Braincontrol Basic Communicator: A Brain-Computer Interface Based Communicator for People with Severe Disabilities

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Abstract. The “BrainControl Basic Communicator” (BrainControl BC) is an augmentative and alternative communication (AAC) system based on Brain-computer interface (BCI) technology. The system has been designed for patients with severe disabilities due to pathologies such as Amyotrophic Lateral Sclerosis (ALS), Multiple Sclerosis, ischemic or traumatic injuries.

The first prototype of the BrainControl BC was completed in mid 2012 and has been completed in the mid 2013. From 2012, 20 locked-in patients have been trained with success and in the last few months 12 of these patients are continuously using the system, as it represents the only possibility to communicate.

BrainControl BC is part of the BrainControl project, aiming to develop a BCI platform that allows people suffering from sever disabilities to overcome physical and communicative impairments. In particular, BrainControl can help patients suffering from diseases that paralyze the whole body or parts of the body, but who retain their intellectual abilities.

Future versions of BrainControl, which are currently under development, will include advanced communication and functionalities, home automation, the control of a wheelchair and robotics.

Keywords: Brain-Computer Interface (BCI), Augmentative and Alternative Communication (AAC), Assistive Technologies, Amyotrophic Lateral Sclerosis (ALS).

1 Introduction

Over 20 million people globally are completely paralyzed and/or have communication difficulties due to degenerative neuromuscular diseases (amyotrophic lateral sclerosis, multiple sclerosis, etc.) or ischemic or traumatic injuries.[1] The needs of at least 3.7 million of them (severe cases) are not met by assistive technologies currently on the market.

Degenerative neuromuscular or cerebrate-vascular disorders are characterized by a gradual loss of muscular function while retaining complete cognitive functions.

[1] Worldwide number calculated based on data from the Population Research Bureau, Christopher and Dana Reeve Foundation, Italian ALS Association, American ALS Association and American Multiple Sclerosis Association.

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Amyotrophic lateral sclerosis (ALS) is a progressive neurodegenerative disease involving the motor neurons. It is pathologically characterized by progressive loss of upper and lower motor neurons. The disease duration is variable with a large spectrum of possibilities ranging from forms with mild conditions and a slower evolution to more severe forms with survival no more than 2.5 years and finally to very rapid forms with survival of less than 6 months. Clinically, ALS is characterized by a progressive complete destruction of the peripheral and central motor system but only affecting sensory or cognitive functions to a minor degree. The disease progresses until the patient loses control of the last muscular response, which is usually the eye muscle or the external sphincter. The resulting condition is called completely locked-in state. If rudimentary control of at least one muscle is present, we speak of a locked-in state. Other conditions leading to a locked-in state are subcortical stroke and other extended brain lesions, Guillain-Barre syndrome, some rare cases of Parkinson disease, and Multiple Sclerosis.

The principle assistive technologies for locked-in patients include residual movement controlled systems [1,2], voice-controlled systems, eye-tracking and brain-computer interface. Voice-controlled systems are based on speech recognition and speech-to-text, but cannot be used by the millions of patients who cannot speak due to the pathologies mentioned above. Eye-tracking systems follow the movement of the user's pupil, but they cannot be used by many patients. Brain-computer interface (BCI) technology interprets the electrical signals that correspond with certain brain activity and allows a computer or other external devise to be controlled with thoughts (Figure 1). [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16]

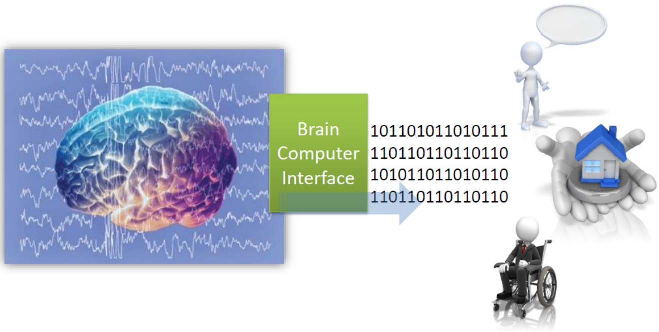

Fig. 1. Brain-Computer Interface

Over the past 20 years, research in the field of brain-computer interface (BCI) has led to significant results, driven by advances in our understanding of brain function and the evolution of computers and sensors. However, no sufficiently usable and robust solutions address the needs of people with severe physical and communication disabilities.

