivation* package aims at describing the elements an organization analyses and settles in order to make choices and define its action. The *BusinessEvent* package contains the meta-model for describing the events able to influence the business behaviours, including rules about their temporal ordering or partial ordering in the business activity cycle. The *BusinessLocation* package contains the meta-model for describing geographic locations, business sites, geographic areas, volumes, and perimeters, political subdivisions and boundaries, and logical connections between them. Finally, the *BusinessObject* package contains the business data types constructors. It allows the modeller to create the types needed in order to model a particular domain or business, without references to their operational features, that are aspects typical of programming language.

Semantics for Business Vocabulary and Business Rules

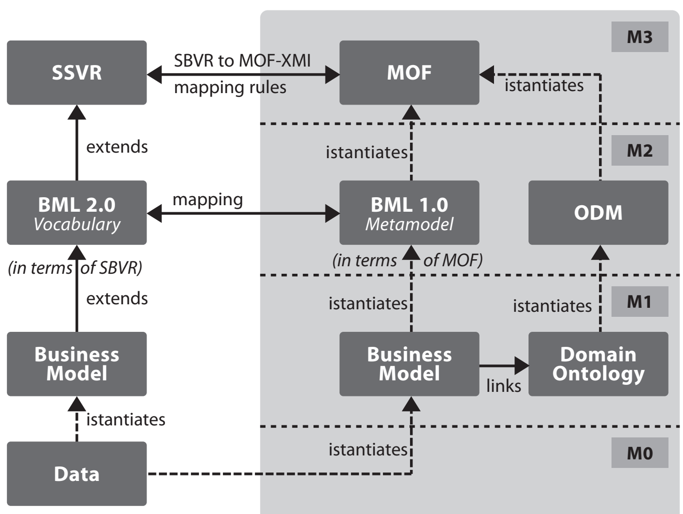


Fig. 3

The SBVR-based BML architecture

During the BML inception and first design phases, while there was wide consensus about using MOF and a meta-modelling strategy, there were many open issue about the concrete syntax to be adopted in the framework. In this first phase, the ontology based modelling was the main candidate to cover this role. Starting from June 2004, the BML team started to have interaction with the OMG Business Enterprise Integration Domain Task Force (BEI DTF) members and to exchange ideas and solutions with them. Starting from shared objectives, this interaction led to a convergence toward the concrete syntax proposed by the BEI DTF. In the wider context of the Architecture of the Business Modelling, BEI DTF produced an OMG Request for Proposal in 2003 (OMG, 2003) named *Business Semantics of Business Rules* (BSBR) with the aim of creating a concrete syntax enabling business people to model their own domain in a natural language and granting an effective MOF and XMI mapping. The adopted submission was the *Semantics of Business Vocabulary and Business Rules* (SVBR) (OMG, 2006), that is based on business rules and vocabularies definition through a Structured English notation.

Even though, this represented a very ambitious and risky objective, it was decided to explore the possibility to adopt this innovative standard, obtaining a new version of the meta-model (named as *BML 2.0*). Figure 3 describes this new perspective in the BML architecture. As en example, the business concept *product*, defined through BML 1.0as a MOF class, using BML 2.0 is described as a BML Vocabulary entry (Table 1):

Table 1

Product	
Definition	**business item** used for describing tangible things or substances produced by natural process or manufacturer
Definition	the **product** allows describing what an organization offers to its customers and **partners**
Genera Concept	**business item**
Example	room or food

Conclusion

Some open issues concerning BML, its adoption and development will be faced in the next future. First of all, the practical application of BML will give the opportunity to test the architecture stability, the meta-model completeness and the concrete advantages for business community in adopting the approach. This application is currently based on the BML 1.0. The immaturity of the SBVR standard, and in particular the lack of specific tools, are the main reasons behind this choice. In this perspective, the most interesting future development is related to SBVR and to the realisation of a business modeller. Such a tool is an SBVR editor that will allow business people to create their own model, through the definition of their own vocabulary and rules. At the moment, the editor exists in a prototypal form,the *SBeaVeR* project (ISUFI, 2006), that should be developed from DBE project partners in collaboration with open source communities

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5 Digital Ecosystem Topology: Information in Nature

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Power Law Distributions in Nature

Power laws describe frequent scaling trends found in nature, in areas as disparate as physics, biology, sociology, economy and semiotics. Among many other examples, Vidondo et al. (1997) described the body size spectra of seston (materials in suspension) as a Pareto (or Bradford) type distribution, which is itself also a power law commonly used in economy for statistically describing the allocation of wealth among individuals or the exponentially diminishing returns.

Power law distributions show long right-tailed (skewed) distributions in linear axis plots, but they are often described by log-log plots and, therefore, they appear as rather linear distributions with a characteristic slope coefficient. However, power laws should not to be confused with log-normal distributions which show a linear distribution in short range loglog plots; power laws show consistently linear trends over 3 or more orders of magnitude.

Power laws can describe the energy or information transport between hierarchical levels of a system, whether natural (ecosystems) or artificial (man-made). The transport coefficient, proportional to the slope of the distribution function in log-log plots, can be representative of the stability, fitness and efficient performance of a system against the environmental conditions. They can be also used for assessing the equilibrium status or succession stage of ecosystems and natural communities (see also Rinaldo et al., 2002).

Scale-Free Networks and the Barabási-Albert Model

Scale free networks are a category of power law distribution networks. Scale free graphs or networks have been proposed as generic, yet universal models of network topologies that exhibit power law distributions in the connectivity of network nodes (Li et al., 2005).

However, despite its popularity, there does not exist a precise definition of scale-free networks ("a common property of many large networks is that the vertex connectivities follow a scale-free power-law distribution"; Barabási & Albert, 1999), either in the context of complex systems or in computer sciences. Scale-free graphs are, essentially, more an empirical evidence than a rigorous definition. Yet, Margalef stated in 1991 that one cannot expect "reasonable answers from models with constant interaction parameters". This is, in mature, stable and efficient systems, the relationships between the components of a system are usually flexible, and show a complex topological structure that systems analysts try to grasp, understand and reproduce by means of generative models (see below).

The Barabási-Albert (BA) was a simple algorithm defined basically in terms of growth and preferential attachment. Growth tends to increase as new nodes are added over time, and preferential attachment describes the ability of a node to grab new links. Proportionally, the higher the number of links of a node the more likely is to receive new links. The non-null preferential attachment probability of a node can follow a linear function.

The network begins with at least 2 connected nodes, and new nodes are added to the network, one at each time step. Each node connects itself to an existing node with a certain probability. This probability is proportional to the number of links that the node already has. Such strategy is analogous to autocatalytic reaction kinetics, which are present in many biochemical pathways.

Information Management

The nature of a system's complexity and behaviour is closely related to its internal structure. In the case of computer networks, as well as other complex systems, topology plays a fundamental role in their apparent behaviour. Topology may be crucial for the system's environmental fitness and stability : fault tolerance, self-healing, self-configuration, selfoptimization, etc. All of them are properties of mature systems.

On the other hand, complex systems are essentially heterogeneous, and show differentiated functional behaviour and hierarchical roles. Complex behaviour depends (or relies) on both the system's topology and a robust hierarchy. Furthermore, topology and hierarchy are closely coupled and, therefore should not be separately considered.

In an open universe in which the network topology may change quickly as nodes join or leave the community, new approaches have to be developed in order to efficiently address search and management tasks. In such a case, the use of global algorithms is no longer possible. Computers will have to learn to manage themselves in this unbounded and highly dynamic environment. This is something which each of the organisms that populate this planet continuously face from birth to death. Therefore, ecosystems and natural communities can be used to help illustrate and improve our understanding of man-made systems like computer networks.

Yet ecosystems show an enviable robustness against both internal instabilities and (external) environmental perturbations and never collapse ultimately. Network servers can still fail, and they do eventually, with increasing economic and social costs, among other significant drawbacks. However, to better comprehend how robust ecosystems actually are, we must fully understand the mechanisms at a level where interaction between individual organisms occur.

The first step to enable the emergence of intelligent behaviour, is to let the nodes interact freely with each other, in order to memorize or recall other nodes and their interaction experiences. This implies that they must have some sort of memory. But essentially nodes must be willing to interact with each other, and to exchange information. The information that nodes will attempt to disseminate is essentially about their own characteristics and properties, but especially about the services they have to offer to others. And each node remembers at least some of the received information input from their neighboring nodes for a limited period of time. Intelligent behaviour is, however, just a byproduct or apparent property of this type of autonomous communication.

Building Distributed Networks

The ubiquitous presence in nature of a specific form such as scale-free is often interpreted as a signature of universal underlying generating mechanisms. One can classify the complexity of a system according to different criteria. This implies some sort of fundamental knowledge about it. But on the other hand, the lack of knowledge about the emergence and development of complexity and hierarchies is still evident and profound.

There is also a clear relationship between the efficiency of a system (or environmental fitness) and its internal structure. But there is still a significant lack of knowledge about how hierarchy and complexity emerge and develop. Mature systems show internal gradients of information and complexity. This feature can be understood in terms of an increasing number of hierarchical levels. However, in the case of distributed computer networks one can force the topology to adopt the internal structure of complex scale free systems. This makes the systems more robust against single point failures, also improving the efficiency of information transport.

On the other hand, when dealing with distributed networks one has to assume that these have no boundaries or well-defined limits. In other words, a user's computer will always directly interact with another user's computer, not with a central server. And this implies that the other computers will continuously join and leave the network and, therefore, their information, services, etc., will not always be accessible. The total information available will always be much greater than that which is accessible through central servers. Information distributed networks will be available in vasts amounts, although not accessible in their entirety, since they are not exhaustive. Central servers have never been complete either, although they intentionally perform that way.

Generative Algorithms

The lack of precision in the scale-free definition evidence a still partial knowledge about the underlying processes that drive to the appearance of well structured systems. However, there is a clear correlation between the overall system's efficiency and its scale-free topology. Therefore, in spite of this limited knowledge about the generative processes that pull systems towards a mature and efficient stage, we attempt to reproduce such structures with the aim of improving the performance of complex processes or systems.

Preferential attachment is often the main generative mechanism upon which many power law distributions develop, but it is not the only mechanism that is able to produce scale-free distribution graphs or networks. The main objective is to scale the proportion of highly connected nodes ("hubs") and less connected ones.

Hubs play different roles (among the most relevant):

1. Holding the network together, thus preventing fragmentation.
2. Re-organizing the network structure or topology according to environmental feedbacks, promoting the development of functional hierarchical levels.

The functional presence of hubs is fundamental for the complex behaviour of the system. They are responsible of its robustness, but they are also its "Achilles' heel". The disappearance of a single populated hub may imply fragmentation, which increases the difficulty of incident recovery mechanisms in distributed computer networks.

The main hypotheses of distributed networks (self-healing, self-organizing, self-optimizing, etc.) rely on the functional activity of highly connected nodes at different hierarchical levels, hence the importance of the coupling between the environmental response of the system and the activity of these hubs.

Relevance to the digital ecosystem problem

As mentioned above, the topology of a distributed system is critical in order to guarantee the system performs well under favorable conditions, and to guarantee that it performs at all under unfavorable conditions, such as random failures and attacks.

Given the resilience shown by biological networks (of cells, of individuals, …) and their self-healing capabilities, it is extremely desirable to incorporate these traits into the design of a digital ecosystem.

In particular, the search problem is one of the first encounters with the radical difference between distributed and centralized systems. In a centralized system searching for a particular item (data, service endpoint, …) is a problem bounded in time. It is also decidable: the central authority either has or it doesn't have the requested item, and its reponse will tell which case we're in front of.

In a fully distributed system (that is, lacking a central authority) there can be no guarantees as to whether a given item exists or it doesn't exist in the network. The item of interest may lie in a node of the network that is not accessible anymore.

It is interesting to note that the distributed system is not less resilient than the centralized one. In the centralized case, the response tells us without a doubt whether the item exists or not, but if the central authority stops being accessible, the whole system falls down. In the distributed case, the failure of a node renders that node unusable and the items it provides unaccessible, but the system as a whole is still working. Centralized systems can not say the same.

If the probability that a certain node in the network may crash is *p*, in the centralized case the whole system works with probability *p*. But in the distributed case, the probability that all items are accessible is:

p^n times   where n is the number of nodes in the network

Given that p is usually less than 1, the probability of all the items being accessible at once is smaller for a distributed system than for a centralized system. However, the probability that at least one node is accessible in the distributed system is:

$1-(1-p^n)$ times   where n is the number of node in the network

This value is greater than 1-*p*, the probability that a centralized system doesn't fail, if $p \in [0,1]$, which is true for a probability value.

But, in order for the system as a whole to be able to keep running in the face of node failure, the system must be able to find a way to reorganize to work around failed nodes, or otherwise be extremely resilient to those failures.

Scale free networks provide an opportunity to avoid system failures as a result of individual node failures. Given their properties, outlined above, they can also search in an efficient way for nodes that can take the roles of the failed nodes, thereby exhibiting self-healing capabilities that don't degrade the performance of the system.

The power-law tail of the degree distribution of scale-free networks means that there is a decreasing number of nodes as the degree of those nodes grows. That is, there are very few nodes with very high degrees. It is those nodes that interconnect most other nodes of the network. The power-law distribution also tells us that these nodes don't connect exclusively with each other. Therefore they are considered *hubs* in the network.

Given that the existence of these hubs is known, it is possible to create strategies that improve the performance of a search for items in the distributed network.

It must be noted that the search problem mentioned above is a particular instance of the more general 1-to-many communications problem.

It can be seen that the potential of scale free networks with respect to digital ecosystems can not be ignored.

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6 Distributed Infrastructural Services

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The Digital Business Ecosystem (DBE) can be described as being a peer-to-peer semantically-aware service-oriented architecture (SOA) for Small and Medium sized Enterprises (SMEs). Architecturally, the DBE has been divided into an Execution Environment (ExE) to host services, a Service Factory to design and develop services, and an Evolutionary Environment (EvE) to help optimise the system. All three of these blocks have extensive requirements for distributed functionality. These needs are met by the DBE's distributed infrastructural services. This paper introduces the key distributed infrastructural services of the DBE, highlighting some of the key technical challenges that they tackle, and the features they deliver.

Introduction

The DBE project software has been architected [1] into three core systems: a distributed runtime environment known as the Execution Environment – the ExE; an environment for designing and implementing services known as the Service Factory; and an autonomous, distributed optimisation system known as the Evolutionary Environment - the EvE.

Whilst the ExE and EvE are both fundamentally distributed in nature, the Service Factory also includes important distributed components: these, for example, allow constructed SME services to benefit from shared ontologies and business models.

The ExE [2] – the peer-to-peer network of DBE runtimes – hosts all of the services of the DBE. It has three main components: the servent, which can be considered to be a DBE service container; the locally accessible core components, which implement fundamental, low level DBE functionality; and finally network addressable services, which are either infrastructural or SME specific. Infrastructural services deliver critical functionality such as the ability to locate specific SME services on the peer-to-peer network [the Semantic Registry], the ability to store arbitrary content in a distributed, replicated space [the Distributed Storage System], and the ability to browse the DBE network using a web-like interface [the DBE Portal].

The servent, hosted on the SourceForge project Swallow, actually provides a container for service adapters. This name stems from the fact that they can provide a gateway to existing services, though nothing in the design or implementation prevents them from being full-fledged, self-contained services. The adapters are deployed onto the servent. The servent creates the endpoints necessary for clients to be able to consume those services, and publishes their existence.

The publication of the existence of service adapters consists of the creation of a data item which contains the URL of the endpoint of the service, the models the service conforms to, and additional, user-defined tags. These data items are then registered in FADA.

The servent also serves as the consumer of those services. That means a client application uses the servent to locate and run service adapters that may be deployed in a remote servent. The exact location of the service adapter is unknown to the client. The servent acting as a client of services uses FADA to search for the service the client wants to run, gets the endpoint data and performs the necessary communications with the remote servent, which then executes the service adapter.

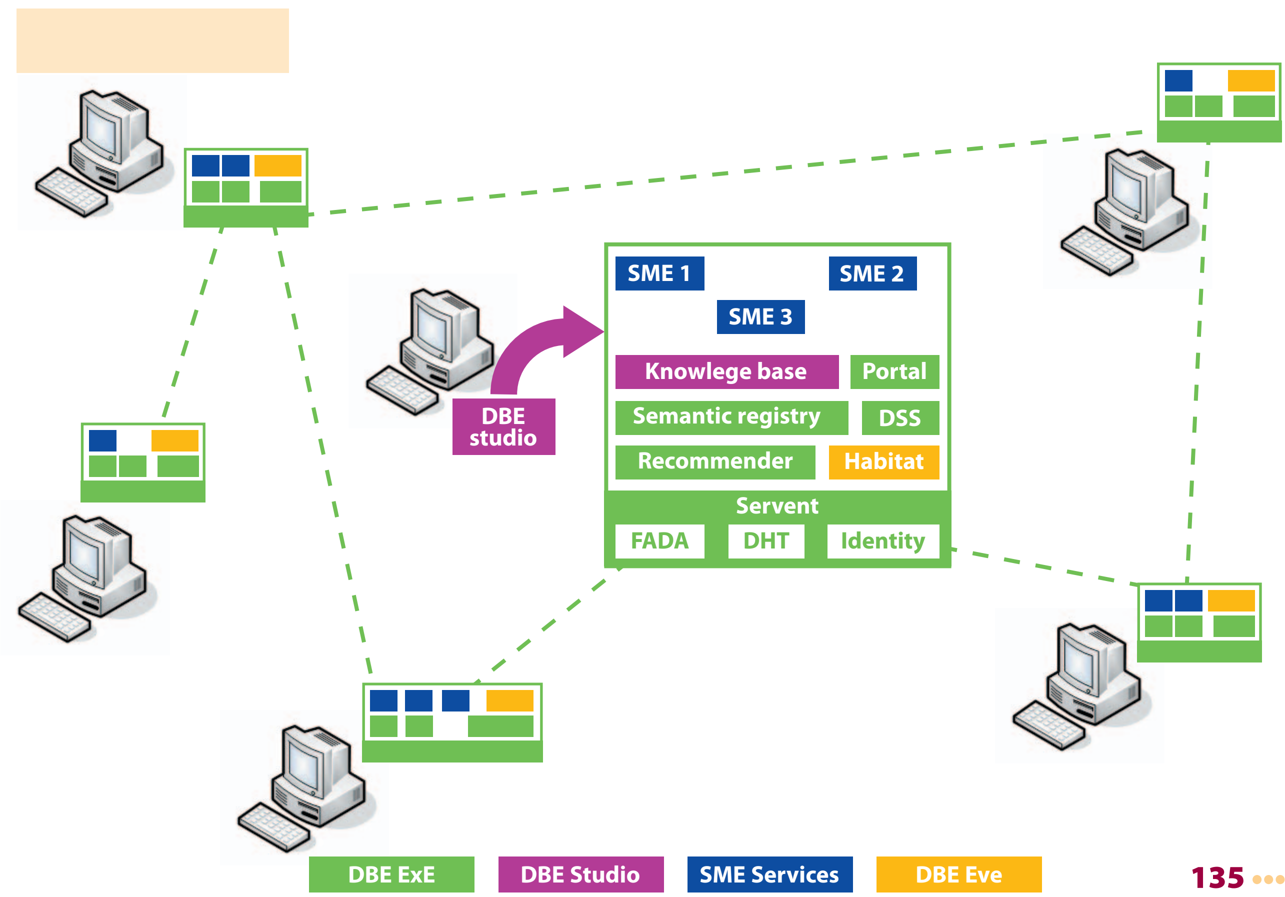
The service adapters are created with the Service Factory, after the service modeling phases have been performed. The Service Factory also deploys the created service adapters onto a user-specified servent.

From an end-user point of view the Service Factory is centred on the Eclipse* based DBE Studio [3] development environment. It includes many editors and tools to support the modelling, implementation and deployment of SME services. However, to allow ontologies and models to be reused, a distributed model repository known as the Knowledge Base has been implemented. Rather than require a dedicated infrastructure, the Knowledge Base is also hosted by the ExE as a distributed infrastructural service.

The EvE [4] – the optimisation engine of the DBE – is designed to monitor the consumption of services on the DBE and over time pre-position pointers to services onto nodes from which they are more likely to be consumed. Thus, queries will produce more useful results faster. It has also been designed to support the automatic composition of services, referencing existing atomic (or indeed composed) services inside entirely new workflows and deploying these new workflows as new services to help satisfy potential user needs. The EvE has been realised by the implementation of Habitats in which pointers to real SME services can be examined and manipulated. These Habitats are another distributed infrastructural service hosted by the ExE.

The key distributed infrastructural services of the DBE are illustrated in Figure 1. The ultimate purpose of these services is to support the deployment of the SME services, the raison d'être of the DBE.

Fig. 1
Distributed Infrastructural Services of the DBE



Although implemented as Core Components rather than pure DBE services as such, the peer-to-peer networking and identity layers of the DBE also deliver fundamental, distributed functionality to the DBE and so are also considered in this paper. These distributed infrastructural services and components are now described in further detail.

Infrastructural Services

Knowledge Base

The Knowledge Base [5] service, implemented by the Technical University of Crete (TUC), provides the distributed storage facilities that enable the Object Management Group Model Driven Architecture* (OMG MDA*) inspired design of the DBE [6], [7]. In it both XMI-formatted metamodels (models that describe models) and models can be persisted, queried and retrieved.

Due to the distributed and dynamic nature of the SME-based network, the Knowledge Base replicates data following a primary/secondary asynchronous model in which one node is always the primary node for a particular piece of content. Should it fail, a secondary node becomes the primary. Content is replicated from primary to secondary nodes asynchronously.

To improve the efficiency of queries, content is stored on nodes that already include semantically similar data. This is achieved by comparing the ontologies and semantics referred to inside the models. Initial queries from a node are propagated to all nearby neighbours, but nodes store information regarding which nodes the results came from and over time a comprehensive set of routing information is built up to help direct future queries more efficiently.

The actual raw data in the Knowledge Base is persisted in a native XML database, Oracle Berkeley DB XML [8], which can be installed to run on the MacOS X*, Windows*, Linux* and Solaris* operating systems. To support arbitrary updating of content, a versioning system has been implemented that can accommodate both the distributed nature of the Knowledge Base and the replication scheme.

The Knowledge Base service is used by the DBE Service Factory to save and share Ontologies, Business Modelling Language (BML) models, Semantic Service Language (SSL) models and Service Description Language (SDL) models. These models are typically used at design time when creating or modifying a service inside the DBE Studio. The Knowledge Base can, however, be used to store arbitrary XMI-formatted data in the DBE, and the ExE, for example, uses the Knowledge Base to store User Profile information.

Semantic Registry

Whilst the Knowledge Base service largely stores models, the Semantic Registry [5] service, also developed by TUC, is used to store published Service Manifests. A Service Manifest is an XML document that completely describes an individual DBE service. It can be considered to be an advertisement for a service on the DBE. It typically includes copies of the BML, SSL, SDL and BML data for the service, as well as additional configuration information.

Due to the similarity with requirements of the Knowledge Base in terms of data format, distribution, redundancy and performance, the Semantic Registry service shares many implementation components (and features) of the Knowledge Base service.

In the DBE, the Semantic Registry now supports the Service Manifest 2.0 specification. Service Manifests are published into the Semantic Registry Service by the DBE Studio, and are mapped to actual service proxies by the Peer-to-Peer layer.

The Semantic Registry is essentially the distributed service-directory for the DBE ExE. The contents of the Semantic Registry are accessed whenever a user searches for a service in the DBE, for example when using the Query Formulator / Semantic Discovery Tool incorporated in the DBE Portal.

Distributed Storage System

The Distributed Storage System [9], implemented by Intel, delivers a generic distributed storage capability to the DBE. Essentially it allows arbitrary content to be persisted onto the DBE peer-to-peer network, and generates an identifier by which the content can later be retrieved from any node on the network. For redundancy, the content is replicated. To avoid the distributed system overfilling with content, all content must be assigned a time-to-live by the entity storing the content.

This time-to-live can be reset by the same entity that stored it. After expiry of the time-to-live, the content will be automatically purged. Content may be secured by encrypting it before persisting.

By default, the DSS uses the DBE DHT core component (introduced later in this paper) to index the location of individual blocks of content. However, the index connector can be easily swapped out should alternatives be required, e.g. for local testing purposes. Alternative indexing mechanisms including indexing using the local disk store, a centralised PostgreSQL* database and a dedicated DSS Indexing DBE service have been implemented.

In terms of storage, the DSS persists content onto the local hard disk of the machines on which the DSS service is instantiated. However, the storage layer is also designed to be swappable, and alternative storage layers could be developed in the future to allow content to be saved in a database, or in another internet-based storage system, for example.

For performance reasons, blocks of content of an excessive size are partitioned into smaller blocks before storing. When retrieving content, the blocks are all copied to the node generating the request, these replicas then being available for future data requests.

To cope with the disappearance of nodes, background processes are used to monitor the quantity of duplicates of the blocks, and replicate them should this number get dangerously low.

For applications that require content to be given particular identifiers, e.g. filenames, a namespace can be overlaid on top of the DSS. For example, for file system functionality a dedicated file system service can (and has) been implemented which uses the DSS to persist the actual content.

DBE Portal

The DBE Portal [10] is a core service, also implemented by Intel, which provides a user-friendly HTML interface to the DBE. Typically, each SME has one portal hosted on their servent. This Portal consists of a completely arbitrary website representing the SME's business. It includes links pointing to the DBE services which that SME has deployed, as well as the ability to search for arbitrary DBE services. DBE Portals can also link to local DBE administration interfaces allowing basic servent configuration and functionality to be administered via the web.

To allow Portals to themselves be searched for, the Portal includes self-registration functionality which automatically publishes the existence of the Portal service within the DBE's Semantic Registry. Ultimately, this enables a peer-to-peer network of DBE Portals to be formed. If the IP address of the SME is static, or if they have registered an internet domain name, their DBE Portal can also be accessed directly over the internet using this address.

Recommender

The Recommender service [5], also implemented by TUC, is an autonomous system that uses preconfigured user profile information to identify the best-matching Service Manifests published on the Semantic Registry that may be of interest.

This ranked list of recommendations can be returned when explicitly requested by a querying application, or alternatively it can dynamically notify client applications when an update to the recommendation list is made. Thus, for example, a user whose profile explains that they are interested in low-cost flights could be automatically alerted when a new low-cost flight booking service is published in the Semantic Registry.

