CONTRIBUTIONS to the online FET FLAGSHIP CONSULTATION

status 30 April 2010

Future &Emerging Technologies Unit
http://cordis.europa.eu/fet

FET FLAGSHIPS

SEVENTH FRAMEWORK PROGRAMME

European Commission
Information Society and Media

CONTRIBUTIONS to the ONLINE FET FLAGSHIP CONSULTATION 2010

(in alphabetical order & status April 30, 2010)

Transforming Production for the 21st Century

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BRIEF EXPLANATION

Transforming Production for the 21st Century

The means to transform the production of goods and services are at hand in modern ICT and other technologies. There is unprecedented demand for services: care of the elderly, healthcare, education, and many more. Currently we produce services inefficiently and products inflexibly. Europe has the capacity to transform the production of goods and services ahead of its competitors. This Flagship will focus multidisciplinary research and development on achieving this transformation.

AMBITION

Adam Smith's explanation of pin manufacture in "The Wealth of Nations":
"One man draws out the wire, another straights it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head: to make the head requires two or three distinct operations: to put it on is a particular business, to whiten the pins is another ... and the important business of making a pin is, in this manner, divided into about eighteen distinct operations, which in some manufactories are all performed by distinct hands, though in others the same man will sometime perform two or three of them." is an early description of the power of humans to reconfigure society vastly to increase their productive power. Smith estimated the new mode of pin production was 200-1000 times more productive than the traditional method. The capacity to achieve this kind of transformation in efficiency stemmed from large-scale social transformation that evolved from the synergy of urbanization, the development of new forms of power, the creation of new tools and the expansion of markets with the capacity to consume new cheap products.

Throughout the following two centuries the rationalization of the production of physical goods has progressed apace. Four notable paradigm shifts that brought about qualitative changes in productivity and the distribution of wealth in societies are:

- **Fordism that moved labour inside the machine and created mass production based on:**
  - The Standardization of the product
  - The use of Special-purpose tools and/or equipment via the assembly line
  - The Elimination of skilled labour in direct production.

- **Taylorism that developed the precepts of "scientific management":**
  - Shift in decision making from employees to managers
  - Develop a standard method for performing each job
  - Select workers with appropriate abilities for each job
  - Train workers in the standard method previously developed
  - Support workers by planning their work and eliminating interruptions
  - Provide wage incentives to workers for increased output

- **The Information Technology Revolution of the 1970s that saw:**
  - The decimation of small batch production of electro-mechanical devices
  - The breakdown of the principle that function follows form
  - Huge increase in the complexity of components
  - Configuration of complex components using software so products are realised by configuring programmable components to the current situation.

- **Globalisation that saw the export of production to low-labour-cost regions and the use of ICT to substitute labour**

The Current situation

The global economy is standing on the brink of another massive transformation in the means of production. We have the capacity to produce most material products at very low labour cost. At the same time we can see massive demand developing for "intangible" products like wellbeing, health, healthy ageing, education, leisure, ... But at the moment the production of these goods and services demands large numbers of (usually fairly low-paid) workers to produce these services. We also know that unless we can substantially increase the productivity of this sector for intangible products we will be unable to care for the elderly and educate the young because we will neither have the money nor the labour resources to produce these services.

In the Future Internet where there will be connectivity with anybody, anywhere, at anytime and with anything, we have the fundamental mechanism to achieve this transformation. The Future Internet will soon play a role similar to Urbanisation in Adam Smith's time. What we need to effect this transformation is:

- the new division of labour between intelligent environments and networks of people prepared to interact in these environments.
- tools to design new configurations of people and systems to efficiently fulfill the demands for high-quality affordable services in a rapidly ageing Europe that is confronted by challenges in energy, climate and security
- tools and governance to ensure the resilience, privacy and security Europe requires to sustain and develop its Democratic principles in the face of severe challenges.

The goal of this FET-F idea is to work to shape the "plumbing" of the Future Internet (among other information technologies) and the configurations of people, systems and other resources to allow us radically to transform the production of key goods and services in the 21st Century.

Achieving this goal will require a massive, multidisciplinary effort involving basic and applied research in Informatics, Electronics, Mathematics, Social Science, Economics, Law, and Organisational Science. The overarching Flagship goal will harness European inventiveness to catalyse this transformation of the means of production.

IMPACT

The goal of this flagship is to achieve a transformation in European productive capacity that will allow Europe to compete in Globalised Markets in the 21st century. Transforming production will have massive economic impact and achieving that transformation demands significant new results in many disciplines. The focus on the transforming the means of production across a range of sectors provides an appropriate level of generality while focussing activity on a key element of European competitiveness. Using a major economic challenge as a focussing factor requires the coordination of a wide range of different disciplinary threads together with integration activity directed towards transforming the way we produce goods and services.

INTEGRATION

A fully developed proposal will articulate the relationship between different work areas. Below there is a small sample of the sorts of threads than would need to be coordinated to deliver this Flagship. We believe that many aspects of the work require significant breakthroughs to achieve success overall:

- Organisational science: developing new approaches to organisational design that take into account the need for flexible reconfiguration of services to meet the needs of users and that exploits Models, Analytics, and the monitoring capacity of the Future Internet to consider radical change in the structure of service delivery organisations.
- Human/Machine convergence: both in creating converged human/machine systems in the production process and the creation of products (e.g. information prostheses) that provide direct aid to customers.
- Modelling and Analytics: How to use modelling combined with reality mining to help predict the dynamics of how products and services are used in order to anticipate needs and to develop ahead of the curve. This will involve deep study of the socio-technical systems we are attempting to build and

will require new breakthroughs to avoid instabilities and cope with phenomena like "performativity" where embedded models change the structure of the system as their use propagates and becomes part of accepted interactions.

Software Engineering: Developing new development and configuration methodologies that are based on instrumenting systems during development so that when they are deployed product evolution and development can continue and effective links can be established with user communities to support and add value to the product throughout its life. Here the users form a "living lab" and the producers can evolve the product in response to use and create training for new versions of the product.

- Coordination: How to develop coordination models that organise massive levels of volunteer effort to address the need for services that involve large amounts of relatively untrained effort (e.g. caring for the elderly)?
- Scale: How to exploit the consequences of extreme-scale devices - we will have terascale mobile phones in the next ten years - what effect will these have on the sorts of products we can develop?
- Personalisation: can we use personalised models and analytics combined with extreme-scale mobile devices to greatly enhance the productivity of people engaged in the production of services and in creating new products that adapt significantly to the user and provide strong feedback to the designers of the product or service?
- Configuration management: work in this area would consider issues like the tension between individual and organisational needs, integrating configuration across products and services. Identifying and recovering from configuration failures, …
- Governance: What new security and privacy technologies do we need to provide the transparency and accountability people need in order to trust new products that use extensive monitoring. Should we look at technologies that reconfigure applications and infrastructures to align with personal security policies that are carried by each user. How might that be achieved? Could a technology be built that most users could comprehend and control?

PLAUSIBILITY

A suitable pilot in transforming production would be a study of service provision for the elderly with dementia. Our approach would be to partner with different care organisations across Europe to begin to develop organisational structures that facilitated multiagency working. These could be based around facilitating family and friends in forming caring communities augmented with devices and instrumentation that is personalised to the needs of the elderly. This would foster an approach to the coproduction of dementia care that is targeted on ensuring the safety of the elderly person, managing the workload of families and friends and requiring only completely necessary interventions from care professionals.

COMMENTS

We are still in the process of exploring a collaboration to undertake the proposed pilot. The highly interdisciplinary nature of this proposed flagship means it will take some time to develop an appropriate community.

World Society Modeller (S-GAIA)

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BRIEF EXPLANATION

This Paper describes a proposed integrating project that will deliver a new kind of toolset to support the complex adaptive system called Society within the imperative of a sustainable world ecology. It enables the science and practice of computational socio-geonomics. WORLD SOCIETY MODELLER (S-GAIA), abbreviated to its acronym 'S-GAIA', draws inspiration from the GAIA metaphor. It is a proposed FuturICT cooperation. S-GAIA will combine the following submissions into a coherent modelling toolset

• INTEGRAL BIOMATHICS [2] examines the fundamental computational basis of bio- and socio-systems. It anticipates the need for a new breakthrough paradigm change towards biologically and socially driven mathematics and computation and the technological challenges of bringing this about. Its goal will be a set of novel mathematical formalisms.

• SOCIONOME-METALOGER[3] will establish the new science of Computational Socio-geonomics based on the coupling of science and social systems within the new ICT paradigm.

• COMPLEX EVENT PROCESSING[4] is an Industry led initiative to provide the ubiquitous applied technology for processing the dynamics of complex events in real world systems.

Modelling is the bridge between Science, Information technology and Society. It is a ubiquitous activity at the centre of Computational thinking, of industrial processes, and also Society itself. The S-GAIA Consortium will embrace all groups of specialists, and people who wish to join in and take forward this great modelling activity. A narrative White Paper is available free on request.

AMBITION

The S-GAIA Ambition is to be the essential science and tool-kit for managing our social ecology world, viewing society as a constantly evolving and mediated process involving people, organisations and computers. However Social science lacks a formal computational basis that needs to be elucidated. S-GAIA will be a ubiquitous toolset to support society in the design and use of its social structures, systems and participation in them, whether work, leisure or any aspect of social life. It extends current organisation systems practice by incorporating complexity science in the repertoire of social systems engagement. It does this by building into the background working of social systems a continual processing of their dynamic interconnections with each other at all levels of their working. The benefit of this is to enable a new joined up view of society to be achieved, to become aware of the ramifications of actions on the wider society and world ecology. The new paradigm will transform society, its systems and the way peoples of the world harness the new opportunities to fashion their lives.

S-GAIA will bring this about by three main devices:

• Embedding the new science of computational socio-geonomics into the mainstream of systems practice; normative models enable integration of systems at any desired level of abstraction across micro, meso, and macro levels

• Developing new forms of computational science, technologies and infrastructures, to support the new practice globally. The two salient features are 'species' representation and a radically extended applied science of Meta-modelling

• Developing new paradigms of social engagement that can be termed 'computer-human confluence' in which the chief component that elucidates complex dynamics is that of socially enacted information.

The toolset that emerges from a huge scientific and industrial collaboration will re-engineer existing systems, bring about new systems possibilities, and extend systems even wider and more fundamentally than the current phenomenon of social computing. Using the toolset, Society will become empowered to tackle its evolution towards a fair, prosperous and sustainable world.

The application of computational socio-geonomics and its practice is essentially a social process. That statement underlies the relative limitation of current computing applications and technologies. To correct this requires applied technology convergence between the science and its practice involving: applying new levels of formalisation, modelling, rich semantic and intelligent human-computer confluent interfaces, new methods and tools for the complex science of social systems; introducing computational socio-geonomics into societal systems at every level from theory and philosophy to practical laboratory and real-life organisations. Together these enable verifiable social systems behaviour.

IMPACT

The premise of S-GAIA is that Society needs to become involved in a collaborative endeavour to secure the well-being of society and our world ecology. The defining scientific and real world feature is that of complexity. Whilst existing systems institutions and popular media address this, they do not yet have a comprehensive, coherent and usable computational means to support their work. Science defines the fundamental features of the problem and uses specific computing methods to support their research; engineering and techno logy will provide the means to apply this when society becomes convinced the resources and effort and above all cost are worthwhile. S-GAIA proposes a toolset that will involve people everywhere, in their everyday lives, their organisations and their governments, as well as the research community. Industrial research, social organisations and institutions increasingly understand the need to deploy new product innovations that meet the client needs and wishes. Society must grow and develop in skills underpinned by science and technology, not continue outdated and inadequate ways of functioning. This is change.

The S-GAIA Flagship approach is to tackle the above imperatives by addressing the levels of fundamental change involved, their scale and do-ability, and the huge transitional process that will be needed. This can be summarised as follows:

• Scientific research will explicate how the concepts of modelling at all levels from the fundamental science, through meta-modelling in societal systems to the meta-models required in the new computational paradigm can be realised and integrated

• engineering and technology will continue applied research to both adapt current computational paradigms and usable computing architectures to address the fundamental new paradigm of bio- and socio- based computing that computational socio-geonomics implies. Tension between adapting current technology to mimic desired new computational paradigms and the cost, lead-time, and resources to achieve paradigmatic breakthroughs will drive progress, (both will win)

• S-GAIA will take the realisable potential and opportunities of new technology forward into a scheme of practical society based implementation. This will involve engaging with Society at every level to establish and get consensus on the road-map and deployment priorities.

• The Flagship process is a continuous development, not a pre-defined and anticipated solution. This mandates simulation and trial as a social and computational model for development. Who knows what discarded theory will become tomorrow's breakthrough?

All the above areas involve a partnership between science, industry, and society. Metaloger claims to be as significant for management as the lever is for mechanics. More specifically and scientifically, meta-modelling is the amplifying global dynamics method at the heart of the toolset.

Three dimensions of impact indicate the scope of downstream activity, R&D economics, Society enablement; and opportunity from S-GAIA:

1. R&D will spread not just across the fundamental sciences nor even the establishment of early prototypes and fast followers of the paradigm: it will be a Khunian effort and outcome. Each discovery will build on the previous ones, revisions to the models-in-use will be continuous. S-GAIA is a soft

robotics environment likely to involve hard-robotics also eventually, since the equivalent of human paper and pen is insufficient to gather and harness the socially enacted data needed by S-GAIA

2. The introduction of S-GAIA will not be achieved by science and technology displaying its artefacts nor even applying them to address specific problems alone: it will require that society is involved in the transformation envisaged. The bench-mark that S-GAIA sets is to prove meaningful in the lives, work and aspirations of its owners: Society

3. Opportunities from S-GAIA include all the industrial grade computing systems platforms deployed across organisations and personal worlds. The ability to process dynamics scientifically will enhance understanding and the practical institutional systems used to solve world problems. In our opinion the largest area of impact will come from deployment of a tool and a philosophy of social engagement that will be not just ubiquitous but rooted in a view of the holism of our world. If we are to address conflict, destruction, the unevenness of opportunity and basic needs provision, there needs to be a joined up approach from the ground up in society.

INTEGRATION

conceptual structure

The core challenge of integration of S-GAIA which by definition marries up the concept of a 'model' with a vision of global scale, is to manage the micro- meso- and macro-dimensions of the project. This suggests that the dynamics of the project will figure hugely in its conception, growth, and progress to maturity. The approach proposed will be to treat the project itself as a complex adaptive system. It will utilise its own methods, technology and social system to nurture the idea through to realisation, with small steps prefiguring more ambitious ventures wider into the world and eventually taking its place as a potent full member of the global village community of resources. This will be to run the project as a living simulation.

Science and use-cases

The development of WORLD SOCIETY MODELLER will include a core scientific enquiry, and specific Case Studies:

• Core components address the three areas of scientific enquiry that will combine to deliver the ubiquitous modelling agenda:

- The fundamental questions of modelling are the relation of the biological and natural science views of the world; resources are living, natural (and also abstract)

- The specific socio-technic focus for this Flagship is that of computational socio-geonomics and its expression in a ubiquitous modelling environment S-GAIA

- The technology and computing aspect concerns the bridge between computational science and its application in real-world applications

• Case Studies focus on the challenges of applying the new scientific insights to real world problems and situations. The examples quoted cover the thematic range of S-GAIA and will be supplemented by other cases as these are identified and research clusters are formed.

- NordWest 2050 is an initiative to address the longer term challenges facing a social and business community in Germany. It typifies the challenge of infrastructure and social change arising from world ecology change, in this case climate driven

- Future Internet is not a technical issue but one of social engagement. It is not about whether EFII is the right framework for S-GAIA but how both will develop to exploit this incredible phenomenon of social connectedness (through all such initiatives)

- NESSI is not directly within the purview of S-GAIA, but the realisation of S-GAIA will be tightly bound with the technologies applications and standards of inter-operability that NESSI will enable. S-GAIA will cooperate in order to exploit the emerging standard framework and also influence its direction and normative outcome.

Implementation

The outcome of S-GAIA which is a deployed toolset, has to embrace the spectrum from pure science, through dissemination and exploitation to a working modelled world. It is science in action. It will call for new modalities of research as has been recognised by FET. The project will recognise this and seek to help fashion these new modalities. Using an analogy given in the White Paper, " We first eat ourselves what we serve to others." [Dutch proverb]

INTEGRATION is the combining of the working parts of all the constituent S-GAIA projects into a working tool-set deployed across Society. Society and social systems are a powerful and effective means to conduct 'life', consisting of a rich assemblage of artefacts, tools, methods, principals, processes, and practice. The challenge is to integrate the twin domains of society and complexity science into the necessary new assemblage. Each of the areas of integration below are a collection of basic science, applied science, behavioural skill, engineering, transition and the bringing of understanding by bridging disciplines (with humility).

Complexity Science

S-GAIA will address the challenge of marrying up people's intuitive grasp of complexity with formal methods embodied in mathematical formalisms and socially meaningful, useful, MetaFOR's (meta frames of reference, templates, systems and engagement models etc). It will be worth all the effort involved to bring to public view and consumption the meaning and usefulness of dynamics.

Modelling & Virtualization: the economy of S-GAIA

The concepts of modelling and virtualization are familiar to computer scientists. These twin dimensions apply also to the Gaia. The idea of a world-wide distributed societal and computational platform extends the meaning of client-server and virtual environments to the entire S-GAIA concept: it is both individually owned and societally owned (and every level of societal constellation in between).

It may seem strange and novel to view societal processes as somehow partaking of the same architectural considerations as virtualisation offers to computing platforms. But the same attributes apply: economies of scale, quality, functionality and management in a world that by definition is fast moving, specialist, and knows the basic problem lies in sharing, individual freedom of use, and leverage of scarce, costly resources. The ecological argument becomes clear: society has always been a balance between individual freedom and authority's view of what is best and how to achieve this efficiently. The reverse has always been misconceived use of power, or market dominance, or even laissez-faire. The reality is in a connected world we need to explore our models of delivery, cherished views, and structures for management, or, in the generic parlance governance. The world can already see both the opportunities and the major challenges of this indicative change in global mindset, and that it is not working or coming about painlessly. Peturbation is ubiquitous.

In the S-GAIA, reality and experiment (simulation or modelling are the synonyms) are at the forefront of the concept. Computational multi-omics is well established in most scientific areas. S-GAIA is an integrated view of this science, extended into the bio- socio-cybernetic fields. S-GAIA will hope to learn from Model Brain and Virtual Physiological Human (VPH) tricks of the trade: we are all into the same quest for the well-being of mankind. To use a figurative but meaningful analogy, S-GAIA addresses the health of the organs of Society which means also addressing its pathology. FuturIcT already includes important goals to address such manifestations of disruptive societal models as extremism, fundamentalism, organised crime and Mafiosi type societies within society. The start of such enquiry is where the dividing line is between legitimate dynamic perturbation and destructive, destabilising forces that offer no valid morphogenesis. We hypothesise that engaged modelling will be an important tool of resolution because it will empower society to choose best practice before chimeras or self-destruction.

A number of special interest areas such as EFII, NESSI and NW2050 are going to use this platform

to tackle their problems and conversely S-GAIA will collaborate with these projects to learn about real world social interfaces and specific technical standards S-GAIA needs to embrace. These are only examples and further collaboration with FuturIcT projects may be appropriate and will be considered as an when these arise. This is all consistent with delivering a global toolset that will serve the specific needs of its Client communities.

Sociology and Change

It is a cliche that the only constant is change. The truth behind this is the quest for betterment, Taguchi's assertion "Quality is inversely proportional to the sum total of loss to mankind" applies to Gaia. The move from theory and philosophical discourse to practical sociological action to change society is well established and working with this field of practical life science is necessary to build useful modelling infrastructure. S-GAIA does not invent the answers, it works with the Master Inventors of the world to do so. They in turn are subject to the discipline of their stakeholders, ultimately society itself. This is the partnership of the S-GAIA Consortium.

Society is the major infrastructure for the running of our world and will go through serious levels of change rather than new invention. This process involves the acting out of individual roles, according to culture, social and family relations, formal organisation positions, and un-formal often not specifically defined roles. There is also in a global world the constant cross-boundary roles and performances that contribute to a picture of a rich societal infrastructure. These are constantly evolving and S-GAIA will evolve new life models based on the ability to transform our world and this will require all the disciplines involved in bringing in such change without disruptive impact or outright polarisation. S-GAIA recognises that bridging disciplines is sometimes difficult. However it is possibly the key Flagship skill. The transformation of the institutions of society is happening world-wide and S-GAIA envisages a wide and purposeful working together to understand the imperatives of change and how these can be managed using the new toolset, its philosophy, advanced science, and new computational basis of socio-geonomics;

PLAUSIBILITY

Plausibility comes down to a judgement of three things: do we want it; can it be done; will it prove useful. The case for the first question has been made consistently since the first Complexity forums in Torino and Paris, and is now formally set out in the ISTAG report. All the constituent components of S-GAIA have a substantial history of progress. The task now is to deliver.

Benefits

The benefit of S-GAIA is in being a practical toolset because it can be incorporated in every computing application directly assisting its successful processing of some useful area of societal working. This can only be achieved by systemic re-examination of how society works (or does not work well enough). It will start with real systems Ubiquitous Complex Event Processing (U-CEP) and from this expand to more fundamental areas of social systems. This is one transition strategy amongst several.

Applied Computer technologies

At all stages of S-GAIA R&D, the focus will be on turning the concepts, new scientific ideas such as U-CEP and meta-modelling into workable artefacts and systems that can be deployed in real social situations to leverage the efforts of people to solve problems. That will go hand in hand with upgrading ICT capability and capacity to meet the demands on infrastructure service provision and safety and security of the new world of socially enacted data.

Progress Beyond the State-of-the-Art

S-GAIA extends the scientific area described in this proposal to society itself, directly, engaged, involved, and empowered. There is no "intervening interface." To bring this about in Society, the S-GAIA Consortium will pool their efforts. We cannot know in advance what synergies will emerge, what serendipity will change the established paradigms, what (to use the hackneyed phrase of industry) killer application will be found.

S-GAIA Road-map: Milestones towards the FET-F Challenge at horizon 2020

This is only a conceptual road map and set of milestones to start thinking:

1. Concept elucidation and planning: 1-2 years Coordination Action: global relationships, science and technology participation elaborated, societal institutions engaged

2. Basic Science research: practical road-map, phased experiment starting in year 2 (on-going)

3. Flagship proof of concept of method for multidisciplinary research and platform: years 2-3

4. Technologies and engineering delivering proof of concept years 3-5 (ongoing)

5. Society engagement environment and initial exposure: years 1 onwards

6. Support and engagement with FuturIcT projects year onwards

7. Fast follower applications years 5 onwards

8. Major delivery by seven years into the programme

9. Conceptual roll out planning assessed and commitment gained by year 8 and on-going.

Outcome

WORLD SOCIETY MODELLER (S-GAIA) will become a laboratory of life.

Research Approach, Structure and Participation

This is just a first stab at key points of working structures modalities and ethos. The aim is to be totally open, involved, and participative in a process that is not just multi-disciplinary but multi-everyone.

1. Stakeholders:

Candidate 'generic' stakeholders include the following:

a. Society through deep engagement typically at least one third of the programme effort, much through targeted live simulation and experiments

b. Social & behavioural scientists, also social system and organisation specialists

c. Users, domain specialists, also organisation, business and governmental strategists, implementers.

d. Complexity scientists, mathematicians, statistical physics and network specialists

e. Socio-cyberneticians, ecology, evolutionary modellers

f. Meta-modelling: Ontology/epistemology/taxonomy/cognition structuralists from all the disciplines involved

g. ICT infrastructure, resources, systems methods and technologies specialists

h. Engagement is a specialist area coupling technology & human/group cognition

i. Applied science/technology/engineering for Design, build, integration, trial, scaling and deployment

2. Society

a. The S-GAIA Consortium: in line with the philosophy of S-GAIA every organ of society will be invited to be represented at all levels of the programme which will take responsibility for effectively servicing their needs

b. The starting list of institutions in society is included in FuturIcT and constituent projects and appropriate collaborations will be entered into. Working and committed involvement will be sought and appropriate service level agreements will be entered into to fulfil obligations on either side

c. Machinery of communication involvement, specialist contributions and general interest will be established and serviced as above.

Research Approach – Implementation

The target of total immersion in society, Industry, the research world within a decade is possible. S-GAIA offers a modelling toolset for use across all social domains. Its essential practicality is to provide a method of rationalising the different models at work in the discourses of the world, industry, organisations, institutions and governments. No one pretends this is easy or simple, but it matters. Solving the problems of the world is a social process before it is a technical one. Priorities, decisions, action are widely recognised to be a social process before they are a technical one; resources are entailed by the social process before they can be deployed. S-GAIA offers a toolset for handling this complex adaptive system that is meaningful life. The Flagship world is the next such project environment.

Conclusion

WORLD SOCIETY MODELLER (S-GAIA) will provide an integrative and coordinating, multi-disciplinary focus to a Flagship that concerns Society and is therefore integral to socio-technics Flagship projects. The emphasis on the ubiquity of modelling as the bridge between Society, solving key pressing problems, deploying ICT technology and involving people, gives a unique identity to a socio-technic

Flagship. S-GAIA is more than a project framework. It is the next paradigm shift in how we address the imperative "Yes, we compute our World".

COMMENTS

Even just quickly reading the so-far set of Flagship proposals gives the clear impression there are further directions of collaboration to be established. Moreover this process needs to be continued and fostered by new modalities and infrastructures of Flagship research, a "World Brain" of Futurist research.

References: CONTRIBUTIONS to the ONLINE FET FLAGSHIP CONSULTATION 2010

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[3] Sutcliffe-Braithwaite, J 2010. Proposal for a Socio-technic project titled SOCIONOME-METALOGER

[4] Von Ammon, R. 2010 Proposal for a Socio-technic project titled UBIQUITOUS COMPLEX EVENT PROCESSING (U-CEP)

3. Academic partners (agreed so far):

a. ETH Zurich FuturIcT Flagship Project, Professor Dirk Helbing under consideration

b. IMSS Research Laboratory, School of Systems Engineering, University of Reading, working with Metaloger technologies, Professor Atta Badii

c. Department of Computer Science, Sheffield University: Multi Agent modelling, Professor Mike Holcombe (EURACE Project)

d. ASSYST to coordinate cooperation with other COSI-ICT projects, education and learning tools Professor Jeffrey Johnson

e. Professor Roberto Poli, Department of Sociology and Social Research, University of Trento, Italy, http://robertopoli.co.cc/

f. Professor Alexander Gorban, Chair in Applied Mathematics, University of Leicester, UK; Chief Scientist, Institute of Computational Modeling, Krasnoyarsk, Russia

g. Professor Peter Plath, Fritz-Haber Institute, Max-Planck Society, Berlin

h. Oldenburg University Germany and the Nordwest 2050 project, Nana Karlstetter

i. Provisional Professor Francis Heylighen, Free University, Brussels, ECCO Research Group

j. Dr David Richards Business Strategy and Innovation, Bournemouth University UK

k. The Zurich workshop Members (specific projects to be instantiated by FuturICT

l. Earlier Metaloger interested parties?

4. Consultants to S-GAIA Consortium

a. Emeritus Professor Denis Noble, Oxford University; the VPH Consortium
b. Emeritus Professor David Luckham Stanford University; founder the Event Processing Technical Society

5. Industrial, technology and technical Bodies

a. Dr Rainer von Ammon, managing director of the Centrum für Informations-Technology Transfer (CITT) in Regensburg, previously he was Professor for Software Engineering, specializing in E-Business infrastructures and distributed systems, at the University of Applied Sciences Upper Austria. He was a founding Member of EPTS and leader in CEP

a. Dr Plamen Simeonov, JSRC, (Berlin), free researcher, ITC & nanobiotech evaluator, industry & VC advisor, former Director Research, Distributed AI Laboratory, TU Berlin (2004-2007) and former Director Active Multimedia, CTO, Siemens Mobile Division (1999-2001).His current research interests include information theory and formal methods, self-organizing and self-assembling dynamic distributed information systems, neuroscience and biocomputation.

b. Dr. Opher Etzion, Event Processing Scientific Leader, IBM Research Lab in Haifa, Chair: Event Process Technical Society (EPTS) Steering Committee

c. Symbiosis with: NESSI, EFII

d. Event Processing Technical Society (EPTS)

e. European Social Simulation Association TBA

6. Global Partners

a. US NSF SoCS Call (TBA)

b. Provisional China and India TBA

SoundICTs: Endowing human auditory capacities and embodying audition faculties into artificial systems

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BRIEF EXPLANATION

SoundITCs

Proof-of-concept ICT models for endowing human auditory capacities and embodying audition faculties into Artificial Intelligent and robotics systems for multi-sensory cognition and reasoning and natural personality, adaptation and evolution

Endowing and embodying Human Audition faculties into robotics systems investigates, develops and proof-of-concept ICT models of acoustic, cognition and robotic systems to leverage the rich though untapped potential of the information associated to sounds, by simulation of human audition perception and understanding and multi-sensory reasoning and population of evolutionary capacities, to embody consciousness faculties, empathic personality and natural evolution into robots.

AMBITION

ACAIA promising visionary idea is to exploit the information associate to sounds for all Artificial Intelligent system and the benefit of the Knowledge Society.

ACAIA Identifies a unifying scientific goal, Audition for all Robots

ACAIA problem is that the justification of the installation of audio-sensors networks for acquiring sounds is the auditory capacity, or the power to extract the useful associated information and the ability to understand it. The complete audition faculties is reached with the multimodal reasoning that embodies consciousness to the robot and facilitates building natural and human robots.

ACAIA solution is distributing and sharing development and experience on Internet to be available for all robots from semantic repositories of Acoustic Processing, Multi-sensory Cognition and Robotics Reasoning, forming and populating two meshes of Artificial Sensing, Thinking and Acting and systems learning, teaching, training and factoring.

ACAIA exploring and modelling concepts and technological of Acoustics processing, Artificial Audition, Cognition and Robotics that can contribute to Multi-Modal sensing and reasoning and Consciousness of robotics challenges of long term importance for Europe.

ACAIA topics are the following:

Understanding The Human Audition, Multimodal Reasoning and Consciousness through proof-of-concept of ICT model.

Personality: Conviction, Anticipation and Intuition by simulation Acoustic Processing, Audio, Cognition and Robotics Technologies Maturing emerging ACAIA community for future problem solving and leading Technologies Robotics for Society

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The human audition for robotics project will have the following objectives:

- to extract all the genuinely meaningful of sounds and noises;

- to generate accurate "quasi real-time" audio-monitoring and audition understanding and continuous learning of "robotics systems";

- to deal audio-raw-data, as "audio streams as film" formed by a sequence of frames of 120ms approx and the mathematical algorithms for - filtering - detection of Acoustic Events, as graphic pictures (frequency x intensity). The audio multi-stream processing device "hears" is filtering 6-8 frames per second for each stream (cinema 24fps, TV 50fps and some video-games 72fps);

- to implement two audio sensing behaviours: active listening to and passive hearing;

- to facilitate a public space "The Future of Internet of Sounds Services" ecosystem of acoustic resources, semantic repositories and open learning and decision-making algorithms in pervasive environments and structure these libraries as a software development to develop, populate, integrate, package and download applications available for all to supply acoustic retraining and cognition and robotic training. This populated, shared and distributed capabilities form an evolutionary ecosystem have to allow the evolution of robotic systems;

IMPACT

The world of sound is not exploited in the Information Society. Being in the XXI century, and given the importance that humans assign to sound in their daily environment, it is interesting to note how few ICT systems are actually exploiting acoustic information naturally associated with sound and noises, such as time, position, event, source, material, size, composition, risk, environment, velocity, traffic, weather, health, disease, context, activity, occupancy, etc.

The project wants to use all the information coming from the environment to enable robots, which can hear and listen, and which can understand the meaning of the acoustically conveyed environmental information and which can hence provide useful services to the knowledge society in an improved, bio-inspired, way.

INTEGRATION

The SoundITCs scheme stimulates non-conventional targeted exploratory research cutting across Acoustics, Cognition and Robotics disciplines and acts as a harbour for exploring and nurturing new research trends and helping them mature in emerging research communities, such as Acoustic Computing for Artificial Intelligence Applications (ACAIA.org).

Harmonic and close interaction between perception and actuation of the audition and cognition for robotics self-configuring sub-systems that consists of five different subsystems:

1.Acoustic Sensing. Acquiring and processing. Listen to and hear the environment.

2.Acoustic Reasoning. Embodying meaning and understanding audio information.

3.Consciousness: Intuition, improvisation and conviction. Multi-modal perception and reflection. of novel experiences consisting of multi-modal perception.

4.Learning and training. Autonomous active learning and natural "pet" training.

5.Human, natural and empathic behaviour. Internal self-organized top-down control.

The Audition perception of robotic systems become aware of the physical world for modelling and control purposes through the acoustic acquiring of audio-sensor and meaning of audio data and multi-modal reasoning to represent, define and qualify the reality to interpret in the light of a pool of shared-experience on Internet and models learnt of behaviour to decide the actuation.

In particular, the main objectives of the SOUNDICTS project are the following:

1. To develop a conceptual and theoretical framework for human audition system for robotics.

2. To design and implement a computational realisation, processing, classification, analysing and packaging Acoustic Events. Main elements of this development include a meta-structure of resources named semantic repositories, novel graph-processing algorithms facilitating multimodal reasoning and development, standards methods that extract sounds meaning and populate these on Internet based on heterogeneous and distributed sources, and user interfaces that facilitate effective and efficient exploration and use of such repositories.

3. To demonstrate the validity of the framework and to evaluate and assess its properties on the basis of a diverse set of demonstration scenarios drawn from different domains, and a range of hypothetical test scenarios with known characteristics, that will be proposed in the project.

4. To assess whether the methodology and its proof-of-concept implementation could lead to a new modular audition sub-system paradigm.

5. To widely disseminate the results of the project, raise awareness in the relevant communities and explore ways of exploiting the project results.

The main disciplines involved:

Acoustics: DSP, Acoustic processing and Detection of Acoustic Event Mathematics: Mathematical algorithms of DSP, cognition risk management, decision making and learning. ICT Audio-sensors and audio-sensors networks. Semantic and ontology. Artificial Intelligence. Systems Architecture. SOA and GPL Psychology: Cognition. Perception. Multi-sensory reasoning. Personality and behaviour. Learning.Robotics: AmI, modularity, integration, machine-learningOther: statistic, ecology, evolutionary theory, sustainability and other sciences.

PLAUSABILITY

Human audition and cognition for robotics Project structureTo reach the goal, advances in understanding and technology development are needed in four closely interrelated areas:

1.the catalogue of technologies for endowing human auditory capacities to robots;

2.the integration of sub-systems for embodying audition faculties into robotics systems;

3.the modelling of natural cognition and reasoning process for design robotic systems;

4.the multi-senses reasoning to strength the robot consciousness and personality.

These four issues are being addressed in five closely intertwined work packages, which form the core of the project. There are two additional work packages, one devoted to project management WP0 and another to dissemination WP5, both of which will be coordinated by the project manager

The main works are to proof the following simple ICT models of modular subsystems:

WP1 ACQUISITION AND PERCEPTION.

Acoustic acquiring and processing by a simple audio-sensors network (ASN) supplying audio-raw data. This simplification excludes all works in sensors, MEMS and microphones, in interactive process, beamforming, sounds tracking and acquiring sounds from remote environments. The acoustic processing device that receive and process the audio information, via multi-streaming, capable of identify and detect acoustic events for extracting meaning and knowledge and manage “abnormal sounds”;

WP2 RECOGNITION, REFLECTION. AND DECISION.

Acoustic reasoning central unit providing meaning and understanding to the auditory and *-perception, for multi-modal reflection, *-senses cues, risk-management consideration and decision-making of actuations. Algorithms and software systems allowing to parametrise the levels of personal behaviour in the reactions (interaction or actuation) and the adaptation to environment and context for generating autonomy, conviction, intuition and pseudo-natural personality to robots;

WP3 ADAPTATION.

Acoustic self-learning and user-training methods and techniques to enhance the features of robotic subsystems and the complete robot system. WP5 designs and develops truly adaptive autonomous systems capable automatically to learn from the experience of all the rest of robots and to teach the rest of robots – shared on the common IoSS ecosystem. The self-learning is based on the management, process and retraining of “unknown sounds”. The user-training will be focused on the behaviours of WP4 personal behaviour, context and missions;

WP4 EVOLUTION.

Acoustic factoring and evolving Getting inspiration from natural ecosystems, the objective of this work is the development of a highly-innovative theoretical and practical Internet of Sounds Services IoSS framework for the decentralized development, deployment and execution of services for future robotic systems and sensing networks. The framework will be grounded on a foundational re-thinking of current Acoustic, Cognition and Robotic (ACR) service models and of associated infrastructures and algorithms. IoSS develops and supplies externally new audition capacities - acoustic events, cognition processing and robotics applications - to upgrade the robotic systems and subsystems. The building of IoSS provide the foundation for sustaining the development of auditory capacities and cognitive systems for robotics. The continuous process of individual retraining will generate a natural evolution of individual robots, depending mainly on the personality, the user-training and the living environment;

COMMENTS

SMES:

Muficata s.l. ESP

AKG Acoustics GmbH AUT

RTD:

Fraunhofer-Gesellschaft Forderung der angewandten Forschung FHG-IDMT GER

Italian National Research Council ITA

ACADEMIA:

AG ESIGETEL FRA

University of Uppsala SWE

Technical University of Munich GER

University of Portsmouth GBR

PLATFORMS:

Acoustic Computing for AI/AmI Applications (ACAIA.org) community

In addition to this consortium supported by this experts community the research works in this area is unknown.

