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Combining ICT and Cognitive Science: Opportunities and Risks

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Purpose

Many experts think that the technological convergence of previously separated sciences like nanotechnology, biotechnology, information and communication technologies and cognitive sciences will have a deep, long-term impact on society and economy. Key actors in society need to become aware of the challenges linked to converging applications (CA) and take decisions in support of developing them. By analysing CA-related opportunities and risks at a very early stage, we hope to contribute to reducing possible adverse effects in the future.

New on the Agenda: Converging Technologies and Applications

Quite often, societal concerns about technological convergence are polarized into extreme positions. Supportive positions, like the one by the National Science Foundation (NSF) in the USA, see converging technologies/applications as a solution for many (societal) problems and dilemmas. They expect much cheaper and cleaner technologies that will lead to improved human health and welfare. They argue that the convergence of technologies and applications will bring rapid improvements to 'human performance'. Others, however, stress the possible detrimental effects of converging technologies and applications on health and safety, equity, environment and privacy. Currently, only a few non governmental organisations (NGOs), like the Canada-based ETC Group, have expressed a formal position on converging technologies. In the ETC Group's view (2003), neither governmental programmes on converging technologies nor any of the specific projects proposed in the NSF report should go forward without a broad process of social consultation.

In 2004, the European Commission published the so-called CTEKS report in reaction to the report by the NSF and the technology-driven discussion in the United States and as a contribution to the debate from a European perspective. It identified four characteristics of converging technologies and applications:

Embeddedness: converging technologies (CT) will materialize in services and products that are pervasive and inconspicuous. The combination of nanotechnology devices with information and communication technology (ICT) infrastructures (mobile), intelligent actuators and sensors allow to construct an artificial environment by which CT devices are embedded within the human environment. For instance, CT devices can be injected into blood vessels and used for microsurgery and communicating and controlling specific bodily functions, as they are almost invisible.

Unlimited reach: the potential of CT devices is almost unlimited and they could be used to enhance human functionalities in ways that were previously impossible. This may relate to internal functionalities (pertaining to the control of specific diseases for instance) or to external functionalities such as human communication patterns.

Engineering the mind and the body: CT devices may be used in micro-scale engineering, and they may extend its domain from 'traditional' micro-scale engineering, such as DNA-replication, towards engineering of the mind. The CTEKS report makes a plea for engineering *for* the mind (and the body), rather than the more threatening engineering *of* the mind. This clearly indicates the normative challenges that CT will pose for society in the future.

Specificity: the instruments developed at the crossroads of biotechnology, nanotechnology and ICT enable a focused and specific use in, for instance, binding pharmaceuticals to specific DNA-profiles so that unwanted side effects can be avoided.

These four characteristics offered a starting point for a preliminary analysis on opportunities and risks of converging applications as a broad pilot study.

Objectives: Improve the Quality of Debate

The research project had the following objectives:

- to review existing literature and structure information in order to initiate discussion on opportunities and risks resulting from converging applications;
- to provide a starting point for setting priorities for discussion on research and strategy within and between the various fields;
- to formulate and structure relevant open questions on opportunities and possible risks of CA;
- to contribute to a balanced discussion on opportunities and risks and further work on this topic.

Methodology: Literature Review and Expert Interviews

The analysis is based upon a literature review complemented by ten expert interviews carried out over the telephone. The interviewees were natural and social scientists familiar with the topic of converging technologies and applications.

As CA is a very wide and diffuse field to analyse, the main focus in this foresight brief will be on the impact of the convergence of ICT with cognitive science (CS). The CTEKS study identified the cognitive sciences as an important emerging field of converging technologies and applications. For the sake of clarity, this brief will focus on three specific areas at the intersection of cognitive science and ICT, as identified by bibliometrical research as major foci of mutual benefit between ICT and CS:

- human brain interface,
- speech recognition,
- artificial neural networks.

Main Findings

Human Brain Interface

The brain-machine interface (BMI) is an example of a medium to long-term application field with wide-ranging consequences and a number of concrete challenges. In addition, ethical aspects are very important according to an international study group that developed a roadmap of neuro-IT development. Recent progress in fundamental neurophysiological research gives the impression that, in the near future, visions from science fiction movies like implanted electrodes may become possible (*technological-scientific dimension*). The human brain could be directly interfaced with computers or embedded in external devices. Information gathering and processing devices could be incorporated in the human body. However, we are still a long way from these applications in real life.