Habitat

The EvE is implemented in the Habitat service, designed by Imperial College London / Heriot-Watt [11] and implemented by Salzburg Technical University / London School of Economics [12] and Intel [13]. Although designed to support features such as autonomous service composition, the initial implementation uses neural networks to identify services that closely match those that have already been invoked. By clustering pointers to similar services, the DBE will be able to give better results faster in response to user queries.

Fig. 2
Screenshots from the DBE Portal template

Every time a service is deployed on the DBE, a reference to the service is inserted in the "Local Service Pool" of the local Habitat service. The Distributed Intelligence System then applies Neural Network algorithms (implemented using the open-source JOONE* engine [14]) to compare the deployed service to other deployed services it has references to.

If a similar service is identified, the usage history of the similar service is examined, and the newly deployed service pointer is migrated to the Habitat services on the nodes where the similar service was consumed.

In this way, pointers to similar services get migrated towards nodes that have consumed similar services. Should the user make a similar request in the future, then a query tool or recommendation algorithm that interrogates the Habitat service will be able to identify these potentially more useful services faster.

Core Components

FADA

FADA [15] stands for Federated Autonomous Directory Architecture (http://fada.sourceforge.net). An open-source project that originated in the European Commission funded Fetish project and now maintained by TechIdeas (http://www.techideas.es), FADA was the first peer-to-peer infrastructure embedded into the DBE.

FADA nodes find each other either using broadcasting on a LAN or via manual configuration and provide a location to store and retrieve proxies to services.

If the FADA node does not have the requested proxy, it queries its neighbours and they their neighbours until the requested proxy (or proxies) are found. To avoid indefinite queries, maximum query times and number of hops can be specified.

As machines are switched on and off, and the services on them become available then disappear, it is important to prevent the directory of proxies from filling up with proxies to services that no longer exist. FADA achieves this by using a lease mechanism. The node with the service registers the proxy to this service in FADA for a certain, relatively short, amount of time. Before this lease expires, the node re-registers the proxy. If for some reason the node does not re-register the proxy, the lease expires and FADA removes the proxy from the system.

Whilst DBE uses FADA as a registry for service proxies, FADA also provides searching facilities whereby service proxies can be assigned tags known as "entries". FADA can then be queried to return not just proxies to specific services, but proxies to all services that have been assigned certain entries too.

Distributed Hash Table

The Distributed Hash Table (DHT) is the realisation by Trinity College Dublin (TCD) of one of the peer-to-peer overlay networks described in their DBE P2P architecture design [16]. Built on top of the open source Bamboo project [17] which is maintained by University of California Berkeley in association with Intel Research Berkeley, the DHT essentially provides for arbitrary distributed hash tables to be layered on top of the DBE network. These tables can store multiple values for each hash entry.

DHTs employ highly efficient lookup algorithms to locate the values for a particular entry, and each query is typically routed through no more than $O(\log_2 N)$ peers. The DHT has redundancy built-in, with entries replicated onto a configurable number of logical neighbours. Just as in FADA, stale data is purged by means of setting a time-to-live. Although the DHT cannot support alternative search mechanisms like FADA, it does guarantee that if an entry exists, it will be found.

The DHT provides the ability for content to be removed as well as added. To prevent unwanted deletion from the table, the node storing the entry can provide a key, which must be provided if the entry is to be edited.

Identity

The Identity core component, also implemented by TCD, provides a customised overlay on top of the DHT that allows identity certificates to be stored, and various related operations to be invoked. By building on the DHT, the Identity system automatically becomes decentralised and inherits the redundancy and autonomous management features of the DHT. In particular, certificate revocations are automatic, thanks to the time-to-live functionality of the underlying DHT.

As well as providing a distributed key store, the Identity core component provides additional functionality including the ability to verify keys. All incoming DBE calls to the servent can be intercepted and any identities associated with the call can be automatically verified. Depending on the servent configuration, calls with no identity associated with them at all can either be halted or allowed to pass through.

The Identity core component is currently based on the web-of-trust model. However, it has been architected in such a way that alternative algorithms can be implemented and enabled via configuration parameters.

Conclusion

The Execution Environment, Service Factory and Evolutionary Environment of the DBE all rely on distributed infrastructural services including the Knowledge Base, Semantic Registry, Distributed Storage System, DBE Portal, Recommender and Habitat. Additionally, distributed core components provide fundamental peer-to-peer functionality that connect DBE nodes to each other and provide for service proxy lookup and identity management. These distributed infrastructural services provide key functionality without which the DBE could not function.

Acknowledgements

Nikos Pappas, Fotis Kazasis, Technical University of Crete; Andrew Edmonds, David McKitterick, Intel Ireland; Claudius Masuch, Salzburg Technical University/London School of Economics; Juanjo Aparico, TechIdeas; Dominik Dahlem, Trinity College Dublin.

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17 Bamboo: http://bamboo-dht.org/

7 A Trusted Negotiation Environment for Digital Ecosystem

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Digital Ecosystems have emerged as a novel paradigm to support the endless evolution of Networked Organizations. Existing tools and platforms enabling business collaboration and contracting are often developed and owned by large companies and big market bodies and, hence, centrally controlled and not fully trusted by small and medium size enterprises (SMEs). Thus, there is a pressing need for a trusted and affordable distributed technological environment supporting the creation of Virtual Organizations with common business goals and facilitating the creation, stability and improvement of business ecosystem performance on a more reduced time frame. The chapter proposes a multidisciplinary trust framework based on current security technologies and reputation mechanisms. A novel research concept of evolutionary trust is identified that reflects the constantly evolving social institutional relations.

Introduction

Now-a-days organizations live in a highly competitive business environment where the availability of low cost broadband services change the way companies operate and behave in the global market. The recursive use of transitory structures based on alliances, partnerships and collaboration is required to overcome local market limitations and to pursue global opportunities. Businesses need a converging and trusted technological environment through which they can cooperate and create alliances to pursue business opportunities and growth.

Current negotiation platforms, such as Business-to-Business electronic marketplaces and Internet trading platforms have been developed in order to help the formation of virtual organization. Current solutions are centrally managed, normally developed and owned by large companies or big market integrators, therefore they are not fully trusted by SMEs and/or too expensive and hence not widely used by European SMEs today.

A new generation of distributed platforms and services are required to support the evolutionary and dynamic networked organizations overcoming the above-mentioned problems. Flexible technologies are needed to enable enterprises to efficiently cooperate in the digital world towards the creation of Digital Ecosystems (DEs).

The DE concept has emerged worldwide as an innovative approach to support the adoption and development of ICT. Inspired from a business ecosystem, a digital ecosystem is a self-organizing digital infrastructure aimed at creating a digital environment for networked organizations. However, current DE technologies lack of suitable models for addressing properties of trust and identity management.

Inspired by the technological nature of DEs, this chapter will provide a comprehensive framework underpinning reliable and trusted ecosystems communications. The objective of the framework is to provide SMEs with a trusted and secure technological environment underpinning their business growth.

Chapter Contribution

This chapter defines the basic components of a generic negotiation environment that supports trusted and decentralized business contracting for DEs. Decentralization is faced by negotiations. Trusted negotiations are built on top of reputation models and existing security technologies. A new notion of evolutionary trust is introduced based on learning, reputation and social institutional trust.

Chapter Outline

The chapter has the following structure. Section 2 introduces the concept of negotiation for decentralized business contracting as inspired by an ongoing EU project, called ONE. Next, Section 3 defines the role of reputation models for DE communication and the intuition for evolutionary trust. Section 4 overviews current security technology and models underpinning a reliable and trusted negotiation environment. Section 5 concludes the paper and outlines future research directions.

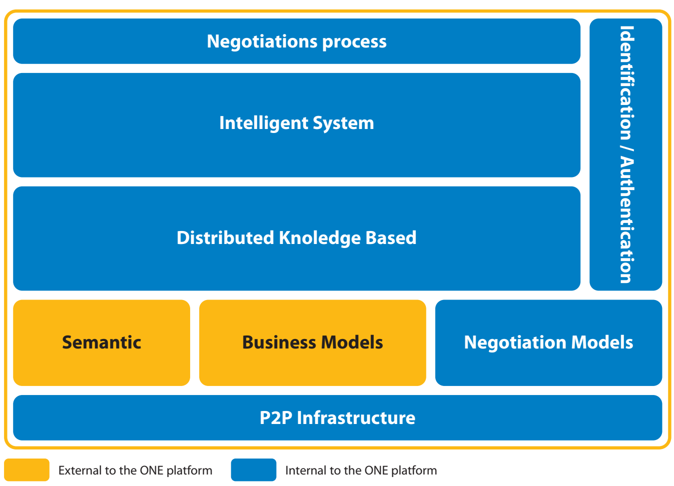
Negotiation for Decentralized Contracting

As already defined in [16] "Negotiation is a process involving dealing and communication among two or more parties, who have different concurring (non conflicting) objectives, which intend to reach a reasonable compromise and a mutually accepted agreement on a given matter and commit to a course of action".

Business-to-Business electronic marketplaces ("B2B e-markets") have been developed to facilitate business transaction trough a common environment and supporting tools for all the parties involved in a negotiation process. Anyway current B2B e-markets are usually centralized, therefore not fully trusted by, and not able to deal with multi-party and multi-issue negotiations.

In order to cope with business complexity a new approach has been defined to cope with distributed resources/services and decentralized aspects in Digital Ecosystems. The ONE[1] (Open Negotiation Environment) Project will develop an open environment supporting tactical negotiation and agreement processes among participants. This environment will support the creation of Virtual Organizations with common business goals and facilitate the creation, stability and improvement of the ecosystem performance on a more reduced time frame. At the same time it will have no central governance cockpit or console for managing negotiation models and ongoing processes in order to avoid the "big brother" effect, which will put at risk the level of adoption.

Fig. 1
ONE Architecture



The ONE platform will dynamically support the negotiation owner through automatic learning techniques applied to the goal of learning the best negotiation strategies in a multi-agent environment. The hybrid [4] and conversational personal negotiation recommender will support a user and will carry out operations on his behalf with some degree of independence and autonomy. It will compute the recommended actions exploiting a distributed knowledge base, which expands the personal knowledge base of an actor, and makes possible to speed-up the policy learning process, exploiting experiences gathered not only by the supported user but also by a community of trusted partners [15]. ONE will support a model of collaboration and trust based on the idea of "collaborative multi-agent systems", where agents work and learn with other trusted agents and develop collaborative learning schemes.

With this intent we defined the concept of trusted negotiations in an ecosystem environment by:

- Securely identify partners in negotiations – provide privacy, anonymity and accountability during (part of) negotiations;
- Assess trustworthiness of partners based on their past behavior and your (agent's) own experience – provide proper reputation models supporting cross-domain reputation assessments;
- Facilitate trust relationship establishment across distributed ecosystems (e-communities) reflecting the constantly evolving business requirements over time.

Reputation Models for Trusted Ecosystems

Close to business contracting is reputation. Reputation assessments have a direct influence on a negotiation process and are strongly linked to the results of bilateral and multilateral contracting. Assessing in a measurable way the trustworthiness of partners in inter-ecosystem communication becomes a key issue for a trusted negotiation environment.

There are two main approaches to reputation referred in the context of agents. With the first approach, agents use trust models to reason about the reliability or honesty of their counterparts. With the second approach, agents calculate the amount of trust they can place in their interacting partners where the likelihood for an agent to be selected as an interaction partner depends on the calculated level of trust. Either of the trust models aims at guiding agents to decide on how, when and who to interact with.

To face the decentralization nature of the ecosystem environment peer-to-peer reputation mechanisms will be provided. Users of services own the best knowledge about the behavior of services based on their own experience. This experience can be translated and expressed as reputation statements [1,14,18].

In some commercial scenarios peer-to-peer mechanisms are not suitable or easily accepted and so the concept of trusted rating agencies[2] has to be provided. Here, partners use trusted agencies to reason on trustworthiness of other partners (service providers). On the other side, service providers subscribe to rating agencies to be included in their list of recommended services.

Evolutionary Trust

The key feature of an ecosystem is its evolution in state and time in order to adapt and respond to new conditions without being slowed down by human related factors. In this sense, an ecosystem should be empowered with a model for decentralized cross-domain trust relationship establishment.

To face decentralized trust establishment we have to look at how to facilitate joining to an online community. Current security models supporting IT digital businesses are concentrated on establishing trust between entities already in the network. But what occur when a new organization is joining an ecosystem? And what happen when an organization already active in one ecosystem is taking a role in another (new) ecosystem?

We need to borrow the concept of institutional trust [11] and analyze the collective behaviour of users when they deal with digital institutions. Institutions, professional or associations, public administration, to name a few, can provide trust to newcomers and affect their behaviour when communicating with other partners.

An ecosystem-driven system should provide additional learning mechanisms based on institutional trust. Trustfulness in one or more institutions (partners) can be initially obtained by examining institutional trust existing between those institutions and the known institutions by the partner. This will create an independent and evolutionary platform capable to adapt and evolve on the basis of the evolution in institutional trust.

1) www.one-project.eu

2) See for example http://www.dotcom-monitor.com

Therefore we identify a new research challenge: combining learning mechanisms with reputation and social institutional trust. As already mentioned in Section 2, some of the learning techniques can be found in [4,15]. The possible synergies will open new research topics complementing the concept of trust as advocated in computer security literature.

Security Technology for Trusted Ecosystems

This section provides an architecture and overview of security models and standards underpinning a reliable and trusted negotiation environment.

A trusted negotiation environment will provide authentication, integrity and confidentiality as basic security primitives. Existing cryptographic algorithms and protocols will be used and employed to achieve it. On top of them a set of APIs will be provided, generic and user friendly as well as design independent from the underlying cryptographic algorithms. The APIs will be easy to use and adopt while providing new algorithms to be plugged in the future.

Digital identities represent individuals' sensitive information and are used when individuals introduce with each other. Identity management becomes a bottleneck when negotiations cross different administrative domains.

There are a number of industrial approaches offering identity management solutions such as OASIS SAML[3], Liberty Alliance[4] and WS-Federation[5].

The key idea behind those is enabling a multilateral federation of partners sharing the same domain (circle) of trust. Each federation supports multiple identity providers and within a federation (circle of trust) a user may traverse all involve partners' services with a single authentication.

However, a proper identity management model that scales to the DE nature should go beyond a federation-based concept and rather provide:

- user-centric identity management: each entity will be the sole holder of its identity information,
- peer-to-peer or a hybrid (partially hierachical/federated) model of trust relationships between identity providers (authorities),
- brokering trust of identities and authentication information between different DEs.

Identity management goes hand-by-hand with privacy protection [12]. Pseudonyms are used to identify parties when negotiating with different ecosystem domains. Pseudonyms can be used to achieve different levels of anonymity. By shifting the creation and management of identities and pseudonyms to the end-entity, the model will benefit improved privacy protection (decentralized identity storage) and accountability: allowing users to remain anonymous while giving service providers strong guarantees about the users' accountability. Close to our needs is the work in [13].

Computer security trust has emerged as a major security issues over the last years[6]. The notion of trust management has vast meaning and definition as depending on the particular context. Referring to the settings of a trusted negotiation environment, we focus the notion of trust to the notion of distributed access control and decentralized access rights establishment.

The basic approach to distributed access control, underlying current systems and models, is the capability-based access control (see [5] for a comprehensive survey): rely on one's capabilities to take access decisions. The term credential has become widely used for expressing digital access rights (capabilities) and credential-based access control management has grown as the proper model for enforcing authorization requirements in a distributed setting [2,9,3,8].

A trusted ecosystem environment will approach decentralized access rights establishment via bilateral negotiations, also called automated trust negotiation [17,8]. Some of the related projects in this field are TrustBuilder[7] and iAccess[8].

3) OASIS Security Assertion Markup Language: http://www.oasis-open.org/committees/security

4) http://www.projectliberty.org

5) http://www.ibm.com/developerworks/webservices/library/ws-fed

6) See the iTrust Working Group at http://www.itrust.uoc.gr

7) http://cdr.cs.uiuc.edu/trustbuilder

8) http://www.interactiveaccess.org

Figure 2 shows the multidisciplinary framework underpinning a trusted negotiation environment. The right side column represents possible technology platforms suitable for ecosystem service execution management. The left side column represents the trusted negotiation environment that SMEs use to perform their business goals.

The horizontal layers comprise the whole range of security and trust issues discussed so far where higher the layer is, closer to the business-level management it is. As all the layers might be interconnected (e.g., security standards and protocols with evolutionary trust layer) for one or another security aspect so the dashed lines are used to symbolically distinguish each of them.

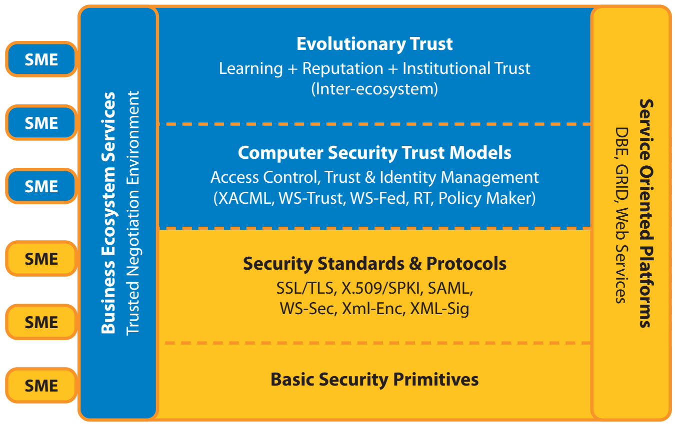


Fig. 2

A Multidisciplinary Framework for a Trusted Negotiation Environment

Conclusions and Future Work

The new generation of technologies underlying current business contracting platforms lack of suitable models for supporting reliable and trusted negotiations. Inspired by this, the chapter advocates a generic framework that underpins a trusted negotiation environment. Drafting the future research directions, the first step is to provide the trusted DE environment with those security technologies that are flexible and affordable by most of SMEs. The aim is to form a comprehensive open technical platform, we call it security middleware, that puts in practice the existing standards and protocols and, at the same time, provides easy adoption and extension of new technologies.

On top of the security middleware, the second main step is to provide a proper model for the concept of evolutionary trust. Again the aim is to incorporate and reuse (where possible) existing reputation mechanisms and institutional trust models into one comprehensive reputation framework affordable and easyly adopted by SMEs.

The final objective of the work is to provide SME's businesses with a trusted and affordable technological environment through which they can create tactical and strategic alliances and pursue business opportunities and growth.

Acknowledgements

This work was partly supported by the projects: 034744 EU-INFSO-IST ONE, 034824 EU-INFSO-IST OPAALS, 038978 EU-MarieCurie-EIF-iAccess.

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8 Social Network Simulation and Self-Organisation

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Approach for Cooperation

Developing the concept of Digital Business Ecosystem (DBE), and implement it at local level trough regional engagement, integrate manifold areas of interest, namely Business, Computing, Science and Socio Economics (see Heistracher, Kurz, Marcon and Masuch, 2006). Consequently it represents a high challenge in communication and collaboration, different research agenda, different vocabularies and languages need to be compared, converged, translated. The concept of Digital Business Ecosystem, in fact, becomes part of different conceptual frameworks that, by the way, need to be constantly interlinked and efficiently connected.

The present article will describe a path of interdisciplinary collaboration that took place in the second year of the project and in which computer science played a pivotal role. Specifically, in the following, we present an effective means of collaboration by introducing a simulation framework called Evolutionary Environment Simulator (EVESIM) (Kurz et al, 2006) Two the main input for the collaboration above the EVESIM: the evolutionary algorithms developed in the science domain and the territorial social network that arose from social science field research. In principle, the development of evolutionary algorithms and the analysis of social networks could be performed independently, thereby, however, excluding any potential of mutual benefits. In this aspect, the EVESIM can be considered a kind of 'middleware' between the Natural Science and Social Science domain[1].

The EVESIM is the software simulation framework, which facilitates the communication between the Natural and Social Science "applications" that possibly base on similar meta-concepts. That does not mean that EVESIM solves all

1) According to Linthicum (2003), middleware is a software that facilitates the communication between (two) applications.

issues of communication but it is a starting point of how different areas of science can effectively collaborate and take advantage of each other. We discuss in the following the issues in the context of Social Science and Natural Science and, preliminarily, we describe in details the Evolutionary Environment Simulator itself.

Role of the Evolutionary Environment and EVESIM

The name Evolutionary Environment Simulator comes from the initial intention to set up a simulator of the so-called Evolutionary Environment in the DBE project (Heistracher et al, 2004). The Evolutionary Environment is a network of DBE nodes and services which enable the self-organisation of the DBE network and provide a test bed for various research topics like natural language business modelling (OMG, 2006), evolutionary algorithms (Colin, 2002) and distributed intelligence (Briscoe and De Wilde, 2006). For more information on the Evolutionary Environment see also (Masuch, 2006).

Although the name Evolutionary Environment Simulator results from this particular Evolutionary Environment, the intention of the EVESIM is not only to simulate the behaviour of the Evolutionary Environment, but also to provide partners from Natural Science, Social Science, Business and Computing a framework to collaborate and test their findings together. During the ongoing collaboration in the past, the EVESIM emerged to be a generic framework for simulating self-organisation and SME networks for a broad audience from different research domains.

The approach of choice for communication and collaboration was to meet the needs of the different partners and to avoid influencing their very particular way of working as long as possible. Therefore, generic interfaces had to be found and a couple of transformation modules, import and export capabilities had to be added.

Specifically for Natural Science stakeholders, a plug in mechanism was developed to use both the evolutionary algorithms developed especially according to the EVESIM model and the evolutionary algorithms with binary representations. Through a transformation module from binary representation to the representation of SMEs and services according to the EVESIM model, additional optimisation algorithms can be added and evaluated in their usage in a DBE. More details about the model used in the EVESIM can be found in subsection 1.7.3. Furthermore, an XML-based import mechanism enables importing real-world business network data during runtime.

Specifically for Social Science stakeholders, the EVESIM provides import capabilities for Comma Separated Files (CSV). That enables non-technically experienced people to export data from any spreadsheet software for subsequent import into the EVESIM. Moreover, the configuration of actors along seven predefined 'social variables' influences the behaviour and set-up of the agents in the simulation. These variables are described in the following.

Natural Science

To imitate Digital Business Ecosystems the real-world behaviour has to be simulated which is achieved by using evolutionary algorithms, well known from the study of life as explained in section 1.1 "Natural Science Paradigms". Evolutionary algorithms are used to find an optimum solution for different types of problems. In the case of the EVESIM, the challenge is to find the best-fitting service for a specific task of a SME. Thus by using evolutionary algorithms the self-organizing features of natural ecosystems are utilized to simulate and enhance business networks.

Furthermore, it is possible to check the effects of different social and business parameters onto the ecosystem. To achieve this, the individual SMEs in the ecosystem are simulated by independent software agents[2]. These agents can interact and individually adapt to the changing business needs. The possibility to adapt dynamically to a changing ecosystem in a self-organizing way is the major advantage of utilizing biological approaches in the Digital Business Ecosystem. Therefore evolutionary algorithms are the fundamental optimisation mechanism of the EVESIM.

As was mentioned in section 1.1.5, it is hard to predict how a real-world ecosystem will evolve. This is true for a simulated ecosystem as well. But by utilising a simulator it is possible to find out key parameters influencing the evolution of an ecosystem. One of these key parameters is the critical mass of participants that is needed to get the ecosystem work as detailed in (Kurz and Heistracher, 2007). As research on evolutionary algorithms, for example, is often done on random high-scale networks (Colin, 2002) the availability of real-world data from Social Science would be highly beneficial to make simulations more 'close to reality '.

2) In the context of EVESIM, the terms agents, SMEs and actors are used interchangeably.

The input of social science in this sense is mainly correlated to the concept of *social capital*; intended in its broad sense of relational and business territorial networks. That of social capital is, in fact, one of the theoretical approach social science researchers choose for interpreting the DBE community building process. From this specific point of view the simulator can be understood as an instrument for visualize, in a dynamic way, ongoing process and as a tool for validate different hypothesis on the capacity of DBE to boost territorial social capital by improving the level and the quality of collaboration among SMEs and other local actors.

Social Science

Researches carried on by social scientists in the DBE consortium have been focused not on technology itself – considered as an independent factor of business attitude - but on the correlation between technological innovation and existing social relations. A key question was represented by the possibility for DBE to reinforce already existing business and social relationships and/or create new links among local players in this way contributing to improving the territorial social capital, i.e. the level and quality of collaborations among local players. The main methodology used for exploring this research's topic has been that of Social Network Analysis (SNA) The EVESIM come into play after the first network analysis research, as an useful tool for improving results visualisation and multivariable analysis.

Before describing the concrete convergence between social science research and computer science domain trough EVESIM, it seams interesting to briefly introduce the theoretical framework upon which the Social Network Analysis has been based. In fact, it generate by on of the main goal of the DBE project, i.e. to sustain European SMEs by offering them a process and a technological solution for clustering.

When analysing results from a range of different researches, it emerges clearly that the capacity to collaborate and take advantage of social capital is a decisive factor in the diffusion of innovation within a given local production system and in its SMEs. SMEs collaboration and cluster is a well know catchphrase in the innovation debate, however, the latest research carried out by Censis indicates the pressing need to abandon the use of slogans and focus, instead, on the various levels of collaboration, highlighting which models they give rise to and which benefits they can bring to companies implementing them. An approach of this type makes it possible to analyse the concept of collaboration more systematically, highlighting the way in which SMEs are still too often involved in so-called 'limited-horizon collaborations' that are implemented through the use of shared services, through participation in trade fairs and by accessing shared credit services. We use the term 'limited-horizon collaboration' to underline how this type of initiative - even when formalised and persistent over time - does not face up to the problem of company development in project terms. This model can guarantees economic benefits in the short term but should not be considered suitable as a facilitator for product or process innovation. DBE has been seeing as an instrument for open up new collaborative process, with a wider horizon.

The advantages of collaboration, in fact, increase in proportion to two factors:
- The centrality of the corporate functions engaged: what is being collaborated on?
- The heterogeneous complexity of the network: who is the collaboration between?

