ICT 2010

Discussing research trends and key policy options

"Digital Roadmap to the Future"
Session Report

Authors: Bojan FURLAN [1], George PENTAFRONIMOS [2]

Affiliations: [1] University of Belgrade, School of Electrical Engineering
[2] University of Piraeus, Informatics Dept.

Reviewer(s): Franco ACCORDINO, European Commission

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What are the changes that hold promise for new societal and economic revolutions which will dramatically change our life? How to pave the way for new forms of disruptive innovation, ensuring balanced, long term growth and prosperity?

Being a neuroscientist, rather than an ICT researcher, Prof. Henry Markram elaborated on the primitive mechanisms that the brain uses, to satisfy basic operational requirements such as energy-efficiency, resilience, robustness, memory, storage, transmission and visualisation. Based on the fact that the same principles also constitute the fundamental challenges that ICT in general faces, Prof. Markram outlined the digital roadmap to the future by projecting the operational sophistication of the human brain to the potential technological advancement in ICT.

Looking back to the history of life and adopting this wider perspective in order to look forward in the future, Prof. Markram argued that while humans are only six minutes old, embryos in fact, the technological advancement of the last 60-70 years denotes that computing is probably the biggest man-made growth of all times. Considering that nowadays there is a million billion times increase in computational power, which by 2040 will have reached the yotta-scale thus enabling quantum computing and providing the opportunity to "search and find anything in an instant", he underlined that the key point to that direction is "massive everything". Referring to emerging architectures (i.e. accelerators, vectors, specialized circuits, FPGAs, GPUs) and the diversity of modern computational paradigms as well as the tendency to go multi-everything and even smaller in size, he specified a number of current system trends i.e. environment-friendly; energy-efficient; open systems software; fault-tolerance; self-repair capabilities; intelligent processing and biomimicry. Moreover, given that people demand intelligent interaction with technology, he emphasized that not only it is inevitable that ICT will become more human-like, but also that this is already becoming a reality. Again, he underlined the fact that "if we can adopt the principles of how the brain solves similar problems we will introduce radical transformation in ICT."

Regarding energy-efficiency, Prof. Markram argued on how computing will manage to reach the goal of 20 MWatts of energy consumption for exa-scale systems (instead of the 3 GWatts required by three-year old technology) by pointing out the brain capability of active power management, where only parts involved in information processing are powered. Therefore, the goal is to reach higher computational speed while lowering energy requirements and it is one of the characteristics that modern systems have only recently begun to provide either at the microchip or at the system level.

As far as resilience and robustness are concerned, it can be examined an interesting human ability of getting wiser in time, although the thousands of neurons are dying every day. Furthermore, despite the fact that neurons and protein flip-flops are billion times slower than circuits in modern processors, the brain still has better performances. Prof. Markram explained that the diversity of morphology is the secret to this behaviour, given that each neuron holds many tiny fragments of different types of information. It is realized that all information is totally distributed and no single point of failure exists considering the number of each neuron's synapses. As a result, dynamical decision making is enabled by the contribution of many neurons in every computing operation. Thus, diversity confers robustness and is able to provide graceful degradation.

Memory and storage are other challenges which will get more demanding in the future given the massive amount of new data that is constantly created. Observing the brain's efficiency by reusing past memories for storing new ones, Prof. Markram pointed out the combinatorial algorithm that brings together all distributed tiny fragments of specific information as the solution to this problem. In addition, he referred to the basic principles of fragmentation, distribution and combination, by not duplicating any piece of information that is already stored in memory, which will introduce the most compressed way of storing data. Similarly, speaking about transmission and its tendency of doubling bandwidth every 2-4 years, it is realized that there is a software bottleneck due to the fact that all amount of information should be transmitted. Therefore, future systems should be able to reconstruct information within a particular context only based on a hint or a clue, rather than requiring all information to be sent to the receiver.

As a final point, the speaker referred to the significance of visualization and considered it as probably the most critical brain's principle and ICT's challenge. For that reason, the radical innovation is required in order to be able to merge computing and visualization like the brain does. Moreover, trying to understand how this is done will bring us to the new solutions in ICT which are absolutely indispensable to move forward in the exa-scale computing era, thus enabling the evolution of real-time digital holography.

In conclusion, Prof. Markram emphasized that one of the key challenges is to understand cognition, which perhaps can be achieved by simulating brain functionalities. Also, he predicted that at the end of 21st century the aforementioned basic principles will lead ICT innovation, thus enabling the evolution of supercomputing, simulation-based sciences, post-genomics and bio-mimic ICT.