All current prototypes are basically one-directional, generally from the brain to the external environment, with no feedback loops, that is, two-way information transmission. For real life applications, like the control of paralyzed limbs or complex prosthetic devices, bi-directional interfacing will be necessary so that the brain can use its sophisticated feedback control strategies. In addition, a number of technological challenges, such as better sensory input or better understanding of neural coding of primary motor regions, have to be solved before this highly invasive technique can be applied to humans.

Bi-directional brain computer interfacing (BBCI) holds great promise in the treatment of neurological and trauma patients (*health dimension*). Before doing this kind of treatment, it is necessary to identify the exact brain regions for electrodes to use BBCI for specific tasks. Furthermore, real-time encoding/ decoding software for brain input/output signals are needed. Further work on improving BBCI techniques, and also alternatives to implanted electrodes, must be done.

As regards the *ethical dimension*, science, society and business in Europe have to decide what should be done if invasive technology causes brain damage. If it does, would it be acceptable to patients? Would chirurgical interventions be acceptable only to disabled or also to healthy people? When is it acceptable to the public? How could the public or stakeholders be involved in such a discussion? In addition, it may be that brain plasticity interferes with the normal operation of the human brain. These are all open questions to be addressed when shaping this converging technology.

This is an example of a converging application that could also have a great impact on European society (*social dimension*). There may also be clear cases of misuse. Mentally upgraded individuals (as shown in some science fiction movies and novels) could theoretically establish new collective forms and dominate society. Although this is still only fiction, it might be worth thinking about the *legal dimension* and European regulatory issues (*political dimension*) at the very early stages of development in order to avoid controversy similar to the one surrounding green biotechnology, where balanced views have been hard to come by. Another interesting question concerns the possiblity of arising socal pressure; for instance, under which circumstances should disabled people or their healthy peers have the opportunity to reject using BBCI and be able to continue their lives as they did before.

Since interfaces to the human brain are in the very early stages of development, the long-term *economic dimension* of these converging applications is not clear. A number of scientific, business and social questions are still open and would need to be addressed before assessing the economic impact. They include: Is there a critical mass of scientists and private companies for developing human brain interfaces in Europe? What role do large companies and SMEs play? What is the economic potential of human brain interfaces and what are the economic risks? What kind of public funding (*political dimension*) is necessary for the development of applications and products that are competitive on international markets? How could stakeholders be involved in finding a common ground for applications and products that are broadly accepted by the public?

Speech Recognition

From an economic perspective, speech recognition is very promising since it is a major development in the convergence of ICT and the cognitive sciences in the short and medium-term and has enormous implications for the way we will work and live in the future (*economic dimension*). According to Lawrence Rabiner, speech recognition aims to accurately and efficiently convert a speech signal into a text message independent of the speaker or the speaking environment. The challenge is to make speech recognition systems robust irrespective of the surrounding acoustics so that they also function well in cars or environments where cellular phones are typically used. A range of signal-processing methods for speech enhancement, noise removal, speaker normalization and feature normalization have been proposed to solve the problems associated with noisy environments. The key challenge is to develop easy-to-learn interfaces between humans and machines for advanced services that are as simple as voice telephone is today (*technological-scientific dimension*).

In the next few years, this area of converging applications is expected to play a major role in cars, mobile phones, personal computers, handheld devices and even household equipment, for instance washing machines. International companies like IBM, Philips or Miele and a number of European SMEs are very active in this field. According to a market prognosis by Frost & Sullivan, the market volume for 2006 in speech recognition technology will be $ 700m in the US alone and further growth is expected in the following years. The market volume and the growth tendency is about the same (*economic dimension*). International agreement on standards for software and hardware would be beneficial for rapid deployment and exploitation of this market potential.

Widespread use of speech recognition applications would not only save costs for the businesses concerned but would also have profound implications for the way we work. Speech recognition would make working with personal computers much easier and thus more productive. In addition, the nature of office work could change as certain ‘simple’ and repetitive tasks would be reduced (*social dimension*). For this reason, a discussion on upside (de-skilling of work) and downside (re-skilling of work) adjustment between the stakeholders might be very useful to find new satisfying concepts of work for highly skilled and less skilled workers. Additionally, it is difficult to predict how social life and privacy could change. Abuse or misuse of this converging technology seems possible. Would speech recognition provide better learning tools for instance for learning a foreign language in a more efficient way? Would everybody who wants to have access to such systems (*ethical and social dimension*)? As regards the *political* and *legal dimensions*, how could public authorities support the development of international standards? Furthermore, it could be very important to find new ways of funding basic and application-oriented research on speech recognition.