2 BrainControl Project Overview

BrainControl project aims to develop a usable and robust framework for assistive technologies based on BCI, by the use of low/reasonable cost, commercial available hardware (EEG headset and Tablet PC).

Fig. 2. BrainControl Architecture

The heart of BrainControl is a proprietary classifier of EEG patterns based on neural network technology and combined with an adaptive Bayesian algorithm for customizing different needs in different patients. The system works like a mental joystick, detecting 6 types of imagined movements (IM), push, pull, up, down, right, left, thus allowing a computer or other external devise to be controlled (Figure 2).

BrainControl's aim is to help users to overcome severe physical and communicative disabilities created by pathologies such as amyotrophic lateral sclerosis (ALS), multiple sclerosis, tetraplegia and various kinds of muscular dystrophies. In particular, BrainControl can help patients suffering from diseases that paralyze the whole body or parts of the body, but who retain their intellectual abilities. It will be possible for them to communicate feelings and needs, to move their own wheelchair, to interact with family and friends through social networks, email or SMS, to turn the lights on or off, and even open or close doors and windows.

A first prototype of the system, able to recognize pull/push imagined movements, was developed in fall the of 2010 [17]. It has been continuously developed between 2010 and 2012 and tested in the same period with more than 30 healthy volunteers providing excellent results and encouraging the development.

The first version of BrainControl, the Basic Communicator, was completed in the middle of 2013. It fills a technological void for patients in locked-in state who cannot use eye-tracking systems or other assistive technologies.

Future versions of BrainControl, which are currently under development, will include advanced communication and entertainment (virtual keyboard, text-to-speech, social networks, email,), home automation (lights, temperature, etc.), control of a wheelchair and robotics (Figure 3). BrainHuRo, a project that applies BCI to humanoid robots, has been started in 2013, partially funded by the Italian region of Tuscany (POR-CREO Fesr 2007-2013 – Le ali alle tue idee) and involving the University of Siena, Liquidweb s.r.l., Humanot s.r.l., Massimi Sistemi s.r.l. and Micromec s.r.l. [18].

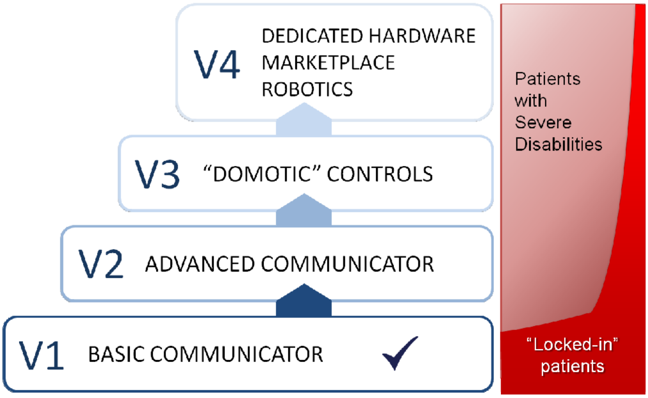

Fig. 3. Roadmap

3 BrainControl Basic Communicator

The BrainControl Basic Communicator has been designed around the needs of locked-in patients. It includes a "Yes/No/Don't know" Selector (Figure 4) and a "Sentence Finder" (Figure 5). The user interface uses a scanning mode to move between available options and utilizes just one movement-related thought to select the desired choice. The pre-defined sentences in the sentence finder are completely customizable, including the addition of images, audio feedback and the creation of sub-menus.