Persons:

Ferran Cabrer i Vilagut is the President and Manager of CONSEN Euro-Group and CEO of MUFICATA S.L. He is Industrial and Agricultural Engineer of profession and Master in Business Administration. He comes from different sectors, remarking the management of the department of Research and development of phito-pharmaceutical products into LAINCO. In a personal entrepreneur project funded MUFICATA as ICT Enterprises consulting and Corporate Finance firm to provide Enterprises Information and Technological services. The Internet was the instrument used to start International services and converted in EU information and project management services. After a pair of year he funded CONSEN as Open Euro-Cluster in Information Society Technologies formed by eight SMES operating at European Level. It is one that has participated actively from 2002 in european ICT projects. Actually he is contributing in diverse european projects and collaborate as Vice-Chairman of the Knowledge@work community, EURO_COOP_ICT_DEV Romanian research project for a sustainable cooperation throughout Europe, Member of the European Association of Research Managers and Administrators (EARMA), member of eBusiness Support Network (eBSN), Living-Labs and several more European initiatives and networks in IST as eMobility, ISI, NESSI and NEM technological platforms. From 2005 is promoting ACAIA.org initiative.

Dipl. Ing. Rene Rodigast studied Electrical Engineering in Hermsdorf and in Jena from 1989 to 1994. He worked as a technician in the field of audio and video technology for theater, broadcast, and live events. From 1995 to 2002 he was technical director for professional audio and video applications. Since June 2002 Rodigast has worked at the Fraunhofer Institute for Digital Media Technology in Ilmenau/Germany. He is manager in the acoustic department of the group “Multimedia Systems”. One of his major projects was the first implementation of the Wave Field Synthesis technology IOSONO in a commercial movie theater. Another outstanding success was the development of a new sound system for the world’s largest open-air Floating Stage “Bregenz Festival”, Austria in 2005. Rene Rodigast is member of the International Planetarium Society.

Fernando Ferri received the degrees in Electronic Engineering in 1990 and the PhD in Medical Informatics at the University of Rome “La Sapienza” in 1993. He is senior researcher of the National Research Council of Italy. He has been contract professor from 1993 to 2000 of “Sistemi di Elaborazione” at the University of Macerata. He is the author of more than 160 papers on international journals, books and conferences. His main research areas of interest are: Geographic Information Systems, Data and Knowledge Bases, Human-Machine Interaction, User Modelling, Visual Interaction, Sketch based interfaces, Risk Management and Medical Informatics.

ICT Beyond Limits

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BRIEF EXPLANATION

The goal of this project is to design future information processing technology that will take ICT beyond the current limits of energy requirements and performances. In order to realize this ambitious goal, the project will require and enable anticipation, insight and validation via simulation through a multiscale approach, from atomic scale including quantum features up to complex system level design. Such simulations will themselves make extensive use of today's most performant supercomputers and distributed computing infrastructures.

AMBITION

Information and Communication Technologies have opened up new and unprecedented possibilities for businesses and citizens alike, and have lead to an exponential increment in our wealth and welfare. Also, it is widely recognized that ICT will play a major role in the next decades, where it will be an enabler for the structural changes that our society will undergo in order to become the sustainable society of the future.

Until now, ICT has ensured constant progress due to the scaling down of its building blocks, the consequent increase in computing power as well as the scaling up of the number of interconnected processors leading to massively parallel/distributed computing. But limits are now very clearly in sight that threaten the further development of a number of applications. Those limits are related to heat dissipation and energy efficiency, and also to hitting the "atomic wall" where the components size reaches nanoscale and below.

In this context, the goal of the ICT BEYOND LIMITS flagship is to open new avenues for future information processing technologies to go far beyond the current limits of performances and energy requirements.

To reach this ambitious goal, ICT BEYOND LIMITS addresses the most pressing scientific and technological demands arising from the way technologies, systems and products are and will be designed. It works in two strongly interconnected strands: Emerging hardware and Emerging Simulation.

The part "Emerging Hardware" addresses the following issues in

- **Supercomputer Technology Beyond the Exascale:**
  The development of supercomputer technology towards the Exascale and far beyond requires the creation of innovative components on all aspects of architectural design, and a mastering of both the limitations and the novel possibilities opened by working at the nanoscale;
  - Immense progress will be achieved in ultra-scalable hardware architectures, optimized energy efficiency and highly scalable storage;
  - -The transfer of HPC technologies from the lab to information and communication technologies for business and society in order to sustain the exponential increment in our wealth and welfare. Championing supercomputing at the forefront will be pushing and propagating innovation to all other levels;
  - The development of European ICT technology will reduce dependence and foster cooperation with USA and worldwide;
  -
- **Quantum Technologies**:

- The exploitation of the full potential of quantum mechanics in information processing, by engineering quantum behavior at the level of logical degrees of freedom;
- The use of quantum coherence to perform tasks in information processing, communication, sensing, imaging and metrology unattainable by systems behaving classically;
- The transfer of these quantum technologies from the lab to the real world, leading in the mid- to long-term to entirely new fields of economic activities, and having an impact on everyday concerns like, e.g., security, privacy, data protection and health care;

- **The solution of the power dissipation problem for current and future ICT devices in quantum and supercomputing by answering fundamental questions on** 1) basic mechanisms behind heat production; 2) the way to take advantage of the fluctuations instead of avoiding them and 3) the mean to merge the physics of heat and charge transport with the phonon engineering in order to advance computing tasks.

The technology fields Supercomputing and Quantum Technologies represent the fundament of the Emerging Hardware part of the initiative, complemented and supported by the resource area Phonons and Fluctuations, and deeply connected with the other areas described below.

- **The part "Emerging Simulations" in turn addresses the following issues:**
  - The increasing importance of simulations of nearly all real-world problems concerning real, virtual or conceptual complex systems: this requires to rethink models and algorithms. A revolution is expected in the way systems are designed that will rely on simulation on a 10-15 year time horizon;
  - The demand for system simulations of ever increasing complexity calls for the development of scalable application codes as well as scalable system software to exploit the full power of supercomputers and distributed computing facilities. Completely novel programming paradigms, program development processes and programming tool chains to address technical challenges of (Exascale) multi-core computing are needed.
  - The contributions will come from four operative research areas: three well-developed fields (Quantum Technologies, e-Design and Supercomputing) where maturity and critical mass have already been attained, and an emerging and promising one (Phonons and Fluctuations) where the same progress is to be expected over the next years.
  - Quantum Technologies will develop the most radical and promising ideas and technological platforms to bypass the scalability limits of conventional ICT, resulting in:
  - new components and devices that will be elements in the long term in high-performance computing facilities;
  - completely new technologies (quantum communication, quantum metrology, entanglement based technologies);
  - new models of quantum dynamics that will constitute physical input for the e-Design simulation environments.
  - Supercomputing Technologies will deliver most innovative all-purpose leadership supercomputing hardware and software technology for key applications, resulting in:
  - rapid progress in computational power (high performance computing facilities and cloud computing) enabling the simulation environments needed by e-Design;
  - pushing the transfer of leading IC-technologies from the lab to business and society;
  - a common software architecture through the development and exploitation of advanced computing facilities to simulate real systems.
  - e-Design will revolutionize the way scientific support is addressed, products, systems and technologies are designed, resulting in:
  - efficient and realistic multi-scale, multi-physics, multi-technologies algorithms and Exascale simulation codes;
  - new computation/simulation capabilities using post-Exascale and quantum technologies;
  - a universal and distributed database at the atomic scale;
  - innovative CAD tools and intuitive Human Machine interfaces.
  - Phonons & Fluctuations will develop a new understanding of basic mechanisms of information transport and energy dissipation for a greener computing technology, resulting in:
  - lower energy and higher efficient components;
  - noise-tolerance computational strategies based on fluctuations.

- o ICT BEYOND LIMITS targets bridging breakthroughs in science and innovative applications through strong synergies between its components:
- o energy efficient technologies will develop thanks to advances in theoretical nanoscale thermodynamics, quantum technologies and computing system design;
- o conversely, e-design will benefit from advances in physical modeling of nanoscale processes both at classical and quantum levels, allowing "quasi-zero approximation" simulation;
- o quantum technologies will take advantage of extensive simulations for the design of new components and devices;
- o supercomputing development will require breakthroughs in computing power and in energy management, possibly benefiting from new computational approaches both at classical and quantum level.

IMPACT

Due to the comprehensive breadth of the research areas interconnected within the ICT BEYOND LIMITS flagship, a very large leverage effect on European research, funding and economic activity is to be expected.

- First, this initiative will enable the coming of a Second Quantum Revolution which will be responsible for key physical and technological advances for the 21st Century. The hallmark of this Second Quantum Revolution is the realization that humans are no longer passive observers of the quantum world that Nature has given us. In the First Quantum Revolution, quantum mechanics is used to understand what already existed. The difference between science and technology is the ability to engineer your surroundings to your own ends, and not just explain them. In the Second Quantum Revolution, quantum mechanics is actively employs to alter the quantum face of our physical world—developing a quantum technology. Thus, although quantum mechanics as a science has matured completely, this initiative will make possible the emergence of the quantum engineering as a technology
- Second, this initiative will foster the rise of a new era in the knowledge-based economy where Europe will be leader. In eighteen/nineteen centuries Europe led a cultural and social revolution that changed forever the way people have considered their way of working and living. The invention of heat engines and progresses in thermodynamics were the two faces of the coin that bought such a major advance in human history thanks to the discovery of the laws of heat and work’s transformation. Today we face the opportunity for a new, similar change. The discovery of similar laws at atomic / nano scale might ignite the progress leading to invention of unprecedented nanoscale machines for sensing, actuation and communication.
- Third, this initiative will clearly foster an even stronger structuring of the European research communities involved, leading in particular to a new organized and identified HPC users community (such as those that already exists in the research areas on Climate or Fusion). Also the new components, devices, tools and simulation environments developed within the ICT BEYOND LIMITS will noticeably accelerate research in basic and applied sciences by providing an easy access to up to date simulation means to the research community at large;
- Fourth, it will have important implications for the future European economic competitiveness in areas ranging from wholly new and innovative technologies to improvements in everyday concerns like, e.g., health care, security and privacy of information, data protection. Energy efficiency will be also thoroughly addressed through the understanding and control of thermal properties. ICT BEYOND LIMITS will strive for turning these promises into reality, strengthening at the same time the industrial dissemination of these new technologies and thus helping in bootstrapping the market for their commercial exploitation;
- Fifth, a new service providing business will be developed (providing a return on investment on a pay-per-connect basis), that will allow a large number of SMEs to access up to date design tools and allow them to do in–house design without unaffordable database costs of ownership. In addition, a number of large scale industry players specialist in system integration will also directly benefit and accelerate the implementation of the ICT BEYOND LIMITS goals.

More generally, it should be noticed that:

- The next few decades will witness the birth of many architectures with homogeneous multicores and accelerator hardware that promise huge performances but will require new efforts to port applications, rethink algorithms and develop flexible software infrastructures. The new multicore era will have a tremendous impacts not only on supercomputing, but also on all scales of computing like departmental or even personal computing; ICT BEYOND LIMITS will ensure not only that the European competitiveness is enhanced by deploying the full power of the next generation of HPC, but also that Europe will be a developer and a provider of these facilities;

- European industry will depend on non-European simulation and database technologies on a 10-15 years horizon: with ICT BEYOND LIMITS, the databases and the simulation environments (including quantum simulators) will become European, thus supporting a European strategic independence;
- Many quantum technologies have gone past the proof-of-principle phase and it is expected that the will reach the market in the ten-year framework. These include: quantum metrology and sensors, clocks based on entangled atoms, nanometer sized rods and cantilevers, quantum imaging, frequency entangled photon pairs for sub-micron biomedical imaging, quantum simulators, quantum communication protocols and networks, and finally quantum processors and computers.

INTEGRATION

ICT BEYOND LIMITS builds on fundamental purpose-driven basic-science and technology-oriented research, which truly is of transformative nature, in the sense of leading to exceptional and unprecedented outcomes (the nurturing of this type of research representing clearly the FET mission).

It is multidisciplinary by nature and integrates diverse scientific and technological communities:

- Basic traditional science disciplines such as experimental and theoretical physics, chemistry, mathematics, statistics, engineering and computer science;
- A diversity of disciplines of computer science such as design and implementation of high performance and power-efficient computers, resource and power management, programming models, resilience, performance tools, CAD systems, adaptive databases, artificial intelligence, Human Machine Interfaces, resource and power management, programming models and runtimes, resilience, performance tools and architectures.

All these outstanding communities and disciplines will be federated under the common ICT BEYOND LIMITS initiative, thus forming an unprecedented critical mass that would be needed to ensure Europe's leadership in the ICT field for the next decades, when the limits on the traditional electronics will be hit. It should be stressed that the theoretical communities in all the aforementioned areas will play an important role in the ICT BEYOND LIMITS flagship: they will push the knowledge of fundamental science topics (quantum physics, and nanoscale thermodynamics, to mention a few) beyond the state of the art, will investigate fundamentally new models and algorithms, protocols and approaches to ICT and in general they will guide and support experimental activity and covering a wide range of physical systems and technologies.

In addition, the ICT BEYOND LIMITS Flagship initiative will heavily rely on the intensive use of European integration centers, specialized labs and clean room facilities for nanotechnologies, large scale research instruments and HPC centers; at the same time it will gather participants from the following industrial sectors:

- Traditional sectors such as energy, nanoelectronics, health, materials, transport, aeronautics which, as end-users will be actively involved in specifying the necessary contents and applications to come from the expected revolution of the e-design and the use of breakthroughs coming from quantum/phonon/fluctuation control.
- High tech sectors, including highly specialized SME providing innovative solutions by leveraging the tremendous capabilities offered by novel classical and quantum technologies.

Finally, ICT BEYOND LIMITS will federate and transcend several European research efforts on the subjects of e-Design, Supercomputing, Quantum Technologies and Phonons & Fluctuations, in particular:

- The EMBL, House of Simulation network, ETSF, CECAM++, HM research, JRC PETTEN, GENESYS;

- The Supercomputing E-Infrastructure “Partnership for Advanced Computing in Europe” (PRACE) and PROSPECT, where industrial and academic partners aim at developing HPC technologies, as well as HIPEAC and EESI aiming for Exascale software;
- The FET Proactive Initiatives Quantum Information Foundations and Technologies, NANO-ICT and Molecular Scale Devices and Systems, Zero-Power collaborative projects and communities, Nonlinear-stochastic-dynamics European networks, and, possibly, initiatives addressing atom chips and atom lasers, spintronics, single nano objects and similar topics.

PLAUSABILITY

The plausibility for such an ambitious initiative as the ICT BEYOND LIMITS flagship derives from a number of various green indicators and ongoing progress which relates to the different components (e-Design, Supercomputing, Quantum Technologies, Phonons & Fluctuations) of the initiative. These include

- the current irruptive situation generated by the arrival of the multicore era and the prospects of Exascale computing has given opportunities to find ways to attack what otherwise might be a very static industrial dominance position in ICT technology. Championing supercomputing technology at the forefront will be pushing innovation on all other levels. Europe has a privileged position in terms of application and industrial software developers. It also has numerous SMEs and highly recognized research teams providing excellent technologies in areas of system software like storage, programming models, tools;
- constant progress in the quantum technologies area has allowed many of its branches to go past the proof-of-principle phase; further advancements will be ensured by the integration of the scientific base in order to encompass the full range of quantum information processing from conception to development of devices and from computation and communication to other technological applications of quantum effects;
- convergences of technologies that are allowed by mastering matter at the quantum level and the nanoscale; this convergence is accelerated by the development of nanosciences and of strategies of technological integration;
- maturity of the large scale instruments and of their capabilities to validate models of unitary processes;
- recent progress in theory and simulation both at the nanoscale and for multiscale integration to describe complex systems;
- recent progress in realization of nanoscale devices and experimental investigation of physical properties at the nanoscale;
- recent development in atomic and nanoscale science including non-equilibrium thermodynamics and associated basic statistical sciences as well as quantum physics;
- proactive development of HPC in Europe leading to a large increase of the available computing power (Petaflop-class computers) and of the simulation expertise, following the existing PRACE agenda and the initiatives around Petascale software development;
- development of distributed computation by cloud computing;
- acceleration of the research agenda on adaptive databases and HIM;
- experience of European CAD industry, to master numerical centers and simulation environments.
- increasing interest in energy efficient ICT for the future reduction of the ICT originated Carbon footprint (SMART2020 report).

In fact, in the past twenty years, with a limited resource available, the e-Design, Supercomputing, Quantum technologies and Phonon & Fluctuations communities have been able not only to elaborate individual research strategies, but also to meet all the timelines identified for the various goals and proofs of principle. From this track of record it is to be expected that the leap in invested effort as well as the federation that ICT BEYOND LIMITS would ensure, will have an extremely high return on investment, with a new wealth of advanced technologies capable of unprecedented tasks being thought, developed and finally commercialized for the benefit and wellness of the whole European society.

COMMENTS

From the Supercomputing initiative:

The proposal has been in discussion between major partners of the PRACEconsortium. A strong support will be given by the community of computer science research institution, the supercomputing centers and the very large community of users.

From the e-Design initiative:

- CAD vendors, PLM providers Large integrating systems industry players Design Houses Physics, chemistry, biology, computing sciences research communities

From the Quantum Technologies initiative:
QUROPE Governing Board

- Rainer Blatt, Institute for Quantum Optics and Quantum Information, Innsbruck, Austria
- Harry Buhrman University of Amsterdam, Netherlands
- Vladimir Buzek Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia
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- Anton Zeilinger University of Vienna, Austria
- Peter Zoller Institute for Quantum Optics and Quantum Information, Innsbruck, Austria

Some of the industrial stakeholders for Quantum Technologies in Europe
ARC Seibersdorf, Atos Worldline, Belgian Defense, Bell Labs, Lucent Technologies, BookhamBSI, Bundesamt für Sicherheit in der Informationstechnik Corning, Crescendo Ventures, D-Wave Systems Inc., DANTE, Elsag, ETSI - European Telecommunications Standards Institute, FTTH Council Europe GCHQ, HP Labs, IBM, Zurich Research Laboratory - Identity Management and Privacy Group, id Quantique SA, Infineon Technologies, JDSU Optical Communications groups, JENOPTIK AG, MagiQ Technologies, Inc., Meriton Networks, METAS, NEC, Omnisec, Ovum RHK - Network Infrastructure, Philips Research, Pirelli, QuTools, Senetas, Siemens AG, Smals-Egov, Smart Quantum, STMicroelctronics, Technology Strategy Board, Thales, Toshiba Research Europe Ltd, Zetes PASS, Zurich Research Laboratory

From the Harnessing fluctuations initiative:

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- Jouni Ahopelto, Microsystems and Nanoelectronics, Technical Research Centre of Finland, VTT, Finland
- Bruno Michel, IBM Zurich Research Lab GmbH
- Sebastian Volz, Laboratoire d'Energétique Moléculaire et Macroscopique,Combustion, Ecole Centrale Paris, France.

- Alejandro Martinez, Universidad Politécnica de Valencia, Nanophotonics Technology Center, Valencia, Spain.
- fshin Ziaei, THALES Research & Technology France
- Francisco Gamiz, Dept. Electronics, University of Granada
- The Catalan Institute of Nanotechnology (J. Pascual, Clivia M. Sotomayor Torres, Sergio Valenzuela and Adrian Bachtold)
- José Sánchez-Dehesa,Universidad Politecnica de Valencia, Department of Electronic Engineering.
- BahramDjafari-Rouhani, University of Lille.
- Adnen Mlayah, Centre d'Elaborationde Matériaux et d'Etudes Structurales CEMES/CNRS, Toulouse, France.
- Lukas Worschech, Technical Physics Department ,University of Wurzburg (Germany)
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Internet Science

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Permission	yes

BRIEF EXPLANATION

"Internet Science" is coordinated, multi-disciplinary research that will lead to a thorough understanding of the complex technological and socioeconomic interrelations of the Internet, and will establish methods and tools to design components of future instantiations of the Internet, and future applications on top of it.

AMBITION Rationale:

The Internet has evolved from an experimental network used by researchers to a ubiquitous network on which individuals, business, and government depend for all aspects of daily operation.

The current and future importance of the Internet is enormous.

However, Internet research is fragmented, unlike more mature scientific areas such as physics, in which progress builds on well-established frameworks and theories.

We lack a thorough understanding of the Internet and the networked applications built on top of it, which represent a highly complex system, which evolves influenced by a large variety of stakeholders (including manufacturers, operators, users, and policymakers).

Unlike well-established engineering disciplines, we also lack methods for engineering future instantiations of the Internet, and for creating applications which make use of its services. There is a need for establishing innovative engineering methods, and for a holistic approach for combining them, which can ensure to meet the needs of emerging applications with ever-growing complexity, including sensor and RFID networks, ubiquitous energy control, and immersive 3D audio-visual communications, taking into account technological requirements such as scalability, flexibility, security and resilience, as well as socioeconomic requirements.

Ambition:

The ambition of the Flagship Initiative on "Internet Science" is to enable coordinated, multi-disciplinary research which will lead to a thorough understanding of the complex technological and socioeconomic interrelations of the Internet, and to methods and tools which allow one to design components of future instantiations of the Internet, and future applications on top of it.

IMPACT

Approach:
A scientific approach towards engineering methods for the design of future instantiations of the Internet and its networked applications, will address the following dimensions:
- Technology dimension (networking and communications)
- User dimension (seamless communication)
- Social dimension (social web)
- Economic dimension (business models)
- Political dimension (regulation, standardization)
- Energy dimension (the 'green' agenda)

The design methods have to ensure the desired properties of the future instantiations of the Internet and its networked applications, such as resilience, mobility and devices attached to several networks in parallel, security (including trust relations, privacy, anonymity), usability (which will be transparent to users), manageability, openness and extendability, and economics.

Areas of activity include:

- Heterogeneity and inclusion of new networking paradigms and technologies
- Control and management of the large, complex Global Internet
- Support of mobility at all levels
- Policy boundaries and trust across administrative and political boundaries
- Security and privacy from multiple perspectives
- Resilience and survivability
- Adaptivity and evolvability that admits future unexpected applications

Impact:

For a society that increasingly depends on Internet, “Internet Science” in turn can help shaping society. “Internet Science” ensures sustainability by designing networks and networked applications that by themselves are highly energy-efficient and sustainable; and which enable, by serving their applications domains, to achieve sustainability goals. A high impact is also ensured by engineering methods that guarantee by design desired resilience and security properties, including privacy and anonymity aspects.

INTEGRATION

This kind of research needs to bring together scientists from telecommunications, systems-oriented computer science, software engineering, information systems, theoretical computer science and mathematics, physics, control theory, economics, politics, sociology, psychology, and from the application domains served by the Internet, such as energy and live sciences.

The research needs to combine theoretical activities with empirical approaches and also realistic experiments.

PLAUSABILITY

We believe that a compelling research program can be put together that makes appropriate use of the respective skills within communities listed above: in fact, we assert that it is essential to base such a program on the contributions of partners from these communities. Each of them has a valid stake in the creation of a Future Internet.

Next Steps:

The “Internet Science” initiative aims to incorporate a variety of methods and tools for forming a science for the Global Information Infrastructure, that is not limited by its current constraints.

It builds on the ongoing activities of the rethinking the Internet architecture, both from a clean-slate view, as well as how to make substantive improvements to the current architecture. This follows on to a certain extent on research of the EU FP7 Challenge 1: Pervasive and Trusted Network and Service Infrastructures, Objectives 1.1 Network of the Future and to a subset of the work of Objective 1.6 New Paradigms and Experimental Facilities (FIRE), and the Future Internet Assembly (FIA). Activities by the US National Science Foundation Future Internet Design (FIND) and GENI (Global Environment for Networking Innovations (GENI), followed by the recently established Network Science and Engineering (NetSE) program, have a main focus on concrete technological steps for developing future instantiations of the Internet. These activities follow a variety of mainly independent, competing approaches, leading to the currently observable, fragmented Internet research scene. Only a few aspects of the challenges identified so far, concerning both underlying theory, as well as holistic design methods, have been explored by the research community.

A FET flagship "Internet Science" initiative would be a consequent continuation of the above-mentioned programs. In uses selected activities of these programs as technological input, combined with theoretical and methodological approaches from a wider scientific community, and in extending it by socioeconomic dimensions for a true multi-disciplinary initiative, is in the position to mobilize a scientific community of needed capacity.

COMMENTS

Arguments in support of an initiative on "Internet Science" have been identified within the Dagstuhl Perspectives Workshop: "Architecture and Design of the Future Internet", 14 – 17 April 2009, http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=09162 organized by

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Robot Companions for Citizens

Paolo Dario

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Position	Full Professor
Country	IT
Permission	Yes

BRIEF EXPLANATION

This FET-F is committed to generate the *Robot Companions for Citizens* of the future (2020+). This new generation of robots will be self-adaptive machines helpful to humans throughout their lifetimes.

AMBITION

Over the last five decades, the development of robot technology has been dramatic. Their accuracy, speed and dexterity have significantly increased while prices have come down. Application areas are manifold. Today's industrial robots cost-effectively produce many kinds of goods at high speed and with high quality in factories. Service robots are remotely controlled to perform surgery, explore Mars and the undersea world, assist disabled people and are poised to relieve us from many of our household chores, such as cleaning. As tools for scientists they support neuroscience investigation, and through embedding of robot technology into other devices, intelligent limb prostheses for amputees can be provided and cars can assist their drivers to improve overall road safety.

Nevertheless, today's technology is becoming more and more sophisticated and, although on one side this enhances humans abilities, on the other its use is becoming more and more challenging, de-facto preventing the weakest part of the population from exploiting such sophistication. Paradoxically, we can say that the most advanced devices have reached such a level of performance that the limiting factor is not always technology, but the ability for humans to exploit its features without stress. This is true now for vulnerable groups such as the elderly, but in the future, this limitation in exploiting technology is bound to become a universal problem unless a clear shift is made from improving technological performance to improving technological accessibility.

We believe that to realize devices that are really accessible to all, the burden of knowing which technologies are available, and how to access them, should be removed from the human user and embedded in the device itself. The human should not be asked to remember all possible uses and features of a device, but the device itself should be able to "understand" which is the most appropriate feature to be used in a given situation.

To reach this new, non-stressing, universal level of accessibility we have to go beyond the master-slave relationship and investigate how to design and realize a new generation of devices supporting humans in a purposive, goal-driven, knowledge and experience-based manner.

These novel devices will not be "slaves" executing orders given by a human operator, but they will act like apprentices able to learn from experience, to understand the goals of their actions, to adapt to contingencies and to anticipate, in a developmental and evolutionary way, the intentions of their human companions (as apprentices becoming more and more skilled up to the level of autonomy desired by the personal human companion).

A Flagship Programme provides the 'powerhouse' to make a creative and intellectual leap forward providing benefit for society, science and industry. The ambition of the robot companions 'Flagship' is to draw together, integrate and progress beyond the state of the art, the technologies and disciplines necessary to realise scientific and industrial goals in the new and exciting domain.

In this framework, robot companions will be conceived as a totally new generation of robots. On one side, they will have the desirable properties of living systems, such as being able to react appropriately in novel situations, and to show skills of learning, adaptation and self-repair, resilient morphologies, and human-like perception and human-friendly communication. On the other side, they will posses all the desirable features of high-tech widespread industrial products, such as dependability, maintainability, safety, security, user-friendliness, attractive design, energy-recharging autonomy, and low-cost.

In this FET-F a bold approach will be pursued aimed at laying the foundation for robot companions for citizens. Robot companions will be artefacts that finally live up to the promise of machines that are truly supportive to humans and helpful as a human companion, or fully integrated with the human body, adaptive, and helpful to humans throughout their lifetimes in the most unobtrusive way.

Robot companions will come in many flavours, depending on the main function they are to perform. For instance, they could: produce goods or perform services; operate alone or in groups; be fixed to one location, mobile, or applied and interfaced to the human body; be sent to explore the undersea world or outer space; monitor and maintain our environment; be connected to the human body as prosthetic devices; or operate within the human body as mini-invasive tools for medical applications.

Robot companions will not necessarily be made of only mechatronic components nor will they necessarily be humanoid. They can integrate new actuators, sensors and bodies based on bio-hybrid, smart and lightweight materials. They can have advanced control and processing units employing novel hardware and parallel computing, and advanced networks allowing for scalable, limited centralized or decentralized control and communications. They can be physically embodied or virtualized in cyberspace.

Robot companions and humans will mutually understand and adapt to each other. They will symbiotically interact with citizens: a robot will not simply be a tool (like a calculator) helping the human to execute 'routinizable' tasks, but it will be a partner sharing similar goals as humans. For this purpose, they will sense and understand a human's physiological and psychological state and will adapt their operation accordingly.

Robot companions will also be able to organize in networks of interactive and smart devices, through which humans will be able to have access to any source of information and web-based service, and will also be able to communicate with humans through physical interaction, thanks to their physical bodies. Thus robot companions will contribute to the overall quality of life by not only assisting in practical utilitarian tasks but also in enriching the human environment and experience.

Over different scales, robot companions will be allowed to communicate and share their own experience of the world, in terms of data collected in their specific tasks, such as cooperating with workers to produce goods, delivering services, environmental monitoring, search-and-rescue missions, exploration of hostile environments, human assistance, domestic services, household chores. In this way they will have the opportunity to continuously enrich and strengthen their skills in order to generalize and solve unstructured and unknown problems. As a consequence, they may try novel behaviours or suggest to the human partner ways in which they could be upgraded when new modules are necessary or new perceptual, cognitive or behavioural schemas are discovered by other robot companions that are available for download.

These artefacts will be extremely complex at multiple levels of organization ranging from their mechanics and electronics to their behaviour and psychology, but at the same time they must be low-cost and extremely safe and dependable. Indeed, fatal system errors and complete breakdowns will not be acceptable for robot companions – they will have to provide their multitude of services and functions reliably and in safe manners at all times. In fact, it would be unconceivable for devices closely interacting with humans to catastrophically fail in the case of a malfunctioning component. Instead, they will be able to anticipate and tolerate faults with no dramatic performance or safety loss.

Robot companions will be also the generation of "self-X" robots. Indeed, they will be capable of self-*adaptation*, self-*knowing*, and, to a limited extent, of self-*organizing*, self-*healing* and self-*evolving* (i.e. "self-*X*"). To achieve such properties they will take on shapes and employ technologies that are best suited for their intended function.

With this new generation of robotic artefacts, it will no longer be necessary to replace human-assistive devices because robot companions aim at adapting and reconfiguring themselves to support our changing needs. Ultimately, we humans will no longer be forced to adapt to our machines.

IMPACT

The development of robot companions will deeply impact society, industry, and scientific and technological progress from 2020 and beyond. Robot companions will give rise to the foundation of smart environments (also named ubiquitous robotics or as network robots), in which they will collect and convey data, develop models of human-environment interaction, monitor environmental resources, predict potential risky (environmental and societal) scenarios, perform physical actions, and elaborate solutions for complex problems. They will have a profound and pervasive impact on virtually all new products. For these reasons, networked robots will be the massive-ICT-based solution that humans will exploit to optimize the governance, administration, and management of economic and human resources, strengthen public safety and security, enhance factory automation, improve logistics, serve and assist elderly and disabled citizens, and generally improve overall quality of life.

The scenario of care for elderly people is particularly representative of ubiquitous robotics. Europe must deal with the problem of the ageing society and the cost of providing care and support for the older section of the community. This is a problem for all sovereign states and will increase in the years to come. The solution, based on social and economic factors, must include better provision for older citizens in their own homes, by means of ambient intelligence and assisted living paradigms, including self-X humanoid robots.

Self-X factors, adaptability, user-friendliness, strong dependability and cost-effectiveness will be crucial properties to enhance the large-scale pervasiveness and deployment of robot companions among all public and private sectors of life: houses, schools, hospitals, industries, primary sector, research centres, cities, public transportation, public management, etc.

This large-scale pervasiveness will push new ICT business opportunities. Indeed, there will be a great chance for both “old” and “new” ICT-entrepreneurs to explore new markets related to design, manufacturing, commercialization and distribution, customization, maintenance and repairing, updating of the robot companions. We expect that this FET-F will give rise to new forms of engineering and a new community of professionals, skilled workers and (more generally) experts in constructing, assembling, managing, and setting up networks of self-X and adaptive robots. This community of professionals and entrepreneurs will be the EU bulwark for competitiveness in the worldwide ICT market. This community, and the market for self-X robots, will allow for the establishment of a virtuous path, leading to sustainable economic and societal progress. In fact, the more that self-X robots spread in all sectors of society, the more efficient the management of societal resources will become, and the more quality of life will be improved.

This virtuous loop will be made possible because scientific and technological progress will be deeply enhanced by this science-driven FET-F. Although the ultimate goal set by this challenge is long term, this does not preclude medium term exploitation opportunities arising from the pursuit of this challenge. Indeed, capabilities such as self-adaptation, behavioural and energetic autonomy together with massively rich and dense sensing capabilities are pre-requisites of a flourishing robot industry serving European societal needs in the next 10-15 years. Indeed, in order to set foundations for robot companions, several multi-disciplinary, and high pay-off challenges will have to be met, including:

Robot “brains”. To develop systems that are capable of: integrating rich and multi-modal perception, solving more than a single task, finding solutions to problems without being instructed, adapting to changing environmental and task requirements, understanding and communicating with humans and with their peers. Although different approaches will be explored, a major drive towards understanding how biological brains solve these problems will boost our understanding of self-X and how to realize it.

Robot “bodies”. To develop technologies that will allow a robot companion to grow its body and to adapt its physical shape to a certain task (class). This calls for materials, structures and actuators that go beyond the rigid plastic and metal structures of today’s robots in that they will be adaptive, compliant, safe for humans, self-repairing and self-morphing, and bio-compatible. We must develop novel sensor technologies that are capable of providing the richness, dynamic range, and multi-modal properties seen in animal perception. To achieve true adaptation to a certain “task niche”, the robot will have to adapt its body in combination with the evolution of its “mind”. It will be necessary to develop electronic architectures that can support these requirements for adaptation, distribution, rich sensory perception and flexible cognition and behaviour, yet at the same time, be compatible with novel bodily structures and requirements.

“Artificial senses” for human and robot. To develop sensing systems that allow robot companions to sense the environment and provide relevant information to the owner. These “artificial senses” may be integrated in the robot or eventually interfaced to the human brain. For instance, these sensors, together with appropriate information processing, will replace degraded human sensing capabilities due to age or health conditions. The user will be able to hear, see, touch or smell, through “artificial senses”.

Robot energy supplies and “metabolisms”. Today’s robot systems are severely limited by the dependence on electrical energy storage and/or on the presence of sunlight for their energy supply. Alternatives could include the use of fuel cell technologies, or to break away from the classical electrical energy cycle and create new cycles with “metabolic” energy converters and/or actuators that can be driven directly – all modelled on energy conversion and actuation principles found in animals.

Miniaturization and Distribution. An important goal will be to develop robots that can be small, bio-compatible and, in some cases, bio-degradable to safely act within or integrated with human bodies in order to carry out monitoring, drug delivery, tissue and functional repair. Micro- and nano-robots could exist in large numbers and should be able to coordinate and perform a dynamic division of labor according to the task requirements and ever-changing environmental conditions. Distributed micro-robots may operate coherently over a large spatial extent in an asynchronous manner, maybe connected to the internet or other wireless networks, and potentially having distributed sensing and actuation capabilities.

Human-robot interaction. Robots designed to operate with humans must also be able to operate in complex social environments and learn from a human partner like a child – as it grows and physically adapts to its tasks. This is a completely new and unchartered field in the context of robotics, but it is a precondition for the ultimate robot to become an accepted “peer” for humans. Major challenges reside in enhanced perception, cognition, communication, and rich and safe physical interaction. Robots integrated with the human body, such as, for example, artificial limbs, neuroprosthetics or artificial retinae, will have to rely on near-physiological bi-directional communication to transmit sensory information in one direction and control outputs in the other. Moreover, in order to optimize their interaction with humans, robots should also be able to exploit other information sources, such as online libraries and databases. In addition, robot companions will increase quality of life by enriching human experience through new forms of education and entertainment.

Ethical issues. The development of robot companions as truly autonomous entities will give rise to a completely new ethics – how can machines that are so close to humans be designed and used for the advancement of society and how can we prevent their misuse against humans or humankind? Another important issue is how we should deal with machines that will possibly display forms of free will and self awareness, or assign ownership and responsibility to the fruits of their physical and intellectual effort? This research will have to involve a re-consideration and possibly a re-definition of human-centred concepts like autonomy, consciousness, free will, decision making, and emotions taking into account that the meaning of these concepts may change as robot companions become a reality.

Answering the challenges posed by robot companions will require a concentrated effort that spans across most areas of the sciences and humanities and will lead to a massive boost in the depth and breath of European research and development while leveraging on the advanced base of European industrial R&D.

INTEGRATION

Research in this FET-F will have to integrate virtually all previous research in robotics, material sciences, electronics, artificial intelligence and cognitive/life sciences. This will include morphologies and materials, sensors, actuation and processing technologies, learning, perception and cognition, multi-modal human-machine interfacing, control and embedded systems, distributed real-time systems, dependability, self-repair, evolvability, adaptation, and much more. In the integration process many human and infrastructural resources will flow together, such as physicists, cognitive and life scientists, physicians, social scientists and philosophers, engineers and research managers from academic and industrial worlds, existing and forthcoming European industry- and university-driven research networks and platforms. Moreover, the integration process will enhance and benefit a new European community of young scientists, researchers and students having a multidisciplinary education and committed to investigate all the scientific and technological issues related to the development and introduction of robot companions in society. These young people, experts from various angles of self-X robots, will be also engaged to be the “new” entrepreneurs in the global ICT marketplace.