In other words, the advantages for companies increase as they move from collaboration on support functions to collaboration on strategic functions (R&D, marketing, internationalisation, and so forth) and as they open up their networks to university, research centres, intermediate actors as Chambers of Commerce and Development agencies an so on. DBE – thanks to its flexible architecture – can easily adapt to different territorial characteristics and include different local actors accordingly to their missions and SMEs real needs and by so doing could become a collaboration facilitator. In order to evaluate in which grade this is not only possible in theory but also already observable in practise, Censis carried out two different surveys on existing networks and present territorial social capital using network analysis methodology[3].

The role of simulator, here, is that of visualizing and making dynamic data that are normally only static. The simulator has been used in order to visualize the growth of the already existing territorial networks during the process of SMEs recruitment. It make possible to picture those networks on which DBE can rely on, individuate missing links, and give in signs to the SMEs recruitment strategy adopted. Evaluating the networks in terms of social capital is essential for at least two reasons:

3) An initial definition of social capital is required here in order to understand the rapid conversion from social capital to networks. In accordance with Bourdieu, we may define social capital as "the sum of resources, actual and virtual, that accrue to an individual or a group by virtue of possessing a durable network [...] of mutual acquaintance and recognition" (Bourdieu, 1980:22).

1. The networks, being relational infrastructures between actors, are, invariably, a useful way of defining the context in which those actors operate, and describe – at the same time - the actor's characteristics.
2. Describing how the network is composed can help the consortium to understand which are the most important actors that should be included in the DBE in order to make the ecosystem grow and reach the critical mass needed to be self-sustaining.

An important element when studying territorial networks is that of group characteristics. In this regard, the research explored various possible types of contacts that can be considered as different types of collaboration. Possible relationship were as follows: personal contact; participation in associations or institutional bodies; participation in projects; sharing of resources; information exchange; and no contact, meaning "I am aware of their existence but have no contact with them"[4].

By diversifying the types of contact, we were able to conduct important research into:
- Formal contact vs informal contact
- Intensive relationships, i.e. highly focused collaboration projects vs extensive collaboration (sharing of information and/or resources)
- Presence or absence of subgroups and types of subgroup: associations, working groups, clusters

Thanks to network analysis first and thank to the simulator in a second step, all those information take the form of relational networks. Interviewees were given the opportunity to provide more than one answer for each relationship, meaning that SMEs representatives may indicate different types of contacts for the same actor. Overlaps of this nature, when they occur, are very interesting because they can function as a tool with which to measure network density.

Indeed, as Portes has stated, "an intrinsic characteristic of social capital is that it is relational. Whereas economic capital is in people's bank accounts and human capital is inside their heads, social capital inheres in the structure of their relationships. To possess social capital, a person must be related to others, and it is these others, not himself, who are the actual source of his or her advantage" (Portes,1998). In short, social capital exists only when it is shared. But is not simply a matter of the extent to which people are connected to others, but the nature of those links. Social capital benefits grow together with the grow of network density. While social capital is relational, its influence is most profound when the interaction occurs between heterogeneous clusters, as we have mentioned the "who is the collaboration between?" is a key question. From an economic perspective, several recent studies conducted as part of the World Bank's Local Level Institutions Study (Grootaert and Narayan, 2000) confirm the importance of heterogeneity in group membership and economic outcomes. From another prospective, Florida also confirmed that the dimension of diversity is strongly connected to the innovation level of a given group or region. In these studies, the capacity of a group to include a high level of diversity comes across as crucial, since a high "level of tolerance", as the author puts it, makes is easier for that group to innovate and, consequently, become more competitive. Making further reference to the metaphor of the ecosystem, it may be said that biodiversity is one of the most important conditions for sustaining the life of the system. In light of this, we introduced the question of diversity. We asked participants to grade the level of diversity in their workplaces, in order only, at this stage, to help us build up a snapshot of SMEs from this particular perspective. The interviewees were asked to consider a variety of factors such as differences in levels of education, wealth, social status, gender and ethnicity, age group, party/political affiliation or religious beliefs and length of residency. In addition to the internal level of diversity described above, the level of network diversity (i.e. the number of actors with which SMEs interact and the 'nature' of those actors) is also important.

All the above-mentioned network characteristics have been introduced in the simulator and constitute what we called Territorial Social Capital.

In recent years, some scholars have proposed an additional conceptual classification. Called "linking" social capital (Woolcock, 2001), this dimension refers to a given individual's ties to people in positions of authority, such as representatives of institutions, public (police, political parties) and private (banks) alike. Whereas the operation of bridging social capital is, as the metaphor implies, essentially horizontal (that is to say, it connects individuals of more or less equal social standing), linking social capital is more vertical, connecting individuals to key political (and other) resources and economic institutions - in other words, across power differentials. Importantly, it is not the mere presence of these institutions (schools, banks, insurance agencies) that constitutes linking social capital, but rather the nature and extent of social ties between such different actors. Defined as such, access to linking social capital is demonstrably central to producing economic wealth.

4) The social network analysis has been based upon face-to-face interview to Regional Catalysts and engaged SMEs.

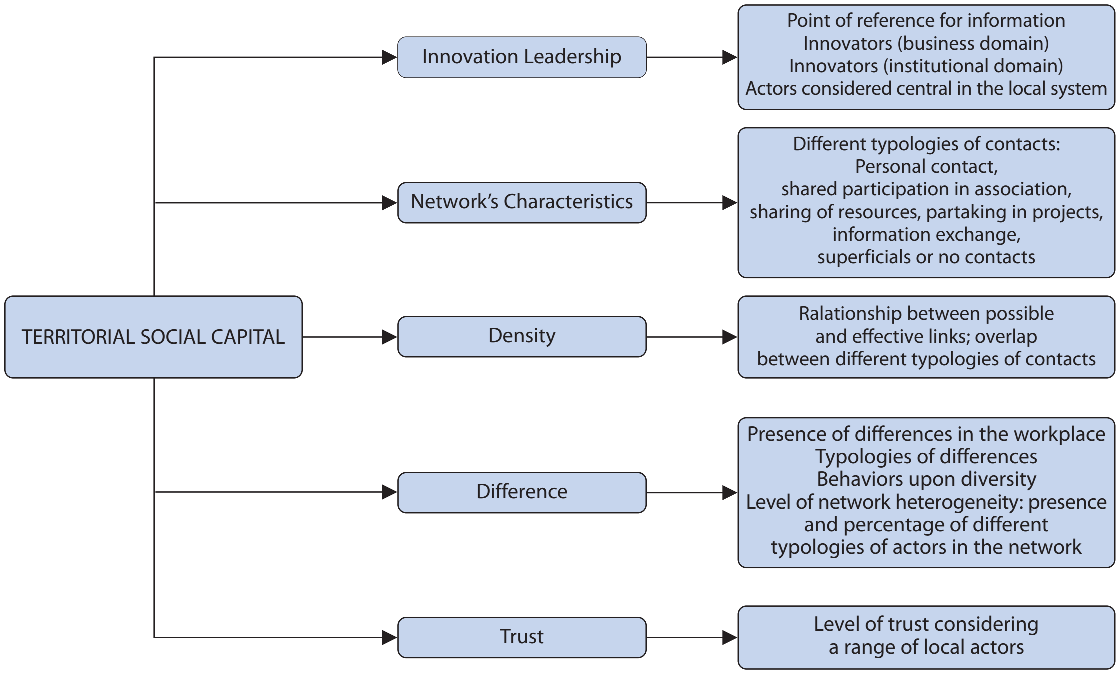


Fig. 1

Territorial Social Capital Definition
Source: Censis, 2006

The survey also explores respondents' subjective perceptions of the trustworthiness of key institutions that shape their lives as a crucial dimension in the potential for collaboration, and this is closely related to the concept of linking social capital discussed above: reciprocal trust is a precondition for collaboration and is the 'glue' that makes it possible to engage with the risks and benefits of long-term projects such as DBE.

Social Networks present and future dimensions

As we already mentioned, Censis carried on a first survey in the associated regions about RC and Driver SMEs' relational networks. Data gathered in Aragon have been the starting point for the collaboration with computer science specialists and the simulator adjustment to social science needs. In this first survey 7 typologies of relation were take in consideration:

- personal contact
- share of information
- share of resources
- partaking in projects
- participation in association or institutional bodies
- superficial recognition
  (I know them but I have not contact we them)
- no contact

In the simulator to each connection typologies correspond a different grade of strength that impact of the network grow rate. In the next research, when more SMEs will be interviewed (drivers, as well as implementer and users) we whish to be able to introduce in the simulator more variables, mainly correlated to SMEs economic characteristics (size, sector, turnover, N. of clients and providers and so on) but also related to their approach to innovation, ICT and collaboration and we'll try to simulate possible impacts of those variables on the network growth rate, service migration rate and connectivity rate.

By introducing those variable the simulator will acquire a new use for social science. Beside the possibility to visualize in a dynamic way static data, it will be also an interesting instrument for training and communication. By modifying each SMEs characteristic, in fact, it would be possible to visualize the outputs in term of collaboration pats and related business benefits. Introducing those new variables will imply a modification of the simulators and will require more research from both side, that of social science and that of computer science.

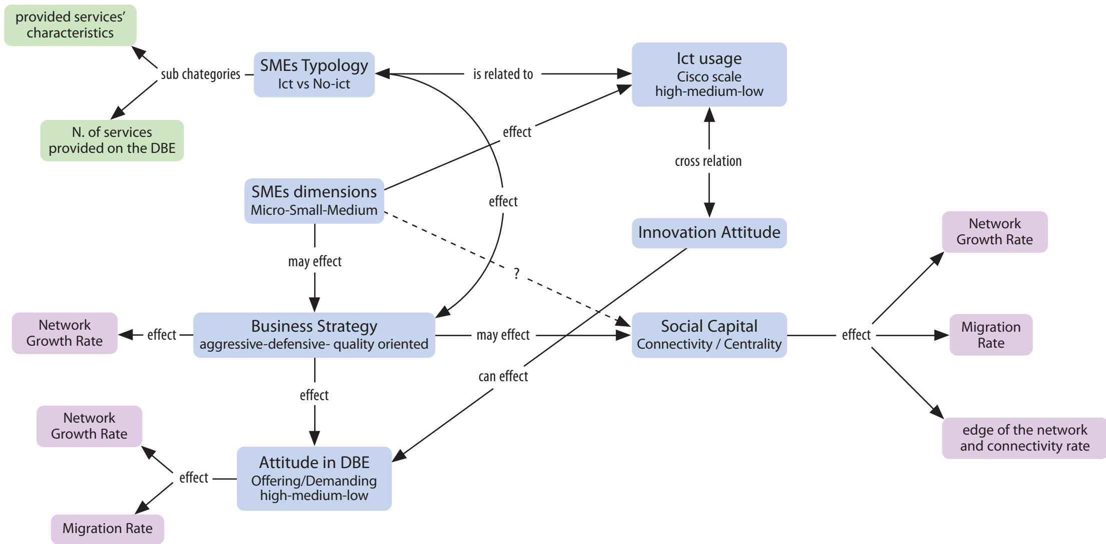


Fig. 2

Possible variable for future simulator development Source: Censis, 2006

Evolutionary Environment Simulator - EVESIM

In the following, we discuss the technical implementation of the EVESIM. The according source code can be found at (Kurz et al, 2006). To keep the simulations as realistic as possible while attaining the goal of speeding up the process of evolution, a number of tools were used to simulate the DBE system. The EVESIM tackles the goal of having a system where the network nodes remember past interactions with different other nodes and services to continually improve the system in a smooth way. Moreover, the EVESIM provides a simulation framework with rich configuration and visualisation capabilities for being applicable for different digital ecosystems during future research (see Fig. 3).

The implementation of the simulator itself required the collaboration of many different disciplines. The EVESIM stands to benefit from the input of partners concerning genetic algorithms, global optimisations, symbiosis and competition, social networks as well as software engineering. These groups, consequently, can utilise the EVESIM sources. By adding code and features to this project it became a cross-domain collaboration platform.

The results of the simulations, though, do not claim to be a one hundred percent realistic. The intention of the cross-domain collaboration is to make the results more realistic and the EVESIM provides a test bed for this endeavour. Moreover, by restricting the variables used in a system, the disciplines can run first there simulations on a restricted area, e.g. high scale networks for genetic algorithms research, and then afterwards apply the algorithms to a more realistic and customized network structure.

Although the EVESIM model is intended to be as close as possible to reality, the model represents an abstraction layer, which enables the simulation of the behaviour of small real-world networks as well as the simulation of well-defined problems in high-scale networks. The representation of SMEs and especially of service descriptions within the EVESIM are an abstraction of Semantic Business Vocabularies and Business Rules (SBVR) and therefore a mapping of SBVR logic into a set of features (flattening), which results in a simplified model that does not take into account the full set of SBVR capabilities. SBVR is a natural language approach for business modelling (see MOG, 2005 and OMG, 2006). Nevertheless, this model is a compromise between the real SBVR representation and the abstraction level that facilitates a simulation that is close to reality. Additionally, the matching of SBVR models and its theoretical implications are still in research status. Consequently, a level of abstraction has to be found so that a generic objective function can be defined, capable of being applied to a broader set of service descriptions (potentially any version of business modelling language).

As delineated as A in Fig. 3, each service is represented by a number of attributes. These attributes can be symbolic (colour of a car) or numeric (discount for a price). As symbolic attributes can be simplified by using natural numbers, the range of attributes could be chosen as real numbers for both, symbolic and numeric values. As SBVR describes models and as the search will also be on the basis of models, real numeric attributes are not the main focus. Therefore, the values of attributes within the EVESIM are currently set as a subset of natural numbers. In case of service combinations, the attributes of the individual services are merged and consequently construct a new service description, e.g. a word processor consisting of word processing, thesaurus and spell-checker. The comparison of two services is a comparison of all the attributes of one service to all the attributes of another service and service combination, respectively. When a new service is produced it appears first in the portfolio of its producer SME. The producer SME is presented by the actor, which produces or offers a service. In case of a service combination of two existing services, the actor who combined the service becomes the owner of the new service. This is why we assume that additional effort was needed to combine existing services. From user perspective for example, a travel agency is the owner of the travel-service, though it merely books the corresponding flights, the airport transfers and the hotel.

The social network analysis within the DBE currently uses a SME table for retaining the relationships between SMEs. Rows as well as columns hold the names of the SMEs. The type of relationship is represented as the value in the intersection of axes. As to provide a common import from a broad range of spreadsheet software, the import files for the EVESIM have to be CSV (Comma Separated Values) using a semicolon for separation.

For visualising the capabilities of the Evolutionary Environment, the actors, services and the whole network topology can be displayed through the EVESIM Display (see Fig. 4). For each type of actor, a picture label can be chosen from the file system to indicate the different actors in the network. The edges between the actors represent the bidirectional relationships of two actors. Beside the visualisation of the network, a label for displaying the gross Network-Fitness was introduced. The algorithm for calculating this network fitness as well as other parameters can be easily modified according to the users' needs.

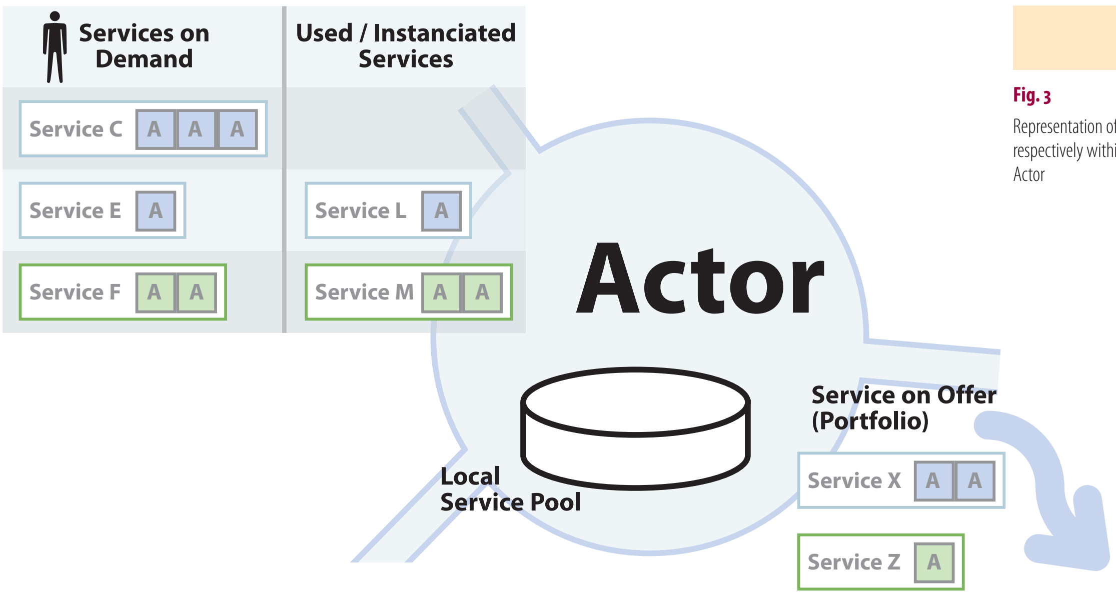


Fig. 3
Representation of a SME and Habitat, respectively within the EVESIM called Actor

In order to set up the network based on the social variables described in Section 2.7.2, we introduced capabilities for variable actor configuration. Each actor can be configured along seven social variables and can be represented by a user-defined picture and a name. For assigning this configuration to the SME agents, two approaches are possible.

First, a network of a region is imported through a CSV file import and the types of actors can be defined through the seven social variables. After importing the SMEs in terms of name and social connectivity to other SMEs, each SME can be associated with a type and therefore the specific behaviour is set, e.g. number of services on offers and demand.

Second, by configuring types of actors and including a number of actors present in the network, a higher-scale network can be extrapolated for testing algorithms for certain topologies and types of actors. One important indicator here is the so-called 'social capital' that indicates the connectivity of a certain actor with other actors in the network. Though, extrapolating a network is hard and not accurate at all, the usage of roughly defined actors make a simulation of a higher-scale network at least closer to reality than using a random network independent of the types of regional actors.

The technical aspects outlined here enable the EVESIM to emulate boot-strapping behaviour of digital business ecosystems based on real-world-data which is an important feature for providing visualisation-based convincing forecasts for new DBE users and organizations.

Collaboration: A Process of Reciprocal Understanding

The collaboration between Social Science and Natural Science has been focused in the first step on the possibility to transfer knowledge on engaged SMEs to the EVESIM. Social research, in fact, focuses on SMEs relational networks and - thanks to network analysis - visualises the correlation among SMEs and other local players.

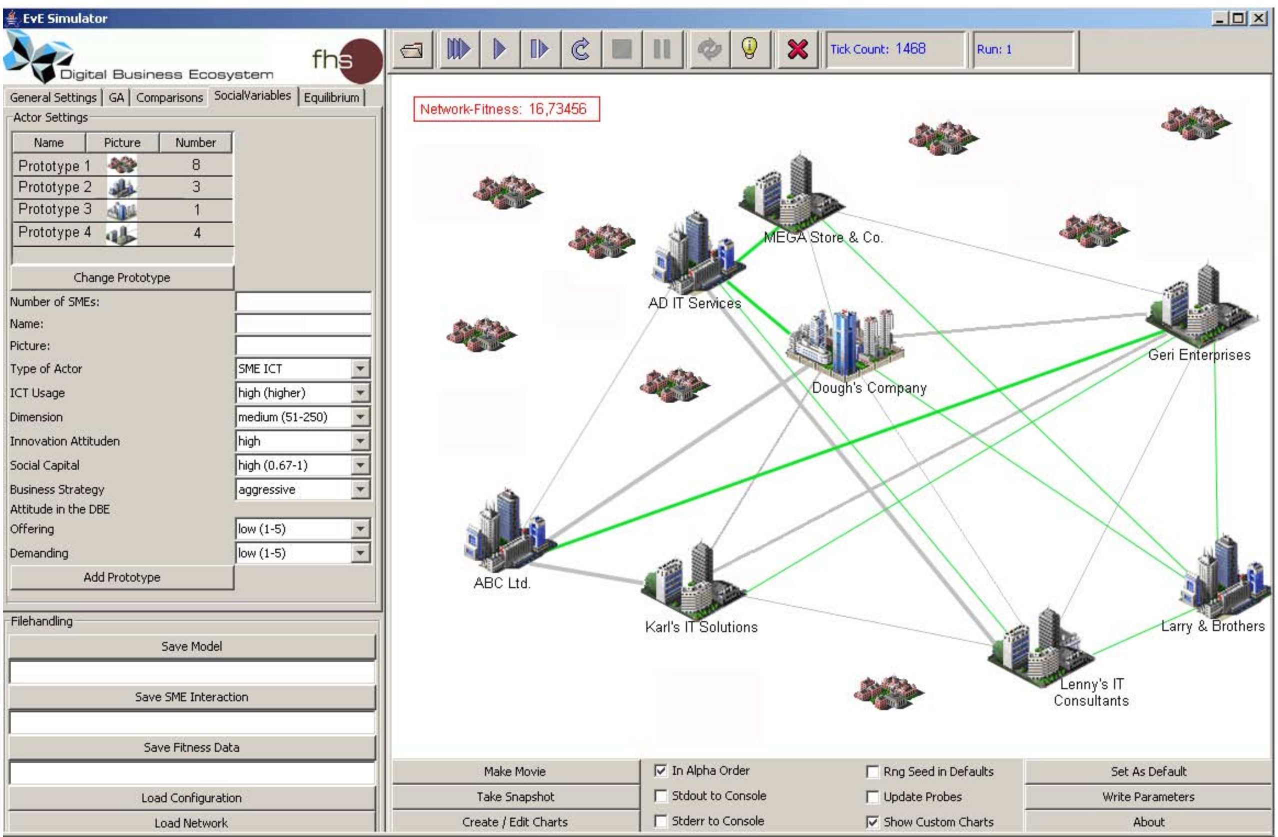
The successful transfer of data is a first result of the collaboration described here. Respective data was related to regional catalysts (RC) and Driver SMEs only and did not impact the general structure of the simulator (variables, SMEs profile, algorithm, etc.). Now that Implementers and Users SMEs have been engaged, new data will be available and will be integrated in the simulator thanks to the input/export features provided by EVESIM. This first impact on the structure of the simulator is now visible. The connection typologies studied so far have been already introduced above. These connection typologies go from personal contact and sharing of resources (as maximum of connection among SMEs) to more sporadic or absent relations. Those networks are not networks of services (pieces of software migrating from one ambient to another) but relational and business networks of SMEs engaged in the DBE. Nevertheless, the two layers - network of services and real-word connections - show important points of contact.

For example, three SMEs involved in several projects together may wish to share an agenda and look in the DBE platform for an agenda synchroniser. Besides this, face-to-face or business collaborations can have an impact on the level of trust between two enterprises. A high degree of trust, consequently, may invite one SME to prefer services provided by an already known enterprise instead of an unknown entity by this way introducing an important element in the migration pattern.

In both examples, a real word connection impacts a digital activity and service exchange. Besides this, the collaboration developed so far provided a common ground for understanding and developing a common language. This is a first step for real interdisciplinary research.

Fig. 4

Screenshot of the EVESIM with different actors in a small network.



The next step was to define different actors by introducing certain characteristics for each actor in a DBE network. We tried to visualise a possible definition of different actors (drivers, implementers, users, other local actors) in terms of interactions, i.e. trying to understand if a connection exists between the actor's role in the network and its level of interaction/collaboration with other local players. Besides this, social analysis provides a sort of typology of SME profile in terms of business domain, business organisation and possibly of a service to be requested.

In the future it will be important - again thanks to the collaboration of Social Science with Natural Science via the EVESIM - to understand the possible relationship between SMEs profile and service migration rate. This will require further analysis but will be of great impact on the simulations itself. At this stage it is interesting to consider different advantages that different DBE partners can take of the simulator.

From a computing perspective, the simulator is an important tool for visualising positive aspects of Peer-To-Peer Networks and self-organisation. From a Social Science perspective and a training respective RC's perspective, the simulator can become an interesting instrument for explaining to SMEs and regional players the relevance of collaboration and of DBE. By modulation of SMEs' profiles and other contextual variables it will be possible to show which are the positive mechanisms of knowledge sharing, collaboration and clustering. Besides the potential of making benefits of DBE visible amongst all stakeholders, EVESIM acts as important building block for the conceptual study of the intrinsic optimisation potential of the DBE. It offers pre-flight features for further steps in conceptual and technical development and it makes it possible to adjust technical aspects of the infrastructure based on hypothesis testing and prior emulation. But not secondarily, it becomes an unexpected field of interdisciplinary collaboration.

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4

Section Four

Case studies of **Technology Transfer** and **Digital Ecosystem** Adoption

European Commission
Information Society and Media

1 The territorial Prospective of Digital Business Ecosystem

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Multi-located ecosystems

The aim of this brief introduction is to delineate, unavoidably in a schematic way, the theoretical approach of DBE's local implementation. In order to do so, it's first of all necessary to clarify the term 'Digital Business Ecosystem'. The term, in fact, assumes at least four different meanings in the present volume indicating different 'objects' and diversified fields of research.

DBE is the name of the first and largest European project among the cluster of projects supported by the European Commission within the sector "Technologies for digital ecosystems" of the 6th Framework Programme (a 3-year, €14m European Integrated Project).

However it also refers to:
- the result of the integration the business environment (business ecosystem) with the software environment (digital ecosystem) in which business applications can be developed and used;
- the interdisciplinary approach to technology design and development;
- the peculiar process of territorial innovation enabled by the availability of a digital ecosystem.

The chapter we introduce mainly refers to the last meaning, i.e. a process of territorial innovation. It is important to note that we preferred the term 'territorial innovation' to that of 'territorial development'. This for two main reasons:
- DBE can be implemented, and has been implemented, in regions with very different socio-economic and infrastructural characteristics. It can be applied to lagging behind territories as well as to advanced ones;
- DBE take the steps from a 'relativistic' prospective to territorial change, i.e. the project does not indicate one or another local implementation as *best practices* transferable to other territories. On the contrary, the local implementation process has been imagined as a path that needs to be carefully adapted to local realities. In this sense, the DBE approach to locality is strongly coherent with the DBE's technological environment, which is open, flexible and able to adjust to users' specific needs.

The above-mentioned aspects are crucial: the following articles describe different experiences of DBE local implementation, which indicate different possible usages of DBE coherently with pre-existing local specificities, innovation goals and future oriented visions.

