International Congress Series 1301 (2007) 15 – 21

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Making human–machine interfaces more brain-adequate

Helge Ritter *, Matthias Kaper, Alexander Lenhardt, Jörg Ontrup

Neuroinformatics Group, Faculty of Technology, Bielefeld University, Universitätsstr. 25, Bielefeld 33501, Germany

Abstract. We believe that augmenting or complementing natural functions of the brain can be an effective way to develop the technology for more brain-adequate interfaces. We illustrate this line of approach with examples from our recent work and report briefly on a major research initiative launched recently at Bielefeld University, joining the efforts of computer science groups and linguists towards more brain-adequate human–computer interfaces by studying the topic of interactive alignment in communication. © 2007 Published by Elsevier B.V.

Keywords: Brain-adequate interface; Brain–computer interface; EEG; Self-organizing map; HSOM; Alignment in communication; Hyperbolic space; Semantic navigation

1. Introduction

Human–computer interfaces are the glue that binds users and applications together. Ideally, good interfaces should connect the human user to the machine in such a way that he or she can experience the abilities of the machine as a natural extension. Current interfaces are still very far from this goal: for lack of processing capabilities that can operate at the high cognitive level of the user, they usually force communication into a rigid, machine-like format. They often require the user to employ artificial devices such as keyboards or exoskeletons to convey information, and they are just beginning to utilize biological signals such as EEG or muscle activations directly,

* Corresponding author. Tel.: +49 521 106 6062; fax: +49 521 106 6011.
E-mail address: helge@techfak.uni-bielefeld.de (H. Ritter).

0531-5131/ © 2007 Published by Elsevier B.V.
doi:10.1016/j.ics.2006.12.026

2. What do we expect of brain-adequate interfaces?

Brain-adequate interfaces – a term coined by Albrecht von Müller to characterize interfaces designed according to the needs of our brains – should diminish the “barrier” between our brain and the technical system as much as possible. On the brain side, evolution has already done very much to provide an excellent basis: highly developed perception and communication abilities connect us in a very flexible way to our environment. Compared with that, our technical devices still appear clumsy: typically, we require rather rigid command dialogs for commanding technical systems, with most input given through highly artificial input devices, such as keyboards or mice. To remedy this clumsiness will require endowing technical interfaces with the ability to understand the much more flexible and natural communication formats used by humans: this necessarily involves the use of natural language, but it cannot stop there. To truly qualify as brain-adequate, future interfaces should embrace highly developed pattern recognition abilities, grounded in a reasonably rich set of perceptual capabilities. A brain-adequate interface will have to be able to recognize its user and the surrounding objects. It must be able to watch and interpret gestures and actions, and it should be able to naturally extend its range of understanding by learning.

Realizing such capabilities will open up a very natural communication with technical systems, very similar to the way we are accustomed to being understood by our fellow humans. A core issue in this context is the effective “alignment” of the frames of reference of the involved cognitive agents to make communication effortless. This concept, originally put forward by Pickering and Garrod [1] to understand the ease and robustness of many aspects of communication, is the core topic of a recently initiated, major Bielefeld collaborative research effort, carried out in the collaborative research centre 673: “Alignment in Communication” [2]. It is bringing together the forces of computer scientists and linguists to elucidate the cognitive processes underlying the interactive alignment of multiple levels and subsystems in natural communication and cooperation, and it is using the insights gained for the development of more “brain-adequate” human–machine interfaces, for instance achieving team expertise during cooperative manipulation with robots endowed with anthropomorphic hands.

However, there may be circumstances where we even wish to elevate the smoothness of understanding to a level that qualifies as “mind reading”, using our brain signals as a direct input source. Due to several advances, this has become an active area during recent years, tying together brain research, adaptive signal processing, and medical applications in a most interesting way. While the best access to brain signals requires implanted electrode arrays – at least with current technology – a more ambitious goal, opening up much wider applications, is the realization of non-invasive methods. These are currently mostly based on the use of EEG signals. Various approaches exist to extract relevant information from these sources, ranging from “simple” binary decisions to the spelling of text or even the execution of continuous actions, e.g., in a computer game. These methods have the potential to realize a range of brain-adequate interfaces that enable control of technical devices by “mere thought”, extending part of what the brain offers for the control of our bodily limbs to external technical systems, such as robot devices.

Finally, returning to augmenting perceptual functions, we also can ask how brain-adequate interfaces might help to augment *our own* perceptual functions. Viewing our