The whole “self-X robot” community will share many existing and forthcoming infrastructures, such as: web-based facilities, networks of remote powerful computing units, databases, open-source software tools, results of in-lab experimental activities, advanced equipment for manufacturing, testing and assembling components, as well as for the empirical investigation of self-X and robot companion including human studies, human-robot interaction, and their interaction with the physical and social environment.

For sharing facilities and information, and for jointly investigating the self-X challenges, the integrated community will federate its efforts and will give rise to a well structured "network of laboratories", promoted by the innate vocation of robotics and being a dynamic and natural network across disciplines and applications. Each node will be either "thematic" (e.g. service and assistive robotics, brain-inspired and cognitive robotics, micro- and nano-robotics, new technologies for sensors, actuators, control and processing units, evolutionary robotics and robotic symbionts, domotics, robotics for teleoperation, multi-robots cooperation, ubiquitous robots, etc.) or will be "application based" (e.g. medical, industrial, agricultural, rehabilitation, prosthetic), and each one of these can be broken down (for example industrial could be automotive, aerospace, food etc.).

This FET-F will lead to a fleet of laboratories, all contributing to a certain extent to develop the robot companions. Of course, some aspects of the project will require special facilities. For instance, unique laboratories may be set up for investigations in critical conditions, such as experiments in vacuum, or in deep-sea exploration, or in space (e.g. a permanent laboratory for space-robotics in low-earth orbit or, even, on the Moon). In each node, researchers of this FET-F will find all the facilities and equipments needed to carry out experiments. Many researchers from different countries in the world will work together and share ideas and experiences, all committed to scientific and technological progress. In the integration process industrial partners will be involved and committed to co-operate in the research activities, as well as to promote a continuous "technology and knowledge transfer" and to enhance the pervasiveness of self-X robots in society. Integration amongst these partners will be optimized by the deployment of dedicated tools for the realization of self-X in the form of new languages for programming self-X and tools for its analysis. Through these common development platforms the emergence and exchange of common principles will be boosted.

Furthermore, in the integration process, strong attention will be given to address societal implications and industrial opportunities. An important part of the required vision relates to how such robots will enter mainstream society. Close attention needs to be given to the precursors (technological, economic, political and societal) that will enable or constrain the widespread deployment of such robots and the growth of a new European Robotics industry. The role of industry will be key in fostering and developing a new multi-sector supply network that will allow these technologies to be progressively delivered to the market in economically viable forms. The evolution of markets and industries needs to be given strong consideration by providing a roadmap for these highly disruptive products, and these markets will only arise through a close alliance of academia, industry and other stakeholders from the outset. The role of regulation and policy need to be considered in providing the framework that will facilitate the practical use of such autonomous robots (particularly addressing responsibility and liability) and provide the impetus for their use in addressing societal needs (for example with pre-commercial public procurements). It will also be necessary to address the societal implications of the deployment of capable, autonomous robots with extensive studies of human expectations and reaction to these novel forms of robotics together with assessments of the wider societal implications (shifts in economic power and access to resources).

It is worth noting that in the integration process of the FET-F there will be strong links with areas of other potential FET initiatives, these include:

• "Understanding Life" and "Brain Simulation": exploitation of insight into ontogenetic and phylogenetic development for the growth processes of the robot's brains and bodies as well as its skill development;

• "Anticipation by Simulation": exploitation of the future solutions for augmented and mixed reality, robust design to prevent risks and faults in products, machine learning, simulation for large-scale systems, holistic modelling and simulation of architectures;

• "Programming and Information Processing technologies": these machines will not only become the most complex systems ever built, but also the biggest challenge in terms of programming real-time sensor-actuator networks, interpreting high volume complex multimedia data flows, ascertaining "safe" behaviour of the system with formal methods, etc.;

• "Massive ICT": clearly, for implementing robotic brains, new sensors and decentralised control strategies, most of the new massive ICT technologies can be directly implemented in the ultimate robot – some of them will even be essential;

• "Material Science": for the development of the body of robot companions new smart and lightweight materials are needed;

• “Hardware architectures”: future robots will require fast, dependable internal control and communication networks; the design of new chips and optical links will be needed for this purpose.

PLAUSABILITY

The plausibility of the accomplishment of the goals of this FET-F basically relies on the following three main points.

First, the community of European robotics has reached a great level of advancement in terms of: know-how, design tools and algorithms, infrastructures for sharing and discussing new ideas, networks of excellence, fizzy joint activities with many other science-driven disciplines (e.g. physics, neuroscience, biology, chemistry, human physiology and psychology, informatics, mathematics, system modelling), active and strong connections between research actors and stakeholders, criteria for benchmarking. Over time, all these points of excellence have flowed together giving rise to a huge number of concrete results, in terms of: technical and (more important) scientific publications on high-impact ISI journals, prototypes, advanced laboratories, industrial leaderships (such as that of the advanced anthropomorphic robotic arms) in the ICT market, a growing community of young students and researchers in strong growth, and shared Strategic Research Agendas proposing incremental short-, mid- and long-terms objectives and challenges to accomplish. Relying on all these concrete results, this FET-F will introduce strong elements of “disruptive innovation” thanks to an extraordinary and systematic alliance with scientific disciplines: this FET-F will definitively confirm the “science-based engineering” paradigm.

Some interesting examples of the high potentialities of robotics, and of how it is innately disposed to face multidisciplinary challenges, be a catalyst for multi-disciplinary research, and promote exploration of new scientific frontiers are:

• neuro-robotics, aimed at fusing neuroscience and robotics for both the investigation of the human brain and biomechanics (some examples are: cognitive and behavioural models, brain functional imaging, motion control strategies, neurophysiology, impedance properties of the human body, and many more) and for the discovery and deployment of novel biomimetic principles of perception, cognition and action;

• micro- and nano-robotics, aimed at applying the design principles and paradigms of robotics at the micro-nano scale to develop new technologies for many medical applications, such as mini-invasive surgery and endoscopy;

• evolutionary robotics, fusing robotics and evolutionary algorithms such as genetic algorithms, and aimed at designing new robots whose control and morphology are the result of an evolution process, driven by specific and predefined optimizing criteria;

• bionics, aimed at developing machines with an high level of interaction with humans, such as limb prostheses, rehabilitation and assistive devices.

Hence, the foundation for the massive multi-disciplinary effort that robot companions is proposing exists in Europe and the first stepping stones towards self-X have been put in place. This is the right time to capitalize on this initial investment and bring robot companions into our society.

The second point is that this FET-F has a well-defined mission statement, that is to develop a “new generation of self-X artifacts that will serve as robot companions serving humans throughout their lifetimes in all possible areas of human activity”. This sets the criteria on which future bidding consortia can be defined, strongly committed to contribute to the final FET-F goal.

The third point is a reliable and trustable agenda, mainly structured in three steps:

• 2013-2015, coordination actions for defining FET-F specific objectives and framework programme;

• 2015-2025, science-driven calls for developing and distributing self-X robot companions in all the application areas;

• 2020+, robot companions start to become available.

A remarkable aspect of this FET-F is that some readers may think our goals are unrealistic or even impossible – because we will never be able to copy the capabilities of living organisms. However, we want to emphasize that the realization of even a fraction of our goals will mean great scientific progress and market development for entirely new ICT-based applications and products. Furthermore, results of this work will be used by so many other technical systems/applications such as transportation, housing, machinery, etc. that there will be a huge spin-off into many branches of science and technology with broad beneficial impacts throughout society.

Backing from different organisations

Organizations

• Christophe Leroux, as R&D project manager at CEA LIST

• Paule Verschure, as Coordinator of Convergent Science Network (CSN)

• Uwe L. Haass, as General Manager of Cluster of Excellence "CoTeSys - Cognition for Technical Systems", Technische Universität München, Germany

• Executive Board of the industry-led European Robotics Technology Platform (EUROP) supports the establishment of a Flagship programme in robotics to promote the emerging service robot market area. Robots that interact with people are going to increasingly become both socially and economically important and it is imperative that Europe takes a lead in developing these new and growing markets. We believe that a huge effort by all stakeholders in robotics is needed to achieve the necessary boost in developing the required technology and in overcoming many of the significant social and market development barriers.

Experts

The following is a list of all the experts supporting this initiative. The undersigned experts are coordinating national and international projects in the areas forming the background of this flagship which involve more than 250 academic and industrial groups in Europe, involved in robotics, neuroscience, material sciences, physics, medicine, mathematics, informatics, chemistry.

• Paolo Dario, Past President, IEEE-RAS, Director, Polo Sant'Anna Valdera, Head, ARTS and CRIM Lab, Scuola Superiore Sant'Anna, Pisa, Italy

• Chris Melhuish, Director, Bristol Robotics Laboratory, University of Bristol, UK

• Alois Knoll, Fakultaet fuer Informatik, Technische Universität München, Germany

• Dario Floreano, Director, Laboratory of Intelligent Systems, Ecole Polytechnique Fédérale de Lausanne, Switzerland

• Rüdiger Dillmann, Institut für Technische Informatik, Universität Karlsruhe, Germany

• Martin Buss, Head, Institute of Automatic Control Engineering, Technische Universität Muenchen, Germany

• Giulio Sandini, Università di Genova and The Italian Institute of Technology, Italy

• Giorgio Metta, Università di Genova and Italian Institute of Technology, Italy

• Uwe L. Haass, Technische Universität München, Germany

• Auke J. Ijspeert, Head, Biologically Inspired Robotics Group, Ecole Polytechnique Fédérale de Lausanne, Switzerland

• Tony J. Prescott, Co-Director, Adaptive Behaviour Research Group, University of Sheffield, UK

• Sir Alfred Cuschieri, M. D., Chief Scientific Advisor, Institute for Medical Science and Technology, University of Dundee, Scotland, UK

• Guang-Zhong Yang, Director of Medical Imaging, Institute of Biomedical Engineering, Imperial College, Chairman, Imperial College Imaging Sciences Centre, founding Director of the Royal Society/Wolfson Medical Image Computing Laboratory, London, UK

• Paul Verschure, Director, Synthetic, Perceptive, Emotive and Cognitive Systems Group, Institute of audio-visual studies and Universitat Pompeu Fabra, Barcelona, Spain

• Raja Chatila, Director, LAAS-CNRS, Toulouse, France

• Peter Ford Dominey, CNRS Research Director, INSERM Stem Cell and Brain Research Institute, Lyon, France

• Maria Chiara Carrozza, Director, Scuola Superiore Sant' Anna, Pisa, Italy

• Sten Grillner, M. D., Past Chairman, Nobel Committee, Director, Nobel Institute for Neurophysiology, Karolinska Institute, Sweden

• Rolf Pfeifer, Director, Artificial Intelligence Laboratory, Department of Informatics, University of Zurich, Switzerland

• Christophe Leroux, Interactive Robotics Laboratory, Laboratory of applied research on software-intensive technologies, CEA, France

• Marco Santiago, Team Leader, Intelligent Signal Processing, Department of Electronics, University of Barcelona, Spain

• Angela Rowe, Department of Experimental Psychology, University of Bristol, UK

• Guido Bugmann, Centre for Robotic and Neural Systems, School of Mathematics and Computing, University of Plymouth, UK

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Towards Augmented Humanity: Tuning Bionic Man

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BRIEF EXPLANATION

Towards Augmented Humanity: Tuning Bionic Man
Augmentation of humans with artificial devices (sensors as well as actuators) will be increasingly popular in the future. This initiative aims at technologies enabling optimal calibration of the extension device customized to any given user (recipient). At the next step the ambition is to facilitate design of adaptive controllers and interfaces for such hybrid organisms, and the long-term goal is to increase the quality of life by a new technology of human augmentation.

AMBITION

The goal of this Flagship initiative is to facilitate augmentation of humans with artificial components, including sensors as well as actuators. For instance, cochlear implants that can help to provide a sense of sound to a person who is profoundly deaf or severely hard-of-hearing, or visual aids that do the same regarding vision for blind persons are examples of sensory extensions we are targeting here. As for actuators, one can think of artificial limbs and hearts, or integrated devices that actively provide insulin to the body in an autonomous fashion. Beyond these existing devices there are many other options one can imagine, for example, memory extensions or information processing enhancements, and it seems safe to predict that the development of such human augmentation-extension technologies will undergo a rapid development in the coming decades. One aspect of these new technologies is the adjustment or finetuning of such devices to any given user (recipient). Today there is no technology for this and developing such technologies is the principal aim of this initiative. This aim represents a hard S/T challenge, for two reasons: 1) there is almost nothing known about the interplay of such extensions and the human mind & body, 2) the tuning sessions are subject to severe limitations regarding time and human effort as a result of fatigue. Realizing the vision behind this initiative it would be possible to run a short interactive session with the fresh recipient of such an extension and achieve a fully customized near optimal calibration of the extension device. While this is already a highly ambitious vision, it is possible to take it one step further and try to include self-tuning capabilities into the devices such that they would get to know their hosts on-the-fly (that is, during the operational period, after deployment) and continuously (re-)calibrate themselves. If and when this becomes possible, the short tuning session right after deployment will merely serve as an initialization step to kick-start the on-the-fly self-calibration process. One more step further we encounter the generic case of developing (adaptive) controllers and (adaptive) interfaces for such extension devices. This is a more general case of tuning, as it implies a bigger design space, where not only parameters have to be optimized, but structural and functional properties as well. This case leads to completely unpredictable dynamics, caused by the complex interactions between the adaptive controllers of the “ silicon part” and the inherently adaptive “carbon part” of the hybrid organisms. To position this Flagship initiative we provide a number of non-exclusive keywords: hybrid carbon-silicon organisms, augmented human body/mind, human-computer interaction, customization, tuning, on-the-fly calibration, controller design. Finally, it is important to note that this initiative is targeting general tuning (calibration, customization) techniques that are reusable over a range of different extensions or devices. Hence, the required development goes beyond algorithmics, including general methodological issues as well.

IMPACT

The targeted impact will be achieved on various levels. For individuals the technology offers an increased quality of life through the newly acquired or lost and regained physical and/or mental capabilities. For the economy and industry the benefits lie in the emergence of a new and most likely booming market.

Considering the extended life expectations and the inevitable physical/mental decay that comes with age, the market for this technology is huge, although latent at the moment. Scientific research and technological development will be among the first beneficiaries of this Flagship initiative, since the grand vision implies S/T challenges that are beyond the possibilities of existing technologies. To realize the full Contributions Flagship Consultation 2010 18 potential of the augmented human body/mind, much research and development will have to be carried out by consortia that have a non-traditional composition, e.g., audiologists, data miners, electrical engineers, and linguists. Hence, one of the impacts of this initiative is that it will act as a catalyst behind novel combinations of collaborative networks. Most likely, such collaborations will not only produce results in the intersection of the participating disciplines, but also advance the disciplines themselves.

INTEGRATION

To realize the full potential of the augmented human body/mind, much research and development will have to be carried out by consortia that have a non-traditional composition, as mentioned above. We cannot provide an extensive inventory of disciplines whose participation is required for realizing the vision of this initiative. Rather, an initial list as follows:
computer science (optimization, machine learning, neural networks), control theory, adaptive systems, human-computer interaction, electrical engineering, medical sciences (physiology, neurology, …), psychology and cognitive science, audiology, even physiotherapy. As of today, there are several existing research projects and tangible products that would fit under the umbrella of this Flagship initiative, but they are segregated and not seen as connected to each other. One of the most immediate actions for further elaboration of these ideas should be the identification of relevant existing work and the positioning of these "bits" on a unifying roadmap.

PLAUSIBILITY

Some of the necessary building blocks of the vision are already available. There are bodyextensions already applied on a relatively large scale, for instance cochlear implants for the hearing impaired. Engineering seems to be ready for of close to producing suitable aids for vision and memory, making interfacing and tuning the pivotal challenges. Parts of medical science are concerned with issues in physiology and neurology that can be helpful here. There are advanced optimization techniques that can serve as the basis behind the tuning methods to be developed, there are data mining / machine learning techniques that can help an individual tuning session by providing knowledge gained by previous tuning sessions of the same kind, and there is knowledge about human-computer interaction that could be used to seed the methodology for conducting successful tuning sessions.

COMMENTS

Did not pursue it yet.

The Social Computer

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BRIEF EXPLANATION

The social computer is a future computational system that harnesses the innate problem solving, action and information gathering powers of humans and the environments in which they live, including computers, in order to tackle problems that cannot be addressed by conventional operating systems and algorithms. Its behavior is algorithmic, and it produces consistent and persistent problem solving performance which improves with time.

AMBITION

The social computer is a future computational system for which the hardware is supplied by people (through the activity of their brains and bodies), the environment where they live, including artifacts (e.g., buildings and roads, sensors into the environment, networks and computers); and where the software is designed to be an extension of human social reasoning conditioned by laws, organizational and social rules and social conventions. A social computer is characterized by being relatively limited in space, for instance within a region or a town and by being connected by high speed networks which enable knowledge storage and transfer. Although grounded in human activity, a social computer exhibits an algorithmic behavior and problem solving capabilities which, are the result of very large numbers of local computations, decisions, interactions, data and control information transfers.

Algorithms for social computation are those which take advantage of the resilience and scale of mass human problem solving and which achieve higher performance by supplementing social capabilities of individuals by adapting the environment in order to provide better feedback and instrumentation for the mass computation achieved by society. This means that the analogue of an operating system for a social computer is not just the computer or the network but is primarily the social and environmental infrastructure that enables large-scale social computation to occur. Although part of the behaviour of social computation is emergent (in the sense that it is derived from the individual intelligences within a society) the overall aim of a social computation is to produce consistent and persistent problem solving performance which improves over time. Individual reactions to the ongoing computation should tend to reinforce the algorithm so that as more people participate its performance improves.

The state of a social computation includes part of the state of the physical, social environment in which the computation is situated. Therefore, it is characterized by being distributed but also situated within a limited space, for instance within a region or a town. The requirement of limitation in space is due to the physical need of being able act within a limited amount of time, for instance in order to react to a given stimulus, or to achieve a goal. Social computations also effect the state of the physical environment, so it must be capable of making its components interact and exchange data, information and knowledge, and also to effect change in the environment. People are one the main natural means for sensing and people are the main actuators of change to system state. The social computer can also act via machines (e.g. pervasive sensor networks, robotic devices) where these enhance the data provision or the effectiveness of scaleable algorithms. The basic sensor-effector model, nevertheless, involves large-scale, personal, human interaction of the sort that is becoming progressively more common as technology becomes more pervasive.

IMPACT

The development of the social computer will have an impact on theory (in ICT and other disciplines); on practice in system design and on society via its consequences for social organization and innovation.

The impact on theory is partly through the need to develop new algorithms (or variants on traditional ones) that take advantage of the ability to operate over a social infrastructure and take advantage of large scale social effects. It is also on the development of social and economic theories that take into account the effects of such algorithms; and legal models of the social contracts necessary for them to operate effectively at regional and international levels. All the science and concepts which have recently emerged under the heading of "Internet Science" will be at the core of this latter work.

The impact on system design is that it requires new styles of engineering that bring the social setting of computation much more intimately within the system design process than hitherto. It also involves integration (in service of the focused aim of social computation) of components of virtually all the ICT sub-disciplines, most noticeably: data and knowledge management, service-oriented architectures, software engineering, privacy and security, and, ultimately, all the Web and Internet focused disciplines.

The impact on society is obtained by developing greater synergy between computational structures and social structure with the aim of finding symbiotic relationships between the two. The development of the social computer will generate a major improvement in innovation capability (e.g., technological innovation, service and social innovation), no matter how far we go in its development, because it puts the end user at the center of the innovation process via the development of new socially aware software development methodologies.

INTEGRATION

Our goal is to enable social computation directly to meet key societal challenges by improving the quality of decision making, targeting, and timeliness of response to need. The social computer will empower us to configure information, human, computational, robotic and environmental resources to create new hybrid structures to respond to challenges in the 21st century. This requires new approaches to architecture that acknowledge the power of an open, transparent, structure that stimulates innovation while recognizing the need for democratic control that protects the rights of individuals, minority groups and property owners. The architects of social computation need a skill set that draws deeply on interdisciplinary research into humans, organizations and society:

Cognitive science, researching the match between human– cognitive capacities and the new environment enabled by the social computer.

Sociology and organizational science, researching the synergy– between the new technologies underpinning the social computer and the existing social and organizational structures together with the trajectory of adoption and successive adaptations and evolution of social structures and technologies as the social computer diffuses through our societies.

Criminology,– researching the evolution of deviancy, conflict and crime in the new environments enabled by the social computer

Economics, researching– quantitative aspects of the transformation brought about be the social computer, including incentives to use social computation, economic impact, the effects of competition, the stability of new markets and mechanisms.

Law, which will– provide us with the means for dealing with legislative consequences of the approach and its negative effects (attacks, viruses and other threats to the social computer). Innovation (both technological and social) which will– provide us with the required knowledge of the difficulties encountered when trying to transfer technology to the real world

In turn, the studies developed by the disciplines listed above will provide input to ICT. ICT will have to evolve the way it is done today in at least two dimensions: by putting the management of diversity over time at its core; and by designing software systems at a much more abstract level, exploiting notions which are much closer to the societal notions (e.g., notions such as goal, actor, plan, activity, community and group).

The development of the social computer will lead to a radical departure from the current practice in ICT and also in the other disciplines (think for instance of the design or experimentation processes, which will have to be deeply aware of the social and economical notions which will underlie the behavior of the social computer). The future ICT will go beyond the differences and barriers which now exist among the ICT sub-disciplines and the other disciplines. The development of the social computer will require a holistic approach which will require an in depth merge of the existing know-how which, in turn, will generate new disciplines which will position themselves at the boundaries of the current disciplines.

PLAUSABILITY

The development of the social computer will require not only engineering, e.g. the construction of new prototypes aimed at solving specific problems, but also fundamental science aimed at explaining the emerging phenomena (some of which are already arising now). This will require experimentation and, more in general, an empirical approach which will provide the basis for the development of the theoretical foundations of the social computer. At the same time, the current, more application oriented, interdisciplinary efforts towards the Future Internet and the emerging research areas (e.g., eEnergy, eInclusion, eEnvironments, smart cities, social networking) can be interpreted as first steps towards the social computer.

We believe that there is an interesting and overall convergence in software and knowledge architecture that makes it timely now to build a social computing architecture. In the internet world, there has been a strong shift towards service-oriented architectures based on the notion of encapsulating significant functionalities as services and making these available to other services as a way of producing larger systems via components with trusted interfaces. In the mobile device world we are seeing services cluster around particular types of data provision and design of components being standardized in order to allow consistency of service over time, based on strong standardization on the means of coordinating those services. In the world of physical, robotic devices we have seen behaviour-based architectures dominate, in which the modularity of "service" is defined in terms of a behavioural competence that can be trusted to a given tolerance as a component of other, more complex behaviours. In knowledge, diversity has been recognized as a feature which must be exploited, thus leading the way towards the integration of isolated and diverse pieces of knowledge. The "ICT forever yours" call and the underlying core emphasis on diversity are further evidence of this phenomenon.

In all of these areas, the core idea (although approached in different ways) is that diversity must be handled based on the consideration that the knowledge and program design metaphor should be that of module definition accompanied by coordination of modules to obtain aggregate behaviours that are evolved through use. However for this to happen two fundamental requirements must be satisfied: there must be a mapping between the software (knowledge and program) modules and their interactions and the corresponding societal components and interactions; the pervasive societal diversity must be mapped into the corresponding pervasive diversity in software.

To achieve this requires integration of two forms. The first is across disciplines in sociology, economics, law and system architecture to provide broad alignment. This first form of integration is, of necessity, "soft" in the sense that it deals primarily with human activities for which there is no precise algorithm and where the engineering aim is to orient the initial phases of design. The second is between the sub-disciplines of computational science that already have inhabited these broader human areas with the aim of understanding them in a computational sense. This second form of integration is technically more precise but very diverse so the engineering aim is to select appropriate computational tools from the vast repertoire already provided (e.g. from distributed workflow, knowledge representation and ontology, agency, security, etc). This provides a challenging integration task for which there is no prospect of a single, optimal architecture. Fortunately, the social computer (like society) does not have to be correctly integrated first time but can be developed progressively buy "going from working to working" with social feedback brought in early to drive evolution.

COMMENTS

A manifesto paper of the program proposed will appear in the Web page of the program proposer by the end of April 2010. Below is a first list of researchers, and corresponding institutions which are supporting this proposal.

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Towards a theory of the evolution of the Web

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BRIEF EXPLANATION

Towards a theory of the evolution of the Web

AMBITION

Since its inception the World Wide Web has been revolutionary in terms of impact, scale and outreach at a time when ubiquitous and pervasive computing devices enable the provision of continuous communications and services to individuals on the internet. Whilst e-Business, e-Health, and e-Science have all been major drivers in the spread and evolution of the Web - so too has the Web\'s social funtion. Yet we do not understand how the current Web succeeds, or what properties it has from a formal, descriptive or predictive point of view. We have no way of telling how the Web will evolve. Providing a sound theoretical understanding is a real challenge but one that we must tackle.

The Web is a piece of technology and a network connecting hundreds of millions of human beings; it is an artefact and a social system; it can be described in terms of formalisms and protocols (HTTP, HTML and URIs), or of interactions of giant human populations (the blogosphere, e-commerce). The relation of emergent macro scale phenomena to micro scale technical development is particularly difficult, yet important for ensuring that the web develops in socially benign ways. It cannot be simply one of cause and effect, as the web and society are actively changing each other. Furthermore, the web is changing at a rate that outstrips our ability to observe it.

This complex interplay of scales, timescales, subjects and conceptualisations of the Web mean that a giant range of expertise is required in order to describe it, analyse its effects and engineer its future development in a managed way. This is not to say that work in this area requires research across the full range of disciplines in science and social science; this, of course, would be unmanageable. The need is to support research into the Web in order to enable a clearer focus to emerge, with consistent and well-understood methods, vocabularies and datasets. In this way, research, curriculum development and training will be focused and made tractable for individual researchers and laboratories.

The focused transdisciplinary effort has been called Web Science and there have been ad hoc moves and some initial successes in this area. The challenge is to consolidate these successes by developing the new methodologies required to enable new theories to emerge to explain, describe and help us understand how the Web has evolved to this point and anticipate future evolution scenarios that will support the development of policies to ensure the Web’s future for social good.

We would argue that this research will be as important for the digital world in the 21st century as the development of the theory of evolution was for the natural world in previous centuries.

IMPACT

The development of the discipline of Web Science will increase understanding of the web, its growth, its relation to its socioeconomic contexts and the drivers of its use. Design of web technologies will be more sensitive to the likely outcomes of their widespread deployment, which will allow more intelligent and targeted development, and greater ability to avoid deleterious unintended consequences. The impact of such research would be felt throughout society, or at least in those areas of social interaction where the web plays a prominent role. The economy, and the digital economy in particular will benefit, as well as related areas of widespread technological mediation such as e-science, e-social science and e-health. In industry that uses the Web has part of its business model will benefit from such research.

Well-trained Web Scientists - people with an understanding of how the Web works from socio-technical perspective - could become some of the most sort after people in the businesses of the future. The technology industry will be boosted in particular, as a body of Web Science knowledge should help reduce the risks of designing and deploying web technologies.

The academic impact will be considerable. The areas of collective intelligence and Web dynamics present such large and novel problems as to have genuinely revolutionary potential, bringing together a large and new interdisciplinary constituency with innovative methods and foundations. Novel mathematical and computational models will co-exist with inventive reworking of social theory for the online space. The web itself will become a new and unique benchmark capability for social scientists.

INTEGRATION

Fundamental research questions and perspectives

Computational Perspective: With the emergence of the so-called Web of Linked Data or Semantic Web a key emerging challenge as we move from a Web of documents to a Web of linked data at a more fine-grained level is how we are to browse, explore and query such a Web at scale. How do we support inference at a Web scale? What types of reasoning are possible? How is context represented and supported in Web inference? Howare concepts such as trust and provenance computationally represented, maintained and repaired on the Web? How we do deal with the substantial amounts of the Web that have atrophied and become non-functional?

Mathematical perspective: How do we model the transient or ephemeral Web? Billions of Web pages are dynamically generated; they exist for the period of a particular query or transaction. How do we model this graph beneath the graph that is the Web? How are Bayesian or other uncertainty representations best used within the Web? What is the topological structure of the Web? How do we measure the level of complexity of the Web?

Social Science Perspective: How can we develop inter-disciplinary epistemologies that will enable us to understand the Web as a complex socio-technical phenomenon? How can we do mixed methods research to explore the relations between ethnographic insights to Web practice and the emergence of the Web at the macro level? How can we draw on new data sources e.g. digital records of network use to develop understanding of the sociological aspects of the Web? What are the on-going iterative relations between use and design of the Web? How and why do people use newly emergent forms of the Web in the way that they do? How is the Web situated within networks of power and in relation to social inequalities? To what extent might the Web offer empowering political resources? How might the Web change further as new populations access it?

Economic Perspective: What are the economics of Web 2.0 (+)? What new economic issues are raised by the opportunities that Web 2.0 gives for users to generate content and share it in self-forming networks? What are the economic forces that shape the formation of social networks on the Web? What are the properties of those networks? What is the relationship between the economic structure of the Web, its social and mathematical structure? What are the commercial incentives created by the Web? What will be the industrial structure? Is the Web inherently prone to concentration, where a large part of the structure is owned and controlled by a small number of players? Or are there forces that will allow smaller scale operations to co-exist with large firms?How can economics help with such issues as piracy, privacy and identity?

Legal Perspective: Techniques for representing and reasoning over legal and social rules – what new tools need to be developed within legal theory to explore and understand the impact of law as a driver in shaping the Web development? Should law be a catalyst for change or merely reactive to it and how should it interact and respond to economic, social and technological influences? Is the present intellectual property regulatory regime fit for purpose in the Web 2.0 (+) environment given that its legal principles were established in the offline world? What is content in the Semantic Web and what rights should attach to it particularly when much is likely to be “computer generated”? Which technologies within the Web should the law ensure remain “open” rather than becoming the “property” of one or more commercial entities and what are the consequences of the choices available? To what extent are the service providers going to become the legal gatekeepers for public authorities in terms of delivering their public policy objectives e.g. Web policing for what is judged to be “illegal and harmful content”? What privacy issues arise in a Web environment of increasingly sophisticated information sharing?

Integrative Research Themes include Collective Intelligence; The Openness of the Web; The Dynamics of the Web; Security, Privacy and Trust: Inference

See http://webscience.org/research/roadmap.html for a fuller version of this research roadmap

PLAUSIBILITY

As we describe above there are many interesting and important challenges that fall under Web Science, but here we focus on collective intelligence as an example on an area that requires radically new research that will advance science and social science in a number of fields and could be used as a tractable pilot study in this highly complex and multidisciplinary area.

Collective intelligence is the surprising result that collaborative endeavour and innovation (often unremunerated) with only light rules of co-ordination can lead to the emergence of large-scale, coherent resources (such as Wikipedia, Digg, Google). The existence and stability of these resources present major challenges for researchers attempting to understand the web and its role in the digital economy. The potential is huge – no less than how people and computers can be connected together so that collectively they act more intelligently and innovate more effectively than any person, group or company has ever done before. How, from a technical point of view, can collaborative innovation and collective intelligence be enabled? How can these qualities be predictably engineered? What are the socio-economic reasons why individuals participate in collective endeavour? What legal framework governs (or should govern) the resources created? What is the psychology of identification with an online collective community? How can collaborative innovation and collective intelligence emerge, given the different languages used by different genders, races, classes and communities? How can the risks and problems arising from community-generated information resources be managed? What role is there for policy-makers to engage in and facilitate collaborative endeavour?

There is currently little understanding of these issues, and a lack of data to analyse. In fact, it is hard to know which data need to be captured for us to analyse and understand the effect of wide scale collaboration. This world of online collaboration is extremely novel, and sufficiently different from offline collaboration as to present significant problems. The issues with respect to data gathering and analysis also call for new research into web dynamics. The web evolves so quickly it is hard to study; indeed, it differs from previously-studied systems because it evolves faster than our ability to observe it. How can it be instrumented? How do individuals, communities and the web co-constitute each other? How can existing business models adjust to the rapid pace of change?

COMMENTS

At present the Web Science research community exists in nascent form. The methods, datasets and communities to support the mix of disciplines are still in the process of formation. Indeed, the exact mix of disciplines is still moot, although it seems clear that it will involve computer science, mathematics, sociology, psychology, economics, law and the various disciplines that investigate complex systems.

Academic scientists and labs who already occupy this community and are interested in developing the area include:

Europe

• Stefan Decker and colleagues, Digital Enterprise Research Institute, National University of Ireland, Galway

• William Dutton, Oxford Internet Institute, University of Oxford

• Wendy Hall and Nigel Shadbolt, Electronics and Computer Science, University of Southampton

• George Metakides and colleagues, Mathematics, Aristotle University of Thessaloniki

• Guus Schreiber, Computer Science, Free University of Amsterdam

• Steffen Staab and York Sure, Web Science and Technologies (WeST), University of Karlsruhe

US

• Tim Berners-Lee and colleagues, CSAIL, Massachusetts Institute of Technology
• Noshir Contractor, Engineering/Communication/Management, Northwestern University
• Joan Feigenbaum, Computer Science, Yale University

• James Hendler and Deborah McGuinness, Tetherless World Constellation, Rensselaer Polytechnic Institute
• Ramesh Jain, Information and Computer Sciences, UC Irvine
• Ben Shneiderman, Human-Computer Interaction, University of Maryland

Asia
• Wu Jianping and colleagues, Shenzhen Web Science Laboratory, Tsinghua University/University of Southampton
• Hong-Gee Kim, Biomedical Knowledge Engineering Laboratory, Seoul National University

The FuturIcT Knowledge Accelerator: Unleashing the Power of Information for a Sustainable Future

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Country	CH
Permission	Yes

BRIEF EXPLANATION

With our knowledge of the universe, we have sent men to the moon. We know microscopic details of objects around us and within us. And yet we know relatively little about how our society works and how it reacts to changes brought upon it. Humankind is now facing serious crises for which we must develop new ways to tackle the global challenges of humanity in the 21st century. With connectivity between people rapidly increasing, we are now able to exploit information and communication technologies to achieve major breakthroughs that go beyond the step-wise improvements in other areas.

It is thus timely to create an ICT Flagship to explore social life on Earth, and everything it relates to, in the same way that we have spent the last century or more understanding our physical world. This proposal sketches out visionary scientific endeavours, forming an ambitious concept that allows us to answer a whole range of challenging questions. Integrating the European engineering, natural, and social science communities, this proposal will release a huge potential.

The need of a socio-economic knowledge collider was first pointed out in the OECD Global Science Forum on Applications of Complexity Science for Public Policy in Erice from October 5 to 7, 2008. Since then, many scientists have called for a large-scale ICT-based research initiative on techno-social-economic-environmental issues, sometimes phrased as a Manhattan-, Apollo-, or CERN-like project to study the way our living planet works in a social dimension. Due to the connotations, we use the term knowledge accelerator, here. An organizational concept for the establishment of a knowledge accelerator is currently being sketched within the EU Support Action VISIONEER, see www.visioneer.ethz.ch. The EU Flagship initiative is exactly the right instrument to materialize this concept and thereby tackle the global challenges for mankind in the 21st century.

AMBITION

A1 Goals

The greatest bottleneck of ICT systems today is the difficulty in making sense and efficient use of the large amounts of data we generate. The FuturIcT flagship shall, therefore,

- develop novel ICT systems (incl. applications and infrastructures) combining the best of human and computational abilities to support the understanding, integrative design, and management of complex systems,
- apply these to model techno-social and economic, transport, environmental and other global systems,
- create instruments to support the self-organization, decision-making and governance in politics, business, industry, and academia, with the aim to foster societal goals (e.g. robust techno-social and sustainable economic systems),
- develop principles and tools that will facilitate the emergence of high quality processes, products and institutions in techno-social networks.

The Flagship is oriented at visionary high-risk research, integrating multiple scientific disciplines to a previously unseen extent.

President Lee C. Bollinger of New York's prestigious Columbia University formulated the challenge as follows: "The forces affecting societies around the world ... are powerful and novel. The spread of global market systems ... are ... reshaping our world ..., raising profound questions. These questions call for the kinds of analyses and understandings that academic institutions are uniquely capable of providing. Too many policy failures are fundamentally failures of knowledge."

Humankind has reached a situation where existing policy instruments are unable to provide sustainable outcomes on a global scale. It is obvious that our economy and society are facing serious new problems, and it will determine the future of humanity whether we will be able to address them successfully or not. Politicians, business people and scientists need to get into a position to better foresee and proactively moderate the on-going systemic changes rather than having to react to them in a state of crisis. The development of new concepts is urgently needed in order to be able to assess and shape future techno-social and economic systems successfully. To overcome the serious knowledge gaps and weaknesses of our current theoretical understanding of these systems, it will be necessary to make big steps forward.

A2 Innovation

A2.1 Grand Socio-Economic Challenges

Ground-breaking ICT research, in intense collaboration with multiple other scientific disciplines, will be crucial to identify the success factors of societies and to address the grand challenges of humanity. This includes

- how to avoid socio-economic crises, systemic instabilities, and other contagious cascade-spreading processes,
- how to design cooperative, efficient, and sustainable socio-technical and economic systems,
- how to cope with the increasing flow of information, and how to prevent dangers from malfunctions or misuse of information systems,
- how to improve social, economic, and political participation,
- how to avoid "pathological" collective behavior (panic, extremism, breakdown of trust, cooperation, solidarity etc.),
- how to avoid conflicts or minimize their destructive effects,
- how to cope with the increasing level of migration, heterogeneity, and complexity in our society,
- how to use environmental and other resources in a sustainable way and distribute them in the best possible way?