The centrality of local dimension

As Kavin Morgan (2001) pointed out, the debate about globalisation and the digital era probably exaggerated the so-called 'death of geography'. The spatial dimension of economic and social process have been somehow neglected in favour of a vision in which technologies could develop new models of business and social interaction somehow independent from original spatial dimensions (Cfr. Friedman, T.J., 2005). Both globalisation and ICT diffusion, for sure, create new flows of information and new paths for cultural and economic exchange; by the way, as Appadurai (1996) demonstrate, while objects and finances move easily from one spot of the world to another, the same is not valid for *meaning* and *knowledge*. A good example can be the 'media sphere' in which images move freely from a country to another but the significance of each image and the value associated with it vary considerable in association with the localization of the viewer (obviously other factors such as gender, age, economic background and education does matter too). In other terms, information and goods are moved and diffused through new channels and reach new territories while the decodification of that information and the value of those goods assume narrower meanings and are integrated in the pre-existing local knowledge and culture (Morgan, 1997).

Tacit knowledge and social capital, i.e. un-codified knowledge and the value each person and organization has, thanks to its relation links, are really more difficult to migrate and translocate from a region to another. Never the less, those assets are vital for local innovation and also at the level of single enterprise, especially for SMEs (Nonaka and Takeuchi, 1995).

'Translation', adjustment, adaptation become decisive because "virtual proximity may well be a surrogate for physical proximity in the context of standardised transactions, but not in the context of transactions which are high in complexity, ambiguity and tacitness" (Morgan, 2001:5). In fact this is the case of local innovation in which we need to take in consideration a multiplicity of actors, their specificity in term of needs and possibilities, the structural economic condition and the cultural related stiles of governances. And this is the case of DBE regional engagement, of course.

The process of DBE implementation, in this context, can be understood as the challenge to translate a process of technological environment development and usage in different local contexts and maximise its potentialities in term of economic development, social capital improvement, Ict diffusion, and so on. As pointed out by L. Rivera León in her article (section 2 of this book) "Investing in DBE implementation is a long-term investment in knowledge creation and dissemination". Beside this, DBE implementation is also a process of network-building, it imply the activation of multiple collaboration and the involvement of diversifies stakeholders (university, intermediate actors, SMEs, police makers and knowledge hub).

DBE implementation: key actors

In this process of local knowledge creation and diffusion and of collaboration reinforcement, the role of Regional Catalysts (RCs) has been crucial. Regional Catalysts is the term by which the DBE project defined local actors that, as in a chemical reaction, got the role of facilitating and speeding up the process of DBE implementation. As the articles that follow show, the choice of recognizing one local organization, firmly rooted in the regional system as responsible of DBE local implementation has been a successful one and it's now ready to be experimented elsewhere.

But what does an RC have to do? Regional Catalysts work to create a climate of reciprocal trust in order to promote DBE approach local exploitation and the concrete usage of the technological environment. It is the RCs that engage the SMEs, coordinating their training programs in order to support their technical systems and monitor their activities. RCs also have three main goals:

- engage local SMEs
- sustain DBE technological development and customization to local needs
- attract policy makers' interest

In order for SMEs to make the decision to engage with DBE, collaborating with other companies, share strategic functions as well as sensitive information, it is essential that they feel they can count on intermediaries with the capacity to facilitate the process of network building and knowledge transfer. The concept of trust, already introduced in other article (see E. Berdou article in this book) comes into play. The project experience confirmed literature results about innovation adoption: beside the technological quality of an innovation the trust towards who is promoting such innovation it's a central variable in the adoption process.

RCs act as S*ponsors* of the DBE, and as *Implementation Units*.

With the term 'sponsor' we mean the capacity of RCs to create consensus among DBE and develop an atmosphere of trust around it; they function as gatekeepers for the territorial community and are able to attract other innovation leaders as additional DBE sponsor (large enterprises, SMEs, research center, intermediate actor such as chamber of commerce, development agencies, entrepreneurial association, etc..). The activation of social local networks (see Kurz, Passani and Heistracher in this book) facilitate the decision of a single SME to get involved. The activation of policy makers resulted also really important, particularly in some territories such as Aragon. The decision of a local government to support (economically and politically) the DBE is an additional form of sponsorship able to reinforce the trust towards it because it helps in achieving an important pre-requisite of trust building: the 'shadow of the future'. In order to trust someone (or something like an innovation process) it's important to be sure that the relation we are establishing in a determinate moment, will have enough time to grow, reinforce and reach first results. The engagement of local police maker, in this sense, can be crucial in reinforcing an European project such as DBE, because it guarantee that the innovation will still running after the end of the EU project and, more over, an investment from local actors and they effective use of the technology assure SMEs that they really believe in such process, that it's not a guess, that it's something that will be extensively used at local level.

Indeed, RCs actually guarantee the availability of technical support, directly or in cooperation with other local actors. such *Implementation Units* of the DBE environment, work to ensure effective operational management, cover the infrastructural requirements, prove technical services and consultancy solutions.

In the pilot regions of the DBE project, the two functions - that of Sponsor and of Implementation Unit – has been played by the same organization (ITA in Aragon, UCE in West Midlands and HTC in Tampere), but the two functions can also be divided and the activities articulated among two different local players. In both cases, the engagement of other intermediate actors is important. A DBE, in this vision, is not an instrument for SMEs only, but it will enable territories to maximize their possibilities in term of collaboration and innovation. A Digital Business Ecosystem that strives towards being systematic in its approach needs to start by engaging companies, but it should not stop there - rather, it is fundamental that intermediaries and policy-makers are aware of how to ensure that all those that can provide the companies with value-add services engage with the environment. Resources should be dedicated not just to responding to their stated needs but also to guiding them towards more complex forms of planning. If the technological environment is populated by research centers, business incubators, consultants and venture capitalists, it will succeed in delivering solutions that go well beyond the short term needs of the SMEs, leading them towards collaborative growth projects that are highly knowledge-based. By participating, the local intermediate actor, will not only facilitate the SMEs engagement, but they will also reach their own goals (spread Ict adoption, facilitate organizational change, offering advances training, etc..). Those intermediaries, in fact, can use the DBE for offering SMEs new tools and methods through which to reach their own missions.

DBE implementation: key factors

The articles of this Section will describe the initial experiences of DBE local implementation and how the process took place in different territories. In order to introduce it, we'll now briefly describe the variables that influenced those processes and that may influence other future experiences as well. In other words we'll try here to delineate those intervenient factors that a new regional should take in consideration when working for DBE implementation. Important variables are the following:

- Pre-existing socio-economic situation
- Expectation/vision about DBE as technological environment and as a local Innovation process
- Typology of selected RC
- Policy makers' level of interest
- Identified business domain/s
- Technological development of DBE components (possible new releases, new services, etc..)

Pre-existing socio-economic situation refers to the centrality of local characteristics as we described in previous paragraphs. During the DBE project Census (2005 and 2006) it proposed a method for mapping those local characteristics: the Regional Maturity Grade. Combining qualitative/quantitative data with Social Network Analysis it took in consideration innovation attitude, Social Capital and SMEs ICT adoption.

The second variable, 'expectation/vision about DBE', indicate the answers to the question "why you decided to experiment DBE in your region?". That means:

- which benefits does a region aspect from DBE implementation?
- in which business sectors do your think it could be more useful?
- in order to solve which problems?
- what is the level of trust you had in it?

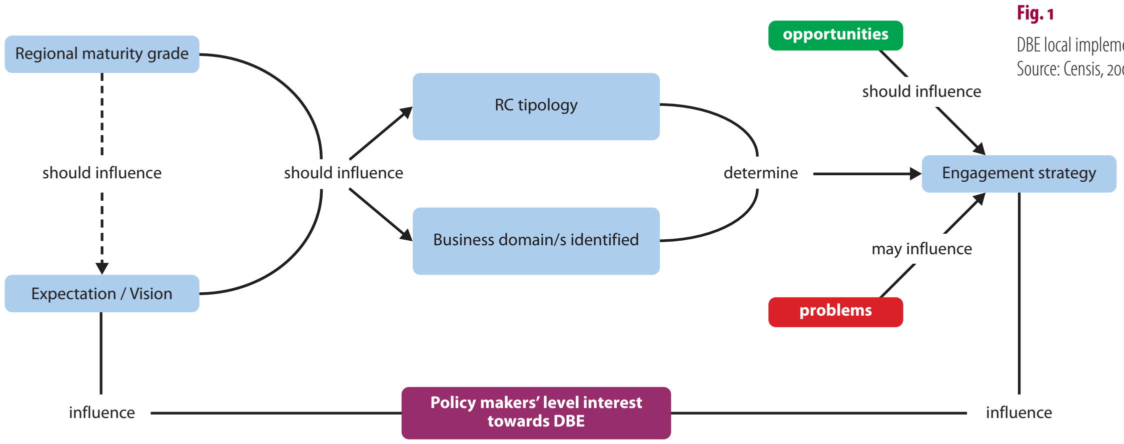
The following variable, 'RC typology', refers to the nature, the mission and the organizational structure of each RCs, whether the territory choose to have one organization active both as Sponsor and as Implementation Unit, or more; the nature of its relations with local SMEs, decision makers, intermediate actors and so on.

'Identified Business Domain' is another variable that influenced the process of DBE local implementation as each regions can choose a different approach (use DBE technological environment only in a specific domain or prefer a cross-domain vision). In the DBE project the business domain selection phase occupied not only the first period of the project, but also the following, both Tampere and West Midlands regions, in fact, changed their activity area in response of specific needs that arose during the project life cycle and the possibility to test DBE in a sector and then enlarge its fields of application is always a possibility.

With the term 'technology development of DBE component' we refer to the constant need for RCs to stay in line with possible DBE environment new releases or new services coming up in other territories or domains.

The schema below represent a possible interpretation of how the just defined variables interact each other in shaping the DBE local implementation process.

Fig. 1
DBE local implementation: main factors
Source: Censis, 2006



The first step would be that of benchmarking the regional situation using the Regional Maturity Grade or another methodology able to make a complete picture of the socio-economic situation. Innovation is never only the act of exposing a territory to new technology but it always implies other dimensions; among others: cultural setting, social capital, SMEs specificities and approach toward ICT, collaboration and innovation attitudes.

We would recommend having an extensive network analysis at regional level in order to intercept those actors that, more then others, can help the process of DBE adoption. Gate keepers - actors that can open the network to a wider group of users – can be SMEs as in the case of West Midlands, projects as in the case of Tampere or intermediate actors such as Chamber of Commerce, SMEs association, Development agencies and so on.

After this research phase, a clear plan of what the DBE implementation goal should be, is needed (in this context, participative methods – such as GOPP or AESW - can help integrating DBE with already existing regional strategies and facilitating the collaboration among different local stakeholders).

Identifying a specific business domain can be significant; it helps to reduce the complexity and the set of competences that the RCs need to handle and possible facilitate services sharing. In this phase (the second in the schema) a fine-tuning about RC typology can be performed in order to recognize additional Sponsors and the better Implementation Unit.

The engagement strategy, defined, as concrete acts for recruiting, selecting and training the SMEs, have to be defined coherently. The strategy adopted in the DBE project (described by Dory In this book) demonstrates it to be successful and feasible and it is ready to be tested in other regions.

The schema we proposed is, of course, is a 'minimalist' one because, as we mentioned at the beginning of this article, we took the steps from a relativist approach in which each territory, each local community, each territorial innovation system has to find its personal declination of the Digital Business Ecosystem.

Conclusions

That of DBE implementation at local level has been defined as a process of regional learning and local knowledge creation. It implies an intense process of interaction in which knowledge transfer runs both explicitly and implicitly through personal contacts and through at-a-distance communication.

Thanks to the actions endeavored by RCs, the knowledge generated by the DBE project can be translated at local level and adjusted to SMEs needs and possibilities. Consequently, DBE as a process can means quite a different thing in different territories, but in each of them it has to took a place at the crossing point of different actors' trajectories and become widely recognized as significant for the local economy and future. The role of RCs - in their function of Sponsor and of Implementation Unit - has been and will be essential in other territories not only because they translated the DBE knowledge in something really soundly at local level, but also because - thank to their pre-existing social capital – they reduced the uncertainties always correlated to an innovative process such as DBE, they assure a certain stability, which is essential for innovation and change.

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2 Policymakers: Making the region a good place to live, to work and to invest, or... How to Increase the Attractiveness of a Region

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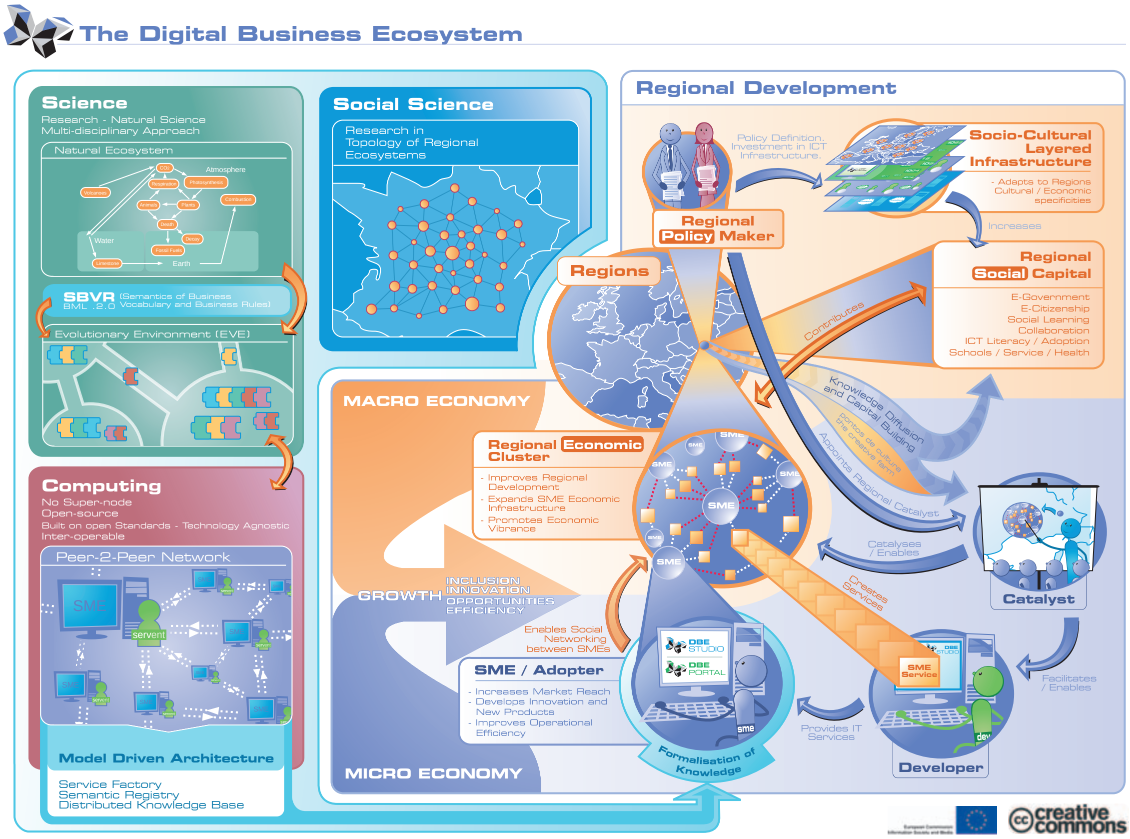
Introduction

The dissemination of the Digital Business Ecosystem concept is typically based on the following model. The approach is a combination of top down and bottom up actions.

At first, a team engages with the regional policymakers or regional economic influencers such as a chamber of commerce, regional and/or economic development agencies and universities. This team can be a group of people which learned about the DBE and formed a group around this concept, or a more formal consortium created to help the dissemination of the concept. The objective of this first engagement is to explain the benefits and impacts that DBE produce in terms of regional socioeconomic development (focusing on Small and Medium Enterprises). At this point, it is really vital to have the endorsement of the policymakers. DBE provides a great variety of benefits to the regions. Its impacts, including an increased competitiveness of SMEs, are not only economic. DBE allows the creation of high-value jobs, and the construction of a social network that enables knowledge sharing and fosters innovation in the region. Other aspects of the region will also be positively impacted: a better community (as people will work where they live) and better services (health, education and local government). As for any wide-scale policy, shaping the implementation of the DBE in a region is primarily a political decision, as resources and infrastructure may need to be allocated in order to support its introduction, as for example when deciding to install and roll out a Broadband programme, to have a Government assisted PC purchase program, to allocate some local or structural funds to help the development of the network and services; and to support SMEs by enabling them to allocate part of their resources to the DBE.

Once the political decision has been agreed, another key milestone is the appointment of a regional catalyst (that could be formed by one or a group of organizations). This model is quite unique for the DBE and is, like in a physical reaction, catalyzing the process of dissemination and of adoption.



From the Political decision to catalyzing the process

The regional catalyst (RC) is one of the pivotal institutions that will make the DBE adoption a success. Its roles and responsibilities range from the dissemination of the programme, the adaptation of the DBE to the region, the communication of the results and progress and the search for SMEs engagement to the adoption of the DBE. The project team has defined and proved the following specific process that can be executed. It includes the following steps:

- **Identification of the clusters and/or industry to start with.** This is a key step, and needs to be done jointly with the regional policymakers. Some industries and sectors are seen as critical for the future of the region, and therefore may need to be addressed as a priority.
- **Identification of the drivers and influencers** that will drive the adoption and the dissemination of the concept in the SME community.
- **Communication within the cluster** about the progress and also making available DBE services and support services to widen the adoption (crossing the chasm).

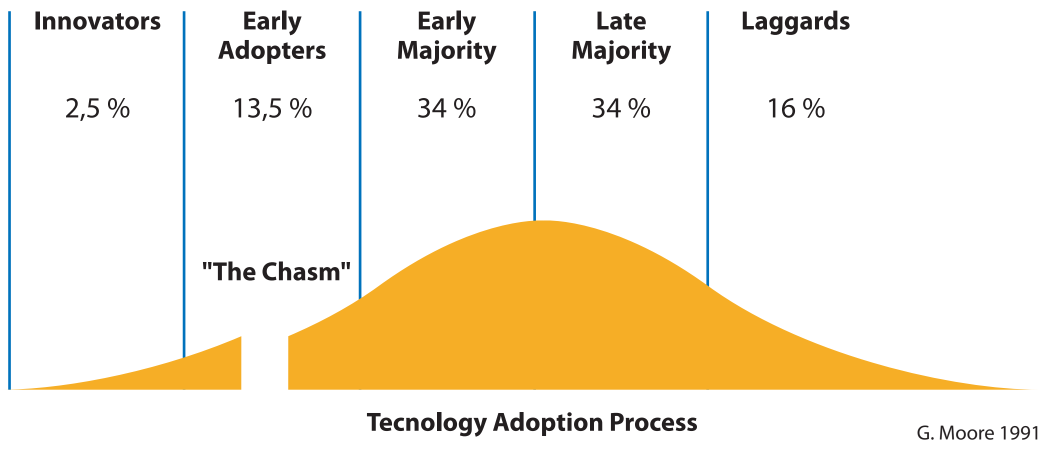
The Regional Catalyst, with the support of other development agencies, local associations and universities will classify the SMEs according to a suggested taxonomy (or typology) of engagement.

SMEs Engagement

This typology has been inspired by the concepts defined by Moore's "Chasm" (1991). According to him, the adoption of new technologies in a mass market is not an automatic process. In other words, the DBE will need to have a core community of active developing participants (Innovators) within the group of early adopters.

Even if some SMEs are really willing to engage, SMEs need to be further classified under two dimensions:
By their ability based on technological (and behavioral) competences, to:

- use the DBE,
- actively take part in developing DBE components, and



- contribute based on previous experience or existing technological skills and assets;
  and by their willingness to engage in:
- knowledge sharing activities,
- building the DBE (sub)-community, and
- further develop the DBE.

This differentiation results in specific-need profiles, motivations and abilities of engagement in the DBE.

This taxonomy, also called the typology of engagement, has been defined by the DBE team and the regional catalysts as a way to help the adoption.

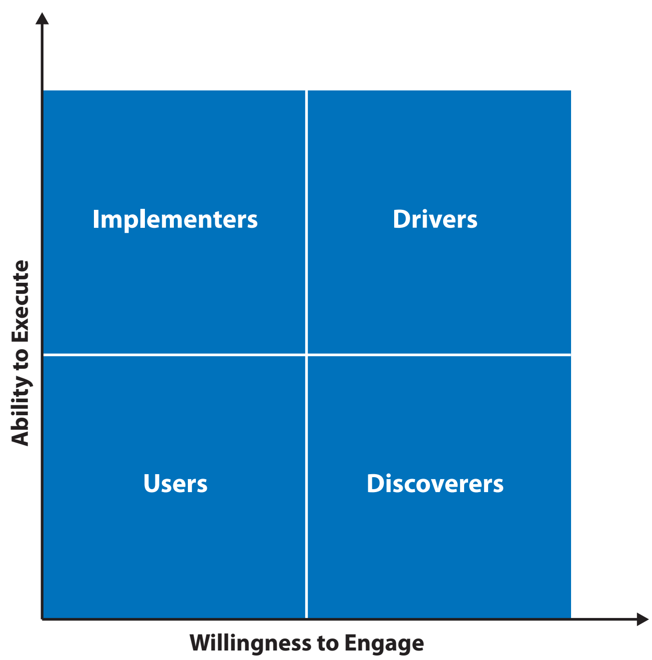
From isolated SMEs to Communities of Open Knowledge…

Under the guidance of the Regional catalysts, and with the availability of services, SMEs, Regional Catalysts, and other key players will start to create a network and will define a common context and purpose. This is the emergence of a community. Over time, trust, reputation of members and social rules will emerge and they will constitute the social rules of the community. This will enable its members to exchange, discuss and share topics around the purpose and objectives of the community. After some time, the community could expand, and new members may join around the shared principles and objectives. This process might allow the growth of the overall reputation of the community. The members will then start to create real knowledge that will be shared and open to all of them. This is the first step towards the emergence of an Open Community of knowledge.

From Open Communities to Innovation Ecosystems...

Once the knowledge is shared openly, and trust, reputation and social rules of open communities are the rules of the clusters of SMEs within the region (and possibly with similar communities of SMEs outside the region, in a digital and virtual community), SMEs will start to share not only knowledge, but also learning material, processes and also ideas.

The communities, and the trust created between the SMEs, will foster the innovation and the creation of new value added services and products. This will be also done by including universities, schools, large corporations and civil services within the communities, leading the creation of Innovation Ecosystems within the region.



…to Regional Social Capital

All of this contributes to increasing the economic and social capital of a region, making it a "good place to live, a good place to work and a good place to invest". The economic development of a set of SMEs at the local level is impacting all the other dimensions of the social capital of the region. Not only the region will have access to more funds (through taxes, Value Added Tax and more local consumption), it will also have access to a better digital infrastructure. The increase in the availability of funds will enable the region to invest more in other infrastructures such as schools, health services, and civic and community centers. All of this will help to increase the well-being of citizens in the region and the creation of community activities that will help to increase the social capital of the region.

The DBE project team… the starting block for an open Knowledge community for Digital Ecosystems

As the DBE is a very complex concept to explain, which is addressed to several audiences and addresses several dimensions at the same time, communication, learning and marketing dissemination material have been produced. All this material has been produced having in mind the creation of open communities. All the material is available from the website (www.digital-ecosystem.org) and will also form the building block for the knowledge created in the Digital Ecosystem cluster of projects. This will help to build, share and enhance the experience and the expertise around the Digital Ecosystems and also around the socio-economic regional development, and foster innovation ecosystems around local SMEs. Some examples of the dissemination material of the DBE results for each targeted audience include:

- *Policymakers' communication film*: explains to policymakers the advantages and benefits of the DBE at the regional and macro (economic and social) level.
- *Business SME film*: shows how the DBE could be used to improve the current business processes of SMEs and create new opportunities. This film mainly demonstrates the advantages of using the DBE at the micro level, and its benefits for SMEs.
- *Technical film*: shows the technical aspects of the Digital Ecosystems common platform, and how services are created, executed and consumed.
- *Evolutionary Environment film*: explains the evolutionary aspects of the DBE and how this will impact the DBE over time. This movie also shows how science and research are fully embedded in the project.
- *Other communication assets,* such as the **1-pager** (see above) that explains the overall project, the impacts on regional development and on all players, are also available, as well as other flyers dissemination material

3 The Experience of the Aragon region as a catalyst of Digital Business Ecosystems

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Introduction

This section presents the opportunities that a project like the DBE, further to the e-business concepts, offers to a region like Aragon. It also shows briefly the implementation of the engagement and training strategy in the Aragon region.

The DBE is not only interesting because of the innovative technological concepts that the SMEs in the region would get. It is also interesting from a political perspective, because it provides more visibility to the SMEs located in the region at an international level. It also helps SMEs to be more competitive since they enter a top-level system of dynamism. This allows all SMEs to meet other SMEs/Large Companies/parties that without the DBE they would never get to know about. All of this is possible because the DBE lets SMEs describe their services and products semantically.

The dynamism that the DBE provides would also improve the enterprise networking, which has already proved its capacity to increase productivity in some countries in Europe. Finally, the DBE framework would provide companies with equal opportunities irrespective of their size, within the network and in the marketplace.

At the same time, the project supports the regional IST SMEs, since it helps with the deployment of technological solutions to final user SMEs in an open source background. And finally, SMEs benefit from the opportunity of participating and exploiting the results from a strategic project at an international level supported by the European Union.

Why was the tourism sector selected for the initial deployment?

The DBE technology is a middleware that can be applied to an unlimited number of business cases and sectors. However, in the beginning it was necessary to concentrate the effort on one specific sector in order to guarantee efficiency. An intense in-depth consultancy study was performed in different sectors, and several variables were analyzed for each of them. It concluded that the tourism sector is a non-structured sector in the region of Aragon, mainly composed of small enterprises that have important difficulties when they try to compete with the large companies of the sector. The objective of the initial deployment was to involve the SMEs of the sector and not the large companies. Large enterprises already own mature systems and making them participate in this pilot would have been much more difficult.

Some other reasons for concluding that the tourism sector was the most suitable sector to deploy an initial pilot are that:

- The system supports a high number of interactions among the different agents participating in the pilot,
- The tourism sector represents an important share of the regional GDP, mainly in the rural areas,
- There is a balance of interest among the different actors in the sector, without a clear dominance,
- The sector has the need to modernize using new technology, and as a consequence its learning curve is short.

Which are the bootstrap strategy and engagement process in the region?

