*Grand Research Challenge*

# Brain-supportive Computing

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**Grand Research Challenge:** *To study and develop techniques allowing next generation computers to directly cooperate with, or become integrated with, the human brain, thus greatly enhancing human capabilities both in the form of an individual as well as in the form of society.*

Traditionally, computer architecture research and development has concentrated on designing stand-alone machine systems, performing some pre-defined (programmed) computation tasks, be it in a centralized or a distributed manner. The utility of such systems for humans has either resided in a seamless, automated operation of large industrial or information systems, thus removing or reducing the need of human action and supervision and enabling large-scale automation, storage and processing, or in facilitating various business and leisure oriented human activities, such as communicating, text editing, planning, gaming, socializing, etc. Systems of the former type typically exist as standalone or networked large-scale computer-systems with terminals, whereas the latter type typically consist of the computing apparatus and some form of a human interface. Massive deployment of such systems in the developed world has led to in enormous increase in productivity and efficiency of the developed societies, as well as to many novel opportunities for individuals in the areas of education, health care, entertainment, and others.

The common aspect of these systems and devices is that they do communicate with their human administrators or users using an interface readable to the human senses, e.g. a readable screen or an interactive voice response. Thus, the results of the information processing, or computing, task, is first communicated to the brain through the senses, and only than the human brain can take advantage of the results in its own specific way.

Recent advances in neurophysiology, communications and integrated circuit miniaturization bring the opportunity to push this paradigm to the next level - to allow the next generation computers to directly cooperate, or even become integrated, with the human brain itself, thus greatly enhancing human capabilities both in the form of an individual, as well as in the form of human society. Although exact means of benefiting from such design can only be considered speculative at this stage and may pose a significant research challenge, obviously the opportunity here is enormous.

The capabilities of individuals may be greatly enhanced by for example strengthening the individuals' memory capacity, by improving the speed of processing of the sense-derived information or by enhancing certain pattern matching capabilities. New opportunities can be seen in making individual experiences accessible to large groups of humans, thus greatly improving the learning and training process. Likewise, such functionality may be used to keep the brain fit by constant training or challenging, or by quick problem discovery. Manifold linguistic capabilities may be acquired directly by the brain. A database or an add-on engine may serve as a means of support in life-threatening, or emergency situations, as well as an off-load for boring, routine tasks, which can be automated and thus saving brain resources for more demanding, or exciting, tasks. Increased multi-tasking may become available to individuals using such well-defined resource sharing. Furthermore, new distributed paradigms can be thought of by distributing brain operations using direct communication between individual brains and thus creating a powerful collective brain of a unit consisting of multiple humans. Novel means of collaboration can be envisaged, as well as of more productive organization of human activities, and of whole human societies.

Naturally, research challenges of such approach are numerous. Among the most pressing would appear:

- *Security and Privacy:* enabling direct access to an individuals brain may pose the greatest challenge in protecting against security and privacy threats as yet, for a malicious use could allow to control or manipulate the individual himself or herself, a totalitarian dream, but hardly a desirable goal;
- *Safety*: brain-supporting engines might prove harmful in many different ways to humans. Firstly, individuals may be harmed by a failing or misbehaving device. Secondly, a malicious attack or misuse of the device might be easier to carry out than an attack on the person himself or herself. Thirdly, the capabilities of the brain itself might degrade over time through the use of supporting engines, thus leaving the person less capable and more vulnerable. Fourthly, and perhaps most importantly, the impact of any such impairments on mankind as a whole, on its genetic development and possible degeneration, would have to be seriously considered and evaluated.
- *Brain-to-Machine Interfacing:* as of today, no viable means of interfacing to the human brain are known apart from the interaction through the senses, or perhaps by stimulating the pain receptors or some primitive forms of radio-magnetic interaction. Enormous amount of research into various tissues and neuron signal-generation methods would have to be conducted in order to develop mechanisms capable of seamlessly interfacing with the human brain.
- *Brain Operation Understanding:* although significant advances in brain operation research knowledge have been made in recent years, much is yet to be discovered to fully understand the ways a human brain operates. Without such understanding, it is impossible to clearly identify opportunities for tasks that the human brain might benefit from being helped with.
- *Novel Brain-supportive Computing Methods:* this challenge is strongly related to the previous one, however clearly distinct. Novel computing paradigms, different from the traditional Von Neumann's model, might be needed to fully realize the goal of enhancing the brain operation. The presence of a "device", operating in an as-yet unknown manner, may ask for a different computation model than that of a traditional processor-and-storage.

Although much is still desired to be answered in the space of brain-supportive computing, inevitably our technical capabilities are fast approaching the point when such devices can be designed and manufactured, and despite the many open issues and challenges, due to the possibly massive benefits, notably in military areas, it is only a question of time before that happens. Clearly, the society and businesses first embarking on such a roadmap shall possess a significant competitive advantage.

**Bio:** Dr. Lukas Kencl is a Senior Researcher at the Intel Research Laboratory in Cambridge, UK, since June 2003. For the past several years, he has been active in research of methods, algorithms and architectures for complex network elements, such as network processors, routers or network monitors. Most recently, he has studied Adaptive Data Structures for networking systems, defining algorithms to monitor and re-organize data structures at run time. His broad research interests include applying methods of combinatorial optimization and graph theory to specific networking problems, and studying communication networks in general. Prior to joining Intel, Dr. Kencl was a member of the IBM Zurich Research Laboratory (1999-2003), where he explored the design of advanced applications for network processors. He has been a key member of the team that designed and prototyped the IBM PowerNP Network Processor *Traffic Engineering Reference Platform (TERP).* Dr. Kencl received a Master's degree in Computer Science from the Charles University, Prague, Czech Republic, in 1995, and a Ph.D. degree in Communication Networks from the Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland, in March 2003. Dr. Kencl has consistently published his work at conferences and journals of high standard (IEEE Network, INFOCOM, ICC). He serves on the program committee of the MMNS conference, and is a reviewer for the top networking journals (IEEE/ACM Transactions on Networking, Journal of Computer Networks) and conferences (SIGCOMM, INFOCOM, ICC). He is a co-inventor on several patent applications in the networking domain.