Many of the world's challenges cannot be solved by technology alone, but require us to understand the collective social dynamics as roots of these problems and key to their solution.

A2.2 Need of Massive Data Mining and Reality Mining

- Massive data mining could reduce serious gaps in our knowledge and understanding of techno-social-economic-environmental systems.
- Crises observatories (for financial and economic stability, conflicts, diseases…) could predict crises or identify systemic weaknesses, and help to mitigate impacts of crises.
- Real-time sensing and data collection ("reality mining" of flu infection data, gross domestic product, environmental data, cooperativeness, compliance, trust, …) could reduce mistakes and delays in decision-making, which often cause inaccurate and unstable control

It would be in the public interest to sponsor open search engines and data collectors, as the public needs to know how massive social data sets can be used or misused.

A2.3 Need of Social Super-Computing

Besides massive data mining capabilities, it is required to build up suitable super-computing capacities for the simulation, optimization, and management of sustainable techno-social and economic systems.

Gigantic computer power is, for example, needed for large-scale computational analyses in the following areas:

- Massive data mining, e.g. real-time financial data analysis
- Network research, community detection
- Monte-Carlo simulations of probabilistic system behaviour
- Multi-agent simulations of large systems (e.g. "whole earth simulation", which may involve up to 10 billion agents and complementary environmental simulations)
- Multi-agent simulations considering human cognitive and psychological processes (e.g. personality, memory, strategic decision-making, emotions, creativity etc.)
- Realistic computer simulations with parameter-rich models (coupling simulations of climate and environmental change with simulations of large techno-social-economic-environmental systems)
- "Possibilistic" multiple world-view modelling (to determine the degree of reliability of model assumptions and to improve the overall prediction capability)
- Calibration of parameter-rich models with massive datasets
- Scanning of multi-dimensional parameter spaces
- Sensitivity analyses (e.g. k-failures)
- Parallel worlds scenario analyses (to test alternative policies etc.)
- Visualization of multi-dimensional data and models of complex systems
- Optimal real-time management of complex systems ("guided self-organization", "self-optimization")

It should be underlined that most challenges addressed by the FuturIcT Flagship concern a combination of all the above points!

A2.4 Expected Outcomes of the FuturIcT Flagship

The FuturIcT Flagship will build a **knowledge accelerator to address the challenges for humankind in the 21st century.** This will include the creation of the following:

- Integrated data collection, modelling, simulation, visualization, design, and decision-support tools for complex systems, based on novel approaches such as "possibilistic" simulation concepts (multiple world view, parallel world scenarios,…)
- Social super-computing, including a socio-economic modelling language
- An innovation accelerator changing the scientific production paradigm, to support efficient progress and investments in science and technology
- A peer-to-peer reputation and privacy-respecting recommender system
- "Knowledge engines" combining real-time data collectors with social information theory to harvest the knowledge of humanity
- Crisis observatories (for financial and socio-economic instabilities, conflicts, epidemics, environmental changes, etc.)
- Individually customizable reputation and recommender systems that respect privacy
- A novel theory of socio-economic robustness and an understanding of "social pathologies" (riots, panic, etc.)
- A Living Earth Simulator for global-scale simulations involving interactions of up to 10 Billion agents, coupled to a simulated and/or measured environment
- Situation-room-like policy simulation and visualization centers ("decision theaters" for policy decisions)
- The tools required for an international socio-economic crisis management center, including a whole earth and policy simulator, plus a contingency and resilience toolset, available for everyone.

- Showcases (demonstrators) regarding the global financial system, sustainable transport, energy generation and production, epidemic forecasting, and a disaster and evacuation management system, ...

A2.5 Paradigm Shifts Expected from the FuturIcT Flagship

- From pre-defined to self-organized ICT systems
- From searching to discovering
- From data fitting to reverse engineering
- From ubiquitous computing to social computing
- From a web of data to a web of models
- From exclusive to possibilistic models
- From particular to systemic models (a global view from the start)
- From information processing to knowledge production, from knowing to understanding
- From solving to anticipating problems
- From producers and consumers to prosumers (participatory consumption, co-creation, individualized products), from supply chains to demand chains
- From quantity to quality
- From an economic to a socio-ecological approach (considering that social exchange is multi-faceted and not only driven by financial forces; oriented at a robust, sustainable financial and economic system with social and economic inclusion of everyone)
- From improvised crisis management to real-time decision systems
- From information communication technology to imagining, computing, transforming

A3 Comments

A Quote from Josh Epstein (Brookings Institution, USA):

"We are poised at the cusp of interacting epochal changes: ICT is propelling humanity into the age of global human connectivity; we are changing the global environment; we are peering into the human genome and unraveling the neurochemistry of human emotion and behavior. ICT is at once propelling these changes, but also permitting us to comprehend them. Planetary-scale computational modelling is now feasible, allowing the study of coupled transitions at multiple scales.

These epochal changes eclipse the turbulence of daily political affairs. And their complexity dwarfs the capacity of any individual's comprehension. Only a collective mind enabled by the ICT resources of our [the Flagship] consortium can undertake credible actionable forecasts embracing all of this, for the first time, in a rigorous replicable manner. And it is imperative that this admittedly bold step be taken: to envision—as comprehensively as the best minds and best ICT permit—how these epochal developments will interact over the next decade. The coupled socio-economic-environmental dynamics will [be] far from linear, far from equilibrium, and far from canonically rational. But they can be understood, and productively shaped, by the Flagship proposed here. It is an experiment we can't afford not to do."

The FuturIcT Flagship will simulate the complex emergent system that society is, and the relevant systems it is embedded in.

Society emerges from the myriad of interaction among its members and with its environment. People are heterogeneous, goal driven consumers and producers of both, resources and information. We endeavor to reverse engineer modern society and, in doing so, come to better understand the emergent processes that have (and will have) profound impacts on people's lives.

The following paragraphs outline the fundamental contributions of the FuturIcT Flagship towards this goal, while the economically and practically relevant challenges are addressed in the Section "Impact".

A4 Methodological ICT Challenges

There are a range of methodological challenges that need to be faced. We list here some of the main issues that have been highlighted

Exascale Computing and Living Earth Simulator: Empower exascale computing through fundamentally new algorithms, data structures and compilers capable of exploiting the massive parallelism of future computational systems; create a global-scale multi-level Living Earth Simulator with large realism (10 petaflops in 2013, 100 petaflops in 2016, 1 exaflop in 2019).

Highly Decentralized and Peer-to-Peer Systems: Develop powerful algorithms to make peer-to-peer (P2P) systems trustable and resource-efficient; explore new kinds of P2P applications (e.g. micro-finance, flexible self-control, etc.); create collaborative ICT systems that can satisfy large-scale computational needs without requiring centralized facilities and institutions.

Reality Mining: Develop concepts for large-scale long-term real-time data gathering and sensing "on the fly"; measure systems and behavior in real time using mobile phones, GPS, accelerometers, RFID tags, search engine requests, web and email use; create sensor networks/smart grids; employ opportunistic sensing; learn how to collect data from users in ways that protects privacy; develop suitable methods to generate surrogate data having the same statistical properties as the original data, but do not allow the identification of individual people.

Swarm Computing: Develop highly distributed, adaptive processing and storage based on principles of collective intelligence; employ emergent computing and artificial immune systems; make swarm architectures programmable like single systems; create ICT platforms that can reconfigure themselves and adaptive algorithms that re-program themselves, to reflect/allow for changing interaction rules; develop a standardized framework for modelling agent interactions; consider cognitive and emotional factors supporting swarm intelligence; enable "cultural evolution" in computer networks.

Social Computing: Conceptualize and analyze social computing as the interaction between digital and social networks; improve integration of human wisdom into ICT systems ("human-computer confluence"); automate ratings of contents by "emotional sensors"; empower ICT systems to sense disagreement in order to learn what the user wants it to do or not to do; develop tools to improve human-computer and ICT-mediated interactions considering human affects and emotions; identify dangers and utilize potentials of collective decision-making and intelligence ("wisdom/madness of crowds", "prediction markets", etc.); allow users to coordinate efforts in on-line communities and steer the collective activity towards predefined goals ("hive mind").

Social Information Theory: Learn how to distinguish meaningful, relevant, or transformative information from unimportant information; understand the role of social, affective interactions for the meaning and impact of information; identify relevant variables, parameters, and stylized facts of complex systems; extract knowledge from information by suitable adaptive filtering techniques.

User-Oriented ICT Systems: Create "non-expert systems", which make the knowledge of humanity, simulation tools etc. accessible for everyone; design models for adaptive autonomous systems that interact with humans and social structures: ICT systems that think like humans, understand what they want, and adapt to them; develop ICT systems that are intuitive, easy to use, customizable, reliable (self-repairing), flexible (self-adaptive), trustable (in particular self-protecting), sustainable, scalable, and interoperable (like plug in's or App's); facilitate an "interface-free" interaction with users.

A5 Applied ICT Challenges

Data Collectors: Support data collection, fusion, filtering, and categorization; suppress pollution of data bases and information systems; improve accessibility and data extraction; support massive techno-social-economic-environmental data mining; manage data deluge; improve handling of inconsistent data; perform model calibration, identifying and filling data gaps (e.g. in case of incomplete or non-representative data); use electronic and sensor networks for automated data collection and hypothesis testing; measure regional differences in social behavior; establish "moral sensors" and "compliance detectors" to identify changing norms; enable crowd sourcing and the participation of the population in political decision-making ("eGovernance").

ICT-Empowered Systems Modelling: Support non-theory-based, data-driven discovery; develop methods of model-enhanced data representation and interpretation; facilitate fast model prototypes; perform sensitivity analyses to model assumptions, structural and parameter variations; identify early warning signs of upcoming critical states and systemic shifts; extract a variety of mathematical laws (including multi-level dependencies) that are consistent with available data sets; evaluate their validity, simplicity, and sensitivity; assess the suitability to interpret these models, to perform analytical studies, and to calibrate them; simplify models to determine stylized facts of the studied system; identify well measurable, interpretable and relevant variables; customize the degree of detail to the modelling purpose; determine implications that distinguish alternative models and derive procedures to test model variants.

Evaluating ICT Systems: Evaluate and rank models according to individual criteria; implement cognitive processes in ICT systems; support multi-dimensional evaluation of reputation-relevant aspects; facilitate customized and community-specific reputation; allow coordination and support cooperation between individuals and stakeholders; simplify community detection and the formation of groups with compatible quality standards/values.

Reasoning ICT Systems: Complement, enhance, and fuse data mining algorithms with models and expert knowledge to create interpretation devices; develop methods for the self-validation of algorithms and models; run potentially relevant scenarios; identify causality chains; explore feedback and cascading effects for all model variants; determine the reliability of implications, given the validity of the underlying models; compute, analyze and use independent information to address the impact of model assumptions and unmask hidden constraints.

Creative ICT Systems: Support the identification of open points and crucial questions regarding data analyses, algorithms, and models; develop a hypothesis generator; use evolutionary computing and develop imaginative ICT methods to test alternative interaction mechanisms and develop integrative systems designs; identify governance options in techno-social-economic-environmental systems; support the creation of propositions, brain storming, and decision making.

IMPACT

The FuturIcT Flagship will create interactive, multi-purpose modelling, exploration, and systems design tools that use the best combination of human and machine intelligence. Experts will be able to choose among the variables, parameters, model variants, simulation scenarios, hypotheses to be explored, and system designs proposed by this semi-automated tool (the "knowledge accelerator"). It will stimulate creativity and extend the limits of imagination. The knowledge accelerator will also provide a living, self-organizing data pool and a cyber-infrastructure for people with various backgrounds.

The integrated, large scale modelling of complex techno-social-economic-environmental systems will promote cross-pollination between different fields. Simplifying and standardizing data collection, modelling and simulation will stimulate interdisciplinary research questions, collaborations and discoveries. Best practices will emerge and shared standards of evidence will result in fundamental and substantial advances.

Using crowd-sourcing and reputation systems, an innovation accelerator will be built to support the collaboration of the best fitting partners. It will help to separate relevant from irrelevant information, thereby increasing the transparency, usefulness and control of the information everybody is exposed to, and it shall be able to deal with inconsistencies by considering multiple model variants and to determine their respective validity. The FuturIcT Flagship will simplify scientific research and evaluation procedures, generating higher-quality outcomes. The application to social and economic systems will deliver a new economic theory that captures realistic human behavior and system states far from equilibrium.

The Flagship is expected to cross-fertilize developments in multiple areas and to improve the capacity to cooperate. Through a free sharing and better accessibility of massive data sets and multidisciplinary scientific knowledge, it will kick off a new age of systemic modelling and simulation, triggering radical innovation in all areas of society, technology and economics. It will provide the tools to make humanity fit to cope with the problems of environmental and demographic change, health, safety, security, and sustainable development. Furthermore, taking into account affective components of information transfer will improve the quality of human interaction with engineered systems, including ICT systems.

The innovations of the FuturIcT Flagship will be practically relevant for many sectors of society. In fact, information has become a critical resource in the economy. The FuturIcT flagship will support the communication with customers and end users, and the development or even co-creation of highly customized products. This will allow a wider variety of interests and agents to be expressed and satisfied.

In this way, the FuturIcT Flagship will create new business opportunities, particularly for small and medium-sized enterprises. However, FuturIcT will also help to reduce losses by financial and other crises, inefficiencies in transportation and production systems, and social problems, thereby saving large amounts of tax payers' money.

B1 Future Living

The fast and wide access to information has changed society on all levels: individuals, groups, companies, and governments. This circumstance is reflected by terms such as "information society" and "knowledge economy". Never before has it been so crucial to transform information into knowledge efficiently.

Customized Information Services: Support information discovery, evaluation, and integration; evaluate information, projects, cooperation partners, or products, based on objective quality criteria and subjective ratings; offer individual decision-support by providing multi-criteria, customized, privacy-respecting recommendations; enable quality emergence and diversity-oriented navigation through multi-dimensional quality landscapes, highlighting alternatives; detect changes in user/customer interests and tastes in a timely manner; support individualized services of all kinds; provide the right information at the right time and the right place as efficiently as possible; suppress unwanted, unneeded, or "polluted" information; archive information effectively for future use; pave the way for a quality-oriented reputation society.

Innovation Accelerator: Support a quick recording and dissemination of ideas, methods, and data; implement new publication concepts ("Science2.0"); develop more efficient ways of scientific co-creation and cooperative quality/value production; support collaboration through new ICT tools; analyze scientific activities; reveal new trends and collaboration networks; identify leading scientists and institutions through novel, multi-dimensional performance measures; study career paths (brain drain); simplify evaluation of innovation, quality, and performance; disseminate knowledge beyond circles of specialists.

Personalized Education: Provide ICT platforms (including "serious game" environments) to enhance individual and collective learning; support efficient sharing of information, scenarios, and best practices; collect depersonalized database of individual "learning trajectories"; apply collaborative filtering methods and extend recommender systems for educational means; enhance learning by linking with institutions (libraries, archives, etc.), experts, lay-specialist knowledge, and folksonomies.

Smart Cities, Transport, Traffic, Logistics: Measure real-time travel activities and their environmental impacts in a privacy-respecting way; provide better planning tools for coordinated and environmental-friendly travel activities and logistics; develop and implement more flexible, efficient and scalable control approaches for transport and logistic systems; improve concepts and user-friendliness of multi-modal transport; understand the interconnection between traffic and land use and consider them in urban and regional planning.

For the first time in our history, the majority of humanity is living in an urban setting and this proportion will increase in the future. Congestion and property price bubbles are symptoms of coordination problems. Congestion generates losses of productive time, wastes energy, and pollutes the environment. It creates economic losses of 10 Billion US$ each year in the US alone. Increasing the capacity of the transport system by 5 to 10% by better coordination could possibly reduce cumulative delay times by up to 50%, amounting to several Billion US$ in the US alone. The related reduction of CO2 emissions would be significant as well.

Smart Energy Production and Consumption: Elaborate new coordination schemes for highly decentralized energy production and consumption in "smart grids" with a large number of generators and loads; optimize the generation, delivery, and electrical grid structure; identify the behavioral laws of electricity producers and consumers (periodicities and extremes); develop new incentive structures to match supply and demand; work out concepts to promote local and diverse energy production and consumption; elaborate ways for a smooth transition from nuclear and coal-based energy production to more environmental-friendly and sustainable ones; study ways, in which people can be stimulated to reduce energy consumption and invest more into sustainable technologies to meet CO2 emission goals.

Safety and Security: Find efficient solutions to reduce corruption, crime, conflict, and war (including civil war); understand asymmetric multi-party conflicts and spillover effects; predict emerging conflicts from complex interdependencies; find solutions to integration problems resulting from migration; explore new responses to the problem of independence/liberation movements and the conflict in the Middle East; test and apply theories and technologies to monitor the spreading of crime and corruption within and between societies; fight criminal (e.g. terrorist, drug dealing and fraud) networks by studying the growth characteristics and structure of known criminal networks; develop techniques to reconstruct unknown parts of the network; identify the most efficient and effective ways to dismantle these networks; apply strategies to disrupt internet crime (including malicious bot networks).

B2 Towards Robust and Sustainable Systems

One of the goals of the following research streams is to derive general principles of how short-term needs can best be met while balancing them with long-term constraints.

Realistic Theory of Economic Systems: Develop a realistic economic theory to give more reliable advise to decision-makers; go beyond the paradigms of the "Homo Economicus" (the "perfect egoist"), efficient markets, equilibrium models, and representative agent models (mean-field models); develop agent-based models of boundedly rational behavior (e.g. limited cognitive capacities, behavioral biases and emotional aspects); consider randomness, extreme events, heterogeneity, non-linearity, emergence, and complexity to yield a greater descriptive and predictive model validity; make models consistent with empirical and experimental data; work out the mathematical connection between microscopic and macroscopic economic theories.

Crisis Observatories: Implement massive data mining and suitable filtering techniques to detect forth-coming or possible crises, e.g. bubbles or crashes in financial or housing markets ("market monitoring"); identify advance warning signs for financial and economic instabilities, for shortages in supply (oil, water, food, …), wars and social unrests, epidemics, environmental change, etc.); extract laws of systemic instabilities; identify interdependencies, feedback loops, and causality chains that may lead to cascade spreading effects.

Contingency Plans and Risk Management: Perform crises prediction and containment, detecting feedback loops and possible cascading failure before they happen and cause wide-spread damage; model individual and social behavior under conditions of disasters/crisis; develop new ICT concepts for an adaptive risk management; facilitate and support better disaster preparedness and response management; create tools for the simulation and a prompt planning of large-scale evacuation operations; develop crises management concepts considering the behavior of complex systems under uncertainty.

Managing Complexity and Institutional Design: Support the coordination between multiple parties; study systemic effects of over- or under-regulation; identify the optimal mix of central and decentral control; find methods to support a consensus or balance between different interest groups and institutions; explore new ways to overcome political blockages in situations with incompatible interests; learn how to utilize self-organization principles to reach system-optimal solutions ("guided self-organization"); find management strategies that support a robust, but flexible and adaptive organization; identify novel conflict resolution mechanisms; develop new ways to increase social and economic participation (e.g. "eGovernance").

Integrative Design of a Sustainable Financial System and Economics: Explore mechanisms and institutional settings, which can create robust, but adaptive social, political, and economic systems under conditions of global change; develop a non-equilibrium theory of economic exchange with and without central markets and reference currencies; model value as emergent property, considering psychology and social interactions; compare properties (like efficiency, predictability, reliability, robustness, signs of failure, etc.) of alternative banking, pricing, auctioning and market systems by extensive computer simulations; investigate different value transfer systems; study distributed and open kinds of credit and exchange systems (e.g. P2P lending, P2P banking); facilitate a more efficient and robust exchange of value between agents, considering mechanisms like trust, reputation, and norms; support peer-to-peer economic exchange between producer/seller and customer; explore financial policies and new institutional or regulatory settings by computer simulations in order to support decision-making.

On the one hand, this research stream is expected to be crucial to avoid future economic crises or at least mitigate them. On the other hand, the economic potential in terms of value creation could eventually amount to many billion EUR.

Global System Dynamics and Policy: Elaborate ICT-based methods leading from data, through models to policy and decision making; create techniques, tools, and concepts allowing the integration of system component models into global-scale systemic models of the living earth; develop new possibilities to gather and incorporate data into models and allow others to work with these data; produce ways of verifying the results of large-scale, integrated, systemic models to capture emergent phenomena correctly and avoid artifacts; uncover counter-intuitive interdependencies by computer simulations; improve the visualization of multi-dimensional dependencies in global models to strengthen intuition and decision-making; provide guidelines for model-based decision support; find ways to consider decision-making constraints in model scenarios; support communication and exchange between scientists and decision-makers; study impacts (such as migration, economic transformation, urban development, social unrest, or conflict) of environmental changes, natural hazards, economic development, exploitation of resources, demographic changes, and social interactions (collective behavior); investigate options to address the problems and satisfy the interests of the developing countries more successfully, considering the local and world-wide social and environmental impacts.

INTEGRATION

To a previously unseen extent, the FuturIcT Flagship will promote the integration between

- different scientific disciplines,
- research institutions in many countries of the EU and worldwide,
- research and education,
- academia, business, governance, and the public media,
- scientists and non-expert users, and
- people of different social, economic, and cultural backgrounds, gender, religion, and age.

C1 Communities and Concepts

The FuturIcT Flagship will bridge between the natural, computational, engineering, and social sciences, humanities, cultural studies, political science, economics, finance, and many more disciplines.

Note that the following list is not meant to be exclusive or complete. Moreover, many of these concepts are used across disciplinary boundaries, but mentioned here just once.

- Computer science (supercomputing, grid computing, distributed systems, human-computer interaction, semantic web, data mining, sensor networks, ambient intelligence, information systems, database design and management, algorithm design, machine learning, automated deduction, visualization, serious games)
- Mathematics (statistics, modelling, catastrophe theory, non-linear dynamics, extreme events, sensitivity analysis, logic, axiomatic deduction)
- Physics (complex systems theory, self-organization, theory of critical phenomena, power laws, chaos theory, network analysis, experimental data, information theory)
- Engineering (agent-based modelling, scenario modelling, cybernetics)
- Cognitive science, psychology (subjectivity, individual preferences, attention, creativity)
- Sociology (social interaction, cooperation, reputation, norms)
- Political Sciences and Law (governance)
- Anthropology (cultural studies)
- Economics (financial markets, systems design)
- Biology (neuroscience, perception, computational biology, epidemiology, evolution)
- Geosciences (global warming, prediction of natural hazards)
- Ecology (environmental data, sustainability)

The integration of these many disciplines is facilitated by several scientific organizations of interdisciplinary working scientists and supported by COST and Support Actions as well as ERANETS of the EU (see Section “Plausibility”).

C2 Infrastructures

The FuturIcT Flagship will involve leading research institutions from all over the EU (e.g. Austria, France, Germany, Great Britain, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Spain, Sweden), from partner countries (Israel, Switzerland) and from all over the world (e.g. Argentina, China, Japan, Mexico, USA, Chile).

This includes international top institutions such as Cambridge University, University College London-UCL, Oxford University, ETH Zurich, Imperial College, Centre National de la Recherche Scientifique, EPFL, Max Planck Institute for Mathematics in the Sciences, Max Planck Institute for the Physics of Complex Systems, La Sapienza University of Rome, University and TU Munich, Potsdam Institute of Climate Research, Central European University, Collegium Budapest—Institute for Advanced Study, Institute des Systemes Complexes, ISI Foundation—Institute for Scientific Interchange and Politecnico di Torino, King's College London, London Business School, Stockholm University, Universitat de Barcelona, University of Amsterdam, Warsaw University of Technology, the Open University and Warwick University, to mention only a few. Many of these institutions have super-computing centers, some of them among the fastest ones in Europe (e.g. ETH Zurich).

In the USA, researchers from various institutions have indicated their strong interest to collaborate with FuturIcT as well. They are located at the Brookings Institution, Indiana University, Northwestern University, Santa Fe Institute, Stanford University, and the University of California at San Diego.

Over 200 scientists from many more institutions, several of them known to be world experts in their fields, have already indicated their interest to participate in the FuturIcT Flagship.

There is also a large interest of business partners, foundations, government agencies, and the media in an involvement into the FuturIcT Flagship. Details of this interaction are currently worked out. Most remarkable at this moment is the support by George Soros and the Institute of New Economic Thinking that he established with an endowment of 50 Mio. US Dollars. Furthermore, the FuturIct Flagship is negotiating with Gap Minder, PLoS, the Wikipedia Foundation, and other relevant organizations about a privileged collaboration.

PLAUSIBILITY

D1 Preparatory Steps

To prepare for the FuturIcT Flagship, the following preparatory steps have been taken:

- A well-connected multi-disciplinary community has been built up.

- Recently, leading journals like Nature and Science have reflected many times upon the need of a bold research initiative addressing socio-economic challenges. - The scientific community is prepared and publicly listened to.

- The grand scientific challenges have been identified.

- The complex systems and social simulation community (CSS, ESSA, ASSYST) has created links to the global system dynamics and sustainability community (GSDP project).

- Suitable institutional settings for a large-scale, goal-driven research initiative are currently elaborated (EU Support Action Visioneer).

- The need for social data-mining and crises forecasting capacities is figured out.

- The concept for an innovation accelerator is developed.

- The need for social simulation capacities and integrative systems design centers is worked out.

D2 What Has Changed?

The FuturIcT Flagship is not the first attempt to address the challenges of socio-economic systems on a global scale. The most well-known example is the system dynamics approach by the Global 2000 study and the Club of Rome, which have raised the awareness for global issues, but have been limited in their success regarding the quality of prediction.

However, in the recent two decades, a variety of new methods and tools have been developed, which allow one to go considerably beyond previous modelling attempts. The success of the FuturIcT endeavor will be based on a combination of the following advances:

- ICT systems are becoming powerful enough to perform global scale simulations.

- There much more test cases to validate models, and further data required for substantial simulations are becoming available through multi-source massive social data mining (e.g. reality mining with mobile phones, sensors, and on the Web).

- Machine learning facilitates to determine significant patterns ("stylized facts") in the data.

- Geographic information systems support the visualization and interpretation of spatio-temporal patterns of global change.

- Environmental science is providing a much more accurate understanding of global and regional scale processes over a large range of time scales and is giving increasingly accurate projections of environmental change.

- Statistical physics, in particular the theory of critical phenomena, phase transitions, and extreme events make it possible to theoretically understand surprising behaviors of complex systems. Non-equilibrium statistical mechanics is providing new conceptual tools for studying the response of non-equilibrium system to perturbations.

-The theory of complex networks and networks of networks allows one to grasp complex systems, particularly the coupling of structure and dynamics, of function and form etc.

- A "Hilbert program" of grand fundamental challenges in socio-economic research has been worked out.

- A quickly growing community of interdisciplinarily working researchers from the social, natural, engineering, and computer sciences is available to perform large-scale integrative systemic analyses, combining the best of all knowledge.

- In view of global challenges like the financial crisis, the need for systemic, multi-disciplinary approaches is now widely recognized.

D3 Scientific Communities FuturIcT Can Build on (see letters of support)

The FuturIcT flagship brings research communities from the engineering, natural, and social sciences together, to combine and integrate the best of their knowledge:

- ICT-focused PANORAMA (pervasive adaptation) research agenda group (PerAda, ca. 650 members)

- Complex Systems Society (CSS, ca. 2.000 members) and Reseau National des Systemes Complexes (RNSC), collaboration with the Santa Fe Institute

- Institute of New Economic Thinking established by George Soros

- European Social Simulation Association (ESSA, ca. 370 members)

- Physics of Socio-Economic Systems Division of the DPG (ca. 350 members)

- COST MP0801: Physics of Competition and Conflicts (ca. 300 members)

- COST Transport and Urban Development (TUD)

- Sustainability-oriented Global System Dynamics and Policy communities (GSD, GSDP, more than 200 members)

- Socially Intelligent ICT (ASSYST and COSI-ICT programme, more than 100 members)

- European Conference of Transport Research Institutes (ECTRI)

- Open University (with an educational program in complexity science)

D4 Leverage Effect

The challenge to leverage 80% of funds from other sources will be a major challenge. However, investing 1 billion EUR into this Flagship is little compared the losses that the last financial crises has caused (about 14.000 billion US Dollar), and also little compared to the investment into recent elementary particle experiments at CERN (9.4 billion EUR) or the Apollo project (about 23 billion in 1969 US Dollars). As explained in the section “Impact”, the FuturIcT flagship will also create economic value by many new business opportunities.

As a next step, we will contact the national funding agencies with this Flagship proposal and the letters of support we have, to lobby for supplementary financial support of this large-scale European research initiative on a national level. Related EraNets will help with this process. At the same time, we will contact business partners and government representatives. The support of George Soros will be very helpful in this process, as well as the expected media reports. For this, we have created a contact list of journalists, who have reported about our work in the past.

Furthermore, we are currently discussing the strategy of introducing different categories of memberships. For example, on the side of the researchers, we may require them to show that they have obtained substantial research grants on related subjects, in order to get particular privileges (e.g. the use of special functionalities of the innovation accelerator). In the open funding schemes, this would largely reinforce the research trend that we are creating with the FuturIcT Flagship. However, it is anyway expected that a goal-oriented research initiative like this, involving hundreds of scientists regularly meeting at international workshops, will create a "herding effect" (in terms of attracting more and more people to work this subject). It is known that people start working on new problems if this allows them to increase their scientific impact. We know that many people who have been studying inanimate matter in the past are inclined to tackle the challenges of humanity, if only the institutional obstacles in this research area are removed. This dynamics in itself is expected to create a large leverage effect.

On the side of business partners and foundations, we may have differentiated memberships as well, depending on how much money they spend on related research. For example, category A members could be required to spend a certain percentage of their business volume, and category AAA members would be expected to give considerable donations in exchange for publicity.

It can be noted that we expect FuturIcT to attract a lot of support from business and government agencies. Most large companies such as supermarkets, retailers and telecoms suppliers have huge databases of customer information and routinely use data mining to run their businesses. For any one of these, access to the enormous cutting-edge expertise of FuturIcT would be of great advantage to their R&D departments, certainly exceeding an investment of a few hundred thousand Euros per year as AAA members. The same applies to companies, which make their business with the internet, the world wide web, and sensor technologies. Similarly, banks, insurance companies and other financial institutions could hardly ignore this unprecedented source of scientific expertise that could help them avoid the problems of the recent past and the unknown future. The FuturIcT Flagship initiative will also be highly relevant for urban and transportation planning, and the energy, health, and security sectors. It is, therefore, confident that it can raise financial support for this highly applicable Flagship research program amounting to a multiple of the contribution by the European Commission.

D5 Examples of Related, Preparatory Research Projects and Fields

- ERANETS: ComplexityNET, Chistera (under discussion)

- Coordination Actions: Exystence, GIACS, ONCE-CS, ASSYST, PANORAMA/ PerAda, AWARE (pending), GSDP (pending)

- FET and NEST projects: EURACE, EMIL, PERPLEXUS, PATRES, MMCOMNET, EVERGROW, BISON, DELIS, EC-AGENTS, PACE, CREEN, IRRIIS, LiquidPub, HITIME, VIVO, GAPMINDER, GLOBALHUBS, ALLOW, ATTRACO, FRONTS, REFLECT, SOCIALNETS, SYMBRION, DREAM, SIGNAL, PEACH, EvoNet, Metaheuristics Network

- Techno-social systems, socially intelligent ICT: SOCIONICAL, CYBEREMOTION, QLECTIVES, EPIWORKS

- Collaborative Research Center SFB 555: Complex Non-Linear Processes (Berlin/Potsdam)

- Global System Dynamics (GSD)

- Global-Scale Agent-Based Models of Disease Transmission

D6 The FuturIcT Flagship Fits the Political Agenda

- 2020 strategy of president Barroso: give sound scientific advice to policy makers based on sound data

- New Energy Sustainable Town (NEST); CO_2-neutral Masdar City (Abu Dhabi)

- Solar City (Austria), Transition Towns (UK)

- Towards a 2000 Watts society (e.g. City of Zurich)

- Ambient intelligence (from personal health care to consumer applications)

- Knowledge-driven economy

- Recent microcredit initiative of EU

- Evolution of the European political institutions

- Homeland security, relationship between crime and terrorism

- International Disaster and Risk Conference (IDRC)

Many more initiatives could be listed here.

D7 Milestones

2010: Preparation of proposal for FET Flagship pilot (Coordination Action)

2011: Elaboration of full program and organizational issues (details of the FuturIcT Flagship)

2012: Evaluation of the Flagship pilot: scientific program, consortium, and institutional settings

2013: Start of Flagship

2015: Design of new simulation and data collection concepts

2016: First Data Collectors and Crisis Observatories in operation

2017: First Version of Innovation Accelerator, Reputation-Based Quality Evaluation Platform

2018: Possibilistic Computation (parallel world modelling and scenario simulation tool)

2019: Demonstration of Reality Mining (new zero-delay sensing applications)

2020: Demonstrators in the areas of future cities, transport, large-scale evacuation,...

2021: Social Information Theory, Non-Equilibrium Theory of Economics

2022: Living Earth Simulator (including Global System Dynamics Models) running

Note that each of these activities extends over several years. First demonstration systems are expected in the indicated years and are expected to trigger off subsequent large-scale research activities to enhance these systems and to make them more sophisticated.

COMMENTS

The FuturIcT Flagship Initiative has been coordinated by Dirk Helbing (ETH Zurich).
By now, more than 140 scientists have registered as supporters of FuturIcT (see http://www.futurict.ethz.ch/FlagshipSupporters), and several dozen more have indicated their support by e-mail or made contributions to the preparation of this proposal. The complete list, which contains dozens of world-leading scientists, is available on request from Dirk Helbing (dhelbing@ethz.ch).

Designing a Life Capsule with Bio-Engineering Ontologies

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BRIEF EXPLANATION

Designing a Life Capsule with Bio-Engineering Ontologies

The Life Capsule is an artificial environment that enables its inhabitants to survive for very long periods in the most inhospitable circumstances. Drawing inspiration from nature, in which many systems persist sustainably in extreme environments, would seem an obvious way to design a working Life Capsule. In this case, such biomimetic design turns out to require an in-depth understanding of biological processes such as self-repair, fault tolerance, and waste and water management. To gain this understanding and successfully employ it for practical purposes, biomimetic design needs to conquer an existing "information barrier": biological data are not available in a form that enables designers to mine them and to emulate mechanisms that underlie desirable features of biological items. Constructing bio-engineering ontologies would be one way to overcome this information barrier.

AMBITION

Applied ontologies, as structured systems of knowledge representation, have proved their worth in managing biological, medical and engineering information. They also might play a role in a much more ambitious and constructive enterprise, namely to use systematically biological knowledge to design artificial, 'bio-inspired' systems. One such system, which combines many of the features sought for, would be a Life Capsule fit for long inhabitation – say for interplanetary travel. In order to sustain human life for a long time in extreme environments, the Life Capsule should for instance be tolerant to minor faults and changes in external circumstances, capable of maintaining stable internal circumstances, self-repairing, self-propelling and able to recycle scarce resources with maximum efficiency.

Attempts in various branches of engineering to emulate one or more of these highly desirable features have met with limited success. One major obstacle appears to be an information barrier: biological knowledge about natural systems is not easily and systematically translated into useful design specifications, let alone into blueprints for bio-inspired systems. Only close, time-intensive cooperation between biologists and engineers occasionally leads to successful translations.

We propose to construct bio-engineering ontologies that could provide systematic translations. Such ontologies could be used to classify and relate biological data, model which mechanisms are responsible for desirable features, and provide the needed information (and evaluation techniques) to reproduce such mechanisms in artificial systems. This proposal therefore perfectly fits the candidate Flagship "Understanding Life through Future ICT" – but adds an ambitious design perspective to a project aimed at understanding nature.

To fit the 'bio-engineering' bill, existing applied ontologies need to be fundamentally revised, in several ways. One necessary revision is that they need to address explicitly the different levels of reality, from physical to chemical, biological, intentional and social , and to represent how properties of lower-level items may give rise to higher-level, emergent objects and properties. Another is a classification of biological systems in terms of design specifications (e.g., self-repairing, recycling) along with a representation of available biological information about the mechanisms responsible for these features. Both of these revisions, and others like them, require foundational work on ontologies as well as a practical outlook, since construction of an ontology is a purpose-driven effort. Designing the Life Capsule through systematic use of biological knowledge will be the guiding purpose of this bio-engineering ontology.

IMPACT

The potential impact of a systematic use of biological knowledge in designing technologies can hardly be overestimated. It might, among other things, enable the emulation of features that are as yet unique to biological systems, such as self-repair.

The impact of this project therefore reaches further than the Life Capsule itself.

INTEGRATION

To succeed, this project would need to bring together a massive amount of expertise from bio-mimetic design in various branches of engineering, the life sciences, behavioural sciences and computer science. Philosophy and system theory could provide the necessary foundational work for constructing bio-engineering ontologies.

PLAUSIBILITY

At the workshop "Natural Resources for Innovative Design" (March 3-4, Eindhoven University of Technology), a team of bio-mimetic designers, computer scientists, and applied ontologists identified this as a topic of huge theoretical and practical impact. The workshop itself was successful in bringing together some of the expertise required for the project.