After an in-depth analysis, 4 main profiles of agents were identified in the region. It is important to differentiate between the agents according to these profiles and their objectives and actions. The profiles are:

- **Regional Catalyst.** It deploys the DBE platform in the region and oversees the objectives of the pilot projects. It also coordinates the recruitment and training activities.
- **SW Developer SMEs**. They develop applications in the tourism sector and have already deployed their solutions with real user SMEs. They are characterized by their high level of experience in the sector. They are the agents that have to be targeted first by awareness raising actions helping them to understand the DBE concepts and the potentialities of this technology.
- **User SMEs** in the tourism sector. In Aragon, they are customers of the SW Developer SMEs, whose SW applications are being used in real business. Through this involvement, their learning curve is minimized and the project resources are optimized.
- **Influencers.** They take the most important decisions in the region. They are the main political agents and the main advisors in the region. They receive requests for recommendations once a project is proposed by a *SW Developer SME* or a *User SME*. If the Influencers are already aware of a proposed project and have a positive opinion of it, the loop is closed and the success of this project is secured.

The **main chain of activities** for the bootstrapping process is the following:

- A survey is applied to all IST SMEs in the region, and the SMEs are classified according to their profiles.
- The support of the main political agents in the region is looked for.
- A 'one day' workshop to present the DBE project is organized with the support of the regional or local government, to which the main SW Developer SMEs are expected to attend.
- Personal interviews are scheduled with the interested SMEs. The aim of these interviews is to structure and clarify the work plan and the activities of these companies in case their final participation in the DBE project is accepted. The interviews also serve to explain the key DBE concepts.

Thus, the **engagement** of the SW Developer SMEs' was conceived in three phases. The main reasons for following this procedure are that:

- The feedback provided by the first groups could be used by the followers.
- The first groups help to obtain a more robust platform.
- They can give suggestions on how to improve the architecture and which new features could improve the platform.
- The last group of SMEs helps to check the robustness and usefulness of the platform (i.e. regarding the management of the platform and making the platform user-friendly).

As mentioned above, User SMEs have been engaged in the project through their SW providers in order to optimize the project resources.

At the time this paper is finalized (January 2007) the situation in Aragon is as follows:

- The first group of SW Developer SMEs (4 SMEs) has already finished their deployment. The User SMEs that are going to join the project (11 other SMEs) have already signed an agreement of participation and they are due to install the solutions in real business in the weeks that follow. Some new features have been added to their applications thanks to the new technology. They have also benefited from easier and faster integration of different technologies thanks to the DBE.

- The second group of SW Developer SMEs (8 SMEs) is still working on their deployment strategy. They have already defined what they are going to implement and each of them has already selected and engaged a minimum of 2 User SMEs.
- The third group of SW Developer SMEs (12 SMEs) has just started working. They do not include only SW Developer SMEs from the tourism sector, but also from other sectors. Like the second group, they have already defined their future implementation and have already selected and engaged a minimum of 2 User SMEs each.

It is expected that at the end of this regional engagement process, more than 30 SW Developer SMEs and more than 100 User SMEs will be involved.

What is expected to happen after the initial pilot deployment?

The DBE project itself has addressed sustainability and governance issues. This pilot is seeking to prove the DBE concepts, and validate the underlying technology. Moreover, it is helping to analyze the possibility of engaging in a large deployment supported by the SMEs themselves.

One initial achievement has already been accomplished, since the Government of Aragon has launched a call for tender for the creation of new services based on the DBE Technology in 2007. This call was closed on 30th of December 2006. The funding is for up to 153,000 euro and further activities are being planned. It is expected that the DBE will be able to provide more visibility to small hotels, and more dynamism to all the agents involved in the sector. It is also expected, as a secondary effect, to enlarge the market and improve the competences and capabilities of the regional SW Developer SMEs. In order to achieve the success of the project in this particular sector, it is essential to reach a critical mass of SMEs that decide to participate, implement, use and develop these services, in parallel with other SMEs from other sectors. This development has already started at different levels. Some SMEs are starting to create small joint ventures to adapt/create products using the DBE. In addition, some important large companies are interested in the project and its technology for a variety of reasons. The DBE allows large companies to identify the capabilities (products, services and skills) offered by SMEs in an easy and fast way. Large enterprises can also integrate their own activities and business in a very dynamic way.

If this milestone is achieved, it is expected that the use of the platform will be promoted in other sectors where the DBE tools may be a successful key to help unlock the local cooperation and growth potential.

4 The West Midlands regional catalyst role in the activation of the Digital Ecosystem

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Introduction

The purpose of this paper is to explain how the West Midlands regional catalyst operated within the digital business ecosystem project (DBE) between 2003 and 2007. Our position in the DBE has been that of a team of 6 people in UCE Birmingham Business School, England. We have been seeking to reach and recruit some 80 companies, who either create or use software services, to form a combined cross-regional pool of 250 companies whose collective services will populate the early digital business ecosystem. They range from the highly innovative software developer to the business willing to try out a new approach suggested by the catalyst or the innovator business.

At the start of the DBE project in 2003, our staff had some experience of working in a catalyst role in European IT programmes, so we knew in advance that the recruitment and subsequent support of such a large number of SMEs would be demanding. But by September of 2003, we realised that we needed to recruit a new team to meet the requirements of this project. This process of growth and expansion of our knowledge and competence has continued throughout the project. This project involved us learning about the DBE vision (Nachira, 2002; Censis, 2005; Salminem et al. 2004), and our own region's IT strategies and associations (Costello et al.2004; Advantage West Midlands, 2004-6; Sharpe, 2005; West Midlands Regional Observatory, 2005-6; Darking and Whitley, 2005).

Phase 1: The development of the early adopter group (2003-4)

At the start of the project, we faced the challenge of creating a critical mass of SMEs which would then use the Digital Ecosystem for managing all their business processes fostering innovation and growth. The process of creating this critical mass had to be gradual as there was nothing to show to them except a set of concepts and ideas. The team formulated an engagement strategy to help small groups of early adopter SMEs to buy in to the concepts and to jointly develop with us the benefits that an ecosystem could offer. This then could become the basis for the recruitment of many more SMEs with their services. This increase in population would create the emergent properties of an ecosystem such as learning, adaptation and niche positions.

Our early adopter of 'driver' SMEs were given small financial support towards their total costs (50% costs up to a maximum of 12,000 euros). Some candidate SMEs thought this amount was too small to justify their participation.

Less tangible attractors between catalysts and their eventual SME contractors that we offered included:

1. To be at the forefront of research into software development with IBM, Sun Microsystems(Barcelona), Intel, Soluta, and other university partners.
2. To gain a subsidy for existing research interests
3. To innovate and have some help with development costs.
4. To have some assistance in the development of the staff team
5. To get more business by connecting with other DBE companies
6. To take a new strategic direction.

The primary focus during this phase was to evaluate the ICT sector in the West Midlands through multiple contact points, share the DBE vision, explain the technology initiatives and the business opportunities the project could offer. This led to the exploration of the business model of each individual SME which had shown interest in the project and to mapping their skill sets and software application offerings to the objectives of DBE in the region.

Multiple one-to-one meetings, four workshops and three seminars to transfer knowledge in the region supported the training delivery during Phase 1. This has been done by developing and using appropriate learning content and also reusing content available in the public domain. These are in the form of Web Articles, Journal Articles, News Publications, White Papers and Public Presentations.

Given that the DBE was a new project and was creating disruptive technology elements, we recognized the need to pay early adopter SMEs for the work that they would be required to do compared with later adopters. This would cover the risks that the SMEs were taking on our behalf in terms of prejudicing their commercial viability or of the project not becoming a mainstream technology initiative.

A training plan was formulated to take the following actions:

- Push the early adoption of the DBE concepts in the region.
- Select 5-10 Driver SMEs and enable their active engagement in the DBE project.
- Explain the project opportunity to regional policy makers and IT community stakeholders.
- Create attractive DBE services to invite 10 to 20 Discoverer SMEs to use these services through the Driver SMEs.
- Help to develop the regional IT knowledge and business base.
- Sustain the regional IT based economic development.

The delivery of Phase 1 training was mainly through one-to-one interactions with SMEs on a monthly basis, group workshops and seminars. The focus was on the following learning blocks:

- DBE vision
- Engagement models
- Strategic benefits of participation
- DBE technical architecture
- Services development
- Open source business models
- Web services and
- Service oriented architectures.

The work in this phase generated interest in the project among policy makers in the regional development agency and amongst IT sector associations and their members. Later companies and public sector organizations which could see a benefit from the project engaged with us to envisage down-stream developments connected with their own projects.

As groups met, new alliances were formed between the participants, in some cases producing new business services which in part demonstrated some of the potential capacities of the DBE vision. We also experienced some limitations in the technology which caused delay and frustration for some of the software developers who had been keen to demonstrate secure and safe services to their business customers.

Phase 2-5 Implementing and evaluating DBE services (2005-7)

The common approach used across the three pilot regions having failed to yield the required results in terms of number or variety of developers joining the project, the regional catalysts decided to change their engagement processes in Phase 2 so as to be effective. The key changes were:

- Tampere becoming SME Driver centric – Developing services dependent on communities around the Open PSA service developed by Bergius for brokering and collaborating work between software developers
- Aragon becoming sector specific – Developing services for the tourism sector and enabling online transactions for the sector and
- West Midlands becoming intermediary focused – Developing services through three strategies around a regional ISP provider focusing on SMEs.

The differences in the approaches indicated to us that engagement in new technology interventions work better when they are aligned to the local regional and marketplace opportunities –as we recognized at the start of DBE– but that it takes time for the catalyst to learn precisely what form this should take. It may be here that collaboration between policy makers could in future help project leaders to become effective more rapidly.

Actions planned for Phase 2 of the learning delivery included:

- Development of DBE specific learning material based on internal documentation and extraction from public domain documents
- Creating regional case studies and customizing materials for each opportunity space such as tourism and manufacturing to explore business potentials
- Developing business presentations focusing on the business drivers for adoption
- Using multiple dissemination modes such as web logs, web contents, targeted publications and promotion events.

The focus groups for training were: SME Drivers, SME Implementers and the Regional Catalyst Associates. As the nature of the players varied in terms of areas of interest, skill sets, role in the region, and nature of establishment we had to design different trainings programmes using different delivery methods.

In brief the training programme delivered during Phase 2 included:

- DBE Technical and Business aspects
  ExE, DBEStudio, BML, Business Models, Service Development (UCE developed services), etc.
- Technological Principles/Ideas/Philosophies
  Service Oriented Architectures (SOAs), "Software as a Service", Peer to Peer Networks, Semantic Descriptions, Ontologies, Open Source/Standards, Model Driven Architectures (MDA), etc.
- Ten Workshops, two "Code Camps" & Programming Sessions
- Four Open day sessions for interested Implementer SMEs
- Reuse of project dissemination material.

The training programme for each focus group during Phase 2 comprised the following competency areas and activities.

DBE Architecture

EXECUTION ENVIRONMENT THE FEATURES OF FADA AND SERVENT AND ITS IMPLEMENTATION REQUIREMENTS

The SME Drivers were required to implement the DBE architecture by following an approach similar to that used in the implementation of the DBE architecture at UCE. This helps them to host their services and to test the aspects of finding distributed services. UCE now hosts a dedicated DBE node that allows the hosting of services developed at UCE and also as an initial node that can be used by the SME Drivers to implement their services. This node has been actively used for all purposes of training in the region. In order to get the Driver SMEs started with their tasks, we planned to use the web log (http://opensoa.blogspot.com) documents where there were two example applications which required the installation of ServENT and FADA on the SME's computers. These two example services demonstrated what a real world service might be like and, more significantly, how to create and implement it in the DBE. The web address of the node implemented by UCE is: http://193.60.142.10:2002/

The delivery methods adopted primarily involved one-to-one and code camps.

Development Environment

ECLIPSE, DBE STUDIO – BML 1.0, SDL & WRAPPER DEVELOPMENT

The training included a step-by-step approach to creating DBE services. The example services created by the DBE project partners and the UCE were mainly used to demonstrate how the DBE services can be created. The key examples used were: Bluetooth, Date Service and Camera Service. The UCE team also developed a guide to migrating Web Services to DBE. This was very helpful as most of the SMEs were able to relate to the concepts and appreciate the simplicity in migration from other standards. Further there has been an on-going discussion related to the client UI. Different approaches have been discussed and proposed including Flash, Java Swing, etc.

The DBE project had evaluated the different options and found Open Laszlo to be a good option to develop the client UI. UCE has focused on this UI development and has developed an example and a tutorial to demonstrate the superior capabilities of Open Laszlo and its integration requirements into DBE.

The DBE Studio was evaluated in great detail, along with the Driver SMEs, using SWOT analysis also shown in the picture below. The following points summarize this analysis:

- Gap between DBE Studio and ExE
  (code generation and deployment – CIM ->PIM -> PSM->Code)
- Defining BML models is UML based and it is not intuitive
- There is no clear advantage in modelling services with BML
- Require more information related to SBVR – More change creates more work
- Versioning and stability have been concerns
- The DBE Architecture is very interesting: Eclipse IDE, easy possibility of migration of services from other technologies.
- Syntactic and Semantic description of services

Business Aspects

NEW BUSINESS MODELS, BUSINESS PROCESSES FOR MANUFACTURING AND TOURISM OPPORTUNITY SPACES AND COMMERCIAL BENEFITS FOR AN MDA APPROACH

It is imperative to understand that there is no single dominant effect or cost advantage that will provide a long-term sustainable competitive advantage to a business. The choices of operating business model are based on certain elements that are dynamic in nature (Alt and Zimmermann, 2001). Business model transformation requires reconfiguration of value chains, business processes, organization structure and value offerings (Lee, 2001).

Three broad business models are adopted by software developer firms. These are: Open Source Software Model; Commercial Software Model and Hybrid Software Model. Each of these models has many sub-types which are based on the different influencing factors. Most of the software developers have traditionally adopted the commercial software model. In recent times, due to the influence of open source initiatives both from governments and large firms, the trend is shifting towards adoption of the hybrid software model. In the hybrid software model, software that has a higher intellectual involvement is offered under a commercial agreement while that with lesser intellectual involvement is offered under an open source agreement. The aim of the training in this area was to evaluate the influence of DBE on these three broad business models, their sub-types and the development of new business models as some of the existing business models are already undergoing a change.

The DBE project provides a good opportunity for understanding the nature and the business dynamics of a business ecosystem based on Internet-based technologies. This is likely to provide a platform for extending this understanding to other business ecosystems that are based on other considerations than technology, for example political, economic, social and industrial requirements.

Since the regional focus for software service development was on Manufacturing and Tourism sectors, the UCE team was involved in exploring the generic business process within these sectors. The UCE team was additionally responsible for the development of M1 business models and helped in playing a vital role in the training of BML 1.0 to the Driver SMEs. Also alternative MDA based approaches were explored using UML based toolsets such as CodeGenie[1]. This business modelling opportunity provided insights into the service composition needs in order to serve the requirements of different business models.

1) http://www.domainsolutions.co.uk

Publication for Engagement

UCE ALIGNED ITS CALL FOR ENGAGEMENT OF IMPLEMENTER SMES WITH THE TWO OTHER REGIONAL CATALYSTS

The first step was to facilitate the awareness of the DBE project and to create interest for engagement through open days. Two such open days were held within the region by publishing the details about DBE on the web sites of regional associates. The open days were organized in two sessions, which included presentations about DBE, business potentials, service development & integration, regional requirements, demonstration of sample services, a brief hands on and Q&A for clarifications. In all, eight new SMEs were introduced during the open days. Most of these new SMEs showed interest in the long term objectives of the DBE project, while showing concern about the research nature of the project, its commercial viability and also the support for funding.

As part of the Phase 3-5 training delivery, UCE had proposed to continue the training plan as proposed in Phase 2 but to spend more training time and effort with the SME Implementers. At the same time we were spending time and efforts towards developing and demonstrating some attractor services including killer application services. The possibility of making a composite service delivery through the local ISP provider was expected to remain the key focus. UCE proposed to focus on SME workshops, demonstration events and the exploration of inter-regional collaborations.

Further development of the DBE architecture being delayed, UCE had to decide to manage the engagement process through the development of a 'Search and Discovery' (S&D) service. This was an alternative to the composite service development planned with the regional ISP. The S&D service was developed using the capabilities of Business Modelling Language 1.0 (BML 1.0). BML 1.0 would support the codification of skill sets, capabilities and knowledge within SMEs facilitating a search that is more meaningful and fit for purpose. The search feature would be the basis for linking web designers and users of web design service – connecting supply and demand. To support this process, UCE planned to use a public relationship (PR) approach and create specific material for distribution through multiple channels.

A similar approach was planned to support the development of business opportunities for the Jewellery Quarters located in Birmingham. The initiative was managed by one of the driver SMEs engaged in the DBE project. The set of services that were explored for integration included S&D and supply chain management to manage work-flow beyond the boundaries of each of the SMEs

Immediate sustainability and dissemination plans

INTER-REGIONAL COLLABORATIONS WERE EXPLORED IN THE LATER PHASES OF THE DBE PROJECT

Particular interest was shown by regions in India. A code camp was convened to create awareness and interest for participation in the future opportunities in the area of Digital Ecosystems.

UCE has continually explored the opportunities for collaboration with other International, EU, National and Regional projects. UCE explored possibilities for future engagements. The four strands considered include:

- Centre for Business Software – To support regional software developers to compete and collaborate in the highly competent and complex software development areas
- Anubis WM – Increasing ICT uptake through micro-financing support
- InfoWeb – Codification of regional knowledge and skill sets using formal and structured languages.

There was a delay in the availability of the DBE technical architecture and this to a large extent created a hiatus in the development efforts of the Driver and Implementer SMEs. However, our actions focusing on specific services, target groups, inter-project collaborations, regional catalyst associations, regional development agencies and business intermediaries have been influential in creating a strong position for the DBE project in the region, and have also fostered creating successful international links.

Conclusion

We have gradually identified the relevant people and agencies in our region and found how they are prepared to collaborate with us. Gaining their trust and understanding whilst we have been researching and developing ourselves has been a patient process especially when we became aware of the different paths other regions such as Aragon and Tampere were on and trying to keep in step with them. As part of this, we recruited new staff to the team to give us more technical skills, so that we could take on more work and deal with the needs of the SMEs for advice and examples of what the DBE could enable.

Our past experience with knowledge management had given us some feel for requirements, but the DBE was more complex. We came increasingly to the need to fit DBE with regional strategy and policy in order to relate well to development agencies and others in the region.

The speed of regional adoption of the DBE was influenced by this absorptive capacity issue –the ability to understand a new and complex idea quickly, relate it to existing projects and policies, and marshall desirable resources in the region behind it– gradually took on greater significance and is a current interest.

We now see the value of involving high-level private and public sector people together to achieve the necessary movement. Looking around our region we see a plethora of agencies concerned with ICT, but the gaps and barriers between them leave one feeling that greater coordination in the research, development and innovation process is desirable (Shelton et al.2006a and 2006b).

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5 Evolution of a Digital Ecosystem for Knowledge Services to Indian Agriculture

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Cooperative efforts of experts from apparently unrelated domains: farmers and agricultural scientists working with computer scientists and economists can lead to effective knowledge creation and growth. Relevant information at the right time could provide farmers with the appropriate tools to make more economically sound decisions. This process of decision making could enhance their competitiveness and, as a result, improve well being. This is the main objective of the project "*The digital ecosystem for agricultural livelihood (DEAL)*".

Developing such an ecosystem requires the development of peer to peer networks, classification schemes, controlled vocabularies, thesauri, authority files, and glossaries as well as the creation of semantic standards for exchange of high quality metadata. The semantic framework would comprise shared data exchange standards and instruments that would allow services exchange (interoperability) between collection of information and knowledge.

There is a need to consult, inform, orient, and involve stakeholders (NGOs, farmers and administrators) in developing, sharing and refining the content of the open knowledge space. This is particularly important since the aim is to facilitate interaction between peers on all relevant issues and to share resources and experiences. This paper explores the crucial elements which lead to the creation of relevant content for effective deployment and use of socio technical networks in the context of Indian agriculture. Identifying and applying alternative roadmaps for self-sustainability and growth of socio- technical networks for enhancing knowledge sharing would lead to our ultimate goal of achieving regional development.

Introduction

Information and communications technologies (ICTs) are present (either in large or small scale) and developing in every area of economic, social, and political activity. Due to the networking possibilities they enable, ICTs reduce transactions costs and change the structure of markets and institutions, resulting in an immediate increase in the potential value of human capital. Further, they embody an enormous amount of knowledge and can serve to empower people at local and national levels.

In India, the adoption and development of ICTs in the agricultural sector takes place through thousands of specific initiatives led by communities and development, donor, and business organizations. The implementation of effective ICT deployment can be a challenge for a diffuse network[1] of local innovation systems, since it requires local knowledge, literacy, skills development, technical capability and effort. There is, however, a government established top-down network of agricultural extension counters called 'Krishi Vigyan Kendras' (KVKs) which could be used to link India's geographically and culturally dispersed rural community.

Agricultural and food security policymakers clearly see the need for knowledge connectivity from the academic/research institutes to the villages and then, from these to the world. The 'best' practices can enhance India's agricultural efficiency, create the "next" practices and promote new opportunities for rural livelihood. There is a national agenda for creating knowledge centres in every village. Nevertheless, the 'soft side' of this challenge needs more attention. There is no concerted effort to create a national 'digital' agricultural knowledge repository that is alive and nurtured daily through feeding, weeding, and pruning (or enriched by interactive usage). A large part of useful unstructured information or tacit knowledge remains at local level. Moreover, agriculture is among the most complex commercial systems, since it requires inputs from myriads of sources including soil, water, environment, goods, asset and labour markets. A detailed study conducted by the Asia-Pacific Research Centre of the Stanford University tried to assess the socio-economic impact of 9 major ICT initiatives in India to conclude that the usage of ICT was sparse in comparison with its potential. The results of a questionnaire survey applied to the potential users of ICT and ICT providers (usually called "infomediaries") to explore the gap between actual and potential ICT usage shows that the majority of the users consider the lack of availability of useful content and programs the significant impeding factors for the use of ICT, whilst fewer 'infomediaries' had a similar opinion. The creation, dissemination and enhancement of appropriate, timely and relevant content for the farmer (user) is the focus of the *'Digital Ecosystem for Agriculture & rural Livelihood (DEAL)'* project (www.dealindia.org).

The digital ecosystem (DE) is an approach through which one can ensure relevant and timely content availability to the rural community through dynamic and amorphous interaction among a multiplicity of small entities to support knowledge sharing, co-creation of knowledge and developing new business models. Moreover, the diffusion and use of ICT can be self sustaining and self enabling despite technological and literacy barriers.

This paper documents our experience from being involved in developing and implementing a DE for knowledge diffusion in rural India. The sustainability of the initiative is associated with challenges due to language and literacy barriers, resource scarcity, dominance of top-down solutions and limited existence of successful participative business models. A DE for agriculture gives farmers from less developed and remote areas opportunities to participate in the global economy. This results in dynamic knowledge sharing and global cooperation among farmers and the world community, fostering as a consequence local economic growth. Co-creation and self-management of digital contents to support agriculture and rural livelihood development activities would result in access to the appropriate information at the right time, resulting in inclusive growth as well as competitive agriculture. It also facilitates cooperation between farmers and agricultural scientists which is critical for further technological progress in agriculture, whether with respect to innovation or technology adoption.

A Pathway to Information Design for Knowledge Diffusion in Rural India

Quick dissemination of technical information from the agricultural research system to the farmers, and its adaptation to the different soil and climatic conditions will result in increased agricultural productivity. Thus, the 'one-way route' of India's conventional agricultural extension system needs rapid transformation to a 'real time and adaptive' knowledge exchange network. The network can provide the necessary traction from other industrial and business knowledge management technologies and processes such as user to user exchange, expert to expert exchange and KM oriented standards for information storage, retrieval and aggregation with analytics.

Limitations of the 'face to face' Transfer of Technology (TOT) model remains a challenge for the public and private extension systems since there are at least 400,000 medium and large villages that need to be reached spread over a subcontinent. With the availability of telephone and Internet, it is now possible to reduce this gap to a large extent, but

1) It is estimated that there are over 104 million farm families spread over more than 590 rural districts and six lake villages (Rai, 2006).

only if an appropriate mix of technologies can deliver 'dynamic content' in response to 'user pull'. Unless the content is 'problem-solving oriented' in order to help farmers take risks in venturing out to crop diversification and the adoption of new processes, the TOT cannot produce a real impact in alleviating rural poverty through competitiveness improvement. A digital ecosystem can help break down the barriers in both, horizontal and vertical knowledge, since it entails a series of interconnected and intra-dependant digital platforms, that are created at key institutional levels (international, national and local/community), and augmented by technical (ICT) and social networking processes.

The Agricultural Ecosystem

An agricultural ecosystem is a unique and reasonably stable dynamic arrangement of farm enterprises, managed by a household in response to the physical, biological and socioeconomic environments. There could be several interacting subsystems within this large ecosystem (as at the regional level), and equally relevant non agricultural systems (as the market system, the rural credit system, etc). Agricultural subsystems include the crop ecosystem, animal ecosystem, soil, weed and insect ecosystem, all of them interacting and depending on each other. We can also find as part of the agricultural ecosystem, farm related factors and inputs such as weather conditions, type of soil, stage of incidence or intensity of weeds; and socio-economic factors, such as availability and nature of credit, costs of agricultural inputs, price of end-products, farmers' personal objectives and resources, etc. An ideal knowledge ecosystem for agriculture would be able to capture all these intricacies and build a large knowledge sharing database to ensure that the implicit knowledge or experience of one farmer is shared with many others without requiring the 'face to face' connection over geographically or temporally separated regions.

Implementation

Figure 3 shows the information flow for rural development activities. From the beginning, there was a need to develop a common ontology, a semantic interoperability that facilitates knowledge storage, retrieval and exchange within the network among the different stakeholders so that a knowledge ecosystem could be developed. In order to create this network, a successful implementation of a knowledge system was required. This included the development of digital content from the tacit knowledge of Krishi Vigyan Kendras (and other frontline entities) through multiple media (i.e. landline phone, mobile phone, audio-video recording and digitization of paper documents). Open content and open source optimization was also needed to make the technology tools affordable and available to everyone while evolving. In order to deal with the language and education divide, "citizen interfaces" to facilitate the access of the users to the extensive knowledge base were required. Because these interfaces are meant to be easily accessed by 'rural citizens', they could be iconic, graphical, or symbolic user interfaces that relate to the ontology. Examples of technology applications are: the touch screen, text to speech, screen reader, visualization and animation, interactive voice-response system computer-telephony integration and application of wireless data services like MMS. Digital content interfaces and tools for a easy user (frontend and backend) interaction with the knowledge base using telephone, mobile data and FM radio were also developed.