BrainControl BC utilizes proprietary software and commercially available hardware that has been made for the consumer market, including a non-invasive wireless EEG headsets Emotiv Epoc and a tablet PC.

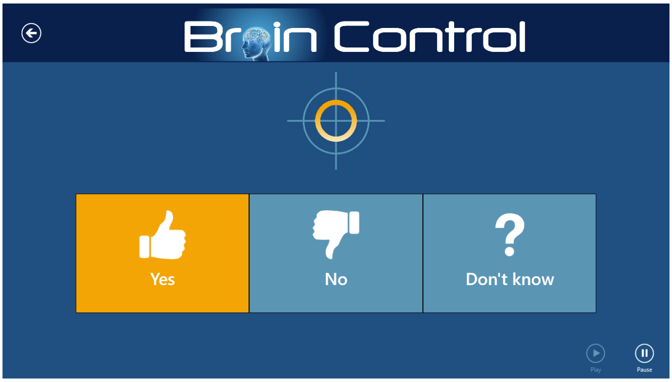

Fig. 4. Yes/No Mode

Fig. 5. Sentence Finder

Fig. 6. BrainControl Basic Communicator

The first prototype of the BrainControl BC has been released on mid 2012 and has completed in the mid 2013.

3.1 Training of Locked-In Patients

The training is carried out in one-hour remote sessions (video conference with remote desktop control). In many cases, one session is sufficient, but four sessions are generally scheduled during the first month.

During the first training the trainers explains to the patients how the system works, its functionalities and the training purpose, then he starts with multiple iterative sessions of calibration and tests. During the calibration phase, the software records the EEG data from the user witch was asked to stay focused for few seconds on the movement-related thought that will be used for controlling the system. The tests phases consists on asking the patients to select predefined sequences of choices.

This iterative session in conducted for 30-40 minutes and is replicated in the next 3 sessions during the first month.

If the user can select at least 5 predefined choices without errors during the test phase, the training is considered successful.

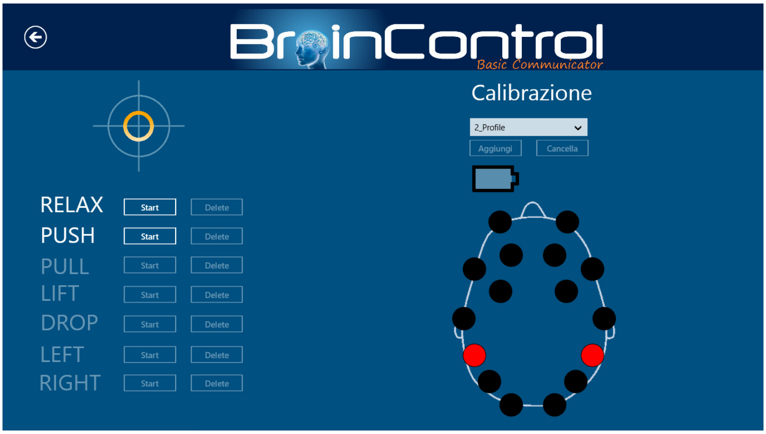

Fig. 7. Calibration

3.2 Results

In the period of August 2012 – January 2014 we carried out sessions training with two group of users:

I) 30 healthy users;

II) 21 patients with tetraplegia, 18 of them in locked-in state.

The training has been completed successfully for all the 30 users of the first group.

As for as the second group, the training has been completed successfully for 20 and failed for one of the patients in locked-in state.

12 patients of the second group are using continuously the system, as it represents the only possibility to communicate.

Aim of the future work is evaluating the use of the system in a long term period for patients affected by neurodegenerative diseases, after entering in a completed locked-in state.

4 Conclusion

The “BrainControl Basic Communicator” (BrainControl BC) is an augmentative and alternative communication (AAC) system based on Brain-computer interface (BCI) technology. The system has been designed for patients with severe disabilities due to pathologies such as Amyotrophic Lateral Sclerosis (ALS), Multiple Sclerosis, ischemic or traumatic injuries.

