Writing for English class discussing the possibility of creating non-invasive BCI with EEG and fMRI.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Non-invasive techniques for mind-reading brain-computer interfaces

Introduction

The main question about our brains is: Can we use electromagnetic fields produced by neurons firing as a carrier of information in human–computer communication? The state-of-the-art technologies allow for creating prosthetic controllers [3] and efficient spellers [1], with the spaceships, as Jacques J. Vidal might muse [15] stirred by the power of thought on their way. Back in 1973, he was the first who formalised this idea, coined the term Brain-Computer Interface (BCI), and reviewed available technologies that neuroscientist could use to implement it [12 15].

BCI seemed realistic solely on the basis of brain wave recordings [15] introduced by Berger in 1929 [2], but it is still controversial when interface between brain and machine will be created even with the technologies that have since emerged [1 7]. Is a spaceship the only thing neuroscientists await to fulfil their dream and control machines? How far have we proceeded towards that dream and what direction of research is the most promising?

State-of-the-art technologies

In order to answer these questions, one needs to consider the requirements for the machine, difficulties to be overcome, and knowledge we have at the moment.

By creating BCI, we expect it not only to enable and restore lost functioning, but also to improve our day-to-day lives. Mind-reading would allow this by directly interpreting human intentions, bypassing muscular movement and providing missing linkage as in case of severe speech and physical impairments, or perfecting our abilities to make them more reliable and efficient [12]. BCI thus needs to be easily maintained and be usable out of laboratories, where its end users want to see their families and explore the world with new abilities [1].

Hard as it may sound, two different approaches prevail in this area: One uses Electroencephalogram (EEG) recordings of brain waves pioneered by Berger almost a century ago. The other stands on rigorous deciphering of neuron connections which became possible with the advent of functional Magnetic Resonance Imaging (fMRI). While EEG-based BCIs rely on correlation between stimuli and scalp electrical potentials [15], the latter adheres to the idea that providing the interface for communication and reverse engineering of the brain are not dissociable, so efforts should be aimed on studying deeper structures with higher precision [14].

EEG

Clinicians and psychologists prefer to use EEG as a cost-efficient and easy-to-use device, which leads to immediate results whenever severely impaired patients need a way to communicate [1]. It consists of electrodes attached to the scalp which detect neural patterns characteristic to a target detection [6 12] when target is presented as a visual stimulus. As electrodes number increased from 16 to 256 [10], scientists became able to use these patterns to encode basic selection commands. Current user interfaces allow the choosing of letters, words, or directions, enabling individuals to move in virtual or real environment [12].

However, several limitations seem to prevent further development of EEG-based BCIs: low signal-to-noise ratio and low spatial resolution [1]. Muscular activity, wires and electronic devices contaminate the signal with artefacts, which slow down EEG work. The maximum rate of typing reported with mind-reading is 10 characters per second [5]. Being an improvement for patients with no other means of communication, the rate is much slower than natural speech, which is 150–250 words per minute.

To allow EGG-based interface functioning without visual stimuli present, DARPA funded a research which aimed to distinguish covertly spoken words. It demonstrated a possibility of using syllables /ba/ and /ku/ as distinguishable enough to tell them based on EEG [4]. As it was arguable the most promising achievement towards a BCI, DARPA continued backing EEG-based projects with the main goal of making such devices cheeper [12]. Hence it is EEG, that may soon power a general-usage BCI prototype outside laboratories.

Despite promising results of EEG, its perspectives are limited by its preciseness [1] and it alone is unlikely to provide enough capabilities for deciphering neural code.

fMRI

Unlike EEG, fMRI allows magnetic fields produced by neurons to be measured on a scale of millimetres in the whole brain [16]. Due to its high spatial resolution, mind-reading with fMRI has been possible up to the extent of directly reproducing one's visual experiences [9 13] and dreams [8]. By detecting neuron activation patterns researches have approached our direct way of thinking, which would provide a natural connection between computer and brain, having reduced the scales and price of such machines.

Unfortunately, the sophisticated instruments such as fMRI are of size of a room and no technology exists to make them portable. Moreover, elements used in them are affordable only for big research institution, where the cutting-edge research occurs. Because of surrounding noise, the BCI based on fMRI can be used only in special shielded rooms (Figure 2). As a consequence, practical use of these machines is only yet to be obtained.

fMRI studies are more promising in terms of possibilities they provide and knowledge they obtain from brain analysis. However, their cumbersomeness is the major and pending issue. This fact limits the scope of its application, and as a result fMRI serves only as a great and intermediate step towards real mind-reading machines.

Conclusion

As the discussed techniques cover non-overlapping applications of BCI, their direct comparison would not be justifiable. Instead, considering their limitations and insights they provide allow for creating a tangible guideline of further BCIs development. For the drawbacks of each technology make them unavailable for a real-life situations, the odds are that these programs are complementary rather than standalone solutions in their current state [4].

Even though many more aspects need amendment before feasible brain-computer interface is introduced, main goal now should be introducing a new neuroimaging technique. Without that, BCI in their current form is limited in operation speed and mobility and is unlikely to be invented in the nearest future. Based on the success that EEG and fMRI demonstrate, the requirements for such technique would be the spatial resolution observed in fMRI and portability available for EEG devices.

In 1973, Vidal stated: «Even on the sole basis of the present states of the art of computer science and neurophysiology, one may suggest that such a feat is potentially around the corner.» Since then, the statement has still been true.

Prepare your thoughts to be read.

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