Workshop participants

Weslynne Ashton, Yale University, USA

Peter J. Bentley, University College London, UK

Andrea Bonaccorsi, University of Pisa, Italy

Stefano Borgo, Laboratory for Applied Ontology, ISTC National Research Council, Italy

Ivey Chiu, University of Toronto, Canada

Gerard Dijkema, Delft University of Technology, the Netherlands

Dario Floreano, Ecole Polytechnique Fédérale de Lausanne, Switzerland

Koen Frenken, Eindhoven University of Technology, the Netherlands

Paweł Garbacz, Catholic University of Lublin, Poland

Pierre Grenon, The Open University, UK

Pauline C. Haddow, The Norwegian University of Science and Technology (NTNU), Norway

Cecilia Hertz, Founder and Managing Director Umbilical Design AB, Stockholm, Sweden

Wybo Houkes, Eindhoven University of Technology, the Netherlands

Gilles Kassel, University of Picardie Jules Verne, France

Ulrich Krohs, University of Bielefeld, Germany

Sabina Leonelli, University of Exeter, UK

Françoise Longy, IHPST (Paris) & University of Strasbourg, France

Igor Nikolic, Delft University of Technology, the Netherlands

Thomas Reydon, Leibniz Universität Hannover, Germany

Susan Stepney, University of York, UK

Pieter Vermaas, Delft University of Technology, the Netherlands

Laure Vieu, Institute de Recherche en Informatique de Toulouse (CNRS), France

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COMMENTS

Coevolutionary Interfaces: Change towards strong sustainable development

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BRIEF EXPLANATION

Coevolutionary Interfaces: Change towards strong sustainable development

AMBITION

Theory and empirical analysis of coevolution are still lacking precision, although the mutual interdependencies between ecological, biophysical, economic and societal systems are intense. Complex processes whether or not they are under scientific scrutiny do exist. They do shape our environment and vice versa. In combining theoretical strands of evolutionary economics and dynamic capabilities with research on ecological complex interrelation the ambition of this flagship is to elaborate interfaces between

(a) disciplines,

(b) issues, and

(c) agencies.

Systems and processes of coevolution depend on specific interrelations. Human actors face essential uncertainties in dealing with complex dynamics. What capabilities must be developed to cope with actual and oncoming challenges? How can local and global agendas be mediated? What tools for a sustainable management do we need? How can conflicts be deescalated? What sort of analytical structure can bridge different time frames? A concretizing of these questions could be possible alongside with a technology based conceptual monitoring. This monitoring could be designed in alignment with results from evolutionary complex systems approaches that shed light on critical (in the true sense of the problem) iteration loops.

Technological innovation alone is not sufficient to solve this task. It can only be successful by innovating societal dealing with norms, values and power systems. As this outlines drastic changes a flagship is needed to figure out carrying capacities for shifting regimes. Earth systems regimes might shift as well as power regimes in society or financial markets. Therefore science urgently needs interdisciplinary frames of concrete relevance. The information representing this relevance must be translatable via different disciplinary languages.

Thus relevance can generate a guideline for flexible steering.

Finding out processes of transferring data into disciplinary language and explicating modes of information processing between disciplines is the goal of this flagship.

Aiming for a sustainable future can only be done by specifying concrete issues of action that then must be worked on continually. Thus the flagship will outline frames for projects on specific issues with exemplify coevolutionary functions of living-together on earth.

IMPACT

A suggestion for these before mentioned issues is:

Biodiversity

Climate change

Financial system

Poverty

Scarcity of resources

To solve specific challenges connected with these issues the development of sustainable solutions can be fostered by means of eco innovation, conceptual new software, governance innovation, conflict management, alliances and networks, bridging economic and biophysical systems, bridging local and global scales, bridging capabilities and uncertainty. Taken together this means to focus on sensible information processing between conceptual/analytical innovative theory and practical use and vice versa. This implies to include a lot of strategies, projects and knowledge that are/is already there. This also implies to be honest and precise in defining what data has to be collected. This also implies to focus on reality-driven purposes.

The Coordination of efforts needs to figure out capable and flexible instruments for managing this coordination across levels, across disciplines and for conflicting interests and time frames. Information and communication in combination with sensitive analytical measurements involves metrics for complex dynamics. These metrics must be compatible with suitable software engineering. Human agents and agencies dealing with these dynamics must be capable of learning therefore needed skills. This means to develop technological and human devices alongside in permanent scrutinizing monitoring. Recursive loops can be made explicit and learning effects might open precious insights into patterns of coevolutionary dynamics.

Note that the structure of the single projects in respect to the before mentioned issues are not yet defined.

INTEGRATION

The integration of disciplines focuses on physics, geology, earth system analysis, biology, bionics, economics, ecology, complex systems theories and mathematics.

Different levels of abstraction can be explicated and matched with conceptual frames. These disciplinary conceptual frames can then be integrated by a modular structure of interdisciplinary information processing that allows single disciplinary approaches but also offers ways for translating and transferring information across.

Agents with such skills must be capable of higher order learning. A framework for this competence can be built with respect to evolutionary economics and connected strands of pathdependency and dynamic capabilities. The sensing of and coping with turbulent environments in economics can be enhanced to changes for sustainable development.

The integrative approach for this flagship needs concretion for actual use. Research must be connected with actual processes. It is not enough to collect data. Information must be transmitted via the relevant trajectories that connect a concrete task with the overall aim. In this sense the focus of the flagship will be to work out categories of interrelation that are in line with an interdisciplinary integration. Thus it will develop languages (including the before mentioned levels of abstraction) to process information. This Processing needs to be sensible in respect to the tasks deriving from the issues (see list above). Hence it can be expected to gain results for structuring data into information for direct use in defined frames of action.

PLAUSABILITY

Each issue can generate a series of tasks. These tasks can be compared with the already existing resources. So the projects on this flagship will constitute an open and flexible backcasting to identify missing sequences in processes for solution.

These missing sequences will then undergo a detailed scientific examination from different disciplinary fields to precisely outline agendas to fill them up. Once these agendas are defined, the different teams working on the tasks will specify operators according to patterns of dynamics that translate interdisciplinary forces and sources into units of function.

In mutual reconcilement with the conceptual structure of the whole process (see above) and the instantaneous requirements these units can trigger the change we need. Therefore to specify process units of change will mean to work out a modular structure of competence blocs. This means to identify relevant teams of agents with relevant competencies in relation with the task. These modular sets will only fulfill their function when the necessary and sufficient information can be communicated between disciplines, namely referring to concrete acting according to the concerning task.

This means continual exchange with projects in praxis.

This means to constantly up-date the conceptual structure of the modular units against each other and with the newest scientific data. Information technologies will be needed for this purpose.

This means to work on dynamics of interaction. This implies experimenting with different sets of hierarchical structures.

This means to figure out innovative modes to formalize the processing of information.

If this flagship is successful, the result would be a series of tasks that is connecting theoretical approaches, conceptual innovation and ecological-economic innovation with the optimizing of already existing project structures (e.g. in conservation).

Further result would be insights in dependencies and operating across disciplines.

Beyond that we could gain conceptual approaches matching with a specific description of the terms of use. These descriptions could be useful for program languages as well as for transfer into other fields of research.

All these findings underpin knowledge in coevolutionary dynamics and thus can foster sustainable development on time.

COMMENTS

There is no concrete agreement about cooperation with specific partners as I decided to submit this proposal today. I am listed in the proposal of Dirk Helbing (FuturICT) who informed me about this call 3 weeks ago and I am participating in the call from Atta Badii (S-GAIA.

Potential reference persons could be:

Carl von Ossietzky University of Oldenburg, Institute of Economics ,norwest2050, www.nordwest2050.de

Pippa Howard, Director of Corporate Partnerships, Fauna and Flora International, Cambridge, UK, http://www.fauna-flora.org/aboutus.php,

Dr. Tobias Raffel, Academic Affairs Manager,Alt-Moabit 101 b10559 Berlin Germany http://www.rolandberger.com/company/academic_network/Contact.html

Governmental commission on climate mitigation
https://www.regierungskommission-klimaschutz.de/Klimaschutz/WebHome,

Environmental Technologies Action Plan http://ec.europa.eu/environment/etap/,

Elisabeth Wessel,Federal Ministry for the Environment, Nature Conservation and Nuclear Safety Alexanderstraße 3, 10178 Berlin

Confederation of Danish Industry (Henrik Dissing)
http://di.dk/English/Pages/English.aspx

Max Planck Institute of Economics http://www.econ.mpg.de/english/,

TU Dresden Fakulty of Economics Managerial Economics
http://tu-dresden.de/die_tu_dresden/fakultaeten/fakultaet_wirtschaftswissenschaften/vwl/me/index_html,

Wuppertal Institut for Climate Environment and Energy http://www.wupperinst.org/en/home/index.html, Potsdam Institute for Climate Impact Research http://www.pik-potsdam.de/

Dr. oec. HSG Harald Tuckermann University of St. Gallen, Institute of Management http://www.ifb.unisg.ch/org/ifb/ifbweb.nsf/wwwPubhomepage/webhomepageeng?opendocument,

Prof. Dr. Kurt Dopfer University of St. Gallen http://www.fgn.unisg.ch/org/fgn/web.nsf/c31e7c476ced62cec1256954003e839e/acd0025ae941e10bc1256a07004d407d?OpenDocument,

CIER Center for Integrative Environmental Research, http://www.cier.umd.edu/

Ernst Ulrich von Weizsäcker, University of California, Santa Barbara

Bryan Boult, Head of Environment Futures and Sustainability Hampshire County Council

Using evolution to compute
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Permission	yes

BRIEF EXPLANATION

Evolution of technical, social and biological systems & applications to real-life complex problems of search, design, optimization, innovation.

Biomimetic algorithms today regularly solve Optimization and Design problems. However, recent advances in evolutionary and molecular biology provide new insights that have not been exploited yet. A renewed roadmap could produce algorithms to solve previously unimaginable or intractable computational, engineering and biological problems; and reflect back to biological and evolutionary issues. This techno-scientific process should itself be considered an adaptive system that constantly loops between computation and biology, and between analysis and design.

AMBITION

Computational scientists have developed algorithms inspired by natural evolution for at least fifty years. These algorithms solve optimization and design problems by building solutions that are "more fit" relative to desired properties. We refer to the current field of studying and applying such algorithms collectively as Artificial Evolution (AE); this term groups approaches that are sometimes distinguished in the literature, such as 'evolutionary programming', 'genetic algorithms', 'evolutionary strategies', and 'genetic programming', and can also be thought of as including some stochastic methods from other domains, like 'simulated annealing' from statistical physics, or 'interacting particle methods' from applied mathematics. AE has traditionally had a strong engineering focus, and has been applied successfully in such disparate areas as the optimization of spacecraft trajectories, nano-transistor design and quantum circuits, and has performed as well as or better than human designers in some areas such as designing analog circuits.

However, the basic assumptions of this approach are outdated. We propose a research roadmap to develop a new field: Computational Evolution (CE). This approach will produce algorithms based on current understanding of molecular and evolutionary biology, and will solve previously intractable or unimaginable computational, engineering and biological problems. It will also reflect back into a largely improved understanding of biological and evolutionary issues.

Breakthrough 1: Solving new, more life-like complex problems

CE will allow algorithm designers to address new challenges. Potential target problems will tend to have the following features: they cannot be completely specified a priori; they are dependent on temporal variations; the information needed to solve them is apparently available, but on the one hand it is not clear which data are relevant, and on the other hand important data might not be observable; their solution requires autonomy and cannot presume on-demand human intervention.

This new capacity in problem solving, search, design and optimization will be transferred to industry, much like what is happening nowadays for AE.

Breakthrough 2: Merging explanatory levels in biology and advancing bio-design capability

Scientific explanations in biology are typically provided at one single level, for instance at the molecular level or at the evolutionary level. Based on a few past experiences, merging evolutionary and molecular explanations would tremendously enrich our understanding of biology. Towards this goal, advances involving evolutionary modelling will be transferred into biological knowledge. Potential target problems will tend to have the following features: evolution acts at more than one single level (genome, individual, population); the issue involves at least one evolutionary and one ontogenic time scale; the biological process under study has a strong epigenetic component.

This new explanatory power will be harnessed towards a renewed understanding of biological objects as processes, and of genomes as encoding the organismal environment. Ultimately, it will be transferred in advanced bio-design capacities, with consequences in biotechnology and more specifically in synthetic biology.

Examples of scientific challenges:

• Physicality and embodiment

• Genotype-phenotype map

• Exaptation / Innovation.

Examples of technological challenges:

• Open-ended problems

• Unpredictable conditions

• Unexpressed specifications.

From the above description, it must have become clear that this programme will require federated efforts from many scientific communities, and from both academia and industry.

IMPACT

The impact of realizing models of Computational Evolution will come on multiple fronts.

1. The ability to solve new problems using CE methods will allow algorithm designers to address new challenges.

Biological systems are by nature multi-scale (from protein to cell to organ to organism) and multi-disciplinary (e.g. one process might involve chemistry as well as fluid dynamics). Most of today's algorithms that address multi-scale or multi-disciplinary problems have to over-simplify some scales or the impact of some disciplines. Lessons are to be learned from these systems that deal with such « multi-difficulties » to be transposed to problem solving.

Biological systems are continuously adapting to changing environments, at different time scales (i.e. from everyday life at the level of individuals to geological changes at the level of species). Furthermore, such changes are only partially observable. Hence, because most complex system are unpredictable for the software engineer, software systems have to be adaptive, and biological mechanisms that allow organisms to rapidly switch from one behavior to another can lead to huge leaps in environnement-aware autonomous systems.

2. Representative challenges that will be addressed by CE are:

(a) Environmental Sensing

CE will enable individuals to discriminate between environmental cues. For example, autonomous robots, especially those operating in environments that they are themselves changing, would be able to use CE to select different sensory data to solve the same problem; a biological analogy would be the evolved use of hearing instead of sight to capture insects in both bats and swallows.

(b) Continuous Data Mining and Data Streaming

CE will autonomously explore databases that grow significantly and rapidly (continuous Data Mining) or that are available as a continous flow of data that is too large to be stored (Data Streaming), allowing researchers to periodically sample inferences for new insights that were not previously available. Potential targets are bioinformatics, terrestrial image databases, monitoring of large software and hardware systems like grids, and computational economics and finance data.

(c) Creative and Innovative Design

The diversity of living beings that result from the development of rather similar genomes is astonishing. Along those lines, CE will allow for new variables to be created or old ones to be eliminated, unlike what is implemented in routine design nowadays, which works within predetermined constraints. For example, innovative molecular design of antibiotics could require that new variables be introduced to account for the adaptive responses of both the host and target organisms, or variables that are considered important initially, such as the ability of a molecule to interact with non-organic molecules, could prove to be unnecessary and be eliminated.

(d) Automatic Hypothesis Generation

CE enables algorithms to vary which sets of data are relevant to a given problem, without relying on presuppositions about which data are important, which features/variables are significant, and which types of hypothesis should be explored. For instance, drug discovery is sometimes like a good mystery story, in that many molecular interactions are known, but it is unclear which are important for a specific pathology. CE could generate potentially interesting hypotheses about molecular interaction pathways.

3. Leverage effects will be produced in the following way:

(a) Because of strong multidisciplinary and technical requisites, the CE initiative will close the interaction loop between biology and computing, producing amplification impact on both sides;

(b) It will contribute to further convergence of NBIC disciplines;

(c) It will continue to harvest the performance gains of future computer generations moving into the Exa scale.

4. The CE initiative will contribute to the competitiveness of European society, economy, technology and science via:

(a) Acceleration of the innovation cycle, with a strong impact on the generation of new employment.

(b) Pervasion of all application fields of Complex Systems approaches, like, e.g. infrastructure networks (transport, energy, communication), software and hardware development and design (becoming more adaptive and automatized), health (epidemiology, systems and synthetic biology, molecular and personal medicine) and agriculture and ecological management (nutrition, ecological networks, resource management).

(c) Challenging traditional paradigms in Economics, Politics, Social Science and Law.

INTEGRATION

- **This wide-ranging, multidisciplinary programme will draw Scientists and Engineers with their ideas, from**

- software engineering

-applied mathematics

- evolutionary computation

- evolvable hardware

- robotics and control

- statistical physics

- network science (a subset of)

as well as

- evolutionary biology

- systems biology

- synthetic biology

- developmental biology

- artificial life systems

and application fields including

- Technological networks (transport, energy, communication, etc.)

- Software and hardware design, adaptive design, automated design

- Health (epidemiology, systems & synthetic biology, etc.)

- Nutrition (food web, resource management, etc.)

- Economics, Politics, Sociology, Law, etc.

- **Infrastructure & resources necessary for the project to succeed**

- A number of networked centers of excellence will form across Europe. They will regularly interact and make use of joint technological platforms.

- Centers of excellence will be nucleated by existing pioneering activities in the areas. A wider range of supporting organizations will provide resources in the form of research grants and support for development and exchange.

- **Research agendas**

We want to renew the alliance between research in natural and artificial evolution. The power of the paradigm of evolution is by far not realized in technology whereas its deep-ranging consequences in science have not been fully grasped either. In both science and technology, many efforts to date have suffered from a lack of joint efforts. The project proposed aims at contributing to a change of culture in this regard.

PLAUSIBILITY

The plausibility of the approach results from the following factors:

1. Our two-pronged approach will foster an entire research field while at the same time providing a unifying research focus that integrates all efforts into a particular goal.
2. The envisioned challenges are naturally occurring in the course of near-future technological and societal developments.
3. The flagship project will be able to ride the continued wave of progress in Computing and Biology.
4. Some embryonic attempts at extending the paradigm of Artificial Evolution will be able to serve as starting points for this much more ambitious agenda, including
   a. Implementations of more complex genotype / phenotype maps
   b. Early models of evolution-development in AE
   c. Existing approaches to artificial development
   d. Online algorithms that have to work with finite resources
   e. Multi-step decoding
   f. Multi-objective optimization.

Our plan encompasses a series of preparatory workshops, to be held in 2010-2012 leading to the gradual focusing of the flagship project until a start in 2013. The flagship will work with as many interested institutions as possible, with the anticipated formation of a kernel of about 10-20 institutions which will serve as a distributed network of hubs for the further crystallization of ideas.

Based on developments in the past 50 years, we expect that the proper time scale to achieve a highly significant progress in this field at the right ambition level is of the order of one decade.

COMMENTS

61 supporters, from 3 continents and 15 nations and 39 institutions

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Life care through ICT

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BRIEF EXPLANATION

Modern ICT architectural concepts, accompanied by a further dramatic increase in available computer processing power and communication bandwidth, allow new health care services as enablers of a personalized medicine. Model guided therapy (MGT) generally, and the patient specific model (PSM) in particular, realized through a therapy imaging and model management system (TIMMS) are key aspects of this potential for a transition in health care. MGT extends and complements the ICT systems developed in the last decades for general health care management (HIS, RIS, PACS, CAD, CAS, etc.) towards knowledge management for patient specific interventions. Research and development in MGT within the context of the ISTAG flagship topic “Understanding life through future ICT” is to provide a solution to the problem of real time information integration for patient specific diagnosis and therapy. The real time aspect of MGT is a particular challenge to the design of novel ICT architectures and software engineering methodologies.

AMBITION

A1 Problem statement

During the last decade, the practice of medicine has been greatly influenced by Evidence-Based Medicine (EBM), in order to maximize objectivity in determining treatment protocols through clinical trials and meta-analyses. As a direct consequence, wherever possible, patients are diagnosed and treated according to medical guidelines based on the general knowledge derived from observations of large populations of patients and controls. However, there are still wide variations between individual patients, in terms of anatomy, physiology, metabolism, and genetics, that cannot be accounted for, or factored into treatment decisions, by EBM, or, by standard methodologies of patient assessment that are currently available to physicians and the healthcare systems. Oncological, cardiovascular, traumatic and chronic disease diagnostic and treatment protocols, in particular, should be subject of taking great care about the specific differences between individual patients.

How can the differences between patients be expressed in quantitative and qualitative terms, and in particular, how can this information be integrated into the therapeutic workflow, for example, of an interventional radiologist or surgeon?

A2 Solution concept

As a solution concept to the above brief introduction to the problem of diagnosis and therapy, it is postulated that the available individual patient data need to be prioritised and suitably integrated into an IT based patient specific model (PSM). This model contains a given set of data and information elements which are structured to indicate relationships between elements and their importance ratings. Such a model would represent the health and disease aspects of a patient for assisting in patient-specific model guided diagnosis and therapy. They key features and requirements of model guided therapy may be summarized as follows:

a) Model guided therapy (MGT) is a methodology complementing image guided therapy (IGT) with additional vital patient-specific data

b) MGT brings patient treatment closer to achieving a more precise diagnosis, a more accurate assessment of prognosis, as well as a more individualized planning, execution and validation of a specific therapy.

c) By definition, model guided therapy is based on a patient specific model (PSM) and allows for a patient specific intervention via a patient adapted therapeutic workflow.

d) MGT, based on patient specific modelling, requires for its realisation appropriate IT architectures and data structures for model representations.

For a model based patient care, a comprehensive patient model needs to be designed, reflecting results not only from imaging modalities, but also from biosensors, data repositories, "omics" and epigenetics, electronic medical records (EMR) and evidence based medicine (EBM). The integration of these data and information items or clinical entities into a PSM must allow for different levels of generalisation and specialisation. This situation reflecting the information aspects of the patient is amenable to be represented by a Multi-Entity Bayesian Network (MEBN) or other forms of probabilistic relational models.

Concepts for model guided therapy, generally, and associated patient specific models, specifically, have been advanced from the beginning and in parallel to the development of image guided therapy. The resulting systems which evolved in the last two to three decades are generally restricted to 2-D and 3-D geometric models, sometimes including temporal or physiologic information as further dimensions. For an image based patient care (i.e. IGT) dedicated IT architectures and data structures have been developed, which support the use of these rather restricting models, mostly in given proprietary settings.

A3 Novel ICT system architectures for model guide therapy

Model based patient care, however, can only be realized with an IT management system capable of handling a dramatically increasing number of therapeutic images and other categories of vital patient data, their embedding into models and associated knowledge management based therapeutic services. An infrastructure with this capability may be termed a therapy imaging and model management system (TIMMS). TIMMS is a concept for an IT-meta architecture allowing for interoperability of the primary services facilitating a MGT based intervention.

For a therapeutic intervention it is assumed that human, mechatronic, radiation and/or pharmaceutical agents interact with the model in real time. This can imply the processing of several thousand images combined with signal and auxiliary data to create and maintain a PSM. Because of dramatic advances towards high performance computer and communication systems, the realization of a PSM is now possible.

Key feature and prime functionality of a TIMMS is to create and manage models relating to a patient specific intervention. Modular, scalable and distributable TIMMS components act synergistically to provide functionality and utility that exceed the sum of their parts.
These components include:

- "engines" - or software modules that can be executed on an appropriate computing machine - that work independently and dependently to account for all facets of complex medical and interventional procedures. (The engines realize functions for intraoperative imaging and biosensor data acquisition, modelling, simulation, workflow and knowledge and decision management, visualization and representation management, intervention and validation);
- engine associated repositories - integrated hardware and software structure that stores and makes available data and/or data processing tools - linked to each of the engines; and
- additional repositories, including situational models (defined as simulated objects and potentially representing patient-specific information, implants, etc.) and medical process references such as workflow models, evidence-based medical data and case-based medical data.

During intervention, the system enables real-time data mining from these repositories. The workflow and knowledge and decision management engine is the central computing kernel or "brain". It may use different forms of logic, database structuring, adaptable software agents and other forms of intelligence, depending on the medical procedure and its applications. Adaptable software agents are software modules that contain some form of artificial intelligence which, with some autonomy and adaptability, can perform essential functions.

In a TIMMS, there may be many different classes of models belonging either to the category of object modelling (e.g. patient models for different clinical requirements and situations) or process modelling (workflows of different classes of therapeutic interventions).

In the following, the category of object models and their potential data structures as well as therapeutic processes are briefly discussed. When object models represent patient data or information, a number of criteria or requirements need to be considered, in particular, the basic TIMMS model must have the following features:

1. The TIMMS patient model must have components which represent the patient as an n-dimensional and multiscale (in space and time) data set.
2. The TIMMS patient model must facilitate interfacing to the surgeon and other operative personnel, the TIMMS engines, TIMMS repositories, and the IT infrastructure.
3. The TIMMS patient model must be capable of linking these components, which may be static or dynamic, in a meaningful and accurate way.
4. For dynamic and interactive system components, the TIMMS patient model must be able to process morphological and physiological data and perform the necessary algorithmic functions to maintain the model in an up-to-date state.
5. The TIMMS patient model must be capable of being incorporated by the TIMMS executing workflow and responding to its changes.
6. The TIMMS patient model must be amenable for further development using readily available and if possible standardized informatics methodology. To escape proprietary constraints, tools may include UML, XML, Visio, graphical modelling, block diagrams, workflow diagrams, MATLAB, Simulink, DICOM (including surgical DICOM), Physiome, CDISC SDTM, openEHR and related products and standards.
7. The TIMMS patient model must comply with software engineering criteria, for example, to open standards and service-oriented architectures (SOA) to allow for multi-disciplinary information exchange.
8. The TIMMS patient model must allow for further extensions to incorporate advances in molecular medical imaging, genomics, proteomics and epigenetics.
9. The TIMMS patient model must be amenable to be used for clinical trials, predictive modelling and integration into the personal health records.
10. The TIMMS PSM must be based on statistically valid, probabilistic principles. Such methodology, which includes Bayesian modelling and inference, will allow the growth of increasingly accurate, and statistically valid, funds of medical knowledge, i.e. model-based medical evidence, to be stored in repositories of TIMMS systems.
11. The TIMMS patient model should support verification, validation and evaluation processing, e.g. for outcome prediction and control. In the long term, it should contribute to a model based evidence methodology.

A search in the literature on computer assisted interventions and therapy demonstrates that at any one situation or project only a small subset of these features is supported by modelling tools. Typical examples are geometric and prothesis modelling, finite element modelling of medical devices and anatomic tissue and a variety of virtual human models. Within a TIMMS architecture these models and associated information are contained in a variety of repositories.

It is important to note that the content of TIMMS repositories of which there may be many as well as the executing workflow reflect the statistical uncertainty of knowledge about the patient and the therapeutic processes.

A4 The patient specific model as an enabler of model guided therapy

The PSM is an approximation of a set of dynamically interconnected features of the patient with joint (dynamic) probability distributions over many random variables. It is one of the roles of the PSM and associated software tools to gather, calculate, record, tabulate or structure, maintain and communicate values for each of these entities, and predict and record the changes in values brought about through the interactions with the entities.

It is one of the great strength of Bayesian related network methodologies to start with baseline (prior) information, construct new (posterior) values based on the addition of new information, and to have the ability to continue updating (the posterior data becomes the new prior data) as more information is added to the system. Further intensive research and development is needed to adapt the strength, for example, of the general MEBN theory to clinical settings.

The definition of PSM entities and their relationships with one another, for example by means of archetypes and templates structured with an MEBN philosophy, remains a major R&D effort. Different interventional workflows may require different PSMs but their creation and management, particularly the human and device interaction with the model require a generic set of methods and tools.

Management of therapeutic processes are a particular demanding task within the domain of workflow management systems. Not only the modelling, specifically the segmentation, analysis and recognition aspects of workflows, need to be better understood, but also their impact on the delivery of health care.

Based on appropriately designed patient specific models, MGT provides the scientific basis for a more accurate, transparent and reproducible intervention with the potential for validation and other services. Examples of such services are visualisation, simulation, workflow and knowledge and decision management, repository management as well as appropriate communication facilities to pre- and post-therapeutic systems. The performance and interoperability of the system components providing the service may be enhanced by tools supporting the management of standardized patient models and process models. A further service which may partially be embedded in the validation system should enable a model based medical evidence (MBME).

In a wider healthcare setting, however, only by coordinated project funding and collaboration between institutions can the ad hoc development of IGT systems of today be replaced by an MGT. Objectives for model design and implementation and associated IT infrastructures and software tools need to be carefully selected and if needed adjusted to fulfil the overall goal of a high quality patient specific care.

IMPACT

Medicine is undergoing a historic transition, moving away from a trial-and-error model of care towards individualized treatment strategies based on patient-specific knowledge management of disease and treatment. Not only the biomedical system sciences, mathematics, medical imaging but also the discipline of computer assisted radiology and surgery (CARS) based on novel ICT concepts, are enablers of this new paradigm. They provide the methods and tools for real time knowledge management and specifically for a patient-specific medicine

The traditional imaging approach applied to patient care’s clinical aspects - known as the “image-centric world view” - has been limited to the images themselves. The model-centric world view approach of a TIMMS, however, extends far beyond images: A wide variety of patient information can be integrated with the images, making all relevant data available for therapeutic interventions and enabling a comprehensive, robust view of the patient and associated patient specific information.

Standards relating to medical imaging and communication as well as information management for real-time therapeutic and related activities are an integral part of TIMMS. Until now, patient and workflow models have not been considered extensively in standard organizations. However, therapeutic modelling and simulation are key TIMMS functions. Therefore, in addition to defining mechanisms to enable real-time processing and communication, standardization efforts will need to create an agreed-upon data structuring of relevant models and related services.

TIMMS provides a process for a comprehensive therapy assist system combing and integrating all necessary information and communication technology - workflow analysis, data processing and synthesis, interactive interfaces between physicians and mechatronic devices, and adaptable software agents - to provide comprehensive assistance and guidance through complex procedures such as image- and model-guided surgeries. TIMMS fulfils the concept of extending diagnostic radiological PACS to therapeutic/surgical real time capable IT infrastructures, accounting for the OR's and other therapeutic departments fundamentally different workflow requirements.

INTEGRATION

As the boundaries between diagnostic and interventional radiology, radiation therapy and surgery are becoming less well-defined, appropriate patient models will become the greatest common denominator for many medical disciplines.

IT systems and standards for creating and integrating information about patients, equipment, and procedures will make the realization of MGT possible in many clinical disciplines.

A well-defined workflow and a high fidelity patient model will be the base of activities for diagnostic and therapeutic disciplines. Radiology, surgery and related clinical disciplines combined with imaging informatics and bioinformatics can play a significant role to assist in defining patient specific models and clinical workflows and thereby enabling a model-guided diagnosis and therapy.

Development towards realizing an MGT with the expected impact can only be achieved within a collaboration framework of R&D centers of excellence and clinical competent partners. In a first phase of cooperation, selected functional modules of a TIMMS infrastructure will be realized by the scientific/engineering R&D community, while a clinical research management system developed within a clinical setting will provide the therapeutic application environment. Conceptionally, the design of an appropriate clinical research management system will imply functional management components such as:

a) study/case protocol management

b) patient enrolment management

c) workflow and knowledge and decision management

d) data acquisition and EMR management

e) data flow management

f) accounting management

g) security and routing management

h) result management

First steps towards realizing this integrative approach between scientific/engineering and clinical partners have been taken within the CARS R&D community in the context of an international cooperation network.

PLAUSIBILITY

The following topics are proposed for a medium and long term research and development effort in MGT:

1. Mathematical modelling and information technological structuring of generic and patient-specific models, for example, on the basis of probabilistic relational models, MEBNs, Petri nets with fuzzy logic, archetypes and templates for a selected number of clinical settings.
2. Methods for use case developments including user interfaces on the basis of patient-specific workflows.
3. Prototype development of MGT subsystems including demonstrations of MGT application examples.
4. Ontologies for PSMs and workflows
5. Development of methods for human-computer interactions with PSMs and surgical workflows on the basis of cognitive engineering.
6. Development of algorithms and systems for workflow as well as knowledge and decision management.
7. Clinical applications and evaluation of a selected number of MGT examples.
8. Realization of repositories with PSMs and workflows for different surgical disciplines including protocols for cross-enterprise sharing of models and definition of appropriate standards.
9. Validation methods for pre-, intra- and postoperative processes.
10. Validation of the impact of MGT on patient, physician, health care settings and society in general.

The assignment of importance ratings, required resources, time lines and participating partner institutions for these R&D activities is a complex undertaking and can only be completing after an exhaustive discussion on all outstanding issues.

COMMENTS

All research topics listed in the plausibility section of this flagship initiative proposal require national and international cooperation. A comprehensive European/worldwide list of interested and competent partners is available as part of the CARS international network, but their specific contribution depends on the final given scope of the R&D project. Key partners will finally be selected from the evolving international CARS community and include institutions such as

- Technical University of Berlin (D)
- Technical University of Munich (D)
- University of Cambridge (UK)
- University of London (UK)
- University of Rennes (F)
- University of Southern California Los Angeles (USA)
- International Foundation of CARS (D)

These institutions, in addition to many others, have expressed keen interest to engage in R&D efforts towards realizing a model guided therapy in the foreseeable future.

Transforming medical education with immersive Virtual Clinical Environments

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BRIEF EXPLANATION

Transforming medical education with immersive Virtual Clinical Environments.

This flagship would involve the development of fully immersive, Presence-laden Virtual Clinical Environments with clinically real interactivity for use initially in medical and health care education. This would involve building a pan-European core medical curriculum with fully immersive Virtual Clinical Environments as an integrated component. It would include interactive high-fidelity simulations of physiological and anatomical monitoring and treatment for training in clinical skills. This curriculum would be embedded into existing teaching and health care structures, with rigorous, clinical-outcome focused evaluations over a sufficiently long time period to give meaningful evidence of impact.

AMBITION

Health, in the broadest sense, is the major determinant of well being and life satisfaction. It is key to economic productivity and competitiveness. Internationally, health is a main priority of social policy. At the same time, the medical profession is under scrutiny like never before. Just as authority in all sections of society is increasingly challenged and no longer allowed power and privilege without accountability, the knowledge, skills and attitudes of practicising doctors are questioned by patients, their families and society.

Training doctors is one the most expensive enterprises of any educational system, and an increasing demand for effective, evidence-based and cost-effective teaching is being expressed by policymakers, teaching institutions, and by teachers and students themselves. Furthermore, medical researchers often come from medical backgrounds, and ensuring that medical researchers have the skills to develop and test hypotheses is important.

Medical research is key to any attempt to build a Smart Economy, and the whole process of innovation, commercialisation and implementation in medical research depends on doctors whose education has prepared them to participate - whether as researchers, or as clinicians advocating for and applying innovative approaches.

Medical education is, therefore, more important than it ever has been before. It too is under scrutiny and a transition from traditional medical teaching to more student- and patient- centred, community-based, clinically focused teaching is currently underway. Furthermore, an emphasis on continuing professional development has lead to a reconceptualisation of medical education as a lifelong process, with a medical education continuum replacing the traditional divide into undergraduate, postgraduate, and then independent learning.

With the ever-closer union of the EU, doctors – who have traditionally been one of the most mobile elements of the workplace – will be practicing across borders and in jurisdictions other than that they trained in. The importance of a commonality of competencies to medical school curricula and to postgraduate training is therefore increasing. The opportunity exists to use ICT as a driver for change as we strive towards acheiving this commonality.

Medical education is a complex process. It involves the development of a body of knowledge, skills (both procedural and cognitive) and attitudes. It also involves ethical development and formation. Increasingly, information technology and

IMPACT

With an ageing population, European policymakers are concerned with health to an extent that will only increase over time. Health is now one of the biggest issues affecting competitiveness, society and the ongoing sustainability of Europe. The cost of medical education is high. The cost of medical mistakes, both in terms of lives lost and financially, is huge. A competitive advantage in this area could save lives and costs.

Medical education is often described being transformed by the use of technology. However, the empirical basis of this statement is relatively weak. Are educational technologies in medical education effective in helping learners achieve learning outcomes, and is this in itself effective in improving clinical outcomes, patient care, and the quality of life of citizens across their lifespan? Developing truly effective tools to maximise the positive impact of teaching would require the development of immersive, realistic virtual environments and represents a true challenge for ICT disciplines. Educational research is normally carried out piecemeal, by individual teaching departments and centres and over short periods of time. An ambitious, multicentre, multinational study would help answer many key questions in optimising higher education.

Building a commonality of competencies underlying medical school curricula throughout Europe would transform the practice of medicine throughout the Union. It would help ensure a consistency of practice and approach.

Multi-site sharing of curriculum, educational material, approaches, cases, experiences etc is at the forefront of today's research. Technology may act as a great asset herein. The use of proper metadata and standards that allow compact descriptions of the aforementioned artefacts will be mandatory. On the other hand, the wide exploitation of Web2.0 technologies that allow the web formation of expert societies and social networks and folksonomies, as well as, the recent medical applications of the semantic web, like the semantic media wiki and the geotagging capability of the different artefacts, hold promise for ambitious medical education research results.

INTEGRATION

We propose that there should to be four strands to this project

- a clinical strand, looking at clinical outcomes in terms of how different educational strategies and approaches impact on patient care
- an ICT strand, developing and evaluating immersive virtual healthcare environments
- an educational strand, looking at innovation in educational techniques
- a information studies/social sciences strand, using sociology, philosophy and anthropology to elucidate both the social impact of medical education/practice, but also the socialisation of medical students to ensure that they become ethical, socially aware practitioners, and assessing how medical students and doctors manage - or not - with a vast demand of information, and how this can be most effectively delivered

Putting these strands together under the Flagship umbrella gives them the breadth and scope to make truly significant findings about medical education, and to test immersive, realistic virtual teaching environments for their utility and applicability. A multicentre, multidisciplinary, multiyear study following medical students from selection for medical school through their education and into practice - assessing every aspect of their acquisition and development of information related to knowledge, skills and attitudes using technology as well as other teaching methods. This study would follow students across the EU, and combine educational research, information processing research, presence research, philosophy, anthropology, sociology, and other disciplines in a search for the key determinants of successful information acquisition by medical students, and how this can be enhanced. Educational research is normally carried out piecemeal, by individual teaching departments and centres and over short periods of time. An ambitious, multicentre, multinational study would help answer many key questions in optimising higher education.