Partnerships were created with existing 'tele-centers' in rural institutes, village schools and Krishi Vigyan Kendras. There is an inherent advantage in using an existing physical infrastructure because it only has to be extended to the project requirements. Also, some of the ICT training can be cost-effectively integrated into the mainstream curriculum of these institutions. A conceptual architecture of the desired knowledge-net was built after several brain-storming sessions with the stakeholders of the DEAL project, as seen in Figure 2.

It is clear that, in order to acquire the characteristics of a self-managed ecosystem, 'interoperability' is needed. Particularly in this knowledge-net whose digital contents are created in different forms by its stakeholders. Interoperability provides potential for guaranteed automation and systemic self-management. Initial experiments within the digital repositories of the project stakeholders showed that syntactic interoperability can be achieved for transfer, exchange, mediation and integration of content. This could be achieved by adopting compatible forms of encoding, accessing protocols and designing guidelines. Identification and naming schemas are important at this stage for pulling together common information.

Lessons

During the implementation of the DEAL project, we encountered the existence of several barriers to information access. These barriers are physical, economic, intellectual or technological, and they usually impede the participation of rural users in the activities that contribute to the digital knowledge repository (see Kralisch and Mandl, 2006).

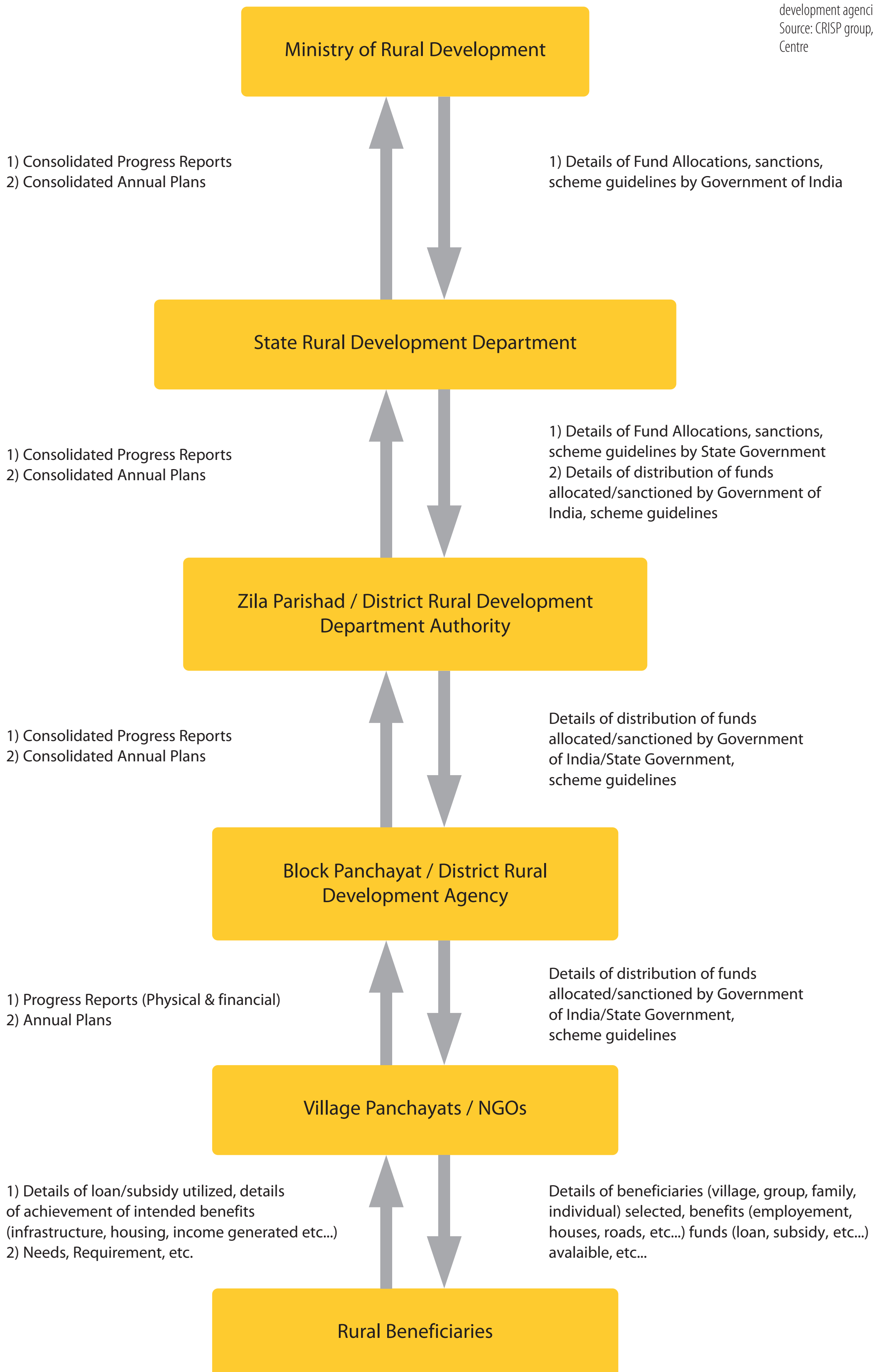


Fig. 1

Typical flow of information among rural development agencies.
Source: CRISP group, National Informatics Centre

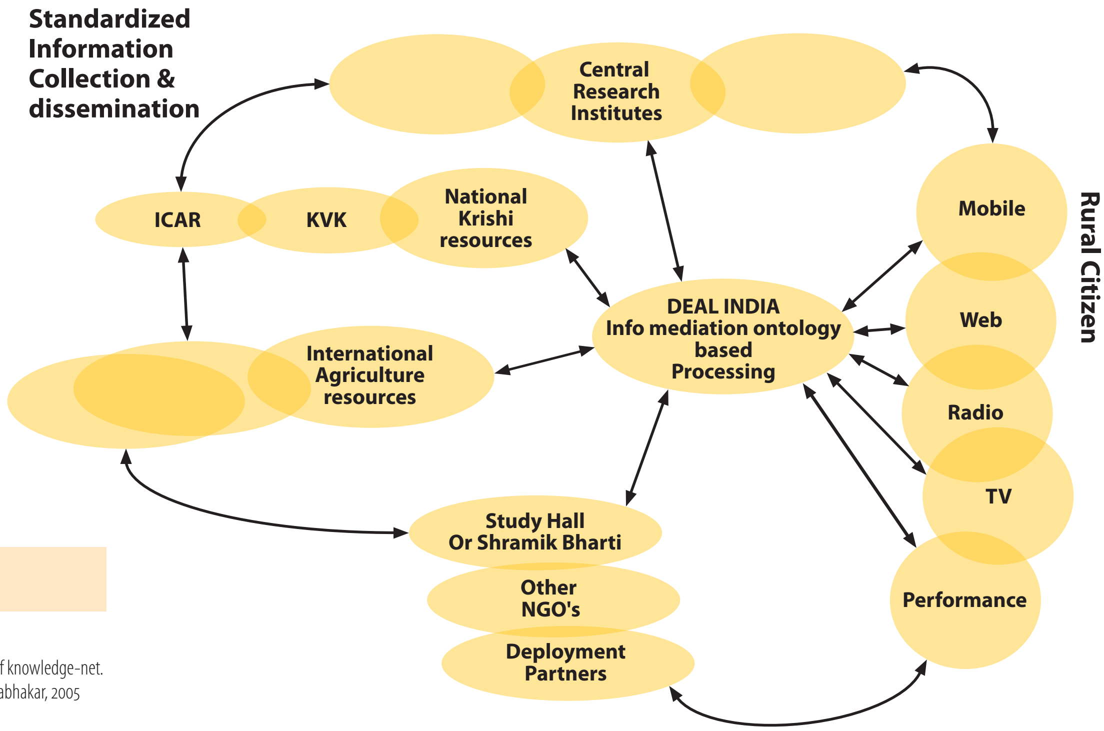


Fig. 2

Conceptual architecture of knowledge-net.
Source: Chatterjee and Prabhakar, 2005

The architects and system designers did not impose the barriers directly, but their lack of action and understanding of the critical user conditions contributed to the formation of these barriers. Other factors, such as demographic, geographic, cultural, social, psychological and economic factors also contribute to the critical conditions of users. Issues related to Information system usability such as ease of use, usefulness (Davis, 1989), decision effectiveness, user response, and user satisfaction (Doll et. al., 1988) have been studied in great detail. Nevertheless, interactions with focus groups at different agricultural market places around Lucknow-Kanpur showed the necessity of developing a more detailed study focusing in different set of priorities.

A general framework for web design that includes human-computer interaction theories (Pirolli, 2001), website usability principles (Huang, 2003), information intensity paradigms (Palmer and Griffith, 1998) and e-customization models is already in place and it is assumed that it sufficiently addresses the question of the definition of broad guidelines for designing any successful website. Following this principle, it was assumed that in order to have a successful website universally accepted (and therefore also in India), it should have accurate, up-to-date and pertinent content. Also, it should be user-friendly customized to particular user groups, and tailored to specific geographical needs. In the case of rural India, it was found that the challenges to agricultural and rural livelihood website usability arise mainly because of the specificity of local needs and the great diversity of the local conditions. The major challenges identified were:

- Poor literacy rate. Low use of written information in daily life and high reliance on oral communication for knowledge transfer.
- Remote village locations. Geographical distances compounding problems of dependence on intermediaries and a nexus of exploitation through information asymmetry.
- Absence of information in vernacular languages (both a cause and an effect).
- Unavailability of economic, low-cost solutions. Any technology solution aimed at benefiting rural India must be affordable and low-cost. The perceived economic benefits of such an endeavor must be higher than the cost of switching over to a different technological solution.

But there were more lessons. The project soon revealed that without a self managed, evolving, ecosystem working as a knowledge repository the editorial overhead remained high and expensive. Users must be able to co-create content and this content could be also "tagged" in order to be recalled and reused in multiple contexts.

The initial research at DEAL showed that the existence of a number of desired features in any ICT system especially designed for rural India leads to higher user satisfaction. Such features aim to satisfy one or many of the following immediate user objectives:

- Ease of access and lower cost of transaction
- Up-to-date content
- Layout, design, consistent themes leading to easy navigation

- Higher interactivity
- Accessibility through multiple media (particularly voice) and higher use of non-textual information
- Language options

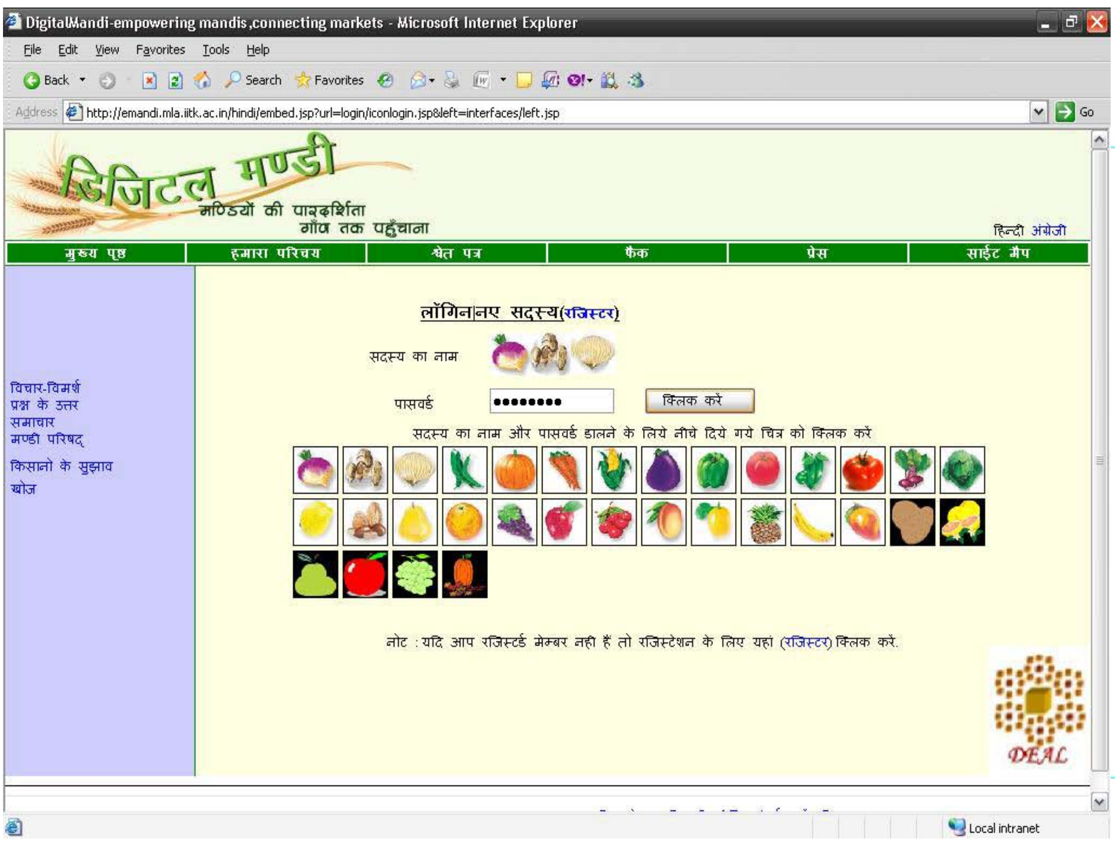
Written information is a challenge, especially at the content creation stage, because most of the farmers are quasi-literate. 'Audio-content' is often the only way under which we can operate. Audio-content is easy and natural to create, and as a consequence it is easily accepted by the creator, the listener and the community. Nevertheless, indexing and searching 'audio-content' poses problems and requires manual intervention.

Figure 3 shows a sample page of the user interface addressing some of these issues. The user IDs and passwords are introduced with the help of icons. The alphabet consists of icons of fruits and vegetables and the users can 'spell' their user names and passwords using this alphabet (i.e. the user can choose a tomato, two onions and a potato as the 'User Name' and another such combination as the password).

A computer based platform appears difficult to maintain because of various reasons. There is the cost of the computer, but there are also problems related to the erratic power and electricity provision. One needs to think of backup power sources like batteries, uninterrupted power supplies and generating sets making the feasibility of the whole solution untenable. A mobile device, like a phone or a PDA, appears to be the most appropriate delivery platform.

The DEAL project thus revealed that ICT tools and technologies could make knowledge and 'in the field' experiences (in the form of digital content) widely available. Ethnographic observation guided design principles, which improved the access and acceptance by rural citizens. Nevertheless, the maintenance, dynamic update and enhancement of the digital content needed regular editorial intervention and the process of finding and assembling information remained largely a manual task. Interoperability is needed in order to achieve automation and systemic self management in the knowledge net, because digital contents are created in various forms by different stakeholders. While initial experiments showed that such syntactic interoperability can be achieved and enforced with the use of a corporate extranet, continuous socio-technical difficulties and the existence of multiple hardware/software in the network pose problems in the domain of rural livelihood.

Fig. 3
Iconic Logic in the Web interface for the DEAL Project



Benefits

Although the benefits resulting from the DEAL project have not been formally documented, some observations can be made. First, the 'ecosystem' approach sped up the process of identification, development and uptake of innovation. Second, rural entrepreneurs benefited from the project because the DE helped them to improve their access to markets and/or supply chains and provided them with a broader base for decision-making.

Moreover, it has been reported by several researchers that in many local communities ICT has increased bottom-up participation in the governance process and helps to expand the reach and accessibility of government services and public infrastructure (Dossani, Misra and Jhaveri, 2005). We have not tested this in the DEAL project, primarily because the mandate of the project was more focused on creating a self sustaining ICT platform rather than conducting a social experiment.

Conclusions

A digital business ecosystem, as a platform to foster business networks, based on a dynamic and amorphous interaction among a multiplicity of firms, is a self sustaining mechanism of ICT adoption and development. It supports knowledge sharing and skill development. This paper analyzed the 'learning from using' semantic web technologies to construct agricultural portals that address the need for customization and localization at the rural level. The digital ecosystem for agriculture and rural livelihood (DEAL) project is an ambitious web based initiative that coordinates back-end infrastructure, media technology and knowledge in order to make agricultural content accessible through multiple channels in rural India. It attempts to overcome language and literacy barriers by the development of iconic, symbolic and visual overlays on knowledge maps. Existing Krishi Vigyan Kendras serve as nodes and catalysts for knowledge-driven self-generative socioeconomic development that nurture innovation in rural livelihood models. By activating and/or strengthening knowledge, skills, technology and market links, the DE is an instrument to preserve and nurture the wisdom of the farmers while improving their agricultural competitiveness.

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6 DBE in Ireland: an Irish Open & Connected Digital Ecosystem Initiative

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Introduction

Enabling sustainable local communities is a high priority for many regions of Europe. Policy and socio-economic strategy are increasingly taking this need into consideration in their medium- to long-term planning. Economically sustainable local communities are very important for the development of regions and for safeguarding the identity, culture and economic development/viability of these regions.

Competitiveness within a global Digital Economy is essential to sustain Ireland's current economic well-being, and all businesses will need to be knowledge-driven and dynamic within a digital context. Small-to-Medium sized Enterprises (SMEs) are vital to the Irish economy and, as is the case across Europe, are particularly at risk of falling to the wrong side of the Digital Divide.

The Project

This Irish initiative will draw directly on the output of the DBE project. *Intel Ireland* as a partner within the DBE project, in cooperation with the *National Institute of Regional and Spatial Analysis* (NIRSA), propose the establishment of such an Open and Connected Platform to enable the growth of targeted [specific] business sectors/clusters in Ireland. The intention is to draw directly on the experience of the other international pilots that are already up and running. This initiative could be the first building-block towards a network of regions that would enable the cross-fertilization of knowledge around Digital and Innovation Ecosystems and contribute towards enabling the exchange of information and business-to-business transactions between SMEs from these regions.

Technically the digital platforms will be created with the following value propositions. To:

- Create initial web presence for SMEs.
- Broaden market reach for SMEs.
- Make service providers easily available to SMEs and their Customers.
- Facilitate value chain creation and expansion among SMEs.
- Generate innovative, inter-operable ICT applications *by* and *for* SMEs.
- Facilitate regional and cross-regional/cluster growth via extended product and service offerings and broadened market reach.
- Assist business and client decision-making and day-to-day productivity by developing an integrated information platform using GIS technology to provide more, and higher quality, data to SMEs and their customers.

Potential Impact

This Open and Connected Platform will lower the cost of entry and lessen technical barriers for SMEs, enabling them to realise the potential of on-line and connected business interoperability of SME applications, which in turn will pave the way for SME involvement in the knowledge economy and thereby increase their competitiveness. The enhanced cooperation between SMEs in a given sector, virtual cluster or even in a particular region, will also have the effect of increasing the trust, cooperation and knowledge sharing required to enable that knowledge economy to thrive.

This initiative is also one of the building blocks for the creation of sustainable communities. By adapting itself to the regions, the DBE[1] will form the main knowledge and exchange platform that will not only enable a better creation, exchange and sharing of knowledge but also facilitate simultaneous real-world business transactions. The platform can interconnect with other relevant players of the ecosystem/s, such as schools, universities and local government. The large scale *regional* ecosystem can become digitally enabled, active, and interconnected, and evolve with and support the region, thus facilitating the emergence, growth and sustainability of the social capital of local communities. As the local community enlarges and gains strength it becomes more viable and attractive to other regions/value chains etc. And so the chain evolves and expands.

Potential Sectors in Ireland

Several enterprises expressed their interest in having a Business Ecosystem deployed in their area. Thus, leveraging the expertise gained via the DBE project, together with NIRSA, Intel Ireland has already explored a number of potential initial sectors. Particularly suitable sectors include Biotechnology and Digital Media in the greater Meath/Kildare region. This region located in the greater commuter belt of Dublin (and which can also include Dublin city), is particularly suited to, and interested in, the application of DE technology as these sectors in this particular region provide suitable SMEs for DE application and also an availability of suitably skilled labour. This region is synonymous with a large, highly skilled workforce which endures an arduous daily commuting to the capital for work opportunities, whilst there is a concentration of SMEs in the area, which if more digitally enabled and interconnected could provide welcome local employment.

Current/On-going Status of this Irish Open and Connected Digital Ecosystem Initiative

At the time of writing, this initiative has been welcomed by Irish Development Authorities and research into specific funding mechanisms is now in place. Local development authorities have embraced the DE approach/concept as not only suitable and applicable to, but also viable for the Meath/Kildare region, both in terms of short-term local, economic feasibility *and* long-term strategy.

Intel and NIRSA[2] have put in place an official proposal for the implementation of an Open and Connected Digital Ecosystem for the above region and are identifying specific SMEs for initial implementation.

1) Reference DBE: www.digital-ecosystem.org and www.digital-ecosystems.org
2) Reference contributing partners to this proposal: www.nuim.ie/nirsa and www.intel.com

We are looking forward to, not only enhancing this *Irish* region's cultural, social and economic viability via Digital Ecosystems but also enabling its cooperation with the already existing DBE pilot regions and thereby contributing to the ongoing proliferation of Digital Ecosystems across the Europe and beyond.

It is our aim to ensure a suitable and successful application and implementation of the DBE architecture and concept to the benefit of this region, its value chains and development strategies. And in turn, substantiate the necessity and viability of applied Digital Ecosystems to SMEs across Europe, in this case, in Ireland, a hot bed of ICT innovation in Europe.

Future possibilities

The potential of using and re-using the technological assets (i.e. the DBE platform and its components) as well as the results of the extensive research achieved by the DBE project team in the various domains triggers the possibility of creating a data Commons platform for Ireland. This platform could facilitate the interoperability between the different County Councils in the Country, enabling them to exchange information, as well as services. In addition to enabling enhanced interoperability of the County Councils and the possibility to create new services for Citizens, this platform could also offer access to the data and information available from these local government agencies. Citizens, companies, government departments and universities will then be able to access all this information.

7 Synergies between Pontos de Cultura and Ecosystems

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Abstract

Amongst the emergent forms of collaborative use of digital technologies it is possible to identify an innovative practise and experimentation, the Brazilian experience of the *Pontos de Cultura*[1], a priority action within the Programme "Cultura Viva" of the Ministry of Culture of Brazil that contributes to the creation of a grassroot digital ecosystem promoting Culture, Education and Citizenship. The methodologies of transfer of knowledge and the processes of collaboration and cooperation experimented in the deployment of the *Pontos de Cultura* can help to enhance the training and knowledge contents, which in the digital business ecosystem (DBE) still appear to be rather rudimental.

In addition the two initiatives would complement each other, representing an interesting case of cultural cross-fertilisation. The usage of digital ecosystem technologies within the "*Pontos*", and its adaptation to local needs, would turn the "*Pontos*" into incubators of new economic activities, contributing to the economic sustainability of the "*Pontos*". Each "*Pontos*" and each community could become a DBE and will contribute to the constant evolution of the network of digital ecosystems and their extension.

This paper presents the experience of the deployment of the "*Pontos de Cultura*" in Brazil and its transposition to Europe.

1) http://www.cultura.gov.br/programas_e_acoes/cultura_viva/programa_cultura_viva/pontos_de_cultura/index.html

Introduction

Brazil constitutes a very interesting case study for the approach being adopted to "enter into the information society". Over a few years, Brazil has developed its own way of bridging the existing gaps using the dissemination of digital technologies as a qualifying factor of overall development. Building digital inclusion policies, the Brazilian Government based its choice on key factors concerning the specific socio-cultural characteristics of the country.

Brazilian society is characterized by an anthropological complexity with the coexistence of different "sub-cultures" that have been able to mix and create a specific cultural identity that finds its higher forms of expression in the Brazilian music and dance. These forms of expression represent an element of strong internal cohesion and of strong cultural identity to transmit to the outside. A second key element in Brazilian society is the strong communitarian basis of society: groups of people establish relations of solidarity to promote many initiatives and to organize their social life (Bauman, 2003). The Brazilian Government's policy of digital inclusion, and in particular the digital culture policy of the Minister of Culture, centred around these socio-anthropological factors, has shown to be effective.

The choice of technological tools based on free software and the collaborative and cooperative approach to digital culture contributed to the success of this policy. Through the creation of teams ("Equipe") composed of young researchers and free software developers, they also developed the methodology to share the knowledge and disseminate the technological competences to the highest number of people, which now master the technologies and the production of contents. As a consequence of this strategy, there is today in Brazil a large and growing number of motivated communities of users and producers of contents and technology. These communities constitute the dynamic element of a complex digital cultural ecosystem and are able to produce contents, provide services and to extend their activities beyond the national border through transnational cooperation. The experience of cooperation between Brazil and the Region of Lazio in Italy, reported in this article, is one experiment that goes in this direction.

The analysis of the Brazilian experience of Pontos de Cultura has moreover concurred to evidence multiple elements of convergence existing between Pontos de Cultura and the Digital Business Ecosystem experience developed in some European Regions.

The exchange and integration of some aspects and practices developed by these two projects is likely to strengthen both of them, as well as their final outcomes.

The context: Brazil and digital inclusion

In Brazil, the policy of digital inclusion linked to the use of free and open source software brought about many initiatives for sustainable development in the country to fight poverty and digital exclusion. In a country like Brazil, with an illiteracy rate of 11.4% and 50.7% of the population earning less than minimum salary[2], what does one mean by digital exclusion?

One basic component of digital inclusion regards access to a computer and the basic knowledge of how to use it, and access to the Internet. Today in Brazil only 10.6% of the population have a computer at home, in a context in which less than 40% have a telephone line, only 20% of people are connected to the global computer network and only 8% have broadband access[3]. The situation in the education system is no better: only 37% of the students have access to the internet in the schools[4]. Here we can clearly see a digital divide between geographical areas at different stages of development, now that information is the dominant productive force in a "networked society" and has become a basic social resource. In this perspective, it is strategic for developing countries to spread the use of ICT to empower society and to keep the knowledge to use and develop this technology. The problem for Brazil is to avoid that the information technology be used to speed up the gap between social segments and limit the redistribution of wealth produced in society. (Silveira, and Cassino, 2003)

Fighting against social exclusion means to regain public space and to promote the social reappropriation of new technology, to stop the growing social gap between the included and excluded of the information society. This gap is leading to a society where the communities are not able to produce and to use technology for social needs.