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Immediately after the keynote speech a panel session continued moderated by Clive Cookson (Financial Times, United Kingdom), where participants discussed the major transformative trends in ICT and the next scientific breakthroughs that will shape future technological developments and application scenarios.

Talking first, John WOOD (CCLRC, UCL, United Kingdom) focused on future research environments. He underlined that doing research today does not demand physical presence anymore as it can be carried out from various locations by remotely accessing computing resources. This type of infrastructure allows coping with the "whole body" problems, brings many diverse disciplines and techniques, thus introducing multidisciplinary. Some of the examples are working at the frontiers between computer science, biology, sociology and neural sciences to advance understanding of the intrinsic mechanism of life. Therefore, an important issue can be identified by inter-disciplinary research and enabling infrastructures. Another point represents diversity and amount of data from various scientific domains, posing a new profile of researcher that could cope with data on an exa-byte scale. This raised a question on how would it be possible to train academics on how to train their students to work in this new environment.

Christian JOACHIM (CNRS, GNS-CEMES, France) underlined the significance of reversed miniaturization, where the focus is not on miniaturizing computing devices, but rather on building them atom by atom using nanotechnology. This could lead to new forms of life that cannot be observed in nature or even building the brain, as he wittily stated. Therefore, the key question that is raised is about how many atoms should be used for building those devices and how to integrate them into large scale systems to support novel classes of applications.

Dieter FELLNER (Fraunhofer-Institute, A0, Germany) draw the attention to a parallel between the era of digital libraries and today's way of information handling and storing. At the beginning of documents digitalisation, raw paper texts were converted to digital form (by OCR) and today, almost whole content is directly published digitally right from the authors. In the same sense, an evolution for handling and storing 3D objects and elements from the 3D Internet, needs to be initiated. Most of today's applications produce digitally born artifacts, but the way how they are stored and thus, retrieved is still primitive, mostly characterized by simple text search. Therefore, the main goal is how to keep the semantics captured from the user interface by storing different type of content, such as multimedia files.

Roberto SARACCO (Telecom Italia, Future Centre, Italy) addressed the problem of how to shorten the path from technology evolution to innovation and how to justify high risk research in order to be funded by industry. In addition, he emphasized that high bandwidth, all-present embedded devices and software will initialize technological revolution by moving industry from production to delivering services.

Martin CURLEY (Intel) focused on concepts of digital transformations, sustainability and mass collaboration. Since Moor's law is almost finished due to the fact that today's microprocessors are just two generations away from the point where temperature inside the core will be on a level of rocket nozzle, one way to cope with this problem is to shift from single core to multi core and ultimately, to many core microprocessors. Looking in that direction, there is the light at the end of the tunnel taking into concern arising paradigms like single chip cloud processors and billion way parallelism.

Zoran STANČIČ (European Commission) described key political steps in order to support aforementioned visions about future research. Some of the activities and policies aimed to address this issue include e-Infrastructures, R&D investments in Public-Private Partnerships, science driven research, SMEs involved in the high risk research and initiatives for shortening the path from research to innovation.

Mr Cookson introduced a further discussion on e-Infrastructures by asking Mr Wood to provide their viewpoints on a couple of critical questions. Firstly, whether the actions taken by the E.C. to move towards e-infrastructures are adequate and secondly, looking a little further, "what will these scientific infrastructures look like in 2030. Where are we headed?". Mr. Wood, based on his experience as chairman of the European Strategy Forum for Research Infrastructures (ESFRI), apart from sharing the opinion that the democratisation of science and the citizens' access to these environments will soon be a reality, remarkably posed the dilemma whether it is worth investing on this domain considering that it will not be needed to have physical research infrastructures in order to face the upcoming competition. Also he underlined the needs of East European countries regarding research infrastructures and as a closing remark, he added that Europe is still far behind in the way large-scale facilities are used. Furthermore, Mr. Cookson asked Mr. Joachin to provide his opinion as a researcher. Remarkably, Mr. Joachin mentioned the fact that although the way researchers work inside labs in general will remain the same, there is a lot to be done in terms of a cultural changeand in the way researchers are educated to cooperate with each other and overcome the traditional lab-to-lab boundaries.