Projects such as Generation 4, in the UK are already showing how Virtual patients can be truly integrated into the curriculum as a replacement for traditional paper Problem-Based Learning; these tools add new styles of learning by offering students decision-making opportunities which begin to mimic the role of the practitioner. The new generation of virtual patients will do so much more, integrating interactive virtual skills sessions through virtual simulators in immersive environments, and delivering core knowledge through interactive high quality learning resources.

An overarching pan-European secretariat would administer the project. Medical schools throughout the EU would be recruited. There would be common elements to the project throughout the participating schools. All students entering the project would be subject, for instance, to baseline assessments and follow up of academic performance and clinical performance. Certain medical schools will be part of ones or other of the strands to a differing degree.

A multicentre, multidisciplinary, multiyear study following medical students from selection for medical school through their education and into practice - assessing every aspect of their acquisition and development of information related to knowledge, skills and attitudes using technology as well as other teaching methods. This study would follow students across the EU, and combine educational research, information processing research, presence research, philosophy, anthropology, sociology, and other disciplines in a search for the key determinants of successful information acquisition by medical students, and how this can be enhanced.

PLAUSABILITY

The use of virtual patients is an area in which Europe has already developed considerable expertise.

The Electronic Virtual Patient project (eViP) is funded under the EC eContentPlus programme and has created a bank of 320 repurposed and enriched virtual patients, in 6 different EU partner languages and cultures. These VPs are now openly available for all to use via their website: www.virtualpatients.eu

eViP has successfully explored issues such as repurposing, sharing, and standardizing VPs as part of this project. However, the main outcome of benefit to this flagship project is that the eViP project has demonstrated many ways of truly integrating VPs into the curriculum:

- Familiarisation VPs: used before teaching sessions
- In-session VPs: within teaching sessions
- Review VPs: after lessons and before exams
- Assessment VPs: for formative/summative assessment
- sVPs: for Self-directed learning

The role of technical standards in medical education has also been at the forefront in European initiatives over the past few years. For a start, MedBiquitous Europe was established. MedBiquitous Europe is a collaboration to promote the adoption and implementation of MedBiquitous technical standards and specifications for healthcare education within Europe.

The objectives for MedBiquitous Europe are to:

1. Provide a European point-of-contact for all activities relating to adoption and implementation of MedBiquitous technology standards for medical and healthcare education.
2. Provide support and guidance for European institutions looking to adopt standards as part of any European Commission initiatives.
3. Promote European input to and participate in the development of MedBiquitous technology standards for healthcare education and competence assessment.

In partnership with MedBiquitous Europe, the Electronic Virtual Patient (eViP) and (mEducator) projects have been the key drivers for change with existing technology standards for medicine and healthcare. Partnering institutions from both projects are also active MedBiquitous Europe members and contribute to the various working groups.

The eViP project aims to create a bank of 320 repurposed and enriched virtual patients. These virtual patients will be available under Creative Commons Licenses. All of these virtual patients are repurposed using MedBiquitous Virtual Patient Technical Standards.

Moreover, the mEducator project, another EU funded best practice network of 14 partners, aims to investigate contemporary ways of sharing medical educational materials of various types. To this end, mEducator critically evaluates existing standards and reference models in the field of e-learning, but also investigates more radical interventions by questioning the usefulness of current standards while simultaneously exploring how web 2.0 and web3.0 technologies may be engaged to build up such standards as wel as exploit them in sharing specialized state-of-the-art medical educational content across European higher academic institutions. New approaches that facilitate the re-purposing of medical educational resources while keeping abreast with contemporary developments in the copyright arena like the creative commons notions are also being tackled in mEducator.

Both projects have succeeded in testing the application of existing standards for current-day practice in healthcare education. As part of this process, they have also proposed necessary changes and extensions to the existing standards based on rigorous testing and use cases. The work that they have done is already being adopted by other international groups and both projects are now considered to be standard setters within their respective fields.

Already there is much research being done in medical education generally throughout the Union. The Association of Medical Educators in Europe (AMEE) leads the way in medical education research and work, in partnership with the journal Medical Teacher. Medical Teacher often has an e-supplement and last year produced a special issue devoted to Virtual Patients. Furthermore, AMEE runs the biggest medical education conference in the world and often has a number of e-learning and VP tracks running through the conference. In fact, this year's AMEE has a special e-learning symposium incorporated into to the beginning of it.

The Centre for Innovation, Technology and Organisation (CITO) at University College Dublin (http://mis.ucd.ie/cito) has reviewed this proposal and has expressed an interest in becoming involved in the evaluation and information studies components of this Flagship project.

Following up the effect of educational interventions on later clinical practice is clearly problematic, as there are multiple confounders even when considering the attributes that go into the formation of the practitioner alone. Within medical education, there is a drive to devise clinical outcomes that can be used to evaluate the effectiveness of medical education research (Chen, Bauchner and Burstin, "A Call for Outcomes Research in Medical Education", Academic Medicine 2004;79:955–960.) and this chimes with the stated criterion for a Flagship project to produce a definable societal benefit.

Each strand of this project builds on research already being carried out. What the Flagship goal adds is the breadth of vision required to turn these projects into an ongoing transformation of one of the most transforming areas- at both an individual and a social level - of higher educational experience.

COMMENTS

Seamus Mac Suibhne, President, Section of Psychaitry, Royal Academy of Medicine in Ireland. Senior Registrar in Psychaitry, Health Services Executive, St Brigid's Hospital, Ardee, Co Louth, Ireland.

Terry Poulton, Associate Dean for Educational Technology, Centre for Medical and Healthcare Education, St George's, University of London,

Chara Balasubramniam, Deputy Head of E-learning at St George's, University of London, Programme Manager for the Electronic Virtual Patient (eViP) collaboration between 9 of the leading virtual patient research and development medical institutions in Europe. He is the Administrative Director for MedBiquitous Europe and St George's project co-lead for the European mEducator programme.

Dr Balasubramniam has indicated that qualified Programem Managers at St George's University of London would be delighted to lead this initiative from a project management point of view.

Panos Bamidis, Assist. Prof. Medical Education Informatics , Aristotle University, Greece; mEducator project director.

Centre for Innovation, Technology and Organisation (CITO) at University College Dublin (http://mis.ucd.ie/cito) as outlined above have indicated their interest in becoming involved in the information studies and societal impact part of the project.

The Registrar of University College Dublin has indicated his interest in maintaining the overall interest of University College Dublin in this flagship project.

Simplicity in ICT

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BRIEF EXPLANATION

Simplicity in IT

Simplification should be established as a driver of innovation. With two effects: 1) simpler products, platforms, tools are easier to adopt 2) it is easier to guarantee (prove, test) properties, therefore lower the risk of adoption for building on top.

AMBITION

What is essential, what is characterizing a model, a product, a method?

We are confronted with a wealth of overblown products (e.g. our mobile phones), methods (e.g. RUP), and platforms (eg some operating systems), that make the original purpose nearly unrecognizable.

Successful examples like the ee-pc show that there is positive response to simpler, streamlined platforms that go to the essence of needs.

Other recent examples like Windows Vista/ Windows 7 also show the danger of complexity and the possibility of simplification.

Simplification, rather than complication or diversification, is a recognized central way of producing innovation. IT innnovation, in particular software, tends so far to add and complicate instead of reducing to the essence.

Challenges here are

- the search for what is essential (in a product, in a method, in a tool),
- how to characterize its properties, as precisely as possible, with levels of necessity (core, wishful, ...)
- how to ensure these properties, largely by means of existing methods (test, validation, verification, proof...)
- how to communicate the properties.

IMPACT

The impact on the productivity and reliability of the adopting industries could be immense, as for revolutionary paradigm changes.

It is well known that he cost of testing and cost of integration make up over 50% of the development effort (in time to market and money).

Also, integration of existing technology is a major risk in the development of new products and in the uptake of technology.

Especially in the software industry, were projects oft fail due to overspending and underestimation of effort, a better starting basis for projects can cut down the effective risks connected with the development.

INTEGRATION

In order to exploit the full potential of simplicity and the known properties of simple artefacts and platforms, basically all the disciplines and societal groups would need to be involved, although at different stages and with different degrees of

The central disciplines would be the core ICT disciplines, starting with software, hardware, and communications.

Engineering at large would follow at the second level, as users of the core technologies and products, followed by a third layer of other industries that use the engineered products in other areas of economy (eg. medicine, chemistry, etc..).

Cognition and communication sciences, as well as social sciences and politics would need to accompany the development of this community in order to transport its message to society at large, organizations and governments, as well as and receive feedback and stimuli to be channelled back to the focus community.

There is a large, but so far submerged, interest in this topic.

We are not aware of any research program that already addresses simplicity and the property characterization of simple artefacts as a central issue. It would be an ideal topic for FET

PLAUSABILITY

The different areas of research have the necessary groundwork and the necessary interest. The need is in the combination of efforts to develop a stream of research recognizable per se under this label. It has happened successfully with open source, with low-power and Green IT. The establishment of simplicity would certainly profit from this pre-existing cultural substrate.

Large part of the addressees are the communities already represented in ICT and in other EU programs, who dispose of research and uptake capacity and of adequate backing at the national and political level. The novelty would be the new focus, supporting for the first time a community that targets simplicity and its consequences as key research objective.

COMMENTS

The backing is increasing – apart from single experts, there were several communities contacted at different events, like eg. Dagstuhl seminars, conferences and more, that adhere to the idea that simplicity is a core criterion for sustainable technological and societal progress.

While they support the idea, there is not yet a manifesto or a roadmap. A proposal for a support action called “IT simply works” with exactly this objective has been submitted in Call 5 (Oct. 2009). If successful, this SA would lay the groundwork for the core community of support and communication to the communities.

The proposal included a list of qualified experts who have expressed interest in participation, to be evolved during the SA via a systematic and balanced expert analysis of participants to assure coverage of ICT areas and of key associated communities.

The already individuated experts span Computer Science, Engineering:, Economy, Healthcare and Healthcare Management, Societal and Cognitive aspects, as well as a selection of Non-EU experts able to provide a global perspective.

Simulating the Human Brain

Henry Markram

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Position	Professor
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BRIEF EXPLANATION

SIMULATING THE HUMAN BRAIN

Simulating the human brain is the ultimate challenge for mankind. This requires massive neuroinformatics, modelling, simulation, visualization and analyses. A facility that can build biologically accurate brain models will provide the ultimate approach to understanding the brain and it's diseases, develop personalized medicine, revolutionize technology, and educate the public on how our brain works.

AMBITION

Simulating the Human brain requires gathering all past data and knowledge of brain, industrial-scale brain screening, databasing exabytes of data, computational biology to describe all biological processes, automated building of computer models (genes to whole brain), exascale supercomputer simulations, building a bio-supercomputer, scientific visualization, a spectrum of mathematical and statistical methods of data analyses, virtual medical diagnostics to explore hypotheses of brain function and diseases, creating virtual laboratories, virtual and physical robotics calibration, internet technologies to allow global use, and social sciences to address social and ethical issues.

IMPACT

How our brain creates our individual realities is humanity's ultimate challenge. Understanding perception, motion, emotion, cognition and consciousness will provide a new perspective for self and global governance. Being able to explore the core pathologies in diseases will allow grounded derivation of treatments for all brain diseases. Brain models will provide a basis for understanding individual differences and develop personalized medicine. Harvesting the design and functional secrets of the brain will transform 21st century technology. Virtual touring of the brain and its diseases will provide the ultimate facility to teach scientists, clinicians and the public about the brain.

INTEGRATION

Experimental biology and neuroscience to derive the structure and function of the brain; Computational Biology (math, chemistry, physics, computer science-based) to mathematically describe all biological processes; Computer science to simulate brain models; Computer engineering to design a specialized bio-supercomputer; Computer graphics to build visualization tools; Internet and information technologies to build virtual laboratories on the internet, data processing to build analytics tools, virtual and physical robotics to calibrate models. Medicine to integrate diseases of the brain; AI and robotics to harvest the technology; Social sciences to address social and ethical issues.

PLAUSABILITY

A vast amount of experimental data and knowledge has accumulated - organization is needed. Different brain areas are being studied – integration is needed. Industrial-scale science is generating a data deluge – a strategy is needed. Exascale databasing is becoming feasible. Exascale supercomputing will be possible by 2018. Math and physics approaches can abstract most biological processes. Computer graphics, Internet, VR technologies can visualize massive data structures. VR and robotics can interface with brain models. Comprehensive brain screening and scanning can provide medical data. AI and neuromorphic technologies are waiting for brain inspired architectures.

COMMENTS

The Blue Brain Project, supported by the Swiss Government, built a prototype facility. The Spanish government committed to the project. The project collaborates with many including Segev, Israel; DeFelipe; Kisvarday, Hungary; Thomson, UK, Hines, USA; Silberberg, Sweden. The flagship will involve many experimental, medical, theoretical, computer, robotics, and technology labs including: Prochiantz, Graham, Fregnac, France; Egidio, Italy; Jonas, Germany; Yuse, USA; Tsakalidis, Greece; Trappl, Austria; Frackowiak, Douglas, Floriano, Anastasia, Magistretti, etc Switzerland, etc and a number of industry partners (pharma, bioservices, computer). IBM(Swiss) is a technology partner.

Beyond users. Human as decision makers in IT

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BRIEF EXPLANATION

Beyond users. Human as decision makers in IT.

The IT industry can be trustworthy only if we are able to make a major cultural shift: humans are not just "users", they are "decision makers", whose decisions our systems must support rather than suffer.

AMBITION

IT system are designed on the idea that users should comply with the system rather than the system should support the system. This meaning is entrenched in the very words

IMPACT

The lack of ability to support the human elements are decision makers has a huge impact on day by day work in many companies that are using IT systems for their daily business.

I will just make an example in the case of computer security where the gap between perception of the problem and reality is wider.

INTEGRATION

We indeed a major integration between information technology, cognitive psychology and decision theory.

PLAUSIBILITY

COMMENTS

Design, construction and Operation of a Neuromorphic Computation Facility (NCF)

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BRIEF_EXPLANATION

Design, Construction and Operation of a Neuromorphic Computation Facility (NCF), (update from first call or ideas)

We propose to design, build and operate a general purpose Neuromorphic Computation Facility (NCF) exploiting the computational principles found to be working in the human brain.

AMBITION

General Ideas

The ambition of the NCF project is to design, build and operate a facility that implements computational principles found to be working in the human brain into synthetic physical models by employing rapidly evolving state-of-the-art micro- and nanoelectronics. The NCF is a general purpose user reconfigurable facility allowing to explore a wide range of network architectures with user selectable execution speeds starting at biological real time and reaching time acceleration factors of 10.000. The choice of execution speed will be an essential feature for the user who can study system dynamics (plasticity, learning and development) and at the same time explore a vast parameter space. The implementation as a physical model of the brain architecture will allow to exploit the main attractive features of the biological example : Scalability, efficient use of energy, fault tolerance, compactness and the ability to learn. These features will not only be important for conceptual reasons demonstrating a real-world non-von-Neumann computer architecture but they are also likely to represent the only accessible technological path to approach the complexity of the full human brain consisting of 10^11 structured complex nodes (neurons) interconnected by 10^15 dynamic connections (synapses) in biological real time or even in an accelerated mode of operation. Novel key technologies for very small size configurable interconnects and very high bandwidth communication together with industry certified and cost optimised large scale manufacturing, assembly and packaging technologies should allow to approach full brain complexity with optimised biological fidelity at a timescale of 5 years after project start. From the beginning it will be important to combine scalability and the ability to incorporate new technology developments occurring outside the project into a continuous NCF upgrade concept. This upgrade concept needs to be designed such that the NCF can start user operation shortly after approval on a smaller scale, typically 10^9 nodes with 10^13 dynamic connections. The growth of the NCF will then proceed through the combination of up-scaling proven components and of technology steps like the use of very-deep-submicron microelectronics and nanoscale components, higher density packaging, high-speed communication and low-power technologies. It will be essential to perform this continuous upgrade in a most cost efficient and non-destructive way to guarantee the continuous user operation of the NCF throughout it's lifetime. Depending on funding and operational experience during the first 5 years the NCF could be the first synthetic and configurable device to tap into complexities exceeding the ones of the brain.

Synergy with High Performance Computing (HPC) Approaches

It is important to note that the computational principles of the brain are not fully known at this point in time. Although a large amount of biological data has been accumulated and is in use for simulations in computational neuroscience it is clear that we do not have the complete information to build a high fidelity synthetic physical model of the brain like the proposed NCF today. However, neuroscience and in particular very detailed numerical simulations of reverse engineered biological substrates are making substantial progress. The availability of high performance computers currently allows approaches like the BlueBrain Project (5) at the EPFL Lausanne to deliver a very detailed comparison between biological data and numerical simulation results. The level of detailing achieved in such simulations is certainly out-of-reach for electronic physical models like the NCF. However, even extrapolating with the expected progress in HPC computing, it appears unlikely that the numerical approach can be scaled to full brain size at real time performance or beyond, in particular when considering the required use of electrical energy transferred into heat. Almost certainly such classical numerical approaches cannot be the architectural basis for a new type computer based on brain concepts. It is here that the NCF as a physical model and the HPC numerical computing approaches have a common interest and an important interface. Reducing complexity of the model while preserving essential defined functions can be performed using the wealth of BlueBrain data. The results of this process would feed the actual circuit design and communication needs to be implemented in the electronic physical models used in the NCF. It is very essential that the NCF technology development and the HPC simulation work are driven forward in parallel. The NCF project should at any point in time represent and implement our best state-of-the-art knowledge, both in neuroscience and in technology. The NCF upgrading concept presented before will allow to keep track with developments in both fields of research while at the same time ensuring continuous operation of the facility. In order to achieve this ambitious goal, it will be essential to make the typical hardware and software development cycles in the NCF project extremely fast, efficient and cost effective. The ability to re-use and continuously improve chip design tools, simulation frameworks, system integration concepts, mechanical and power distribution structures, communication technologies and software ecosystems developed in the project will most likely be one of the most valuable assets to ensure a continued use and development of the NCF.

The Facility Concept

The use of the NCF as a user facility creates the need to develop and maintain important infrastructures around the central neuromorphic computing device. Most essential is a supporting conventional computing infrastructure for configuration, simulation, network routing, monitoring, data analysis and visualisation. Apart from substantial hardware computing and mass storage resources this infrastructure will require a large amount of software to be developed. Furthermore the conventional computing facilities at the NCF can be used to operate as hybrid computing devices merging neuromorphic physical models with numerically simulated components. Establishing this mode of hybrid operation will also be essential for processing non-biological data which is among the list of possible uses of the NCF (see below). Finally the user access has be made easy and efficient. A meta-language to formulate network structures and experimental protocols as well as analysis tools have to be available for the non-expert user. The NCF needs to set-up a user management concept and has to be accessible via the internet.

IMPACT

The currently foreseeable use of the NCF will be in 4 areas : A research tool for neuroscience, a demonstrator for the system application of nanoscale devices, a novel brain-like computer architecture to process sensory and non-biological input data and a facility to explore concepts to downscale size and complexity of neural architectures for future application in low-cost, low-power appliances. In this paragraph the 4 areas will be described further and their impact on science and technology as well as (where applicable) their impact on European industry and society will be described.

Neuroscience research tool

The NCF project needs to be in close contact with research in neuroscience and, through the continuous upgrade concept described before, implement the latest knowledge in the field into electronic architectures, although with a certain delay. As described before, this delay will be kept as small as possible (typically one year) by using efficient tools for the implementation and by re-use of infrastructure. The NCF will reflect neurobiological models only to a limited degree of complexity due to the limits of physical implementations compared to numerically precise calculations. The NCF will however have the feature of running at user selectable execution speeds reaching up to 10.000 times biological speed which allows to study efficiently dynamic processes arising at very different timescales from milliseconds to years in biological real-time. To this end the NCF is unique and will provide the only tool to systematically access mechanisms of learning, development and possibly evolution which are among the most important features of neural systems. Due to the high degree of configuration accessible to the users and the capability for remote access interdisciplinary research groups can use the NCF to verify, falsify or further develop theories for learning and development in neural systems. Their feedback and the comparison with biological systems will serve as an important input for the further development of the NCF and may well be of relevance for neuromedicine, neuropharmacy and neuropsychology.

System Demonstrator for Nanoscale Devices

The neural architectures physically implemented in the NCF rely on the availability of compact circuit elements. This is in particular true for the synaptic connections of which finally 10^15 or more need to be realised. Synaptic connections need to be compact, configurable in their efficacy and act on timescales defined by the biological example. Synaptic circuits and their very high bandwidth communication requirements in the network totally dominate the real-estate on the computing substrate. It is evident that these components need the highest possible integration density. Proposals have been made to employ resistive memory devices or molecular switches for this task. Such devices are available in many labs but have so far not made it into large scale system applications. The problems to address are their limited reliability and their integration with standard CMOS technology as a backend process. The NCF requirements are a very good match to those requirements and boundary conditions. As an example memristive synapse circuits are compact, exhibit some precision to store analogue information at reasonable time-scales, have low power requirements and are in principle suited as a backend process to deep-submicron CMOS technology which would be used to implement neurons and the communication infrastructure. The NCF would be the first industry like very large scale challenge for resistive storage technology on the nanoscale. The NCF architecture could tolerate imperfections in precision and manufacturing but still use the important features of the devices : Small size and the capability to dynamically store information. An employment of nanoscale components in an industry-like very large scale facility would provide European research centres and European solid-state manufacturers with a real life demonstration case. Experiences gained in the NCF project will almost certainly be a strong basis for the application of such devices in other systems.

Novel Computing Architecture

The computational power and properties of the brain are so unique that any successful attempt to exploit them with synthetic systems will necessarily generate major impacts to information technology. Many of the features have been described before in this document. For the impact to technology and society the characteristics of processing diverse sets of input data needs to be re-iterated. The brain is capable to process noisy und unexpected input data from sensors with low quality, to build internal maps from such inputs and use the data to make predictions. This process is subject of intensive research in sensory perception and certain aspects of the results have been used to engineer systems capable to perform pattern recognition, speech analysis and similar tasks. Whereas these applications will certainly be among the topics of research performed at the NCF it can be expected that the universality of neural substrates can also be used to process non-biological data in a similar way. Our environment is recorded by large number of distributed sensors generating time series of physical data like temperature, air pressure, wind speed, pollution, and many others. Even more abstract is the data generated by social and financial systems. It can be speculated that a large scale facility like the NCF will be used to explore the possibility to process non-biological data and to use it to make predictions like the brain does for sensory inputs. Successful results in this context would undoubtedly have large impact in society.

Downscale to low-cost, low-power devices

The NCF will be a large-scale localised research infrastructure. While delivering impacts in the areas described before, it will always be a unique facility and not be duplicated for use by consumers. It can be expected, however, that certain principles explored at the NCF can be simplified in terms of circuit complexity, size and power consumption. Such reduced circuit concepts could make it to the mass market and provide European industry with totally new products. A concrete example would be “brain-inspired” add-on cards to consumer appliances processing sensory data and monitor them for unexpected events. The automotive industry offers many potential applications like engine management, driver surveillance and others. Such applications would help to revive European hardware industry and create new business opportunities.

INTEGRATION

It is proposed to design, build and operate the NCF as a large-scale European infrastructure. By nature the project would be very interdisciplinary, so integration towards the common goal of actually constructing a facility would be a major challenge. The project would in the early phase need to set-up a governance structure for management, financial planning and quality management. Working examples from other large scale projects in particular in physics can serve as a basis for such a governance structure but need to be adjusted to take the interdisciplinarity into account. The NCF will in practice be a Europe-wide distributed effort although a site for the actual device construction needs to be identified early-on to enable user operation from the beginning of the project. The following contributing disciplines / work areas can be identified :

- Neuroscience
- Computer Science
- Software Engineering
- Microelectronics Engineering
- Nanoelectronics Engineering
- Circuit Manufacturing
- Circuits Assembly and Packaging
- System Integration
- Access and User Management
- Costing
- Governance Structures
- Project Management

For a project of the proposed size it will be essential to fund a pilot-study with the goal to produce a detailed conceptual design report (CDR). Apart from chapters describing the scientific and technological case for the NCF as well as a concrete proposal for the actual implementation, the CDR needs to provide a time planning and a costing study based on proven numbers. The CDR and in particular the time planning and the costing study will need to be reviewed by independent experts. This process can be carried through within one year and should be successfully completed before project start. Evaluating existing experience from smaller scale projects with similar scope like the FACETS-IP in FET it can be seen, that the NCF would fit into the envisaged size of a Flagship-Project, but this needs to be quantified more precisely by a CDR.

PLAUSABILITY

The European Commission in it's FET programme has been a pioneering effort to establish brain-inspired computing as a strong research topic in Europe. Europe has been leading the field for many years. Recently similar activities in the US and strong industry research units in Asia and the US have started to establish research in neuromorphic computing. An NCF flagship project would be just right in time to compete with such activities at a very substantial funding level and with a more systematic and scientifically driven approach.

The neuromorphic community in Europe is largely based on FET-IP projects like DAISY, FACETS and many others. The community is estimated to correspond to approximately 300 FTEs. For the NCF project this community will need to be complemented by a strong contribution from engineering and technology. The engineering and technology part would at least be of the same size, as the design and construction of the NCF is a major technological effort. From preparatory work it appears that this community is available in Europe.

The neuromorphic community in Europe and worldwide has a well established network of workshops and conferences. Annual meetings at Sardina (Cognitive Neuromorphic Engineering, CNE) and at Telluride in the US have been very successful for many years.

A very essential part of the NCF proposal is the contact to academic institutions and in particular the education of interdisciplinary PhD students. The community around the FACETS project has been very active in building this new breed of student community. Within the project about 100 PhD students have performed their thesis work. Based on the positive experience, a dedicated Marie-Curie Training network has been set-up to put this effort on a sustained basis. The response to calls for stipends has been overwhelming. The Marie-Curie Network offers a dedicated training programme closely related to the activities of the NCF project. It will be essential to expand this programme as part of the NCF project proposal including a grant programme for students from different disciplines as well as a visiting scientist programme for the design, construction and operation phases of the NCF.

COMMENTS

The project idea has been developed by a technology subgroup of the FACETS-IP in close collaboration with neuroscience groups. It is being supported by 3 major European semi-state funded solid-state circuit research institutions and several high ranked research universities.

The group will be prepared to work on a detailed study.

NGN & NGN New Generation Network for New Governance Network

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BRIEF_EXPLANATION

NGN x NGN

New Generation Network for New Governance Network

Starting from IDEAAS (Innovation Development for Enhancing Administration Action & Services), we propose to address the issues of co-evolutive development of New Generation Network (broadband and ICT) and New Governance Network, i.e. NGNxNGN. We believe that this approach provides a relevant contribution for accelerating the transferring of all of the new FET ICT projects. The NGN^2 environment is expected to be rich in innovative technologies, reflexivity, cultural willingness and expertise to sustain the overall process.

AMBITION

The overall ambition is to strengthen the capability of human organizations in leveraging the management of their own evolution trajectory. This means to learn how to successfully coordinate (in a more transparent, democratic, and conscious ways), many different actors as well as the action strategies.

This turns out be one of those issues summarized by the metaphorical expression "acting at the edge of chaos", popularized by complexity science.

In this respect the notion of capability of human organizations is to be addressed both conceptually and operationally. What have been learnt from the application of Complexity Studies is that such a capability is the result of three kinds/levels of knowledge: a) the understanding of phenomena (which is typically addressed by sciences); b) the folk knowledge (which belongs to people); c) the action-oriented knowledge (which is typically searched by policy makers). An appreciative setting is the context which is able to leverage (connect and support) these three kinds of knowledge.

The ICTs are an extraordinary toolkit for carrying out such a leverage whenever the actors will actively engage in the process.

The expected outcomes of the creation of an appreciative setting can be listed as follows:

- at European level: the development of suitable environments where FET oriented projects can become effective more quickly and with a more socially desirable impact. This will improve the environmental conditions for the richest FET projects capitalization.
- at regional governmental level: the development of more effective regional strategies, where science and innovation are foundational to the policies;
- an easier connection between the above levels, thus favoring interdependence between different governmental levels and spill-over between the policies at the different levels

Creating the appreciative setting requires several contributions from at least three main societal sectors: technical sciences (ICTs, computational engineers), humanities (social, economic, geographic, … sciences), institutions (governmental bodies at different levels).

The challenge is to establish what can be called NGN^2, meaning New Generation Network for New Governance Network, an appreciative setting, where the actors by means of ICTs engage themselves in connecting the three kinds of knowledge while updating the ICTs, their use, and their application.

Such a Network should be viewed as a renewable resource, which is mainly anchored at the local level, and, while deploying itself, could be scalable at higher levels (regional, national, European, world-wide)

The establishment of the NGN^2 requires a federation process in which the participants non only share the goals but:

- engage themselves to create and maintain the network (coordinating the actions, making available expertise and sharable resources)
- appoint a shared design for supporting the overall networking process itself (making it possible the co-evolution between the technological and governmental network)

Multidisciplinary research teams must be involved, with representatives in the different societal sectors (technical sciences, humanities, institutions), from a large number of the EU27 regions and coordinated at European level.

NGN^2 is not a theoretical concept. In several European regions kernel components already exist. They must be nurtured and made grown. This requires their identification, analysis and appropriated developmental path.

Building upon our research expertise, the regional dimension is highly recommended as the most effective for carrying out both the preliminary investigation and the further development of the new network.

IMPACT

A general reflection about the impact is the viscosity of the transfer of the several products of science and scientific thinking into practical life. There is a need to shorten their time to society. Education has already been one of the main field of engagement with this respect, but now (because of the increasing pace of ICT development itself) is not enough anymore.

Although the NGN^2 impact is not easily foreseeable, we can identify at least three domains of impact related to the role of ICT usage in improving the functioning of a human organization:

- improvement in the system productivity
- increasing the variety of the existing opportunities
- creating novel system functionalities

The ultimate impact will depend on NGN^2 evolution capability to nurture itself and grow.

In other words, NGN^2 play a primary role in orienting and guiding the desired impact, taking into account both European and local policies, according to the regional development strategies.

It is worth noting that although “creating novel system functionalities” is the domain most directly concerned with the capitalization of FET Projects, the other domains have a crucial role in sustaining the former one. That’s why we expect all the three domains to be addressed by the NGN^2: each regional system, involved in NGN^s, will have a responsibility in choosing the main domain impact for a societal actor, according to its specific regional situation, without neglecting the others.

INTEGRATION

As already mentioned, contributions are expected from a variety of expertise/experiences covering the societal sectors: technical sciences (ICTs, computational engineers), humanities (social, economic, geographic, sciences), institutions (governmental bodies at different levels). The challenge is not just to create a formal multidisciplinary group but to really produce a scientifically sound and socially viable shared design.

This focuses the need of learning how to share the common design. Again, the contribution of complexity science (model building activity and applications) will be fundamental.

PLAUSABILITY

By definition, a NGN^2 project pilot, will involve research centers, enterprises, social institutions, and regional(national) governments, dealing with ICT infrastructure, innovation and ICT-laden socioeconomic opportunities.

It could last four years.

The overall ambition will have to be taken up by each participant and modulated according to the regional strategies. The project roadmap, then, will have to take into account the different NGN^2 deployment paths.

A draft agenda could be the following:

Year 1:

Federating the regions (actors) and identifying their NGN^2 profile: recognition of the kernel components by the appropriate investigation methodologies and approaches

Year 2:

Pointing out the tailored goals and the relative roadmap for each regional system and Developing the shared design

Year 3/4:

Pilot application

Year 4:

NGN^2 evaluation and European guidelines Capitalization of the project for the establishment of NGN^2 in the regional systems (and identification of the monitoring system).

COMMENTS

It must be acknowledged not only in the conventional innovation strategies (such as SMEs) but also in those concerned with more general socio-economic development issues.

This also implies a coordinated backing from those European DGs likely interested in the idea underlying NGN^2.

So far we got manifestations of interest by:

Regione Piemonte, Fundacio Observatori per a la Societat de la Informacio de Catalunya, AE Bucarest, Region of Crete, University of Crete, the network of the Italian regional research institutes, private companies dealing with ICTs.

Currently we are in contact with regions and universities from the EU27 countries.

Tranforming Modelling and Simulation for European Growth

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BRIEF EXPLANATION

Transforming Modelling and Simulation for European Growth

Numerical modelling and simulation has become disconnected from computational hardware. Fundamental research in this domain is required to reconnect mathematics, informatics, computational science and European industrial challenges. There is a compelling economic growth argument for timely investment by Europe in this area.

AMBITION

Over the past half century, modelling and simulation has come to complement theory and experiment as a key component of the scientific method. Used where the problem is too big, too small, too short or too long to perform an experiment on directly, many of our scientific breakthroughs rely on models, simulated on supercomputers. Over this period, the scale and complexity of supercomputers has grown in a symbiotic relationship where it is often unclear if the technology has been driving our ability to perform the science or the science has driven the design and production of larger and more effective systems.

The large number of failed supercomputing hardware manufacturers is testament to the small size of the hardware market and its customers' relentless pursuit of larger, more powerful systems. At the top end, the sector today is dominated by a small number of non-European companies who integrate components designed for the consumer electronics market.

Being at the forefront of design and manufacturing is a central driver of the European economy. To maintain our key positions on the world stage in areas as diverse as the automotive, pharmaceutical, financial, biological and renewable energy sectors requires that Europe invests in its ability to model and simulate the scientific advancements needed to develop our future products and services. However, the economics of the supercomputing market have resulted in a complex impasse that will hinder our economic development over the next decade and beyond and has at its heart the need for fundamental research in informatics, mathematics and computational science.

A small number of scientific grand challenges have driven the need to build larger and more powerful supercomputers over the past decade. At the same time we have witnessed an ever slower increase and, most recently, reduction in the clock speeds of microprocessor cores. This has resulted in higher and higher core counts – the largest systems today have in excess of 100,000 cores and in the near future systems with millions of cores will be built. Whilst a small number of simulation codes can take advantage of such systems, the vast majority in use today cannot because of fundamental limitations arising from the architecture of the simulation codes and the mathematics used to describe the physical phenomena they seek to model.

With the exception of the non-computational consumer electronics industry and low-power microprocessors such as those used in mobile telephones, Europe does not have a hardware industry capable of competing with the US microprocessor or the Taiwanese memory manufacturers. Unless funded to the tune of many billions of Euro, money spent in this area will be wasted. We should be cleverer and play to our strengths in informatics, software, mathematics and the other sciences to develop alternative approaches to modelling using the systems available now and over the coming years.

Unless a truly disruptive technology arrives (and this may well happen in the context of quantum computing but probably not in the next 20 years) we have a good picture of what high-end computers will look like over the next decade: gently lowering clock speeds, higher and higher core counts (both on chip and across the whole system), poorer and poorer memory to flop/s balance and communication networks failing to keep up. Almost none of the modelling and simulation codes in use in Europe today will benefit from such systems and many are already struggling on current systems (some no longer scale on a single multicore microprocessor).

Europe's ambition through FET-F should be to fundamentally rethink our approach to modelling and simulation by bringing together the best mathematicians, informaticians and computational scientists working in collaboration with Europe's key industries to tackle the challenges posed by a hardware industry over which we have little control.

We should set ambitious goals and aim to tackle the modelling methodologies used by all of the major simulation challenges in materials, structures, fluid dynamics, electromagnetism etc which impact on European industrial and commercial competitiveness today. In each of these areas we should rethink from first principles the modelling approach and develop new mathematical approaches and computational methods to tackle them on the type of systems we know will exist over the next decade and beyond. This fundamental research will ensure that European industry can remain at the forefront of design and manufacturing in the increasingly competitive global economy.

IMPACT

Modelling and simulation is a key enabler of scientific and industrial innovation today. The global economies that invest in modelling and simulation are those that will, over time, gain the greatest competitive advantage and reap the largest economic benefits.

Due to the tangible nature of the outputs of this research it should be possible to directly quantify and measure the impact of this public intervention on the European economy. Jobs will be sustained and created in the software industry and in the new consultancies that will be formed to create the models and analyse the simulated results of the products and processes which industry is interested in. Furthermore, jobs will be created and sustained in European industry by enabling the companies to create new or enhanced products and services through better understanding.

In economic development terms it will be possible to predict and assessed the impact of the work in terms of directly attributable Gross Value Add (GVA) to the European economy.

However, the economic impact will go well beyond that which is directly measurable. New mathematical methods, coupled with a new understanding of the possibilities of modelling and simulation will be created. New users will benefit. Previously infeasible simulations will be considered. Substantial, sustainable progress will be made that will have a long-term impact on the European economy.

INTEGRATION

Europe has a strong tradition of commercialising the modelling and simulation applications originating from our Universities. These are nowadays sold by what are termed Independent Software Vendors (ISVs). Many of our industries rely on applications owned and developed by ISVs. However, this process of commercialisation has also had a deleterious effect over time on the ability of many ISV codes to respond to the rapid changes we have seen in the scale and complexity of supercomputer systems.

Often quite small, ISVs lack the skills, openness and financial clout to invest in the key multi-disciplinary challenges facing modelling and simulation today. Many ISVs have become victims of their own success. Hemmed in to codes that no longer execute properly on today's systems but which produce accredited results and hence meet the limited needs of their existing customer bases. With small user bases and limited revenue streams there is too little innovation and research and development of new modelling and simulation approaches.

We need to step beyond the current situation and bring together experts from industry, the mathematical and physical sciences, informatics and computational science to take a clear step forward in Europe. No single community can do this – it must be a joint effort.

Many of today's modelling and simulation codes were initially developed 30 years ago on serial or vector computer systems that bear little relation to the computers of today. In the intervening years a disconnect has grown between the mathematics community and numerical modelling community such that the methods employed in simulation today are little changed since the last century. The FET-F programme can tackle this disconnect – reconnecting communities of knowledge to tackle what are hard research problems but which have a clear goal.