2) Fonte IBGE, Pesquisa Nacional por Amostra de Domicilios 2001
3) Pesquisa Ibope, Internet POP,Oct./Nov. 2001
4) Ministério da Educação e Cultura, Brasil

The figures provided by Unicef are clear: in South America at the beginning of the 21st century, 60% of the children are poor, without access to food and medicine, and their mortality rate is 4 times higher than in developed countries. The information revolution, as a negative effect of neo-liberal globalization, did not have positive effects on reducing poverty on the continent.

The only way to react to this situation for Brazil has been to fight for digital inclusion and to give to the communities and to the most excluded groups the possibility, not only to access, but also to produce knowledge in the digital era. In Brazil there has been a large consensus on the need for developing public policies of digital inclusion, recognizing that digital exclusion stops human development, both local and national. Digital inclusion policies are intended to give autonomy to the most excluded groups and to encourage the process of creating their identity in the cyberspace. This process helps to keep diversity and multiculturalism starting from the community creation of cultural contents through the internet using information and communication technology to gain a new citizenship (Castells, 2004). Digital alphabetization will depend on the action of the Government and not only on market forces, so that freedom of expression and the right to communicate are not considered a privilege but a social right for all of society. The right to communicate is considered a question of citizenship rights: access to internet and the possibility to freely communicate and to master digital technology are what we can call "new social rights" in the information age.

Since 2000, the Brazilian Government has put in place an integrated policy on digital inclusion, access to broadband and free software. The reason the Brazilian Government chose to include free software in its digital policy was to fight software monopoly and the logic of proprietary software (to avoid investing taxpayers' money for licenses to a few non Brazilian multinationals), but also the use of open software for building local capacity to produce and create (Pekka, 2001). The main action in this direction has been the development of the "Telecentros Project", a network of thousands of public spaces with internet connection, free operating system and free digital alphabetization for all the population. The Telecentros have been implemented by the Coordenadoria do Governo Electronico and became the most important experience of digital inclusion in Brazil. (Silvera, S. A et al. , 2003)

Phase 2: From Telecentros to Pontos de Cultura. Gilberto Gil and the third generation of digital access policy

When Gilberto Gil became Minister of Culture in 2002, Brazil took up very innovative policy actions in the field of digital policy that concerns the use of free software, the promotion of an alternative to copyright such as the use of the Creative Commons licences for multimedia contents: a set of policies ranging from digital culture to alternatives to patents on drugs. With the "Cultura Viva" programme implemented by Gilberto Gil in 2003, Brazil started a new generation of digital inclusion policy, in which the approach to technology and digital divide has a very radical cultural connotation.

We can distinguish three generation of digital access policy:

- the first relates to access to computers,
- the second relates to computers connected to the Internet (Telecentros);
- the third relates to genuine multimedia stations that use all the possibilities of digital convergence (Pontos de Cultura).

Pontos de Cultura is a socio-digital inclusion programme which goes beyond the general use of the term.

Points of Culture (Pontos de Cultura) will establish free-software studios, built with free software, in a thousand towns and villages throughout Brazil, enabling people to create culture using tools supporting free cultural transmission. This initiative is focused on the full understanding of the new processes which characterize the essence of digital culture, in which broadband access to Internet is the main element, but where real digital content creation using free and open software becomes more and more important. This vision aims to spread digital culture through the encouragement of collaborative networking, and also enables the appropriation of digital tools for an autonomous and multimedia production. It helps create new languages through free media production tools, knowledge sharing, experimentation and networking. One of the expected outcomes is to constitute an archive of Brazilian music, which will be stored in digital form and governed by a license inspired from the free software GPL. The programme is shaped towards the need of non-governmental organisations (NGOs) and communities, and involves the direct funding of several projects to empower communities and their actions.

To facilitate the implementation of the Pontos de Cultura programme, Minister of Culture Gilberto Gil set up the "Cultura Digital Equipe", an experimental research group made of researchers, software developers and multimedia activists conducting studies in the field of digital culture, networking and sustainable economy. *Pontos de Cultura* are defined as public spaces to experiment new cultural practices and community empowerment, seeking to encourage direct participation and to affirm the cultural identity of each Brazilian Region. Autonomy is the basis for these public digital spaces. Looking at technology from a cultural perspective, each community can guarantee the political and financial sustainability of every action taking place. Socially, it means giving the possibility to produce immaterial cultural common goods, and economically it means the possibility to generate income.

Once selected by the Ministry of Culture under the 'Cultura Viva' programme, each *Pontos de cultura* will receive a digital 'multimedia kit', a new digital tool that goes far beyond the simple access to Internet. Through the partnership with the GESAC Programme of the Ministry of Communications, each Pontos will have broadband available for sharing the digital cultural work produced. The multimedia kit includes a multimedia studio which will enable professional-standard works in five modes (audio, video, software development, text and image). Each "*Pontos de Cultura*" will also receive a budget of around 1000 € per month for two years to help it gain autonomy and self-sustainability in the long term, stimulating other initiatives and creating a network of new cultural economy.

Many of the selected projects never used FOSS (free and open software) before and some never used computers at all. The contact between the Equipe Cultura Digital and these grassroot organizations is therefore very important to provide training, share knowledge and experiment the use of digital technology according to local and social needs. For this reason, the main objective of the work is the networking itself, which aims to strengthen cooperation and knowledge sharing (a principle of FOSS) between the Pontos in different areas, from technical problems with the multimedia kits, to community problems and management issues. The Digital Culture team understands that, in the search for autonomy and sustainability principles, even more important than the interaction of the Pontos with the Ministry of Culture is the direct interaction between the Pontos themselves, generating convergence and flows of information exchange which are fundamental for the long-term sustainability of the Pontos de Cultura.

The Coordinator of the digital policy of the Ministry of Culture of Brazil, Claudio Prado, stated: "*At a time when cultural conflicts, intolerance, terrorism and clashes of civilizations are being stirred up, the development of open source software establishes public spaces for communication and technological collaboration between individuals from very different cultures and backgrounds, in a global process. This is another virtual ecology*". (Novaes, Caminati, Prado, 2005)

The strength of this policy relies on three main components:

- The Cultura Digitale Equipe
- The Anthropological and Cultural perspective
- The Methodology.

Cultura Digitale Equipe

The main action of the Cultura Viva programme was the creation of the Equipe Cultura Digitale. First started as a voluntary team of 15 people (the trainers of the trainees), it is now made up of more than 65 people hired by the Ministry of Culture through the IPTI (Institute of Research on Information Technology). The researchers have different backgrounds, mainly coming from the open source community, community radio and independent media. From 2004 till 2006 the Equipe organized throughout Brazil a series of workshops and sort of bootcamps called "officinas de conoscimento livres" to share knowledge and transfer the technology implementing the multimedia kit following a defined methodology. The Equipe created a trusted and collaborative environment between interested groups and the Pontos de Cultura communities (www.estudiolivre.org, www.converse.org, www.xemele.org).

Since the start of the programme's implementation, the Equipe constitutes the core element to structure, develop and steer the project.

Anthropological and Cultural perspective

The cultural and anthropological element is always a key issue in the speeches of the Minister of Culture of Brazil, Gilberto Gil, who underlines the need for a cultural approach to technology and to digital inclusion policies. The first and most important digital inclusion initiative following Minister Gil's perspective in Brazil are the Telecentros, configured as access points of second generation, in which the priority is on digital alphabetization.

Within the concept of Telecentros, the focus on contents production as expression of local cultural identity is still absent. The aim of a digital inclusion policy of third generation is to transform the technology into an enabling tool to document, share and preserve cultural diversity and identity. In this vision, the cyberspace becomes a new public sphere in which it is possible to create rich cultural ecosystems based on complexity and differentiation rather than homogeneity. The focus is not on the technology itself, but on the philosophical, cultural and socio-economic approach to technology. It is the integrated approach that creates value: it is only by adding to the reappropriation and knowledge of technology the willingness to affirm cultural identity, that it is possible to create the power and the conditions for the autonomous development of communities and individuals (Dertouzos, 2001).

Methodology

The Cultura Digitale Equipe is developing a complex and interesting methodology to transfer knowledge and technology to the Pontos de Cultura. The central part is the organization of the "officinas de conoscimento livres" and the development of the virtual environment and the social software. The methodology defines a theoretical framework to new technologies and to internet development based on the ideas of autonomy, reappropriation of technology and identity, knowledge sharing and meta-recycling[5]. The main aim of the workshops held in the "officinas de conoscimento livres" is to provide the community with the knowledge to continue the work in an autonomous way, by being able to use the technological tools for their own purposes. The virtual environments are based on social networking tools for community building, to work in a collaborative way and to document the activities of the Pontos de Cultura and of the Equipe.

Italy and Brazil: a transnational cooperation on Digital Culture and access to knowledge

On 3rd July 2006, Minister of Culture of Brazil Gilberto Gil was invited by the Italian Presidency of the Chamber of Deputies and by the Region of Lazio to an international conference on "Youth and Labour Policy in the Information Age", with the participation of various Italian Ministers, Local Authorities, the University of Rome La Sapienza and international experts in this field.

A session of the conference was dedicated to an analysis of the DBE experience. This conference was the starting point for cooperation between Brazil and Italy regarding Digital Inclusion Policy. The cooperation between the Region of Lazio and the Ministry of Culture of Brazil is following an interesting approach, because it turns around the usual logic of the programmes fighting against the digital divide, where the developing countries have to adopt the technology and the models as an aid from more developed countries. Often such projects create dependency and provide solutions that are not sustainable and inappropriate to the socio-economic context of the country that receive the financial or technological help.

In this case, the Region of Lazio, in cooperation with the University of Rome "La Sapienza", will research, study and implement the policy of the Brazilian Minister of Culture, trying to adopt the approach and methodology of the Cultura Viva project. The policy aims to empower local communities and to create a network of transnational cooperation that research and implement free software solutions, infrastructures and platforms for the production and sharing of knowledge, free digital culture and sustainable economy.

The project of the Region of Lazio will create public spaces,"Art Factories", in which to implement the Pontos de Cultura, following the Brazilian methodology but adapting the project to the local context and to local communities. At the same time, the Brazilian and Italian "*Equipe*" will research and cooperate to build a common digital infrastructure that will be a collaborative working tool between the different pontos de cultura in Brazil and the pontos in the region of Lazio.

Moreover, the cooperation between Brazil and the Region of Lazio will hopefully lead in the long term to a common experimentation to implement Pontos de Cultura in Italy integrated with the Digital Ecosystems.

5) "metareciclagem": that means to deconstruct and rebuild technology through new contexts and new languages (e.g. arts).

The main strategic elements for future cooperation will be:

- A common approach on transnational cooperation on Digital Inclusion Policy with the aim to create a privileged channel between Europe and Latin America to fight the digital divide and to promote opportunities for common economic initiatives
- A common focus on local and sustainable development to preserve cultural and regional identity
- The creation of a digital common in the cyberspace based on the free software approach and the integration of Pontos de Cultura and Digital Ecosystem methodologies and instruments.

Pontos de Cultura and Digital Ecosystems: a common approach towards an ecosystem of innovation

The Pontos de Cultura project and the Digital Ecosystems have common socio-economic objectives, vision and values. The aim of these two projects is to learn, create and produce in a bottom-up approach starting from the community, in cooperation and according to local needs, in such a way that each specific identity and local culture becomes a real corner stone to build a strong regional economy. The collective creation and distribution of immaterial goods (culture, knowledge, software, services) become a productive element to also compete on the global market, but starting from innovative practices developed in relation to vocation, know-how and the identity of each territory.

Strong and innovative elements of Pontos de Cultura:

- community empowerment and capacity building;
- the use of free software and social software platforms addressing the needs of communities;
- collective creation of immaterial goods, sharing of data base systems and viral networks;
- cultural and anthropological perspective on technology.

Strong and innovative elements of DBE:

- self-evolutionary architecture to plan and implement objects, services, life and work environments with attention to flexibility, effectiveness and security;
- empowerment of SMEs through the creation of an integrated territorial structure able to supply them with cross-sectional resources that they need in their activity and that they do not have directly
- building a territorial environment of reference for SMEs providing a competitive advantage which attracts investments while at the same time guaranteeing the quality of life for its inhabitants
- differences of context turned into added value in competitive terms.

The Pontos de Cultura Project and the Digital Ecosystems are hence based on similar principles and approaches:

- the creation of know-how which is localized in the region;
- the creation of global networks of cooperation;
- the creation of synergies and possibilities to cooperate and share knowledge;
- respect for local cultures and differences, which become a source of identity and an advantage for cooperation and competition.

Conclusion

The technological infrastructure of the DBE can become an ideal virtual environment of cooperation for communities and Pontos de Cultura, integrating know-how on Networks and business models that could lead to a long term economic sustainability for the productive activities in the Pontos de Cultura. The methodology and transfer of technology and know-how adopted by the Equipe Cultura Digitale, and the strong emphasis on engaging local communities and on valorization of cultural identity, could on the other hand represent a social basis on which and appropriate approach to develop the Digital Ecosystem. To turn into sustainable economic activities, the cultural activities and creative competences developed in the Pontos de Cultura should be integrated in a value chain in the territory. The creative and artistic abilities must be conjugated with the capacity for building Networks of cooperation and solutions for an alternative economy on a local basis. The Digital Ecosystems, based on free software, allowing the sharing of knowledge, the dissemination, integration and self-organization of services and networks of cooperation between producers, provides the ideal immaterial open source knowledge-based infrastructure to empower the Pontos de Cultura. From a tool for capacity building, the Pontos could become a tool to create employment for the new generations and to innovate in the local economy.

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Section Five

Digital Ecosystem Projects Cluster

European Commission
Information Society and Media

1 The "Technologies for Digital Ecosystems" cluster of FP6 projects

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This FP6 cluster of IST research projects is specifically focused on technologies for local growth and SMEs needs. It implements a strong integration between European R&D policy (under the ERA/European Research Area agenda) and national/local growth policies. It is of a highly multidisciplinary nature, with strong interaction between business and technological aspects, and related socio-economic issues.

Aims of the Technologies for Digital Ecosystems cluster

The Technologies for Digital Ecosystems (DE) cluster aims to foster local economic growth through new forms of dynamic business interactions and global co-operation among organisations and business communities enabled by the most recent, user-oriented and efficient combinations of information and communication technologies.

The main research targets basic enabling technologies supporting the local implementation and deployment of a network of interconnected digital ecosystems. The work conducted within the DE cluster contributes to identifying and developing the technologies as well as the scientific and economic models leading to distributed and co-operative bottom-up development and deployment of a pervasive network of digital ecosystems populated by a diversity of ICT-based services, components, knowledge, practices and business models adapted to local conditions.

The "digital ecosystem" is an evolutionary self-organising system aimed at creating a software environment for networked organisations that supports the cluster development of open and adaptive technologies and evolutionary business models. The key enabling technologies developed within digital ecosystem research are geared at providing an ecosystem-oriented infrastructure[2] that supports the spontaneous composition, distribution, evolution and adaptation of ICT-based services, business services, knowledge and models.

1) The views expressed are those of the author and have not been adopted or approved by the European Commission.
2) See the descriptions in Section 3: Digital Ecosystem Technology.

This platform should allow:

- The SME software industry to develop co-operatively – and to launch on the network – services and software components that are composed together to form complex solutions of increased added value, suited more precisely to users needs.
- User SMEs to find the affordable ICT services which support their specific and evolving business networking needs, enabling them to co-operate within and among business ecosystems.

Hence the cluster is addressing the two following strategic issues, with high potential contributions towards the Lisbon objectives:

- Re-boosting the software ICT service industry in Europe, by proposing a new, more efficient, paradigm for software production - through new forms of co-operation, developing reusable components Europe-wide and enabling multi-revenue-models;
- Preventing the decline of Small and Medium Enterprises currently unable to adopt ICT in order to increase their productivity[3] and to cooperate among each other towards higher visibility, creativity and added value by combining services and joining resources, enlarging their global presence.

Specific outcomes expected from DE deployment include:

- Enlarging the ICT market, as it adapts to the specific needs of SMEs/micro-enterprises, increasing their productivity
- Boosting software competition, with increased interoperability, reusability and flexibility (i.e. durability) of software components
- Increasing quality of service and quality of life (for both producers and consumers)
- Boosting training and knowledge diffusion, creativity, innovation and SME-based employment
- And as these improvements diffuse progressively across SMEs/micro-enterprises in all sectors and reach down to final users/consumers, they will help bridge the digital gap throughout society.

Development of the DE cluster up to FP6:

The concept of digital ecosystem has recently emerged in Europe as the next step towards ICT adoption and a European model for the ICT-based enabling infrastructure needed to support the local business ecosystems.

In September 2002, the e-Business unit of the Information Society Directorate-General published on the 'Go-Digital' website and widely disseminated the discussion paper "*Towards a network of digital business ecosystems fostering the local development*". The debate which followed within the scientific community confirmed that the digital ecosystem is a complex and ambitious multidisciplinary field of research, which is defining its identity, structure and exploitation potential, and whose outcomes provide the technological support for innovation in the local business with an impressive potential in generating positive economic impact.

Between and 2002 and 2003, workshops and on-line debates have explored:

- The interest of the European research community in improving and enriching the research area related to digital ecosystems.
- The views of incubators and main players from local and regional communities on whether and how local digital ecosystems could support the transition of SMEs towards the digital age.

As part of the 2003-04 implementation of the FP6 IST work programme, the development of the Digital Ecosystem concept aggregated a large multidisciplinary community and led to the presentation of several relevant proposals for Integrated Projects (IPs) considered above threshold, plus other large projects and specific targeted research projects (STREPs) in related areas.

In 2004, owing to the growing interest in digital ecosystems, DG Information Society and Media created a new sector, "*Technologies for Digital Ecosystems*", within the "ICT for Business" unit – which was since renamed "ICT for Enterprise Networking".

A Cluster on Technologies for Digital Ecosystems was defined, with three projects initially, including one large Integrated Project (DBE).

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3) It has been estimated that 50% of the differential in productivity increase between US and EU SMEs over the last 5 years is due to the differing adoption rate of ICT in their internal/external business processes.

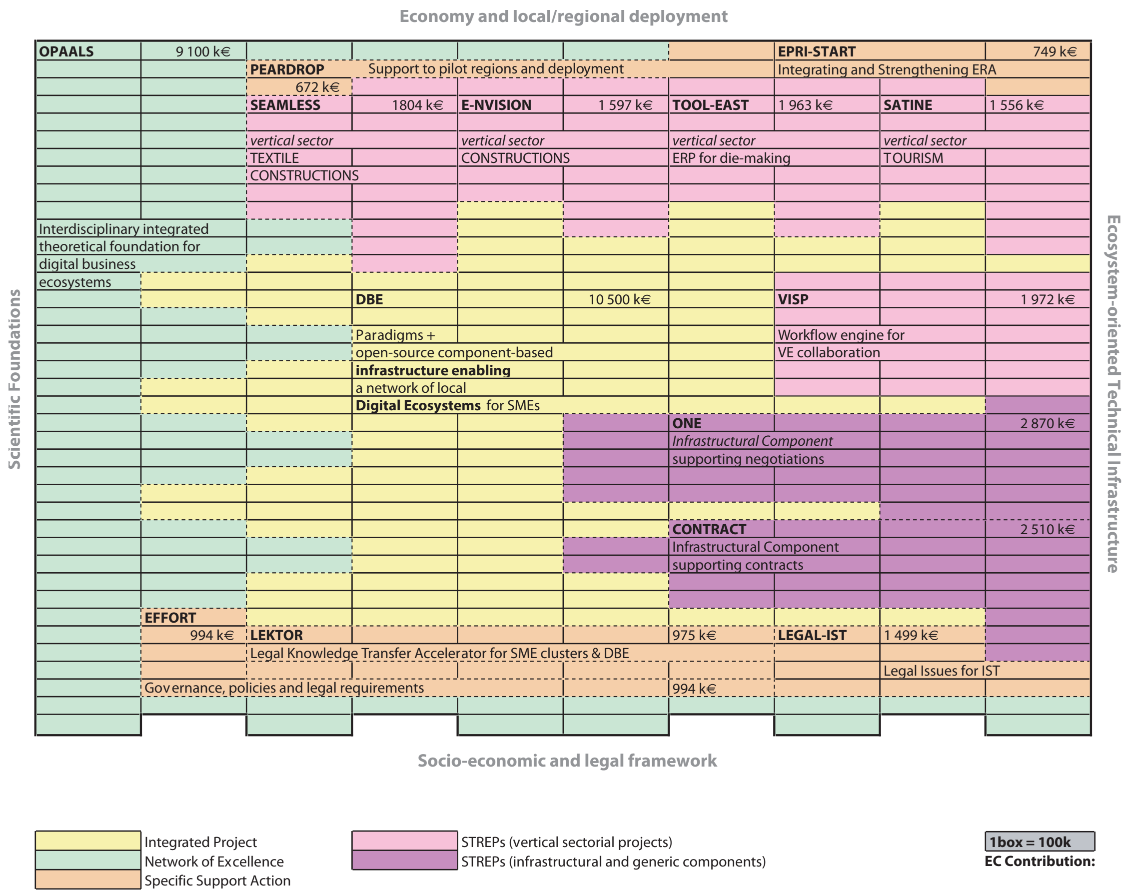
This cluster has since grown with the addition of new sets of projects, and in 2006, with the last projects launched within the FP6, reached its current configuration described in the table below. The complementary roles of the various projects in the DE cluster are further highlighted on the next page and in the DE project summaries included in the next section.

The EC-funded research in digital ecosystems is largely complemented by ERA national and regional initiatives together with local policies, which activate a virtuous cycle based on research innovation, deployment, adoption and growth.

In addition to the three initial EU-funded pilot areas (Aragon in Spain, Tampere in Finland and the West Midlands in the UK), a number of further regions have already joined or are in the process of joining the DBE project initiative, like Extremadura, Lazio, Trentino and the regions of Ireland.. Interest outside Europe is also flourishing, with some cooperation commitments with partners from Africa (such as Rwanda), Asia (such as Kanpur, in India) and South-America (in combination with the Brazilian Puntos de Cultura).

Fig. 1

The Cluster of FP6 Research Projects on Digital Ecosystems



Overall achievements of the DE cluster up to the end of 2006:

To date, FP6 results of the DE sector include:

- Individual projects research results (including open-source software regarding not just the DE infrastructure developed in the DBE Integrated Project, but also vertical applications geared to the needs of SMEs in various sectors – in support of the tourism, construction, textile and die-making industries but also new services related e.g. to Internet Service Provision, logistics/fleet management, design etc.).

- Joint results (e.g. due to result from specific collaborations between projects, such as between the CONTRACT and ONE Specific Targeted Research Projects regarding horizontal services to facilitate electronic contracting and negotiations) or their re-use (e.g. following adoption of the DBE architecture by the SEAMLESS STREP) and a strategic research roadmap stemming from close collaborations within and among DE projects (see http://www.digital-ecosystems.org/de/refs/ref_proj.html).
- The foundation of a new interdisciplinary science helping to bootstrap, observe and guide the development of Digital Ecosystems supporting innovation and development within/across territories, organisational systems and cultures (through the OPAALS Network of Excellence).
- Collaboration & uptake from regions across the EU & the world, with active support from the DBE and OPAALS projects as well as from Specific Support Actions either specific to the DE cluster (such as PEARDROP aiming at DE deployment, EFFORT aiming to develop DE governance) or with more general objectives (such as LEGAL-IST and LEKTOR on legal issues, EPRI-START to help Enterprise Networking uptake in countries which recently joined or are candidate for joining the EU).

Perspectives of further Digital Ecosystems research and uptake under FP7, CIP and Regional funds:

- In the Applications Research part of IST, the FP7 programme specifies the following tasks: "new forms of dynamic networked co-operative business processes, digital eco-systems in particular for small- and medium-sized organisations; optimised, distributed work organisation and collaborative work environments such as knowledge sharing and interactive services (e.g. for tourism)".
- While Digital Ecosystems research activities are not called for in the initial FP7 work-programme among the priorities covering the period 2007-08, most of the DE cluster projects launched under FP6 will continue within this period.
- The Competitiveness and Innovation Programme (CIP) being set up in parallel to FP7 includes ICT demonstrations via large scale pilots and networking actions, which should be applicable to Digital Ecosystems (some feasibility studies are due to be called for initially).
- DG Regional Policy is also intending to cooperate with DG Information Society and Media in order to identify how deployment of Broadband and Digital Business Ecosystems across Europe may be boosted within the "Regions for Economical Change" framework.

In summary, due to the important economic and regional development stakes addressed by the DE cluster, the soundness of its objectives and progressive implementation path, and the remarkable quality of the results attained so far within this sector of FP6, an uptake process has been triggered which goes much beyond the three EU regions originally involved in the DBE integrated project (with over a dozen regions now either actively engaged in or contemplating DE uptake), and has the potential to spread much more quickly and efficiently across the EU if knowledge transfer actions of the DE results are launched within the CIP Programme and as part of Regional Policy actions.

These results have been achieved thanks to the intensive work and high academic and scientific standards of the members of the DE research community, and their strong personal engagement and enthusiasm towards the shared objectives of this new research discipline - whose foundations they are helping to lay, and which the February 2007 IEEE Conference devoted to "Digital Ecosystems for SMEs" in Cairn, Australia, will help to further disseminate on the international stage.

2 Summaries of FP6 projects from the "Technologies for Digital Ecosystems" (DE) cluster

1. Network of Excellence structuring the Digital Ecosystem Knowledge/Research

OPAALS

Open philosophies for associative autopoietic digital ecosystems			
Project Acronym:	OPAALS	**Project reference:**	034824

Contact person	
Organization name:	LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE
Contact person name:	DINI, PAOLO

Description

Objective:

Digital Ecosystems are emerging as a novel approach for the catalysis of sustainable regional development driven by SMEs. The two overarching aims of the OPAALS NoE are to build an interdisciplinary research community in the emerging area of Digital Ecosystems, and to develop an integrated theoretical foundation for Digital Ecosystems research spanning three widely different disciplinary domains: social science, computer science, and natural science.

