Brain-Computer Interfaces for large public applications

Mots clés :
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Résumé du projet de recherche (Langue 1)

More and more systems use electromagnetic waves, in particular for telecommunications. New interfaces exploiting the interactions of such waves with the human body are emerging and will certainly be more and more developed in a near future. A particularly promising direction is brain-computer interfaces (BCI), which record the brain activity of a subject in order to transfer commands and orders directly to a computer. Several projects have been carried out in this domain, such as Open-VIBE project (http://openvibe.inria.fr/) in France or BBCI project (http://www.bbc.de/) in Germany. In all existing projects using non-invasive systems (i.e. without using implanted electrodes), the recording is performed using electro-encephalography (EEG) devices, using helmets with a lot of electrodes (typically 64). The main applications are dedicated to neuroscience studies, which are also classical applications of EEG, both for research (for understanding brain processes) and for clinical applications (for pathologies such as epilepsy and strokes). A review of recent trends can be found in Mak and Wolpaw (2009) (J. N. Mak, J. R. Wolpaw: Clinical Applications of Brain-Computer Interaces: Current State and Future Prospects, IEEE Reviews in Biomedical Engineering, Vol.2, 187-199, 2009.). Emerging applications focus on personal assistance, but very little on large public applications such as video games. New devices are developed for this aim (http://emotiv.com/ for instance), but are still at a very early stage of development, and not adaptable for specific applications. A lot of open issues should be addressed to promote this new technology for real applications under easy usage constraints.

Résumé du projet de recherche (Langue 2)

The aim of this thesis will be to investigate these open issues, focusing in particular on reducing the number of electrodes, signal analysis and source localization to interpret the signal. The first part of the thesis will be dedicated to a thorough review of existing work, on data acquisition, devices (in particular non-invasive ones, with a reduced number of electrodes), source localization techniques, potential applications and users, limitations. A good starting point is the bibliography on BCI for neurosciences and clinical applications, and a critical analysis of their limits for extensions to other types of applications. This should lead to clear conclusions on devices and methods that could be used for developing large public applications. The second part of the thesis will focus on data acquisition, either by establishing collaborations with hospitals (the team already has contacts and on-going collaborations with several hospitals in Paris), or based on commercial devices. As an example, P300 event-related potential BCI could be investigated: EEG activity would then be recorded in the centro-parietal region of the cortex. Some recent studies showed that volunteers wearing virtual reality helmets could control elements in a virtual world via using their P300, e.g. turning lights on and off, bringing a mock-up car to a stop or controlling the motion of a ball or a cursor. So P300-based BCI appears as quite reliable in helping motor-impaired patients. Similar directions relying on P300-base BCI could be pursued for some large public applications, e.g. video games. The third and core part of the thesis will consist of theoretical developments. Source localization and signal classification methods will have to be revisited for a low number of electrodes. A careful analysis of the induced imprecisions and uncertainties will be performed, in order to have a clear insight on the actual information that can be extracted from the measured data. Classification of signals for their interpretation will then call for machine learning techniques. Since the candidate has already some experience in independent components analysis (ICA) and fuzzy sets theory, the developments will, at least in a first step, focus on these tools. This is also consistent with the research directions of the team. In particular modeling the imprecisions induced by the reduced number of electrodes (and hence measured data) using fuzzy sets could be helpful to make better decisions at the end of the classification process, and to assess the potential ambiguities of the final decisions. Finally applications will be developed, to be discussed with Orange Labs.