PLAUSABILITY

Because of its diverse nature, modelling and simulation will make a highly suitable pilot. In a pilot a limited problem set can be identified and the necessary communities brought together to tackle a specific problem. Obviously more value would be gained from tackling the overall set of problems (perhaps identifying synergies and common challenges) but a focussed pilot will have the potential to demonstrate the potential of the approach. Tackling one area would effectively act as a proof on concept demonstration that a large-scale flagship would work.

In terms of capacity, in Europe today there is a large supercomputing community which has access to a wide variety of very large modern supercomputer systems, a large mathematics community and some of the world's leading informatics and computational science organisations. We have a strong industrial base with much existing modelling expertise in many ISV companies. A FET Flagship could join these individual capacities together to tackle the complex challenges that face in modelling and simulation. Challenges that if solved have a large economic benefit to Europe.

COMMENTS

Strong backing for this FET Flagship will come from the supercomputing communities across Europe - represented by the PRACE, DEISA and PlanetHPC networks in particular.

There is a widespread recognition in industry of the challenges but little understanding of how to create the overall capacity to tackle them

Living Technology: Exploiting Life's Principles for ICT

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Permission	yes

BRIEF EXPLANATION

Living Technology: Exploiting Life\'s Principles for ICT.

ICT lead catalysis of our ability to engineer systems whose power is based on the core features of life. To make possible the convergence of nanotechnology, biotechnology, information technology and artificial intelligence such that we can engineer robust, self-repairing, evolving, smart - and thus sustainable and inexpensive - living technology.

AMBITION

To develop truly living technology catalyzed by ICT.

For a Whitepaper reference please see:

M. Bedau, J. McCaskill, N. Packard and S. Rasmussen, Living technology: Exploiting life\'s principles in technology, Artificial Life 12 (2010) 89-97.

IMPACT

Living technology (LT) is an enabling technology that has applications across all sectors of industry and governance.

INTEGRATION

A living technology FLAGSHIP would catalyze novel collaborations between ICT, bioscience, nanoscience and the infrastructure technologies.

PLAUSIBILITY

The stakeholder communities for living technology cuts across most sectors of industry and governance.

COMMENTS

A core group:

Mark Bedau

John McCaskill

Norman Packard

Steen Rasmussen

will assemble a broad representation from the potential living technology stakeholder communities.

Integral Biomathics: a New Era of Biological Computation

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BRIEF_EXPLANATION

Integral Biomathics: a New Era of Biological Computation

It is not the question to invent yet another novel approach to computing, but one that integrates the multiple levels of organization and activity in a living system, and beyond that, one that evolves autonomously with extending and refining the model, thus mimicking the system itself.

AMBITION

In past centuries, physics was engaged with applying general statistical mechanics for understanding distinct system states. This approach was inherited in biology and computer science (Bohm, 1980). Although now a special case in modern physics, Newton's world picture still dominates computer science (Blum, 2004), engineering (Lee et al., 2005) and biology (Bower, 2005). Turing Machines used in biology and elsewhere in science today are Newtonian in the broad sense that they deal exclusively with syntax and inference rules based on discrete logic in absolute space and time to deliver predictable behaviour. Extraordinarily useful though this has proven for planning tasks which include people and machines, this approach has been much less successful for tasks which require direct interaction with the real world which has come true to be vague and relational in many ways.

Over 50 years ago Rashevsky pointed out that "the relation between physics and biology may lie on a different plane from the one hitherto considered" (Rashevsky, 1954). He supposed that while the physical phenomena are the manifestations of the metric properties of the four-dimensional universe, biological phenomena may reflect some localized topological properties of that universe which we might interpret as effects that only occur at very small distances (e.g. reconformation of ion channels due to high voltage gradients across cellular membranes or quantum effects in microtubules). [Recent research in scale relativity and integrative systems biology (Auffray & Nottale, 2008; Nottale & Auffray, 2008) continue this line of thought.] Realizing that biology needs stable fundamentals such as those of post-Newtonian physics, his goal was to develop a set of principles which connect the different "physical phenomena expressing the biological unity of the organism and of the organic world as a whole". Therefore, a profoundly new understanding about the role of biology in analytical natural sciences and synthetic engineering sciences has to be set out.

Recent research roadmaps both in computational systems biology and autonomic computing and communications target the perpetuation and enrichment of the knowledge, technology and methodology transfer between analytic life sciences and synthetic engineering sciences. However, we dare to question the firmness of the bridge between converging sciences and claim that it is impossible to make any significant progress in this multidisciplinary field of research without inaugurating a breakthrough paradigm change towards biologically driven mathematics and computation.

Our driving argument is that living systems have fundamentally different notions for self-organization from those conceived in engineering sciences today. Whereas artifacts are designed and programmed to serve human needs as tools and mechanisms, organisms are beings whose sole purpose is to maintain, survive and reproduce in a changing environment. The former are closed deterministic systems that conform to the laws of physics; the latter are open non-deterministic systems that also follow the patterns of biology. Therefore, when devising the plan for future converging sciences, one should be aware of the limits of engineering and of the fact that various relations within organisms are outside the scope of metric mathematical biology and contemporary science (Rashevsky, 1954-1955). This holds also for computer science which still suffers from the inertness of exclusively bounded syntactic and mechanistic computing models.

Further, to achieve a conceptual breakthrough both in biology and computation "a new paradigm is needed for a complex biological phenomenon beyond the current parameters of networks and of systems" (Mesarovic & Sreenath, 2006).

Modern physics provides through thermodynamics and quantum mechanics new model bases for biology and computation. While thermodynamics connects to development, QM connects to vagueness and internalism. Realizing that the one constraint on science, as on all thought, is (conventional) logic, if we wish to go beyond it, the only possibility at present is to address vagueness, not algorithms.

Hence, it is not a question of inventing yet another novel approach to computing, but one that integrates the multiple levels of organization and activity in a living system, and beyond that, one that evolves autonomously by extending and refining the model, thus mimicking the system itself. Yet, it is not possible to have a realistic concept and understanding of a natural system by sticking to the limited capabilities of reductionist models. This is exactly what Feynman had in mind when he said he was not happy with using numeric computation in quantum research (Feynman, 1982).

Furthermore, we do not have a logic and formalization of information processing to match this challenge. But natural systems such as neuronal networks and multi-cellular organisms provide the resource for studying and understanding true bio-logic based on different premises from the logic of today's engineered systems (Elsasser, 1981; Conrad, 1989; Hong, 1992; Simeonov, 2007; Smith, 2008).

Therefore, we need to investigate the biological imperatives of computation in a profoundly new way. It should be based on understanding the premises for, and the fundamental characteristics of emergence, organization, development and evolution in biology, in particular with an emphasis on the so far widely neglected perspective on internalism (Matsuno, 1989; Salthe, 1993; Salthe & Matsuno, 1995; Rössler, 1998; Coen, 2000; Noble, 2008). Its goal should be a set of novel mathematic formalisms capable of addressing the multiple facets of an integral model and a general theory for biocomputing (Hong, 2005ab) within an adequate engineering frame of relevance. Its base should be a long-term fundamental theoretical research in mathematics, system biology and computation.

We call this research field Integral Biomathics (Simeonov, 2007-2010).

Several research issues have to be considered on the way. One of them is that "ultracomplex living systems cannot be simulated with any finite number of such robotic, mechanistic, or complicated computer models … by utilizing numerical computation algorithms which are based on recursive functions", (Baianu, 2006). Furthermore, "… in contrast to causality on one level there is a biological uncertainty principle of causality across levels – akin to Heisenberg's principle in physics – embodied in the concept of a bounded autonomy of levels (BAL)" (Mesarovic & Sreenath, 2006). Another dichotomy to keep in mind is development vs. evolution. Development is knowable, scripted, while evolution is the effects of historicity (Salthe, 1993).

The attained knowledge in this quest can be used in the design of biosynthetic systems which go beyond Turing's discrete computation model and von Neumann's self-replicating automata, thus unleashing science to grow towards new horizons.

IMPACT

Present day systems engineering relies on specifying deterministic systems programmed to execute its tasks with pre-defined responses to each case. If there is no programmed response to a specific combination of external signals, there is no response or (usually) an inappropriate response to them. The system fails. Yet, as the world for which we build systems becomes increasingly nuanced, complex and unpredictable it becomes even more difficult to map within a limited set of specifications. There will inevitably be new interaction possibilities introduced into the system or its environment will generate new situations and the system will always have gaps, conflicts or ambiguities in its own knowledge and capabilities. The system's semantic and semiotic analysis of overwhelming amounts of (often ambiguous) sensor data to select or invent an appropriate response will become in future an insurmountable obstacle if we do not develop a new paradigm and discover a profoundly new way to engineer and deploy systems.

Integral Biomathics is envisioned to discover and establish new relationships and deliver new ecological insights into the interaction and interdependence between natural and artificial (human-created) phenomena (Bateson, 1972-2002) for a number of scientific fields. It is expected to invent and develop new mathematical formalisms and provide a generalized epistemological framework and ecology for symbiotic research in life, physical, social and engineering sciences. Our objective is to unify classical mathematical biology with biomathics or biological mathematics (the study of mathematics as it occurs in biological systems) with system biology on the way to genuine biological system engineering.

We anticipate that Integral Biomathics and its new way of thinking will have an impact well beyond the domains of natural sciences on such disciplines as biology, physics and medicine, computer science and engineering, information technology, electrical and mechanical engineering, bioengineering, material sciences including nanoscience and nanotechnology, aeronautics and astronautics, civil and environmental engineering, architecture and design, energy and earth sciences (geology, ecology, meteorology, geophysics, seismology), business and education (global and political economy, economics, management science and engineering, finance and marketing, organizational behavior, decision and risk analysis, production strategy and policy, operations management) and the humanities (visual and performing arts, history, languages, literature, psychology and philosophy). Therefore, the support of such a potentially tremendous transformation in science and society requires a deliberate and well prepared not only European, but global approach.

In particular, we anticipate that this field will have impact on the interpretation that is put on very small structures that have active (non-linear) capabilities (whether electronically, or in some other technology). Such structures may involve highly localized physical interactions, or highly localized molecular or ionic interactions. Currently, their interpretation for synthetic information processing has relied on an ability to interpret the different states of such systems in a discrete (and usually binary) way. The development of the theoretical underpinnings of Integral Biomathics may point the way towards a different (and more expressive) way of interpreting such nonlinear structures. Such a development could pave the way for a different type of computing system from those currently in existence.

INTEGRATION

Our objective is to unify classical mathematical biology with biomathics or biological mathematics (the study of mathematics as it occurs in biological systems) with system biology on the way to genuine biological system engineering. Our approach is a systemic one. It is about asking what is computing and cognition, and about understanding where the biological imperatives for them come from and lead to, rather than being about replicating some isolated aspects of them. In this regard, our goal differs from most present day efforts of biomimetics in automata and computation design such as neuromorphic engineering (Mead, 1990; Jung et al., 2001) to develop autonomic systems by emulating a limited set of "organic" features using traditional mathematical methods and computational models.

We will develop a profoundly new theoretical framework integrating systems biology into computation and capable to answer such questions as:

o What is computation? – within the biological context, because there is "no computer into which we could insert the DNA sequences to generate life, other than life itself" (Noble, 2010).

o How useful is computation? – for living systems, where "usefulness" is studied from the viewpoint of the entity performing the computation.

o To what extent can a computation be carried out? – in an organism or an ecosystem, with the available resources (energy supply, time, number of 'computing' elements, etc.).

To face these issues, it is mandatory to revise the conceptual framework of contemporary computing and communication theory, rather than addressing other issues such as computability which are essentially irrelevant to biology. Since historical contingency prevents classical Turing computability in dissipative systems, including the biological ones, alternative theoretical approaches to defining biocomputability in line with those in (Hogarth, 1994; MacLennan, 2003) are required.

This research will be carried out both from the perspective of traditional (analytic) life and physical sciences, as well as from that of engineering (synthetic) sciences. Thereby, classical information theory (Shannon, 1948) should be also developed along the same line of research in order to obtain an authentic picture of natural biological systems (Rashevsky, 1954-1955; Rosen, 1958-1959) that will enable the creation of artificial ones. This viewpoint has certainly become an important issue in the design of complex networked systems deploying large numbers of distributed components with dynamic exchange of information in the presence of noise and under power and bandwidth constraints in the areas of telecommunications, transport control and industrial automation. What is important for the design of naturalistic systems in this areas is the perception of signaling and information content (including their processing and distribution) from the internal perspective of biological systems (Miller, 1978) and in correlation with autonomous regulation of power consumption and other life maintaining mechanisms. This topic has not been addressed sufficiently by present research in either natural or artificial systems. Therefore, it should become an integral part of the models and methods for approaching naturalistic computation.

As a first step to this integration of ideas, people, infrastructures, resources and research agendas from different disciplines within the framework of Integral Biomathics we proposed a FET Proactive Support Action project i) to devise a set of challenges with this perspective for future EU FET research at proactive initiative level, and ii) to release a white paper for the EC following the recent Call 6 (FP7-ICT-2009-6).

PLAUSABILITY

We anticipate that the focus of this research will meet the interests of and (eventually) find broad acceptance in the scientific community. This initiative is expected to deliver answers to such questions as: (i) what is computation? – in biological context; (ii) how useful is a computation? – for living systems, where "usefulness" is studied from the viewpoint of the entity performing the computation; (iii) to what extent can a computation be carried out? – in an organism or an ecosystem, with the available resources (power, time, number of computing elements, etc.).

The proposed research focus is different from those in previous FET funded schemes and calls such as "Neuro-Bio-ICT", "Unconventional Computing" and "Bio-chemistry-based Information Technology (CHEM-IT)". These research fields accentuate alternative and complementary formalisms and approaches to automation and computation as compared to those of Turing and von Neumann with a fairly known physical base while remaining faithful to the fundamental capabilities of programmability and control (despite using biological terms like "self-organization") that have become so indispensable. Yet, we cannot truly rely on these machines to autonomously discover and explore new worlds which are impenetrable for us. They simply lack the ability to grow, develop and evolve under the two other fundamental capabilities that living systems possess: effectiveness and innate adaptability/learning (without any human intervention).

Therefore, Integral Biomathics offers an open and unifying approach to understanding Nature with the objective of unravelling and explaining the gap between machines and living organisms not by applying mathematical physics and chemistry, but by developing a truly biologically driven mathematics, logics and computation (Rashevsky, 1955; Rosen, 1959; Elsasser, 1981; Conrad, 1989; Matsuno, 1989; Hong, 1992; Salthe, 1993; Siegelmann, 1995; Pattee, 2002; Zeigler, 2002; Smith, 2007; Simeonov, 2007-2010).

Tentative R & D agenda:

2010 – 2012: Challenges & community building

2012 – 2020: Theoretical and technological foundations

2020 – 2025: Delivery of first prototypes

2025 – 2030: Market introduction

(Comments and detailed planning are welcome.)

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COMPUTATIONAL SOCIO-GEONOMICS

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BRIEF EXPLANATION

SOCIONOME-METALOGER will establish the new science of Computational Socio-geonomics, a wider conceptual term than the earlier 'socionomics', based on the coupling of science and social systems within a new ICT paradigm. SOCIONOME researches the properties of social systems, their computability, structure, ontological basis, and real-world usage. METALOGER designs and builds the computational environment, methods, engagement, applications and organisational instantiations. The outcome will be a ubiquitous organisational real-time simulator that verifies social systems behaviour. The key application is Governance. The simulator is a toolkit for use by any Flagship project, organisational system, or world ecology project that addresses sociological systems complexity. Already further Flagship collaborations are emerging to take this work forward on a global scale.

AMBITION

The SOCIONOME-METALOGER Ambition is to be the essential science and tool-kit for managing our social ecology world. LIFE as a constantly evolving and mediated process involving people, organisations and computers. Computers pervade all areas of life. Pervasive Social systems define & govern our lives. Intelligent Human-computer confluence requires human social systems confluence. However Social science lacks a formal computational basis that needs to be elucidated.

SOCIONOME proposes a new research area, computational socio-geonomics, involving routine embedding of computational methods in the functioning of social systems. A hypothesis is that this will lead to a paradigm change in social systems and evolutionary computing technology. SOCIONOME is a scientific enquiry into the properties of social systems and their behaviour in real-life dynamic emergent social interactions; it will investigate and develop the scientific scope, significance, and practical implications of the new discipline. The fundamental sciences are complexity science and evolutionary systems theory. The applied sciences involve the coupling of computational and social science methods. The computational realisation requires a radical simulation platform for which METALOGER is a strawman; it will bring verifiable rigorous formalism to computational socio-geonomics by translating the properties into computable abstractions susceptible to formal mathematical treatment AND intelligent translation to the world of human social cognition.

The application of computational socio-geonomics and its practice is essentially a social process. That statement underlies the relative limitation of current computing applications and technologies. To correct this requires applied technology convergence between the science and its practice involving: applying new levels of formalisation, modelling, rich semantic and intelligent human-computer confluent interfaces, new methods and tools for the complex science of social systems; introducing computational socio-geonomics into societal systems at every level from theory and philosophy to practical laboratory and real-life organisations. Together these enable verifiable social systems behaviour. It will be a society wide system-of-systems. SOCIONOME will be a significant advance in our understanding of complex adaptive systems, enabling their significance to be translated into effective action.

An initial study already proposed to FET will initiate computational socio-geonomics by: building a Community of Practice (CoP) involving scientists, technologists, engineers, practitioners and users to innovate and launch the new science; scoping the rationale for computational socio-geonomics, the scientific domain and research challenges, the societal and ethical challenges; defining a Future State

Vision and a road map, proposing on-going coordination and support within FET, and building relationships with industry and government to apply the emerging technology.

The challenge we face is to both advance the science and change the world (literally). Whilst key areas of public concern attract much attention, computational socio-geonomics has yet to appear on the public radar, yet alone capture the imagination. A key challenge is to bridge the worlds of sociology and computing. Our task is therefore to engage society and people with the proposed new thrust and discover jointly what we can do together. Launch of a new science requires an eclectic approach since synergy and serendipity are possibly the main meta-factors in achieving any breakthrough. We have a road map of promising areas of exploitation as well as the necessary integrative and multi disciplinary focus that FET advocates. We will work with existing research modalities; advance the field within the EU and globally, starting with collaboration with the US NSF SoCS programme, and show that the scale of Computational Socio-geonomics requires and justifies a FET Flagship (FETf) thrust. We envisage cooperation already agreed in writing, with FuturICT. The proposed cooperation is to scale this programme to a truly ambitious level of world take-up, a programme called World Society Modeller (S-GAIA). This will extend the societal focus up to the World ecology level of concern..

IMPACT

Computers need to support emergence which is the defining feature of all social systems. SOCIONOME-METALOGER starts from a position that the main application of computers world-wide is to support human activity whether at Government, business, organisation or personal levels. This simple definition of 'pervasive' computing underlines the nature of our computational socio-geonomics vision: "what is going on in the human social and computer worlds and can these be combined in some new form of symbiosis". That means human in scale, intelligent, working together. SOCIONOME - METALOGER proposes that if we can make a computing system 'behave' like people, it will be Human-Computer Confluent. Therefore we must build such a capability into computing systems. The principle research and design activity is how to wrap the computing application in its own complex adaptive system. The most novel feature of such a platform will be the seamless interchange between the twin complex adaptive worlds of social exchanges and their representation in the real-life simulation. It couples the human level processes and the computational ones; both are an emergent reality. In terms of human action and decision making, constantly switching between the virtual world 'pondering what to do next' and the real world 'what is actually happening'. However it would be hubris as well as a missed-trick to conceive of computational cleverness as able to operate without the coupling we propose. That would perpetuate the all too familiar problem of HCI, involving complex translations outside the system that people inevitably end up just 'working round'. The key is to use the best of social thinking that has evolved over several millennia: the challenge of emergent data is that it can be expressed as the exponential ∑(human knowledge), but the crux is what is the pattern of relevant data to any emergent situation and what are the triggers.

Almost all science includes scientific informatics the application of ICT to modelling the target scientific area. The social sciences lack this at the level, for example, of bio-informatics, or the modelling of the Physionome. Computational Socio-geonomics will correct this. Socio-geonomics is the theory and practice of social/organisational systems. Research in this new area particularly must be mindful of its overriding responsibility to improve our world, applying the best tools that scientists technologists and engineers can fashion. Computational socio-geonomics seeks to avoid complexity science becoming another barrier to involvement, whilst at the same time seeking its insights and contributions to managing our current dynamic but dangerously unstable world. A cooperation with expert scientists such as described in the Biomathics proposal is envisaged and agreed in outline with the World Society Modeller (S-GAIA) proposal.

Formal computational socio-geonomics is the application of mathematics and statistical physics to elucidate the unfolding patterns of life expressed through society and its social systems. It is also about, as well as living in the real world, playing and trialling in the virtual world. The two are synonymous: they combine in the world of learning from childhood onwards. In both we deploy a phenomenal (literally) repertoire of resources, become resourceful, act out our existence. Today we can start to contemplate, build, and eventually bring to the game of life, the sophisticated tools of computational socio-geonomics. The science maps onto the virtual world and mirrors real life. It is better to play with the virtual world than destroy the real. No one wins that game.

Computational socio-geonomics sets out to model this world in a form that defines the structure and interrelationships among processes that define how organisations and society function and evolve. These are then modelled in a computational engine, using new computational methods that that will not only model and simulate, but also support and enhance real-world organisational processes. Computing will be able to get beyond the current level of social websites that are primarily a protest against an alienating super technocratic world, back to one where the norm is to be involved, to be informed, to share in the processes of evolution of social systems, and hence the sharing of responsibility for our (the world's) future.

The proposed programme will thus have a Janus-like approach: the specialist science and technology will also have as its mandate the requirement to be built around the needs of society, its stakeholders, and their cognitive world. Only by real-time living simulation is this possible. Socio-geonomics defines at the theoretical and practical levels how we function; applying computational methods to this field holds out the prospect of adding to social science the leverage of ICT, in as fundamental a way as the lever is to mechanics. In that sense the applied science of computational socio-geonomics is a tool-set: philosophically because modelling is the ubiquitous human activity that underpins our view of, understanding, and engagement with, our world; practically because tools are fundamental to leveraging results. The key challenge is to formulate what can, simplistically, be called a language of this new extension of complexity science that is as ubiquitous as natural language, and for the obvious reason that real-time social systems are intrinsically bound up with human language – taking this term to embrace the totality of how we think, communicate, and then act as social systems participants. A Metaloger environment is simply the toolset for this activity, the sum total of a series of interacting Metaloger environments is an evolutionary process platform. An essential goal of the research is to uncover the underlying psychological and sociological mechanisms of organisational processes, including individual behaviour within organisational contexts, to enable the mapping of their complex and ever-changing interrelationships. We can define computational socio-geonomics as the science of processes but this begs the question of what a process is (Bateson et al). Our starting hypothesis is that all process is about evolution. Perhaps the most significant feature of this research is to establish it as an evolutionary process: that is it will utilise its own experience to test the computational-socionomic hypothesis:

"social action persists while its actors calculate advantage › risk; when advantage ≤ risk there is a switch to finding better social solutions, either: (a) an ecological issue of the command and consumption of resources, or (b) the pursuit of a higher level strategy to survive and thrive."

The emergent conundrum is when should the switch be engineered; the ecological issue is everyone else faces the same conundrum? Computational socio-geonomics offers social science an improved tool-set for routinely evaluating such challenges.

We are concerned with improved decision making in the escalating Hurley-burley of modern life. The generic application area is governance of the affairs of mankind.

World Society Modeller (S-GAIA) has agreed a major collaboration with Industry and Technical Standards bodies to research and develop the vendor systems required to enable ubiquitous technological exploitation. This is a partnership with the Ubiquitous Complex Event proposal from CITT in Germany

INTEGRATION

INTEGRATION is the combining of the working parts of SOCIONOME-METALOGER into a working tool-set. The Science and Technology of Computational Socio-geonomics is a new working of COSI-ICT building on rigorous enquiry into the properties of social systems. Society and social systems are a powerful and effective means to conduct 'life', consisting of a rich assemblage of artefacts, tools, methods, principals, processes, and practice. The challenge is to integrate the twin domains of society and complexity science into the necessary new assemblage. The research aims to elucidate a new formalism to address this combining complexity science and social systems practice. METALOGER calls these Meta-models (Meta Frames of Reference, or MetaFORs) and the social sciences calls these Ontological abstractions. To Von Neuman computers they are algorithms. All involve real-life processes, combined in a rich mediated world of presentation and engagement that 'speaks to people as people' . The simulation of the social system is as cognitively realistic as a flight simulator, and for the same reason. It is based on what happens in the real world. The entire social autonomic auto poietic construct informs the computational design, computed as evolutionary entities following a GST (Rosenean) model of existence. Biomathics shows the dimensions of this modelling challenge are wider than this description indicates.

The research will also build a comprehensive understanding of how people engage with the working model, establishing the limits to which simulation can be taken as a useful tool and process for handling emergent phenomena. The Metaloger will become a practical system helping to manage human affairs, providing solutions in support of specific social problems, and helping groups and individuals engaged deal with emergent and planned change. The novel paradigm to be employed in the Metaloger programme is to conceptualise the research challenge as a model of the socionome, consisting of a structure of Meta-models which form a hierarchical network, which will itself possess emergent properties to be simulated and built into the working Metaloger engine. As with its counterpart in the physionome, the building blocks of the Metaloger model and system are the cellular and molecular equivalents in the world of sociological, psychological and organisational processes. All of these must be identified, researched, understood and accurately represented in the Metaloger computational engine. They are exceedingly complex [Bassingthwaight National Simulation Resource Washington]. What are the ingredients of this new world of computational socio-geonomics?

Complexity, Organisation and social systems

How systems work in the real world is the underpinning enquiry of SOCIONOME-METALOGER. The focus is how to extract from this a generalised abstraction that can be expressed in a form capable of computational methods.

Species 'Socio-cybernetic Science'

The species model has been presented as a granular component of a socio-technocratic system. Many different classes of species will be required and the project intends to start from a basis that everything is a species This model then behaves as an autonomous entity (Agent), only it is also constrained by its environment including what other species do. Adopting this R&D paradigm will force the project to test the concept to death and thereby build a complete knowledge of how the model works and any limits on this.

Systems of Systems

In our world of evolutionary answers to complexity, systems of systems are not that perjorative artefact that claims, always wrongly, to have the answer to everything. They are a view of an ecology, its evolutionary life, the process, the tool, and the support that generates better answers because the world constantly evolves. In starting with this concept we are merely recognising the common weal across all ecologies.

Ontologies and Meta-information

Whilst all proprietary systems define a working ontology to inform the operational process that then ensues, meta-systems define some higher-order of classification that defines interacting processes at some higher level of abstraction – what that higher-level denotes is specific to the domain of the higher level. The study will need to discover a schema that enables all such meta models to be related to each other. We can note that this is the basic idea of 'meaning'. We hypothesise that this is the basis of societal Global Dynamics and World Society Modeller (S-GAIA) proposes cooperation in this crucial area, specifically Governance Systems.

Sociology and Socio-geonomics

The structures of social systems and their real-life domains represent a vital, rich, huge, and pervasive, set of structures, methods, and working artefacts that enable life to proceed. It will be necessary to dip into this world in partnership with expert professionals, practitioners, and social scientists to arrive at some working model. This means entering the world of culture, complex behaviours and rich artefact (as well as the raft of specialist knowledge and practice that is always involved).

Computer technologies

The practicalities of computational technologies will follow the requirement and the implications of handling emergent data, perhaps the key issue. The fact that a huge evolutionary multi-agent modelling platform is envisaged, creating evolutionary patterns we call emergence, and that these are susceptible to mathematical treatment applying statistical physics concepts – is important in the context of the value of being able to examine and possibly revise our view of the constantly unfolding world. All data is both ephemeral and current. A new paradigm of computing will emerge. We call this socially enacted information.

Engagement Layer

The interface between all domains of the model we are contemplating is the single most innovative layer – why? The answer lies in one of the key abilities of humans to construct and process a view of reality from sparse data that never the less captures extremely rich concepts and communicates them. Technically this means that agents will combine the ability to process complexity with at the same time the ability to always refer their 'life' qua 'agent' back to the real world view that inspires and provokes their behaviour. The link is the semantics of meta-modelling that this project will scope. The technologies then involve the rich world of evolutionary intelligent multi media.

Real-world Events and dynamics

Whereas most agent based simulations start from a predetermined repertoire of behaviours and can only exhibit limited evolution, the raison d'etre of SOCIONONE-METALOGER is to simulate the unfolding of events over time, both in the real world and the virtual world. Modelling emergence, seen as a property and outcome of many interacting meta-layers of the model is a key area of research. This is algorithmic real life.

PLAUSABILITY

Plausibility comes down to a judgement of three things: do we want it; can it be done; will it prove useful. The case for the first question has been made consistently since the first Complexity forums in Torino and Paris, and is now formally set out in the ISTAG report. SOCIONOME-METALOGER ticks most of the ISTAG boxes; although a New Science it has had a lengthy gestation already. Computational socio-geonomics is the new game in town.

The Benefits

Computational socio-geonomics (arguably the most significant remaining 'multi-omics') harnesses a new ICT paradigm to the critical task of understanding 'life'. It will achieve this by reverse-engineering computing technology to simulate social activity and critically, basing HCI/IO on human thinking and experience. The outcome is real-time simulation as on-going 'life' unfolds, of our attempts to marshall the resources of our ecology. SOCIONOME-METALOGER is a problem solving technology and a tool for Team Players. Ubiquitous deployment across all society globally, in totally user-oriented ways indicates cooperation with particularly the new European Future Internet Initiative, and an initial approach has been started by Society World Modeller (S-GAIA) Project. This aims at total involvement of society on its own terms with the science subordinated to the social goal of an empowered enabled and involved society – as current social websites are showing already.

Technology Context

ICT technologies required only exist as ideas and laboratory constructs. SOCIONOME-METALOGER has a blueprint for at least the initial prototype. The most important input to partnering with technologists is the new Meta-model software paradigm. The Rosenean system concept is the evolutionary component of the meta model which can be designed and built using existing large scale autonomus Agent principles.

We have not yet considered adequately the relation between soft-robotics (which is a view of Meta-models) and hard-robotics that are likely to share the Metaloger world of action and simulation. We consider that cooperation with Robotics research will be timely and productive.

World Society Modeller (S-GAIA) will address the challenge of successive computing paradigm changes needed for the level of take-up that programme envisages. Initial prototypes and experiments will mimic the required functionality using current technologies. This aspect will be led by the Biomathics project.

Progress Beyond the State-of-the-Art

The Metaloger is a scientific tool that models soft aspects of our existence so that they are rendered amenable to measurement. As stated in the paper to the road-map (ONCE-CS 2005):

The Metaloger (project) targets vital "... industrial and societal advantages for Europe. 'Behaviour', especially decision making, the mainspring of both creative and pathological action, will be brought into an empirical and observable framework which will both support it and hold it up to scrutiny .... The benefits accruing from developing the Metaloger are in the support of a new science of governance. .... The Metaloger will make it routine to surround data and decisions with recorded and verifiable audit-trail of their aetiology so that pathological misuse of data and wilful mal-practice becomes more visible. ... ."

Socionome-Metaloger Road-map: Milestones towards the FET-F Challenge at horizon 2020

Computational socio-geonomics involves science, technology and people and it demands major structural and institutional change to bring it about within FET and the research community. The initial CA seed-project will deliver a road-map for subsequent research, product development and commercial exploitation. Milestones set in the ONCE-CS Briefing submitted by Metaloger are indicative:

1. SOCIONOME demonstrates the validity of meta-model structures to codify complex behaviours

2. Meta-modelling shown to usefully describe patterns of complex human behaviour

3. Mathematical definitions defined for structures of meta-models

4. A meta-model process-engine built, elucidating fundamental patterns of information, process, dynamics relating to specific and generic aspects of human behaviour

5. Specific industrial/organisational problems solved using a Metaloger engine. Metaloger evolves towards a generic social tool-set. Reverse-engineering of common existing systems begins to take shape, yielding measurable results

6. Society perceives the Metaloger as useful and NOT Big Brother, Metaloger environments are as ubiquitous as the Internet

Outcome

The target of total immersion in society within a decade would be to demonstrate a paradigm change. The dissemination activities of Metaloger will capitalise on its real-time embedded capabilities as a processor of the dynamics of socio-technocratic life, usable because it is socially intelligent and seamless with current ways of behaving as a social species, whether at work or play. It will truly become a laboratory of life.

ORGANISATIONS INVOLVEMENT

SOCIONOME-METALOGER is a new research area and the basis of our approach is to use the seeding FET Study (if successful) to engage with the EU and global research community to establish a new form of social research process that we can then use for the main flagship effort. FET Flagship projects are an example of long term emergent reality. The driving model of the proposed research should be to apply the SOCIONOME-METALOGER model to this FET-F project and when successful to institute it as a core FET artefact. This idea is further outlined in World Society Modeller (S-GAIA).

Wide engagement is the sine qua non of computational socio-geonomics and FET Flagship research. The key potency of the Metaloger solution is that its take-up and use is a self-organising scientific discovery process. For this to happen its trajectory will need to demonstrate:

• Applicability in the scientific big world view, i.e. that it is pervasive; leads to wider and thus more valid cooperation on the science as well as domain-specific applications, and most importantly gains public acceptance. Computational socio-geonomics addresses society

• Applicability in the applied technology large world view, i.e. continued innovation in applications (the pervasive incorporation of the Metaloger engine as a core component of ICT systems); mainstream use in disparate areas of governance (the extension of current initiatives such as e-government, which offer administrative convenience and efficiency, into use of the Metaloger engine as a core component of scientific management (this is the measurable prediction of emergent phenomena.)

• Applicability of the Metaloger application of bio-cybernetics to disparate small-world phenomena i.e. the growth of meta-models of real-world socio-technocratic phenomena (this is the wide take-up of the Catalogue as a repository of valid constructs that can be used to model real-world phenomena).

The sum total of this activity will be to gradually evolve an understanding of the socionome and the geonome (sic). Techniques and methodologies will be critical to establishing a coherent basis for the evolving Metaloger world: as the ONCE-CS Road-map Briefing stated:

• "Translating this into a processable (and itself emergent) computing platform requires basic research going beyond current human-technology interface management. The continuous configuring of the Metaloger requires a seamless language of emergence which is applied to people, process, platform and performance within the ecology of the world we inhabit."

• ... the dynamics of [social] behaviour will be held up to scrutiny in real time. .... The outcome will be a ubiquitous toolset to support working with the manifestations of complexity in modern life, rooted in everyone's everyday life, but applying complexity science to compile the information, measures, decisions, actions, management and potential outcomes on which optimisation of our fragile ecology depends.

Research Approach – Implementation

The social dimension of implementing SOCIONOME-METALOGER determines the approach to research. A CATWOE model below analyses and describes the world of computational socio-geonomics (Checkland Soft Systems Methodology). The target of total immersion in society within a decade is possible. Perhaps the most extraordinary result would be peoples accountability for social systems and behaviour. People power would replace both technology push and unaccountable, ungrounded, social computing proliferation. That would be to demonstrate a paradigm change at the level Addison sought: "It was said of Socrates that he brought down philosophy from the Gods to dwell amongst men; I am desirous of having it said of me that I brought it out of closets and universities to dwell in coffee-houses and at the dinner-table". [Addison, Volume 1 The Spectator]

Table 1 CATWOE Model of the Proposed Metaloger Solution for computational socio-geonomics

CATWOE Definition: applies to virtual and real world

Customers Everyone involved with society its organisations, and their aspirations to achieve more, do things differently, be creative, be involved in enterprise growth and success.

The Metaloger librarian will be the custodian of an organisation;s Metaloger instantiation.

Actors Everyone working at the 5 levels of the VSM

1. Social scientists, practitioners,and all who labour to improve society

2. Actors, operational people, resources, agents, partners, supply-chains

3. Governance bodies, process owners who recognise their world is continuous change, complexity, and emergence

4. (but also we need to be mindful of pathological forms – Metaloger is a neutral tool-set.

We are likely to see a more rigorous model of emergence than was formulated at the time of the early pioneers of complexity thinking.

Transformation Delivers a holistic model of Society's enterprises which can be manipulated in order to change it via emergence discoveries, and re-engineered processes. The crux is combining computational methods and the wide sweep of social activity (including its 'stories')

The Achilles heel is still the richness, subtlety and inclusiveness of culture. They outstrip our current expectations of what is realistically possible – but who knows?

World View 'Thinking' technology defines, models and changes the world within parameters of complexity, ecologies, governance, and morality. Metaloger instantiations become pervasive and talk to each other – a sort of intelligent Internet.

Governance is the pervasive application.

Owners The decision makers (who theoretically only survive by delivering improved results) and all stakeholders in the network of affected individuals, groups, organisations, and society. In fact everyone takes decisions on their life plan, better for them to be informed decisions with the best chance of success.

We all own the global Metaloger environment because we create and populate it with our ideas.

Environment The success of the SOCIONOME-METALOGER Project depends on successful coupling of computational socio-geonomics with a real-time societal simulation environment and its acceptance and use by society. Also the trajectory considerations of introducing a paradigm change: ICT modelled society, action, thinking, decision making, management and governance.

Social computing has shown that people want involvement.