The main claim that OPAALS makes is that in order to achieve sustainable digital business ecosystems of SMEs and software components we need to understand in depth the collaborative processes and ICTs that underpin the continuous creation, formalisation, and sharing of knowledge in the form of business models, software infrastructure for e-Business transactions, and new formal and semi-formal languages. Our strategy is based on the development of an Open Knowledge Space.

Because this process must be sustainable and scalable it must be recursive and self-reinforcing. It follows that OPAALS is the first step in a recursive, reflexive, and self-reinforcing community building process that will culminate at the end of the project with an Open Knowledge community of research and innovation inclusive of all the stakeholders of digital ecosystems but mainly of academic institutions and SMEs.

We will integrate the research outputs in automatic code generation, autopoietic P2P networks, and distributed accountability, identity and trust into the existing infrastructure from the DBE project. These technical and scientific research activities will be balanced by research in the role of formal and semi-formal languages in epistemic communities and in new Open Source models emerging in public and commercial projects. Finally, we will develop a unifying evolutionary framework for language in order to base the evolutionary and adaptation characteristics of the digital ecosystems on the main medium of social constructivism: language.

Start date: 2006-06-01 **End date:** 2010-05-31
Web site: www.opaals.org

2. Integrated Project developing the first core of the Digital Ecosystem infrastructure

DBE

Digital Business Ecosystem			
Project Acronym:	DBE	**Project reference:**	507953

Contact person	
Organization name:	T6
Contact person name:	NICOLAI, ANDREA

Description

Objective:

The overall objective of the DBE is aimed at proving Europe with a recognized advantage in innovative software application development by its SME industry, launching a disruptive technology paradigm for the creation of a digital business ecosystems for SMEs and software providers thus improving their value network.

An open-source distributed environment will support the spontaneous evolution, adaptation and composition of software components - which also embed business rules - and services allowing SMEs, that are solution and e-business service providers, to cooperate in production of components and applications adapted to local business needs.

This will allow EU small software providers to leverage the possibility of new distribution channels providing services at local ecosystems and extending their market reach through the DBE. Easy access and large availability of applications, adapted to local SMEs, will foster ICT adoption and local economical growth of innovation nodes. This can only be achieved with a vision leading to a paradigm shift: the complexity of distributed software production and the new forms of networked business require a multi-disciplinary approach based on biology, physics and social sciences mechanisms and models.

DBE transposes from living organisms mechanisms like: evolution, adaptation, autonomy, viability, introspection, knowledge sharing, selection, and will lead to emergence of novel architectures and technologies, business processes and knowledge. The DBE will change the way SMEs and EU software providers use and distribute their products and services. It will allow SMEs to link enterprise-wide external resources and value networks, and to allocate them based on their business priorities.

The DBE is based on the key finding that with such evolutionary and self-organising system Europe could harness the complexity of software production and its SME software industry could regain competitiveness.

Start date: 2003-11-01 **End date:** 2007-01-31
Web site: www.digital-ecosystem.org

3. Specific Targeted Research Projects developing horizontal services to provide enhancements to existing infrastructures, with a focus towards the DE infrastructure

ONE

Open Negotiation Environment			
Project Acronym:	ONE	**Project reference:**	034744

Contact person

Organization name: CREATE-NET (CENTER FOR RESEARCH AND TELECOMMUNICATION EXPERIMENTATION FOR NETWORKED COMMUNITIES)
Contact person name: TELESCA, LUIGI

Description

Objective:

The main objective of the ONE project is to enrich Digital Business Ecosystems with an open, decentralised negotiation environment and enabling tools that will allow organisations to create contract agreements for supplying complex, integrated services as a virtual organisation/coalition.

The project is especially geared towards SMEs, providing them with a trusted, secure and free of charge technological environment through which they can create the tactical and strategic alliances to pursue business opportunities and growth. To be competitive in Digital Ecosystems SMEs will need to develop alliances and collaborate to provide joint service offerings and also address large tenders.

Current negotiation platforms, such as Business-to-Business electronic marketplaces and Internet trading platforms are centrally managed, not fully trusted by SMEs and/or too expensive and hence not widely used by European SMEs today. Without the support of proper tools, SMEs cannot easily find trustworthy partners to provide services or be found themselves. Access to reputation information is not readily available and negotiations are time consuming. To solve these problems, a negotiation environment must be affordable, open, not centrally controlled, support the sharing of knowledge via flexible security and trust policies and be able to learn and evolve with the changing market conditions.

ONE provides such a solution via an open-source approach ensuring transparency and sustainability. By using the ONE environment all business players (SMEs, Corporations and others) will benefit from reduction of time to market and transaction costs. The ONE environment will also provide wider ecosystem benefits in terms of an increase in the number of participants; better negotiation performance and collaboration while creating new business opportunities.

Start date: 2006-09-01 **End date:** 2009-02-28
Web site: www.one-project.eu

CONTRACT

Contract based systems engineering methods for verifiable cross-organisational networked business applications

Project Acronym:	CONTRACT	**Project reference:**	034418

Contact person

Organization name:	UNIVERSITAT POLITECNICA DE CATALUNYA
Contact person name:	WILLMOTT, STEVEN

Description

Objective:

As technologies for new generations of digital business systems have forged ahead, new and exciting applications have become feasible. However, along with this potential it has also become clear that very significant challenges remain in the need for rigorous analysis of possible execution behaviour and the need for business interactions to be underpinned by sound, binding legal agreements. The main aim of the CONTRACT project is therefore to provide innovative new solutions, which specifically address the need for sound software and business guarantees in digital business applications. In particular, CONTRACT will build on existing theories of software contracts to create new formal models and practical tools for use of dynamic contractual agreements in electronic business environments.

The results will make it possible to:

- specify electronic business interactions in terms of contracts,
- dynamically establish and manage contracts at runtime,
- apply formal verification techniques to collections of contracts in a digital business environment, and,
- apply monitoring techniques to contract implementation to help increase confidence in business infrastructures.

The contract based approach promises to be a significant breakthrough in the formal specification and verification of business software systems since it raises the level of abstraction at which verification methods can work from detailed execution code to obligations, commitments and rights. Project results will include publicly available theoretical models and a reusable contracting language specification, open source software components compatible with leading business environments and tools implementing innovative verification techniques that make it possible to check contract properties both at design time and run time.

The consortium includes 1 major industrial partner, 3 Universities, a research institute and 3 associated SMEs participating in distinct business case studies.

Start date: 2006-09-01	**End date:** 2009-02-28
Web site: www.ist-contract.org	

4. Specific Targeted Research Projects developing enterprise networking applications (which could be installed on, or linked to the DBE infrastructure) targeting SMEs

SEAMLESS (Construction + Textile sectors)

Small Enterprise Accessing the electronic market of the enlarged Europe by a smart service infrastructure			
Project Acronym:	SEAMLESS	**Project reference:**	026476

Contact person	
Organization name:	UNIVERSITA' DEGLI STUDI DI MODENA E REGGIO EMILIA
Contact person name:	BONFATTI, FLAVIO

Description

Objective:

The SEAMLESS project studies, develops and experiments an embryo of the Single European Electronic Market (SEEM) network where a number of eRegistries are started up in different countries and sectors. Distinctive features are:

- Addressing Craft & Trade (C&T) companies through the respective mediators (chambers of commerce, entrepreneurial associations, local development agencies, ASPs).
- Focusing on two sectors, Textile (TEX) and Building & Construction (B&C) that are relevant to C&T companies and present overlapping areas (e.g. fabrics for tapestry).
- Starting up experimental RRs in both EU-15 and new member states (NMAS) and establishing interactions between them based on a proper collaboration framework.

In adopting eBusiness solutions, the target companies present figures lower than those of larger enterprises and increasing at a slower pace. The situation in NMAS, where the percentage of C&T is even larger than in EU-15, is generally worse, with significant differences between countries. The SEEM vision is towards a web-based marketplace where companies can dynamically collaborate without cultural and technological constraints. The SEEM allows an objective comparison of profiles and offers of company of any size and location, and this could open the eBusiness space to the many small companies (providing high quality products and services at lower cost) that now risk to be left aside from the electronic market.

The main project activities are devoted to define a collaboration framework and proper business models, realise evolving sectoral ontologies, develop a technological infrastructure and a number of applications and services on top of it. Six eRegistries are experimented, in Poland and Slovenia (B&C sector), in Spain, Slovakia and Romania (TEX sector), and in Hungary (generic). The SEAMLESS project intends to provide an independent contribution to the Digital Ecosystem initiative and strictly collaborate with the relative cluster of projects.

Start date: 2006-01-01 **End date:** 2008-06-30
Web site: www.seamless-eu.org

E-NVISION (Construction sector)

A new vision for the participation of European SMEs in the future e-Business scenario			
Project Acronym:	E-NVISION	**Project reference:**	028067

Contact person	
Organization name:	FUNDACION LABEIN
Contact person name:	ANGULO, JOSEBA INAKI

Description

Objective:

The future business scenario will be global, open and collaborative, dynamic and adaptive, frictionless and consistent. The main barrier SMEs have to face in order to exploit, adapt and migrate to this e-Business scenario is the lack of SME-oriented methodologies or tailored solutions.

The main objective of e-NVISION is the development and validation of an innovative e-business platform enabling SMEs to model and adapt particular business scenarios; to integrate all their enterprise applications and to incorporate legal, economical, social and cultural services, with the final goal of facilitating their participation in the Future European e-Business Scenario.

The main outcomes of the project are:

1. A specific SME-oriented e-Business Model formally described by a set ontologies.
2. A semantically enriched web service-oriented e-Business architecture providing modularity and integrability.
3. A set of business contextual services enabling SMEs to incorporate legal, social, economic, and trust aspects in their business model.
4. A number of semantic integration components facilitating the integration of the most common enterprise applications: Enterprise Resource Planning, Customer Relation Management, logistics, etc.
5. A range of Semantic Tools providing the necessary decision support for governing the behaviour and progress of e-Business, through inference processes.
6. An Open Source e-Business Platform integrating the previous elements in an efficient SME-scale Information System, open and configurable enough to be adopted by SMEs.

This Semantic e-Business Platform will be validated in the framework of four different scenarios involving SMEs of the Construction and Building industry.
The consortium is composed of 3 RTD organisations, 1 University, 4 ICT & consultancy companies, 4 SMEs and 3 Clusters of organisations from 5 European countries (Spain, France, Lithuania, Slovenia, and Poland) with the clear aim of incorporating and validating as much experience as possible.

Start date: 2006-01-01 **End date:** 2008-12-31
Web site: www.e-nvision.org

SATINE (Tourism sector)

Semantic-based interoperability infrastructure for integrating Web service platforms to peer-to-peer networks			
Project Acronym:	SATINE	**Project reference:**	002104

Contact person	
Organization name:	MIDDLE EAST TECHNICAL UNIVERSITY SOFTWARE RESEARCH AND DEVELOPMENT CENTER
Contact person name:	PROF. DR. ASUMAN DOGAC

Description

Objective:

SATINE aims to develop a secure semantic-based interoperability framework for exploiting Web service platforms in P2P networks for tourism. Quantified objectives achieved:

- Exploiting semantics for Web services in the travel domain: SATINE provides a component to wrap existing information resources to make them appear as semantically well described Web services. It provides an easy to use tool for SMEs to easily create Web services from their existing enterprise applications. The wrapped resources are able to exchange information with other Web services in a Peer-to-Peer network.
- Semantically enriching Web Service Registries: Currently, the main service discovery mechanism is the service registries like UDDI and ebXML. SATINE project enriches the UDDI and ebXML registries with mechanisms to store and access Web service semantics to facilitate the discovery and automated composition of complex Web services for travel.
- Semantic Discovery of Service Registries: In SATINE architecture the Web service registries are connected through a Peer-to-Peer network to facilitate their discovery performing semantic routing of the queries.
- Semantic Interoperability of Diverse Tourism applications: Although there are efforts to standardise the messages exchanged in the travel domain such as Open Travel Alliance, not every travel company can be OTA compliant. In SATINE, the interoperability of all sorts of Web services is addressed at the semantic level through ontology mapping.
- Semantic Web Service Composition Tool: The platform provides a set of tools supporting the semi dynamic composition of semantically enriched Web services.
- Support for SMES: Web services could not be registered to any service registry but simply made available through a Web site, especially by SMEs. SATINE provides a mechanism to facilitate automated discovery of services through P2P technology.

Use and Impact:

- Providing an easy to use tool for Small and Medium Enterprises to easily create Web Services from their existing enterprise applications including a component to wrap existing information resources to make them appear as semantically well described Web Services.
- Extending the reach possibilities of tourism enterprises by making their own semantically enriched web services available to others either through service registries like UDDI and ebXML or directly through the peer-to-peer network.
- Extending the life of existing software by exposing proprietary functions as Web services.
- Saving time and money by cutting of software development time by wrapping already existing travel information system applications as Web services.
- Allowing complex service composition exploiting the semantics of travel services.

Start date: 2004-01-01 **End date:** 2006-06-30
Web site: www.srdc.metu.edu.tr/webpage/projects/satine/index.html

TOOL-EAST (Die-making sector)

Open source enterprise resource planning and order management system for Eastern European tool and die making workshops			
Project Acronym:	TOOL-EAST	**Project reference:**	027802

Contact person	
Organization name:	FORSCHUNGSINSTITUT FUER RATIONALISIERUNG
Contact person name:	IMTIAZ, ALI

Description

Objective:

Tool and die making workshops provide critical support for industry by providing and designing customized mechanical components. It is estimated that within the EU these enterprises, especially the Eastern European, are mostly organized as SMEs. They do not have the financial and human resources for the implementation of complex ERP applications from the powerful software suppliers. Furthermore the functionalities of these standardized applications do not fulfil the specific requirements of the tool and die making industry.

The project Tool-East will provide a cost-efficient ERP application for tool and die making workshops on the basis of existing open source ERP applications. Within the project the open source application will be adapted and modified for the specific requirements of this branch. The new adapted and modified ERP application supports the efficient coordination of intra-enterprise order processing and strengthens competition and competitiveness of Eastern European SMEs. Primarily, orders management, work planning, resource allocation and CRM need to be optimised and linked together in a dynamic work environment. Moreover ERP applications are necessary for the electronic collaboration in dynamic business networks. To enable industrial cluster to e-collaboration the consisting process and data standards will be considered for the Tool-East project.

One main challenge of this project is to use open source technology for the development of an integrated business application for tool and die making enterprises with high performance regarding availability, safety and maintainability at the very onset. Strengthening the open source initiative in general and particularly in this field of business opens an enormous potential for SMEs. Since demands for business software from other branches with specific SME structures are predominantly comparable, results from this project can be transferred easily, so that a large impact can be assumed.

Start date: 2006-01-01 **End date:** 2007-12-31
Web site: www.tooleast.org

VISP (Internet Service Provision)

Virtual ISP			
Project Acronym:	VISP	**Project reference:**	027178

Contact person	
Organization name:	PERCEVAL TECHNOLOGIES SA
Contact person name:	MANNIE-CORBISIER, ERIC

Description

Objective:

The VISP project will enable a cluster of SMEs to operate, as a single business entity, in multiple dynamic business models, for the production of tailored Internet Service Provider (ISP) solutions adapted to local business needs. VISP will specify ISP services by combining building blocks chosen in a list of a few hundreds that can each be parameterised. This will allow selling tailored services with a fine control and to differentiate from incumbent operators.

Ontologies of building blocks specified in a language like OWL will enable software based service design and ordering. It will result in a precise description of the services (knowledge base) to be implemented and provisioned that will be advertised in WSDL using UDDI. Implementation and provisioning of building blocks by different partners will require business and technical processes in the cluster. They will be modelled as workflows using choreography and orchestration formal languages in order to be executed and monitored on distributed workflow engines.

Technical workflows will act on network components through an abstract object representation based on existing standards like MIB, CIM, etc. Global data will be stored in LDAP following the Directory Enabled Networks (DEN) principles to be accessed by cluster's partners.

VISP will combine multiple innovative technologies mainly based on XML in the field of ontologies, workflow technologies, network modelling, DEN and Web services. VISP will build an integrated and automated software platform made of a modelling environment linked to a distributed, secured and manageable workflow execution environment interfaced with ERPs. VISP intends to use and produce Open Source software as much as possible.

VISP will also contribute to standardization by extending existing standards to encompass ISP services and their implementation. It will adapt and complement business workflows, and specify technical workflows as contribution to standards.

Start date: 2005-11-01 **End date:** 2008-06-30
Web site: www.visp-project.org

5. Specific Support Actions supporting specifically the DE cluster

PEARDROP

Promoting ecosystems and regional development - in support of regional operational programming			
Project Acronym:	PEARDROP	**Project reference:**	034735

Contact person	
Organization name:	ASSOCIATION REGIONALE EUROPEENNE SUR LA SOCIETE DE L'INFORMATION
Contact person name:	HUGHES, GARETH

Description

Objective:

The principal focus of PEARDROP is to make more accessible and more practicable for regional policy makers and key local actors the instruments for exploitation and adoption of research and deployment results in ICT for Enterprise Networking and, in particular, in Digital Ecosystems.

PEARDROP aims to draw together the most salient results of the innovation and digital business ecosystem cluster of FP6, including some first regional deployment experiences and results, converting these where necessary into 'layman's' terms, as well as into a number of EU languages (minimum 5), with a view to making them more accessible and of more practicable use to regional policy makers, especially those concerned with regional operational programming and with eBusiness development.

PEARDROP expects to increase significantly the number of regions that are interested to adopt it, and actively participate in, or considering deployment of, innovation and digital business ecosystem research and models. PEARDROP will seek to better understand critical success factors in terms of the behaviour of regional development agents, and will propose systems (tools, methodologies and models) for assessing the risks and barriers, as well as the benefits and effectiveness, of such approaches and related policy interventions with a view to supporting regional policy makers and programmers in formulating more effective policies.

PEARDROP acknowledges and will take due account of the diversity of European regions and the inter-regional variations of context and conditions that exist. PEARDROP does not propose to identify, develop or promote a single DBE approach or deployment model but rather to collaboratively define alternative approaches or models that could be adopted according to specific regional circumstances.

Start date: 2006-09-01	**End date:** 2008-08-31
Web site: www.peardrop.eu	

EFFORT

Governance behaviour, policies and legal requirements for facilitating access to market by dynamic clustering of SMEs			
Project Acronym:	EFFORT	**Project reference:**	035088

Contact person	
Organization name:	UMBRIA INNOVAZIONE S. CONS. A. R. L.
Contact person name:	CARDONI, GIUSEPPE

Description

Objective:

The objective of EFFORT is to gain understanding of the behaviour, governance, sustainability and constituency drivers of dynamic cross-border and cross-regional clusters of SMEs to improve their ability to access the global market, facilitating collaborative production of products and services, as well as responding to procurement contracts of public or private organizations.

EFFORT will investigate also the legal framework and policy activities needed to address the setup of the innovation ecosystem governance structure. Market access will be improved through a double process of "extended" and "dynamic" clustering. The "extended" clustering implies aggregating capabilities of clustered SMEs at different level overcoming the geographical boundaries and operational limitations of traditional clusters. The "dynamic" clustering implies adaptability in configuring "virtual" clusters to respond to specific market opportunities.

The fundamental challenge is how to facilitate dynamic external clustering, and to build capacity across clusters and networks of SMEs. This challenge involves building 'internal' capabilities enhancing the organizational, knowledge and technological capacity of SMEs, and building 'external' capacity in the environments in which SMEs and their clusters operate. The key issues have to do with regulation/policy, legal framework, governance mechanisms and technological conditions that can function as the enabling framework for completing the Internal Market and to complement the vision of the innovation ecosystem objective.

EFFORT will bring a multidisciplinary perspective on the current status and future possibilities of cross-border and cross-regional "dynamic and extended SME clustering" based on the notion of building SME cross-cluster capacity by selecting complementary partners out of SME networks that extend beyond the boundaries of a traditional cluster. Thus, our working hypothesis is that dynamic clustering will facilitate market access for SMEs.

Start date: 2006-09-01 **End date:** 2008-08-31
Web site: www.effortproject.eu

6. Further Specific Support Actions included in the DE cluster

EPRI-START

STimulate the pARTicipation of SMEs from NMS in IST activities

Project Acronym:	EPRI START	**Project reference:**	015801

Contact person

Organization name: TELEPORT SACHSEN-ANHALT GMBH
Contact person name: LANGHOF, MARCO

Description

Objective:

EPRI start aims at stimulating, increasing, but at the same time qualifying the participation of SMEs from New Member States of the EU in the IST Programme.

In particular, it aims at:

- establishing a Qualified Partner Pool of at least 500 IST oriented SMEs from NMS, qualified by LoIs and concrete project ideas;
- developing a Certified Partner Pool of 200 qualified IST oriented SME partners from NMS described by Company Fact Sheets developed by a Guide for NMS participants;
- ensure an overall number of 100 project participations from IST oriented SMEs from NMS in the different IST Calls during the lifetime of the project.

The process of stimulating and developing SME participation will feed a second, parallel process which involves political decision makers of the target countries and Political Decision makers on the level of European ICT Policy in order to discuss socio-economic impacts of ICT and to prepare and support the discussion of the 7th Framework Programme. **EPRI start** aims at the broadest possible coverage by involving partners from all New Member States of the European Union.

On the other hand **EPRI start** works with a clearly specified and realistic focus on the field of SME participation in the IST programme. It addresses three important target groups:

- The group of highly innovative research oriented SMEs from the New Member States with no or low experiences in participating in the IST programme;
- The IST community who will benefit from new and innovative resources as an enhancement of existing or newly arising consortia;
- The societal environment receiving impacts from participation of NMS SMEs in IST research projects being represented by political decision makers of the SMEs regional and national environments.

The consortium refers to comparable experiences in earlier programmes. Its coordinators have carried out a similar project during the accession process of the German New Laender.

Start date: 2005-03-01 **End date:** 2006-08-31
Web site: www.epristart.org/

LEGAL-IST

Legal issues for the advancement of Information Society Technologies

Project Acronym:	LEGAL-IST	**Project reference:**	004252

Contact person

Organization name:	ESOCE NET (EUROPEAN SOCIETY OF CONCURRENT ENGINEERING)
Contact person name:	SANTORO, ROBERTO

Description

Objective:

LEGAL-IST aims to provide support to the IST programme execution and to facilitate the rapid adoption of the relevant research results, by addressing legal issues and barriers which are hampering the implementation of IST related technologies and business models and by identifying an evolution strategy for the EU regulatory framework in the IST/eEconomy domain.

The Legal-IST initiative is capturing, analysing and framing the legal aspects of innovative technologies and methodologies emerging from within the Information Society, in order to:

- **harmonise and consolidate legal research results** undertaken in IST and support their use
- **support the IST research activities** from a legal viewpoint, by studying the legal implications of current IST research initiatives (in terms of both new emerging technologies and relevant "networked" business models) and providing implementation strategy suggestions. This is achieved by **conducting research studies on selected IST legal issues**, and **providing legal support to on-going IST projects;**
- increase the awareness of legal issues affecting ICT adoption/implementation
- **contribute to the definition of emerging policies to strengthen the EU regulatory framework**, validated through consensus building with **Governments**, **Policy-Makers** and **Public Institutions** representatives (for **SMEs** which cannot evaluate legal implications of their research)
- **provide IST-related legal support to industry (SMEs) and the IST research community.**

The LEGAL-IST project delivered:

- A **State-of-the-Art survey** on the IST research undertaken under FP5 and FP6. A public report highlighting research findings, recommendations and roadmaps is available and can be used by the European Commission, policy makers and researchers to consolidate results and facilitate their use;
- **Nine different studies** on selected legal issues relevant to IST areas of investigation, which are consistent with the needs identified in the State-of-the-Art survey. The reports on the studies give cases and recommendations on IST hot topics from a legal point of view and can be consulted by researchers, practitioners and lawyers in order to support their own activity in the field;
- **Legal support services** to facilitate the implementation of **Collaborative Innovation Clusters, Virtual Professional Communities** and **Business Ecosystems,** including**:**
  - **Training on legal issues relevant to IST** related topics and relevant business models;
  - **Support to IST research initiatives**, based on the Legal-IST approach and methodology;
  - Provision of legal/business consulting;
- **A roadmap for the implementation of the collected suggestions by the European and national regulatory frameworks,** validated through a consensus building campaign, aiming to contribute to defining emerging Policies for an IST related regulatory framework (with as target audience: the European Commission, policy makers, consumers, trade and industrial associations).

Start date: 2004-04-01 **End date:** 2007-03-31
Web site: www.legal-ist.org

LEKTOR

Legal knowledge transfer accelerator for SME clusters and digital business ecosystems			
Project Acronym:	LEKTOR	**Project reference:**	034932

Contact person

Organization name: INMARK ESTUDIOS Y ESTRATEGIAS S.A.
Contact person name: URSA, YOLANDA

Description

Objective:

LEKTOR is a 24 months SSA intended to raise awareness of potential legal obstacles in the context of eBusiness and to provide solutions by creating a platform for autonomous legal knowledge exchange among the target groups, i.e. SMEs. LEKTOR is geared at SMEs, SME clusters and digital business ecosystems for SMEs and all multipliers involved.

LEKTOR will not investigate on its own into legal matters but will identify, compile and assess those existing (from other European, national and regional projects and initiatives), making the results available on the LEKTOR platform. Furthermore, it will identify legal eBusiness issues from the user side.

Final goal is to create a mechanism, the LEKTOR P2P (peer-to-peer) platform for legal knowledge exchange that will be based on OSS and functioning P2P models such as Wikipedia or flickr.com. It will be usable for all involved in eBusiness to showcase legal achievements and solutions in a global business environment and to foster the exchange of legal knowledge between those directly affected: SMEs. The increased knowledge will dissolve doubts or insecurities and accelerate the take-up of ICT in various business processes, thus, enhance the competitiveness of European SMEs in the global digital business environment (as postulated in the i2010 programme, amongst others).

To achieve these objectives, the LEKTOR Consortium partners will take advantages of their respective experience and networks that link SMEs in Europe (EU-25) and outside, through the international partners in India, USA and Chile (for Latin America). The 6-step methodological approach is reflected in the work plan, split into 6WPs: Identification of legal and regulatory issues affecting eBusiness; draft an eCatalogue; technical implementation of P2P platform; test phase of the legal knowledge exchange platform; Dissemination strategy and implementation activities in 9 EU countries and 3 outside Europe; and project management.

Start date: 2006-06-01 **End date:** 2008-05-31
Web site: www.ubique.org/lektor

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