Following, Mr. Saracco mentioned the upcoming requirements for wireless infrastructures which will need a pervasive fiber network that can attach many antennas all around. Moreover he envisioned that in future the devices will become the infrastructure themselves as they will all be able to operate as base stations and communicate with each other using the lower layer of the spectrum and nano-antennas, while on the other hand he underlined issues like channel limitations and the devices' energy-efficiency and computation requirements. His closing remark was that "the more antennas we are going to have the less the pollution will be, given that less energy will be needed" and envisioned that in the second part of this decade there will be very pervasive wireless access while in the next decade unlimited bandwidth will be a common reality. Being asked whether industry is able to provide what Mr Saracco talked about, Mr Curley replied positively mentioning the advancement of current research while he underlined the need for mass collaboration and investment.

Raising the crucial issues of future user interfaces and data privacy, Mr. Cookson addressed to Mr. Felner who immediately advocated to the previously expressed view that "technology is, there but we have to agree on the rules". Regarding future user interaction with technology he believes that in the next few years this will be realised in a natural way given that closed loop applications will allow partial visualisation during the computation, in contrast to today's common practice to firstly compute data and then visualise the results. In this way certain re-changes and re-adaptations will be possible, thus enabling integrated computational steering.

Moreover, Prof. Markram raised the debate between the need for information to be free and privacy, underlying the role and responsibilities of the citizens. Adding to this he mentioned that the solution to this problem can be searched in the fact that people are the unique key that unlocks their own data while the level of sharing is an individual decision. On the other hand, Mr. Saracco shared the opinion that although privacy is valuable, at the same time it is stopping us in leveraging from the Information Society and for that reason he proposed to consider privacy as a subset of ownership and provide the analogous technologies.

Talking about quantum computing Mr. Joachin indicated a number of critical factors that are required to accelerate the development and commercial exploitation of this new technology. Specifically, these are: education, time, money, risk, and extractors, that is, people able to extract knowledge to create a new business. Mr. Curley identified the need for concentrated efforts on how to codify and explain Information Science in the same way as another significant innovation of the century was, namely electricity. Additionally, Mr. Wood underlined the need for high risk pre-commercial Procurement in order to support innovative developments and Mr. Stančič, expressing the ambition of the E.C. , agreed.

Notably, Mr. Saracco identified a similarity between electricity and ICT in the fact that from an economical perspective, the critical factor is not the applications or services provided but rather the available infrastructures and the level of pervasiveness. The current shift towards this direction will enable anyone to develop and deliver services thus, boosting innovation and multiplying the economic value of ICT. Replying to the question on quantum computing, he also draw attention to the fact that while until the end of this decade it will be feasible to factorise numbers, this innovative technology undermines existing foundation for the secure establishment of various payment transactions (e.g. PKI) and this will cause serious problems in the future. Following, Mr. Felner came back to the subject of pre-commercial competition underlying the need for high-risk research and under certain circumstances the disconnection of research funding with the evaluation of the final results.

Finally, referring to the book "The Nature of Technology" Dr. Markram remarkably identified the need for innovative technological solutions that succeed in leveraging existing scientific principles rather than metabolising and consolidating previous technologies. This way ICT will leave incremental development and meet radical innovation.

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At the end of the discussion a comment was made on the fact that no women were in the panel and this raised further awareness in developing appropriate policies and providing career opportunities for women so as to achieve diversity, which is absolutely necessary in all sciences. Adding to this, Dr. Markram elegantly provided the case of India as a vivid example. Also the issue of science democratisation was raised and all panellists agreed that citizens should not only use technology but also to provide their valuable feedback in order for future developments to have greater impact. Moreover, the need to include citizen-scientists or cyber-scientists in research activities and extend e-infrastructures to all scientist communities was identified while Mr. Saracco referred to a program for educating students in a different way, such that to enable them to educate their parents regarding technology. Generally, he argued that the Italian government is moving fast towards the e-government reality. Then, Mr. Cookson asked Dr. Markram about other forms of biology applied to computing. He replied that neuro-prosthetics is a technology that will become more and more sophisticated in the future. On the other hand there are major problems with interfaces and long-term stability while Mr. Wood raised the ethical issues that come up when facing mental illnesses in terms of the medical actions that should be taken. Finally, Mr. Curley asked Dr. Markram whether it would be possible to simulate brain when 7 or 8 billion people will be completely interconnected with high bandwidth speed and Dr. Markram replied by referring to the emerging properties that will come up while at the same time underlying the fact a system that process faster than the brain cannot be considered as better than the brain.