COMMENTS

Research Approach and Structure – Stakeholders

The seeding proposal we have submitted to FET for research in computational socio-geonomics will launch and service a Community of Practice that enables completely eclectic participation in the furthering of the flagship aims. Participants represent the entire spectrum of society's interest in the flagship:

1. Core partners:

a. IMSS Laboratory, Reading University, working with Metaloger technologies

b. Department of Computer Science, Sheffield University: Multi Agent modelling

c. ASSYST to coordinate cooperation with other COSI-ICT projects

d. The fast emerging levels of interest and sign-up are more specifically set out in the World Society Modeller (S-GAIA) proposal. There is already a written commitment to cooperate with FuturICT as each firms up its scope, science, technology, engineering and above all societal engagement proposals.

2. Metaloger comes from the industrial world of process engineering, so there is a strong emphasis on exploitation already. Process/Enterprise Engineering firms will be touted as partners and are already signed-up via the World Society Modeller (S-GAIA) cooperation already mentioned at the start of this proposal

3. Candidate 'core' stakeholders include the following (from the partner list in the earlier Bid):

a. Social & behavioural scientists, also social system and organisation specialists

b. Users, domain specialists, also organisation, business and governmental strategists, implementers.

c. Complexity scientists, mathematicians, statistical physics and network specialists

d. Socio-cyberneticians, ecology, evolutionary modellers

e. Meta-modelling: Ontology/epistemology/taxonomy/cognition structuralists

f. ICT infrastructure, resources, systems methods and technologies specialists

g. Engagement is a specialist area coupling technology & human/group cognition

h. Applied science/technology/engineering for Design, build, integration, trial, scaling and deployment

COMMENTS

Already the emergence of alliances and opportunities across the Flagship world is showing the potential leverage effect of the Flagship model. It is also showing the need for new modalities rather than proprietorially owned projects. This indicates a profound change in the way science is approached. This will itself require new social models of engagement, governance and evolution of projects rather than any misguided attempt to define it all in advance in a rather deterministic way. World Society Modeller (S-GAIA) proposes itself as a living experiment of such a process, in collaboration with many projects and FET. This structure would not be owned by the project; it would be owned by the Flagship Society. This is the " We first eat ourselves what we serve to others" model [Dutch Proverb].

Virtual Physiological Human (VPH) Infostructure

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BRIEF EXPLANATION

Virtual Physiological Human (VPH) Infostructure

Future ICT for the personalised, predictive and integrative understating of life.

This proposal is in close resonance with the ISTAG priority, "Understanding Life through future ICT". We propose to tackle the challenges listed in the ISTAG document by developing radically innovative ICT solutions for harvesting the huge amount of human physiological and pathological data at all scales from molecule to whole populations, and to transform them into knowledge using multiscale integrative modelling, according to the VPH approach.

AMBITION

Rationale

- The development cost for new drugs are increasing exponentially;

- genomic and post-genomic research, in spite of the huge observational body it created failed so far to make a significant impact onto healthcare practice;

- longer and better life expectation, ageing population, and the increasing prevalence of certain life-long chronic diseases and resulting multimorbidity of patients make any long-term prospect of public healthcare financially hard to sustain.

These challenges, apparently unrelated, all share a common root: the end of biomedical research and practice as a purely reductionist exercise that is mostly based on observational empiricism. Only a highly ambitious goal can overcome these challenges: we need to re-think and conceptualise the human body as a single integrated and dynamic system, which operates simultaneously at dramatically diverse space-time scales, from molecules to whole populations, from nanosecond to lifetime.

Reaching this goal is possible only if we develop an entirely new generation of Information and Communication Technology applications that allow us to generate this collective systemic representation of human physiology and pathology:

a) FROM DATA TO INFORMATION: Secure Life Data Cloud. Biomedicine is all about data -- clinical automation, high-throughput genomics and medical technology are producing a huge amount of raw data in the research labs, in the hospitals, and over whole countries. The problem is not the lack of data: on the contrary, many now talk about data overflow. The problem is to transform these data into information useful not only for the specific purpose they have been collected, but also for contributing to the general understanding of life. We need a progressive accumulation of all available observations in digital form, regardless of their location, time, and format of collection, and global sharing of these infinitely large data collections in full respect of the legal, ethical, and organisational needs of all stakeholders (patients, medical professionals, policy makers, industry).

b) FROM INFORMATION TO KNOWLEDGE: personalised predictive models of human pathophysiology. In order to transform the huge collection of data into useful information, we need a whole new technological framework of data processing, simulation, high-performance computing, post-processing and visualisation. All these algorithms must be implemented with a high-throughput perspective, imaging them as independent agents that crawl the Life Data Cloud and “transform” the raw data into derived data, compose them into predictive models, and store back into the cloud the simulation results.

c) FROM KNOWLEDGE TO WISDOM: toward a world wide web of predictive models. But even if we could capture all available information into predictive models, this would not be true knowledge. As mentioned above, the most challenging aspects of life sciences emerge from the complex systemic interaction of complexes and processing taking place at radically different space and time scale. But if we can transform the metaphor of the web, which is currently only a web of data, into a web of information that is captured inside predictive models each simulating a fraction of the system according to the current state of the art, then we can dynamically compose and extend the web to form incredibly complex integrative models of human pathophysiology.

Exemplary challenges

These are a few examples of the technological challenges that the creation of the VPH infostructure involves:

1) Secure data cloud: the idea of data clouds is becoming a reality, but all consumer implementations have no security frameworks, or at most implement very static security models. The Life Data Could must provide the highest possible level of security (not only achieved, but also perceived by its end users that must entrust to it their sensitive data) implemented into a dynamic model within which the data owner (typically the patient) can dynamically establish access policies to decide who can access which data and for what purpose. It also needs to implement “need-to-know” automation, which makes possible to automate anonymisation, pseudo-anonymisation, information clustering and aggregate statistics, so as to provide to each requester the minimum amount of information that is necessary to his/her scope. No one would accept to have their health record made public, but very few would be against having their data used to generate statistics, and then these statistics made public.

2) Data transformation agents: the VPH infostructure cannot provide only physical access to the raw binary information. Its usefulness would then be quite limited. We need to access the raw data from where they are stored, process them into the information and format that is needed, and make them available to all possible users, again under secure access policies. Typical examples of data transformation are: file format conversion, progressive resolution, image processing, data mining, or full simulation models.

3) Multiscale interactive visualisation: how can we visualise simultaneously interacting systems defined at whole body and at molecular scale? How can we effectively explore datasets whose space-time resolution is some order of magnitude larger than human perceptual limits? Google Maps is great, but can we come out with a similar interaction paradigm for full 3D+time interaction over multimodal data (volumes, geometries, fields, signals, etc.)?

4) Web of models: can we generalise the idea of text hyperlinking to models and use it as paradigm for an the Internet Life Cloud, an infinitely expanding system that represents in an integrative way all the available knowledge on human pathology and physiology, in ways that make it immediately accessible and fruitful for personalised, predictive and integrative healthcare?

IMPACT

We expect impacts not only on healthcare ICT research but, primarily, on the general ability of healthcare to meet the needs of future generations. As results from early outcomes in the healthcare sector percolate outwards, we also expect secondary impacts on ICT research at large that will strengthen our societies\' overall innovation capacity.

With respect to healthcare, the promise of integrative medicine cuts across the four levels of the knowledge pyramid, integrating a variety of factors:

- the patient data stored in different hospitals in different member states or in clinical research databases can be seamlessly accessed by authorised personnel from anywhere in the world, thus helping to realise the dream of effective healthcare for mobile citizens and drastically lowering the barriers between member states in this respect; it may also help in reducing the individual-society conflict surrounding the privacy of health data;

- the information relating to various elements and processes of pathophysiology can be organised into a systemic understanding, making the fight against diseases such as cancer, diabetes, AIDS, Alzheimer's disease, etc., much more effective;

- the knowledge digitally captured in metadata, ontologies and models to help in the fight against the combinatorial explosion of cognitive complexity and, thus, to allow the biomedical professionals to operate effectively even when immersed in a very dense information flow;

- the wisdom produced in research laboratories and in clinical practice, so that it can be formalised in guidelines, standards and protocols and applied in decision support systems, allowing medicine to become truly evidence-based, with errors and malpractice being drastically reduced and supporting enormous resource savings.

A new generation of integrative biomedical technology will make it possible to provide personalised, predictive and integrative medicine to millions of European citizens. We expect that this will not only have a psycho-social impact in terms of improving the duration and quality of the lives of European citizens, but will also help to reduce the cost of healthcare provision. Particularly with respect to the ageing population and its associated chronic diseases, which are already putting tremendous demands on the health expenditure in member states, a trend is set to become more pronounced into the future.

After the past underperformance of Europe when compared to global markets in important sectors such as pharmaceutical, medical devices, etc, these new technologies can open up another chance for Europe in the biomedical industry. This can happen by leveraging on the other sectors in which Europe is still strong, such as medical imaging and biomedical instrumentation. This, in turn, should translate into socio-economical benefits in terms of well-paid intellectual jobs, with negligible environmental impact – precisely the type of industry we imagine when we talk of the European knowledge economy.

While we anticipate the impact on the biomedical research community to be fairly immediate and to continue to expand in influence for an extended period, the indirect medium-term impact on the area of general ICT research could be even bigger. If we imagine a new Internet in which all my personal information can be stored anywhere in the cloud, while remaining totally secure and under my complete control so that I can share (and revoke) portions of it to anyone else at my discretion, a huge range of social and economical possibilities are opened up.

ICT solutions for health are faced with a mixture of requirements from consumers, non-technical professionals and producing ICT industries. We need solutions that provide suitable interfaces for all of these stakeholders.

We need to expose a consumer interface to the patient/citizen, and this must provide the lowest possible barriers to access, a minimisation of the digital divide, in a language he understands. At the same time, we also need interfaces for medical professionals, who are highly skilled in their own field but have limited technical skills and no great motivation to undertake training to acquire them. These professionals need high-throughput solutions that map fully on to their view of the task and, according to their experience and training, the logical way to approach it. Even though the underlying technology will be extremely powerful, this should be hidden from this type of user who may sometimes even be a little hostile to it.

Last, but not least, production back-ends have specifications for safety, reliability, security, etc., comparable only to the most mission-critical industrial solutions. Thus, it is not a surprise if radical innovations that are initially motivated by needs that are expressed in the area of ICT for health can result in technology that migrates out of the sector and produces a broad impact far beyond its original area of application.

ICT challenges central to healthcare in general, and to the VPH initiative in particular, are also strategic in many other areas including:

- interoperability of on-line communities
- global, secure and flexible ID management
- global indexing, search and controlled access of shared digital resources
- application of the concept of the data cloud to sensitive data
- data translation services for format interoperability
- semantic data mediation to integrate incompatible IT systems
- mark-up languages for the description, sharing and reuse of models
- integration of heterogeneous predictive models running everywhere

- Web 4.0: Web of models

These and many other issues being discussed by the VPH community go clearly beyond the frontier of this specific domain and frame a scenario of extreme horizontal impact in many areas of ICT.

Presently, Europe, thanks to the support received from the EC, is a global leader both with respect to VPH research and translating this knowledge into clinically relevant applications - a vantage position which must not be lost in such a powerful field.

INTEGRATION

Research Agenda

We believe the first step is the consensual development of a research agenda on its own. The VPH community already wrote a VPH Research Roadmap[1] from the perspective of ICT for Health; but while that important document aimed primarily to the low hanging fruits that could show the impact of the VPH integrative approach on European healthcare, it is now necessary to run a similar consensus process to develop the VPH FET Research Roadmap, where we define the research agenda for the years to come from a Future and Emerging Technologies point of view. Members of our community submitted a proposal for such support action, which is currently under evaluation.

It is clear that the elaboration of such a research agenda, and more in general the vision of a flagship initiative, requires a well-established, skilled, and diversified research community. Thanks to the actions funded by the ICT program (STEP Support Action and now the VPH Network of Excellence), and to some landmark services such as the Biomed Town Internet community[2], the VPH community is today a solid reality. Its latest incarnation is a non-profit international organisation that is being established according to Belgium law, called the VPH Institute. Such organisation, already envisaged in the 2007 VPH Roadmap and in various more recent vision documents produced by the VPH NoE, provides the persistent,collective identity that such long-term endeavour desperately needs. The Institute is currently operated by a pro tempore Board of Directors that is in charge of the incorporation process, which is expected to be completed by the end of 2010.

People

Without a formal membership mechanism it is difficult to give numbers. Currently, there are 15 projects funded under the ICT programme specifically targeting the VPH health applications, and five more aimed at international cooperation will start early 2010. To these we should add a number of projects funded at national level, whose goals and approach, while not explicitly referring to the VPH, are definitely consistent with the VPH vision. There are various RTN and RTI under the People Programme that are related to VPH and at least one Senior Research grant from the ERC of which we are aware of. Overall, we can estimate a community of approximately 2000 researchers. Indeed, this is roughly the number of members of the Biomed Town community.

Given the strongly application-oriented perspective of the current projects, the majority of these researchers are biomedical engineers, medical physicists, physiologists, and clinical scientists. It has been estimated that they constitute only about 10% of the research community that could and should be involved. Besides expanding into the aforementioned academic groups, the VPH community will have to see a considerable increase in the participation of researchers involved with basic science, both on the biomedical side (biologists, geneticists, biochemists, etc.), and on the exact sciences side (i.e. physicists, mathematicians, but also computer scientists).

In particular, with respect to the FET Flagship proposal, it are these latter communities that we plan to reach out to: to develop the visionary technology described above, we need to bring on board the best researchers in cloud computing, cryptography and security, image and signal processing, knowledge management, information and scientific visualisation, software architectures, data modelling, etc.

But already at this stage also highly qualified experts from industry are involved, coming from fields like mathematical algorithms and modelling, simulation and virtual reality, imaging technologies, advanced IT devices, etc.

Infrastructures

The VPH infostructure requires primarily e-infrastructures. VPH is already connected with the two principal European e-infrastructure initiatives, EGEE and DEISA/PRACE. In particular the VPH already received a specific allocation for computing time on the DEISA supercomputers. The problem we have is the access model of these infrastructures. As part of the VPH FET Flagship initiative we plan to collaborate with the principal HPC research groups in Europe to reinvent the accessibility of HPC resource in the light of secure cloud computing and of urgent computing, which is required for a number of medical applications. We want to explore completely new use modes, where multigrid approaches are combined with urgent computing models, to provide in quasi-real time the first approximation result, and with greater delay more refined solutions, if this is requested.

Resources

At this stage the VPH initiative is very well funded, but the funds are oddly distributed with respect to our development roadmap. While there are significant resources available for the most applied technological developments, there are currently very little resources available to explore the most radical, and in the long run most interesting, technological innovation. Figuratively, the VPH Initiative is now broad but somewhat shallow; the VPH FET Flagship could provide much more thickness to this "virtual body", fulfilling the VPH promise of a true and long-lasting revolution.

[1] http://www.europhysiome.org/roadmap

[2] http://www.biomedtown.org

PLAUSABILITY

The plausibility of this proposal relies on two pillars: the momentum that already exists around the VPH vision as a whole, and the plausibility of the specific research areas we proposed here.

The momentum of the VPH initiative is significant:

- 1 NoE, 3 IP, 2 CSA and 9 STRP VPH projects where funded in Call 2 under Challenge #5 (Toward sustainable and personalised healthcare), targeting early clinical applications
- 5 additional STREP were funded in Call 4, with the specific scope to internationalise existing VPH projects by linking them to other similar initiatives and groups outside Europe.
- A new call for VPH proposal, again under Challenge #5 is now open.
- A European VPH institute is being established.
- The International Union of Physiological Societies (IUPS) and the Institute of Electrical and Electronics Engineers (IEEE) have created working groups on integrative research.
- The European Alliance on Medical and Biological Engineering and Sciences (EAMBES) made an explicit recommendation to the European Commission in support of the VPH initiative in FP7. A similar recommendation is currently under preparation for FP8.
- A new international coordination organism is being established under the secretary of the IUPS, which should see the participation of representatives from many research societies worldwide.
- In the USA, the Interagency Modeling and Analysis Group (IMAG), a coordination organism between NIH, NSF, NASA, DOD, DOE, EPA, etc. has been running various initiatives related to VPH, the most important being the Multi-Scale Modeling (MSM) Initiative, and the Predictive Multiscale Models of the Physiome in Health and Disease (MSM Physiome) Initiative. There is close cooperation between IMAG and the VPH institute.
- The first conference entirely dedicated to VPH, VPH2010, is scheduled for late September 2010 in Brussels.
- The Philosophical Transactions of the Royal Society published a two-volumes special issue entirely dedicated to VPH research in 2008 and 2009; the 2010 issue is currently in preparation, while the 2011 issue will be hosted by the new Journal of the Royal Society Interface.
- The European Commission is considering the possibility to fund a European Large Scale Action on eHealth; the VPH Community has been playing a key role in this process from the very beginning, ever since predictive, personalised, and integrative technologies have been the core of this action[3].

The second aspect is the plausibility of the specific research activities we propose as part of the VPH FET Flagship initiative. Since an exhaustive discussion cannot be done due to the lack of space, we shall limit our discussion to the four exemplary technological challenges we mentioned above.

- Secure data cloud: no commercially available cloud computing service is currently compliant with relevant healthcare regulations like the USA Health Insurance Portability and Accountability Act or the European Data Protection Directive (Directive 95/46/EC). Most business users perceive this as a serious limitation to this otherwise extremely interesting model; in a UNISYS poll among its customers in June 2009, 72% said security was their biggest concern about moving workloads to the cloud. Very recent announcements from OpSource[4], Cloud Security Alliance[5], Novell[6] and Google[7] do not seem to address the core of the problem (i.e. retain security and control over data stored in the open) but confirm the plausibility of this research target.
- Data transformation agents: the concept of data transformation is quite consolidated in the context of databases[8], but much less in the context of large binary objects storages. A similar approach was explored some years ago in the context of multisensory signal processing[9]. The use of Agent-based computing in VPH has been introduced by the Epitheliome project using the Flame agent framework[10]; the COAST project used the Jane Agent framework[11] to develop a multiscale simulation of the treatment of coronary artery diseases; the VPHOP[12] project is now exploring the possibility of developing a hypermodelling environment based on agent technology; both Flame and Jade environments are being explored.
- Multiscale interactive visualisation: the recently formed Common Tool Kit (CTK)[13] consortium and international effort aimed to develop the ultimate biomedical imaging and modelling open source software framework has set multiscale visualisation as one of its priorities. One of the VPH cooperation projects, MSV, which involves the VPHOP, NA-MIC, ANEURIST, and IUPS PHYSIOME consortia, will start in January 2010 with the scope of developing effective interaction paradigms for multiscale biomedical visualisation.
- Web of models: this is probably the most radical technology among those here listed. The concept emerged as an alternative expression for semantic web, where the idea was that collections of metadata could be regarded as models, which transformed information into knowledge[14]. Preliminary explorations have been conducted in the context of models' reusability[15]. In the context of VPH the idea of a web of predictive models has been first presented to the FET Proactive unit during an invited meeting at EC premise in 2009[16].

[3] http://www.biomedtown.org/biomed_town/vphop/reception/news/elsa/
[4] http://websphere.sys-con.com/node/1222819
[5] http://www.cloudsecurityalliance.org/csaguide.pdf
[6] http://www.novell.com/news/press/novell-unveils-strategy-and-roadmap-to-lead-in-intelligent-workload-management-market/
[7] http://code.google.com/p/google-secure-data-connector/
[8] http://en.wikipedia.org/wiki/Data_Transformation_Services
[9] Y. Xu, H. Qi, \

COMMENTS

Proposing Experts (on behalf of the VPH community)
These are the researchers that contributed to the present document.

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- Jose Maria Cavanillas Atos Research & Innovation Spain
- Michel Rochette Ansys France France
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Organisations

- Europhysiome: this initiative, driven by the STEP action, wrote the VPH Research roadmap. Gordon Clapworthy was the co-coordinator.
- VPH Institute: while the institute is currently being incorporated, a petition in support of its creation, posted only a few days ago, already collected over 100 signatures[17]. All proposers are members of the VPH institute Board of Directors, except Denis Noble, Andrew McCullogh, Jose Cavanillas, Michel Rochette, and Olivier Ecabert.
- VPH Community: a public list of the over 2000 researchers, industrialists, clinicians, policy makers, and representatives of various stakeholders who are involved with the VPH is not available. A Preview of this community can be seen in the VPH Research roadmap, which reports in the appendix a list of over 300 experts that contributed to the consensus process. All proposers are key figures in the VPH community.
- EAMBES: the European Alliance on Medical and Biological Engineering and Sciences represents over 8000 European biomedical engineers. Jos vander Sloten is the Vice President.
- VPH Network of Excellence: this NoE network has over 50 member organisations and over 100 additional organisations that are partners of the other 14 funded VPH projects. Peter Kohl is one of the two coordinators.
- VPHOP and EU-HEART: the two largest VPH integrated projects currently funded target two key clinical communities: musculoskeletal (osteoporosis) and cardiovascular diseases. Marco Viceconti and Olivier Ecabert are the coordinators.
- IUPS: The International Union of Physiological Societies has an active working group on integrative research. Denis Noble is the current President of IUPS.
- IEEE: also the Institute of Electrical and Electronics Engineers has created a working group on integrative research, of which Peter Hunter is the chair.
- ARGOS: The EU-USA eHealth cooperation is now being re-valuated from a policy perspective through the ARGOS observatory that recently has started with funding from DG RELEX. Andrew McCulloch and Karl Stroetmann are the US and EU leaders for the VPH arm.

[17] http://www.biomedtown.org/town/biomed_town/VPH/petitions/institute/

Ubiquitous Complex Event Processing (U-CEP)

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BRIEF EXPLANATION

Already since a long time when we try to explain the phenomena of the world, philosophers and researchers are referring to a universe based on events (see e.g. the research about synchronicity of events in modern physics or psychology). The nature of 'events' is not the simple concept of current generations of computing systems. It needs new understandings, methods of handling, and most of all computational resources. An emerging discipline of Complex Event Processing (CEP) introduced the concept of events in the computer science as a new paradigm [1, 2, 3, 4, 5, 6]. CEP underpins all computation that addresses complexity phenomena. As examples:

• Sequences of happenings across time and space require to be captured to model global phenomena in the natural world.

• The world ecology, the bio-model and mankind expressed through Society evolves over time and space.

• Most of all intentional behavior consists of sequences of responses over time and space.

The above statements presume first some understanding and definition of what topology of time-space seems to be relevant to a particular domain. Even in the physical world this is not simple. In the biological world the evolution of the species is not the whole story. Human behavior and social patterns have been discoursed upon since Plato (or earlier, his mentor Socrates).

In today's world, Complexity makes all these aspects very difficult to handle; this is the world of dynamics, interactions, and all the interesting outcomes from emergence including sudden changes in state that forewarn of a need for 'special action'. This is the world of Complex Adaptive Systems. Three examples show why the ability to compute 'complex adaptive systems' is important:

• FuturIcT [C1] has identified critical applications such as: understanding and predicting societal phenomena and behavior including risk management, counter terrorism, fraud management, epidemic, global emergencies etc.

• INTEGRAL BIOMATHICS [C2] examines the fundamental computational basis of bio- and socio-systems. It anticipates the need for a new breakthrough paradigm change towards biologically and socially driven mathematics and computation and the technological challenges of bringing this about. Its goal will be a set of novel mathematical formalisms.

• SOCIONOME-METALOGER[C3] will establish the new science of Computational Socio-geonomics based on the coupling of science and social systems within the new ICT paradigm.

• World Ecology Modeller (S-GAIA) [C4]]has identified that Society is a complex adaptive system and processing its events, the product of intentionality, lies at the centre of improving the outcomes of action.

• Computational event processing applies on vast scales to disciplines as different as Bio-sciences, fundamental energy/matter, the brain and physiome. The list is endless.

Prof. David Luckham/Stanford University as one of the main inventors said about the forecast of CEP that within the next decades the paradigm of Ubiquitous Complex Event Processing is predicted as the precondition of an execution and simulation platform for a lot of more global and interrelated applications. Current computing methods to handle complex phenomena are not well understood or developed and the ability to handle the scale of event traffic does not exist yet. An IBM sponsored report said:

“ .... the transparency demanded by regulation (such as the Markets in Financial Instruments Directive (MiFID)) requires visibility into the operation of business networks, which again is dependent on electronic information flows. Furthermore, the stresses and strains these forces exert on organisations are changing all the time, and this means that organisations have to be able to sense and respond to internal and external changes... “

This is Global Dynamics, Policy management, dynamics of complex interactions, understanding and management of the world ecology . This is the context of Ubiquitous Complex Event Processing.

AMBITION

Vision

Ubiquitous COMPLEX EVENT PROCESSING is an Industry led initiative to exploit the opportunities of the science of CEP into the mainstream of computational practice across diverse fields of science, not just the aspect of computational modelling but the fundamental physical world phenomena exhibited. Elucidation of this discovery will lead to new applications of CEP across the bio-ecological world, and all the artefacts of human involvement and management of this ecology, such as: commerce, industry, government and Society. It will be the ubiquitous applied technology for processing the dynamics of complexity in real world systems. It involves: fundamental science; elucidation of the computational meaning of ‘event‘; development of technologies appropriate to the scale of domains of different event patterns; their incorporation into modelling platforms that are useful to their clients – scientific fields, society, the world ecology.

Science of CEP

The fundamental hypothesis of CEP is that the pattern of events determines the existence, identity, significance and outcomes of every living entity within the biosphere. The complex interactions this hypothesis involves need to be understood observed and the means found to influence them. This may sound like interfering with our world ecology and very existence. In fact the reverse is the case: currently damage to our biosphere is the result of ignorance; reversing this is a moral quest.

The message of many disparate studies is that complex events in the real world are the triggers of action, or even more profoundly, of identity; identifying, processing, and responding to them is the canvas of CEP. Examples show this ubiquity and the enormous variation in scale, that work in combination:

• Chemistry and bio-chemistry are about CEP, studies by scientists such as Professor Peter Plath.

• The discipline of the New Biology of Epigentics studies the environment as a global cloud of signals, energies or so called events are at the end responsible for the way of life of a cell.

• At the level of basic energy and matter quantum physics and the “Heisenberg uncertainty relation” defines events as eddy of quarks and photons that are a high-end challenge for the CEP-technology.

• The human physiome is a united cell structure of 50 trillions of single cells where each cell is doing event processing on the base of its receptors of its cell membrane. So, a human being can allegedly process 120.000 events per second unconsciously (by the right side of the brain), but logically a human can only process a few information units at the same time (by the left side of the brain).

CEP researches and mimics the bio-logic, structures, and methods because it is a computational model of the same phenomena. Event Processing Agents (EPA’s) are actually cells where event adaptors are the receptors of a cell membrane and the event processing logic based on an Event Processing Language (EPL) are the effectors of a cell. Event Processing Networks (EPN’s) are actually a united multicellular structure and so on. The Epigenetics explains how the environmental signals (events) control the activity of the genes. The primacy of the DNA is no longer valid, and the new found information flow is now called the “primacy of the environment”. Recent experiments of The Epigeneitcs have proved that our beliefs and thinking is energy in the sense of environmental signals. The Epigenetics found that all these kinds of environmental signals influence the regulating proteins which control the activity of the genes and that the global event cloud as environmental signals influences and changes the DNS (so called reverse transcriptase). In the realm of society in addition to the bio-cellular model, every construct of social system is a newly designed constellation of interacting cells defined to achieve a social/business/organization purpose. The details are the properties defined in the SOCIONOME of Society.

The Technology of CEP

The first requirement is to be able to construct a model of the topology and features of the global event cloud; in most cases this is itself evolving and always specific to the scientific field of study. However fundamental features can be abstracted, e.g. in the case of complex adaptive systems, and top-level normative models used as templates for designing systems to process that event cloud.

As with most systems oriented work, there is a progression to standardized modeling techniques, a language of discourse that can be applied to construct, 'compile' processable environments to conduct experiments on the observable phenomena. The entire process is iterative and evolutionary. The learning that takes place is to find meaningful patterns in the dynamics of sets of experiment and action. This always involves the relation between experiment and experimenter.

This project will research and devise technological solutions appropriate to the different kinds of entity discussed above, the scale of the cellular interactions that belong to the life of that entity, the specific events and the required response of the entity. In the business/organization world this is the total set of events arising from the conduct of the business/organization at every level from everyday activity to the highest levels of governance within the world ecology. It will position this research in the context of extreme complexity and the tools required to deal with this in the life-cycle of each 'species' of bio-socio life. This can be envisaged as the potential interactions of the entire set of competing and cooperating species and their members, living out their purpose and consuming the resources of the ecology in doing so. This requires processing the dynamics of multi-layered complex events. It requires the relation of multiple ontologies to be constructed and modeled. The technology has to integrate on a scale required to deal with this complexity, involving identification and responses to events in huge numbers of concurrency. The technology involves continuous re-configuring since all facets of the processing are themselves complex adaptive systems.

IMPACT

The fundamental importance of U-CEP is that it reveals the dynamics of the environment of a bio- or-socio- entity which condition that entity to behave in particular ways and to construct and execute strategies to deal with that environment. The question U-CEP answers is how to achieve sufficient mastery of the environment and the events that permeate it, the 'global event cloud', to influence the otherwise chaotic outcomes, or the outcomes determined by alien peturbations.

Ultimately such experimentation across the universe of observable phenomena will lead to new and novel understandings of how anything and everything becomes instantiated, lives out a life, and gives way to some other phenomenological pattern. The most interesting question is that of quantum experimentation: who decides what is really happening?

This would seem to be of immediate import in the social sciences field where the questions of goals, influence, behaviours and outcomes for the world ecology are determined by the models that are designed, but still influenced by clouds of events not obviously triggered by designed models. Resolving such conundrums is of crucial importance.

The outcome of this work will be progressive compilation of ordered views of the model topology and complex event changes to instantiations of this, which are then translated into inferences about what is happening, its significance, and even ultimately its 'meaning'. The latter takes U-CEP into the important realms of human intelligence and consciousness, the paradigms of meaning already constructed, and paradigmatic shifts to new models.

INTEGRATION

U-CEP requires the twin worlds of domain behaviour and computational advances to be combined in order to design and execute experiments and operational environments that process complex events. The reality of CAS is there is no deterministic solution in advance or ever. As the IBM Paper said:

" Although event processing technology is not trivial to understand, you need to find ways to get IT specialists working with business domain experts.... Domain experts have the most useful insights into significant events and patterns, decisioning rules and actions – the "content" for event processing systems – ''U-CEP research concerns fundamental questions that are both universal and specific to each area, typefied by the following example areas that is a conceptual canvas of the required research:

1. David Luckham's forecast 2008 – from Simple CEP to Ubiquitous CEP in an event-driven world

   1.1. Which are the applications of Ubiquitous CEP of the next decades? Neuroscience, Epigenetics, Brain Research, CERN Large Hadron Collider, Higgs Boson, …

2. Ray Kurzweil's understanding of CEP – "Singularity is Near"

   2.1. Mapping of Ray's and David's forecast until 2050 and beyond

3. Enhancing human intelligence and cognitive or physical abilities

   3.1. Jeff Hawkins's understanding of CEP – "On Intelligence"

   3.2. Memory-prediction framework

   3.3. Prediction and (event) patterns

   3.4. Intelligent machines – based on a layered CEP like human brain's cortex

   3.5. The Blue Brain project – Henry Markram (EPFL Lausanne)

   3.6. Brain Computer Interface – Kevin Warwick (Reading University)

4. Epigenetics and CEP – Bruce Lipton's "Biology of Belief"

   4.1. Cell membrane as an organic information processor, receptors, effectors, protein machinery, reverse transcriptase and event processing, an individual as a combination of fifty trillion of collaborating event processing cells

   4.2. Event adapters, Event Processing Agents, Event Processing Networks as the analogy of CEP

   4.3. Epigenetics-research-portal for Germany, Austria, Switzerland

   4.4. Rationale of EU FET-program: Biological cells are highly sophisticated, chemical information processing systems, capable of responding to changing conditions. The information processing capabilities of such systems could be exploited by future information technologies if this 'information chemistry' could be 'programmed'.

   4.5. General objective of EU FET-program: Develop the foundations for a radically new kind of information processing technology inspired by chemical processes in living systems. Enable the development of ICT systems and devices that utilize interactions between components to assemble complex functional information processing materials. The research should enable a new generation of systems capable of interfacing with conventional IT systems that are self-replicating, selfrepairing and/or capable of rapid adaptation/evolution as well as flexible reconfiguration in response to changing conditions

5. Brain research and CEP – the long and the most recent discussion about "Free Will"

   5.1. The position of the brain researchers Wolf Singer, Gerhard Roth et al.

   5.2. The world as a deterministic whole based on Event Processing

   5.3. Concerns, e.g. of Jürgen Habermas

   5.4. The Blue Brain project – Henry Markram (EPFL Lausanne)

   5.5. Brain Computer Interface – Kevin Warwick (Reading University)

6. Consciousness and memory technology – Storing, modifying, transferring of consciousness and the relation with CEP

   6.1. Theory of Hans Moravec, Otto E. Rössler, Ray Kurzweil

   6.2. Concerns, e.g. of Klaus Heinerth, University of Munich

   6.3. Individual consciousness, consciousness of groups, cosmic consciousness (Jörg Starkmuth) – what would we store, modify, transfer?

7. Universe and Events – Large Hadron Collider of CERN

   7.1. Higgs Boson, Higgs Field, Big Bang, From energy to matter

   7.2. Event processing at CERN means:

- 600 millions events per second, a lot of sensors for different event types

- event filtering, event enrichment, event processing as cloud computing by more than 100.000 computers, at present C++ coded

- goal: find the Higgs boson

Questions to be discussed could be:

- strategy for the detection of Higgs boson

- can be solved by a CEP approach?

- what kind of EPL would be appropriate?

- is there a need for a flexible and fast changing EP-logic?

Etc.

8. Computational Socio-Geonomics

8.1. Concept of Weak and Strong Emergences à to be mapped on Complex Events

8.2. An ICT platform for Social Simulation means:

- around 10 billion human agents in future

- millions or even billions and trillions of events per second,

- a lot of sensors for different event types ("smart dust", foglets)

- appropriate modeling approach for simulation scenarios

- easily to use and domain-appropriate Event Programming Language

9. A list of use cases and scenarios from the Zurich workshop "European FET Flagship Initiative":

- interdisciplinary and systems thinking to advise private and public organizations on such matters as diverse global trends, plausible scenarios, emerging market opportunities, and risk management

10. Discussion about future interdisciplinary CEP-based projects:

10.1. SmartHealthcare and Diabetes: Simple CEP/ed(B)PM?

10.2. SmartHealthcare and Depression: Depression - A defect of Event Processing?

10.3. SmartEmergencyManagement: City/Location specific emergencies as Simple CEP/ed(B)PM versus global emergencies taking the example of Solar Storm 2012

10.4. Brain Research: A new Libet experiment regarding Free Will based on CEP?

The application of U-CEP thinking has been accepted as a relevant discipline in the FuturIcT project Virtual World Modeller (VWM) where it will lead the focus on complex events and the technologies to handle them.

Thus this project will provide insight into the fundamental questions to be asked, and hopefully reach some conclusions leading to processable constructs, that term applying to both the modeling framework and its computational representation.

PLAUSABILITY

As stated above, computing has always addressed 'events'. The new work envisaged in this project is to raise the level of this to the ability to deal with the phenomena of complex events, occurring in vast numbers and scales.

Progress Beyond the Current State of the Art

The drivers for this research are the growing recognition across every field of science that their phenomena are rooted in the basic questions regarding what determines their existence and how is this manifest in observable, measurable, and predictable collections of entities and events.

The above definition is a blueprint for the construction of a model, also termed a hypothesis, that relates to existing Frames of reference in our world, and that can be translated into a computational form. Since it is now becoming clear that complexity is the nature of all phenomena even where limited abstractions are amenable to deterministic rules, a convenience to support bounded reality, there is no alternative game in town. The pursuit of modeling in both domains and computers is ubiquitously directed to addressing indeterministic systems.

Road Map

The outcome of this effort is leading both real-world experimentation and computational representation to new fundamental methods and solutions. The experimental means are the focus ahead of its application to derive insights, answers and real world action.

The infrastructure for this is a combination of pure science, applied science, technology and engineering, and the application of all these fields of research in real world applications. The practical signs of progress and achievement are the formation of institutions to oversee the progress, consolidate the research, and command the resources and funding to deliver results. The following are specific examples:

• The Complex Systems Society is spearheading the drive to bring the science into the mainstream of practical application, especially science and computational methods

• The Event Processing Technical Society has been formed to spearhead and consolidate the many disparate efforts to deliver practical computational approaches by industry. It is leading the required drive for standards and methods that will avoid the Tower of Babel syndrome

• Events, Conferences, practical applications and pure science are underway in many fields.

Aspirational dates, forecasts until 2020 and Beyond, e.g.:

• See the forecast of David Luckham [1]

• See the forecast of Ray Kurzweil [7]

All these are the real signs of a new branch of science moving from theory to practical use.

Implementation

Benefits

This project will bring the science and technologies of Ubiquitous Complex Event processing into the mainstream of ICT and all the real-world applications dealing with complexity.
Conclusions

U-CEP is a critical new field of pure and applied science and engineering that will deliver ICT capability that can support the solving of practical problems involving critical time and space based dynamics (where these dimensions also include further levels of abstract ontological entities). It is thus a critical component of many fields of enquiry involving real-world complex adaptive systems

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COMMENTS

The following is a list of typical active partners; it is only a sample:

• The World Society Modeller (S-GAIA) Consortium

• The Event Processing Technical Society (EP-TS)

The most of the FET proposals are based on some features of the Future Internet (FI).

• European Future Internet Initiave (EFII)

• Networked European Software & Services Initiave (NESSI).

Although we will and have to cooperate with the organisations around FI (e.g. providing an event streaming interface to FI), the research topics of FI and U-CEP will be carefully separated.