BMI: Lessons from Tests with Impaired Users

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Abstract— **Brain-machine interfaces (BMI) have largely been demonstrated in laboratory conditions involving, mainly, healthy users. We have recently carried out a series of studies with a substantial number of motor-disabled end-users operating different brain-controlled devices in ecological conditions and without the assistance of BMI experts.**

Keywords-brain-machine interface; EEG; motor-disabled end-users; spontaneous EEG rhythms; probalistic classifier; shared control.

In the framework of the European integrated project TOBI (Tools for Brain-Computer Interaction, http://www.tobi-project.org), we have started to combine brain-machine interfaces (BMI) and assistive technologies [1] in order to develop a variety of practical devices for motor-disabled people [2, 3, 4]. These BMI prototypes have been extensively tested by motor-impaired users after a short training period. A substantial number of tests have been carried out at end-users' home and clinics, outside well-controlled laboratory conditions. Equally significantly, non-BMI experts (assistive technology professionals and therapists) have run many of these tests independently or with a minimum of remote assistance from researchers [5].

A central concern in our research is how to facilitate the operation of brain-controlled devices over long periods of time. This is a challenging problem due to the limited (and variable) information carried by brain signals we can measure, no matter the recording modality. I will argue that efficient brain-machine interaction, as the execution of voluntary movements, requires the integration of several parts of the central nervous system and of external actuators.

In this talk I will summarize this work and the main lessons learned from this major effort, highlighting new principles incorporated in the brain-controlled devices.

In particular, our approach is based on spontaneous and voluntary modulation of EEG rhythmic brain activity that does not require any kind of external stimulation, thus reducing user's fatigue. Our BMIs analyze EEG signals to determine user's intents through the use of a probabilistic classifier with evidence accumulation [6, 7, 8]. Our BMI approach incorporates some additional principles —in particular, shared control, see [9] for an exemplary application of this principle— so as to increase reliability, reduce workload, and facilitate split attention [10].

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REFERENCES

[1] J. d. R. Millán, R. Rupp, G. Müller-Putz, et al., "Combining brain-computer interfaces and assistive technologies: State-of-the-art and challenges," Front. Neurosci., vol. 4, 161, 2010.

[2] L. Tonin, T. Carlson, R. Leeb, and J. d. R. Millán, "Brain-controlled telepresence robot by motor-disabled people," in Proc. 31st Annual Intl. Conf. IEEE Eng. Med. Biol. Soc., 2011.

[3] A. Biasiucci, R. Leeb, A. Al-Khodairy, V. Buhlmann, and J. d. R. Millán, "Motor recovery after stroke by means of BCI-guided functional electrical stimulation," in Proc. 5th Int. BCI Meeting, 2013.

[4] S. Perdikis, R. Leeb, J. Williamson, A. Ramsey, M. Tavella, L. Desideri, E.-J. Hoogerwerf, A. Al-Khodairy, R. Murray-Smith, and J. d. R. Millán, "Clinical evaluation of BrainTree, a motor imagery hybrid BCI speller," J. Neural Eng., to appear, 2014.

[5] R. Leeb, S. Perdikis, L. Tonin, A. Biasiucci, M. Tavella, M. Creatura, A. Molina, A. Al-Khodairy, T. Carlson, and J. d. R. Millán, "Transferring brain-computer interface beyond the laboratory: Successful application control for motor-disabled users," Artif. Intell. Med., vol. 59, pp. 121–132, 2013.

[6] J. d. R. Millán, P. W. Ferrez, F. Galán, E. Lew, and R. Chavarriaga, "Non-invasive brain-machine interaction," Int. J. Pattern Recognition Art. Intell., vol. 22, pp. 959–972, 2008.

[7] F. Galán, P. W. Ferrez, F. Oliva, J. Guàrdia, and J. d. R. Millán, "Feature extraction for multi-class BCI using canonical variates analysis," in Proc. IEEE Int. Symp. Int. Sig. Proc., 2007.

[8] S. Perdikis, H. Bayati, R. Leeb, and J. d. R. Millán, "Evidence accumulation in asynchronous BCI," Int. J. Bioelectromagnetism, vol. 13, pp. 131–132, 2011.

[9] T. Carlson and J. d. R. Millán, "Brain-controlled wheelchairs: A robotic architecture," IEEE Robot. Autom. Mag., vol. 20, pp. 65–73, 2013.

[10] M. Tavella, R. Leeb, R. Rupp, and J. d. R. Millán, "Towards natural non-invasive hand neuroprostheses for daily living," in Proc. 32nd Annual Intl. Conf. IEEE Eng. Med. Biol. Soc., 2010.