Artificial Neural Networks

Artificial neural networks could be widely used in industrial applications in the long-term (*economic dimension*). However, according to the roadmap of the international “Neuro-IT” network, in the majority of cases industrial applications have been very specialized and of limited economic significance. The difficulty of moving from the laboratory into the field is at least partially due to a number of intrinsic weaknesses in current technology, which in many cases coincide with areas where artificial models have little resemblance to natural processes. Traditional artificial intelligence (AI) applications, such as machine translation, data mining or intelligent software agents, have been far less successful than originally forecasted because of unresolved technological hurdles. To overcome this, it will be necessary to make substantial progress in complex algorithms that can emulate human and animal cognitive competencies in artificial neural networks (*technological-scientific dimension*). There seems to be an increasing perception that established software engineering concepts are not sufficient to overcome these scientific challenges and that it would be beneficial to explore the suitability of alternative – yet less developed – models and methods of evolutionary biology (e.g. gene regulation and expression in the evolution of novel phenotypes, the roles of gene duplication). Artificial neural networks are based on abstract models of biological neuron and synapse functions. An important aspect is that the artificial neural networks are able to learn and to generalise from what they have learned.

Future applications and products (*economic dimension*) could, for instance, be ‘elastic’ designs for autonomous robots, highly flexible software for pattern recognition and categorization, self-adapting systems for the protection of autonomous systems against threats or hybrid chemical-computerized development environments. Currently, it seems that there is enormous future economic potential should a number of technological-scientific breakthroughs materialise. Besides, it seems that introducing the advantages of these types of technologies into the debate with stakeholders might also be a necessary element in the process of technological evolution (*social dimension*).

As some research into artificial neural networks is driven by the long-term vision of creating artificial intelligence, the *ethical dimension* becomes important. Would this development lead to the ‘end of nature’ as Bill McKibben feared in 1990?

Or is it an illusion that the world is human-generated and human-managed independently of nature? These and other more fundamental questions have to be considered when discussing the 'intrinsic limitations' of human beings. Apart from this, long-term *legal and social questions* arise – for instance, what legal status should artificial neural networks in Europe have? And finally, what kind of public funding and decision making process (*political dimension*) is necessary for an ethically sensitive development of competitive applications and products?

Prospects of Successful Utilization

Expectations

Many experts believe that technology convergence will lead to ground-breaking innovation in science, business and society in the 21st century. The prospect of large potential has generated a high level of expectation, particularly on the side of researchers and industries likely to exploit it. Tangible products, however, are still in their early stages since converging applications are less developed as compared, for example, with more 'traditional' biotechnology applications and products. For any possible strategy, it is necessary to take into account the long-term nature of CA, the long-term time schedule for socio-economic returns and the risk of pushing a short-term hype.

Economic Potential

The innovative potential of converging applications can be leveraged when technological possibilities are matched with real user needs. To analyse these 'matching patterns', adequate platforms of cooperation between science, industry and other relevant stakeholders are necessary. This would allow the identification of 'show stoppers' (in the sense of innovation obstacles and dangers) at an early stage. Such platforms could be based on round-table discussions between all relevant stakeholders (also including the representatives of NGOs). A differentiated monitoring of the economic potential may point out trends and possibilities, which may facilitate investment and (public) funding decisions. The predicted economic potential may be analysed, for instance, in health care, entertainment and markets for the European ageing population.

Sectorial Considerations (the Case of Health Care)

In times of an ageing population throughout Europe, the health care system may benefit from using converging applications and products. New diagnostic and therapy procedures offer various opportunities for patients as well as for the health care systems in general. The various uses in medicine could be stimulated by an analysis of the broad spectrum of medical applicability and preventive medicine.

Technology Acceptance

One option for promoting the acceptance of CA in the ageing European societies is to highlight the potential for future applications by referring to existing products, such as pacemakers or hearing aids. For this, scenario building exercises might be very helpful. From short, medium or long-term societal scenarios we could learn more about societal and individual requirements and reservations concerning converging applications. It might also be interesting to think about how to integrate the perspective of intergenerational justice between young and old, rich and poor, and non-disabled and disabled into the analysis.

The relevant stakeholders, like science, business, politics and NGOs, follow different logics of action. Therefore, societal scenarios could also contribute to a common language, clear parameters for the scientific community and a better understanding of the real needs of users and the product world. Furthermore, it might be asked, how successful dialogue processes between experts and citizens can be organised. The effects of converging applications on special policy areas and their specific structures (e.g. economic policy, health policy, social policy and housing policy) are unexplored. It is worthwhile to get more information about the possible impact of converging applications in special policy areas. Converging applications could be one very interesting model for tackling the challenges of ageing societies in Europe.

Sources and References

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