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References

1. Carlson, T., Demiris, Y.: Human-wheelchair collaboration through prediction of intention and adaptive assistance. In: Proceedings of the IEEE International Conference on Robotics and Automation, pp. 3926–3931 (2008)
2. Carlson, T., Monnard, G., Leeb, R., Millán, J., del, R.: Evaluation of Proportional and Discrete Shared Control Paradigms for Low Resolution User Inputs. In: Proceedings of the IEEE Intl. Conf. on Systems, Man, and Cybernetics, pp. 1044–1049 (2011a)
3. Carlson, T., Monnard, G., del R. Millán, J.: Vision-Based Shared Control for a BCI Wheelchair. International Journal of Bioelectromagnetism 13(1), 20–21 (2011b)
4. Carmena, J.M., Lebedev, M.A., Crist, R.E., O'Doherty, J.E., Santucci, D.M., Dimitrov, D.F., et al.: Learning to control a brain-machine interface for reaching and grasping by primates. PLoS Biology 1, E42 (2003)
5. Birbaumer, N., Ghanayim, N., Hinterberger, T., Iversen, I., Kotchoubey, B., Kübler, A., et al.: A spelling device for the paralysed. Nature 398, 297–298 (1999)
6. Buttfield, A., Ferrez, P.W., del R. Millán, J.: Towards a robust BCI: error potentials and online learning. IEEE Trans. Neural Sys. Rehab. Eng. 14, 164–168 (2006)
7. Birbaumer, N.: Breaking the silence: Brain-computer interfaces (BCI) for communication and motor control. Psychophysiology 43, 517–532 (2006)
8. Lebedev, M.A., Nicolelis, M.A.L.: Brain-machine interfaces: past, present and future. Trends in Neurosciences 29(9), 536–546 (2006)
9. Sitaram, R., Caria, A., Birbaumer, N.: Hemodynamic brain–computer interfaces for communication and rehabilitation. Neural Networks (2009)
10. Allison, B.Z., Wolpaw, E.W., Wolpaw, J.R.: Brain-computer interface systems: progress and prospects. Expert Review of Medical Devices 4(4), 463–474 (2007)
11. Dornhege, G., del R. Millán, J., Hinterberger, T., Müller, K.-R.: Toward Brain-Computer Interfacing. MIT Press (2007)
12. Van Gerven, M., Farquhar, J., Schaefer, R., Vlek, R., Geuze, J., Nijholt, A., Ramsey, N., Haselager, P., Vuurpijl, L., Gielen, S., Desain, P.: The brain–computer interface cycle. J. Neural Eng. 6 (2009)
13. Pfurtscheller, G., Allison, B.Z., Brunner, C., Bauernfeind, G., Solis-Escalante, T., Scherer, R., Zander, T.O., Mueller-Putz, G., Neuper, C., Birbaumer, N.: The Hybrid BCI. Frontiers in Neuroprosthetics 2, 3 (2010), doi:10.3389/fnpro.2010.00003
14. Zander, T.O., Kothe, C.: Towards passive brain–computer interfaces: applying brain-computer interface technology to human–machine systems in general. Journal of Neural Engineering 8 (2011)
15. George, L., Lécuyer, A.: An overview of research on "passive" brain-computer interfaces for implicit human-computer interaction. In: International Conference on Applied Bionics and Biomechanics, ICABB (2010)

16. Tonin, L., Carlson, T., Leeb, R., del R. Millán, J.: Brain-Controlled Telepresence Robot by Motor-Disabled People. In: Proceedings of the 33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 4227–4230 (2011)
17. Fedele, P., Tavanti, M.: "BrainControl project" poster and demo. In: Mind Force Conference, October 7-8. Centre for the Study of Complex Systems, University of Siena, Siena (2010)
18. Casals, A., Fedele, P., Marek, T., Molfino, R., Muscolo, G.G., Tommaso Recchiuto, C.: A robotic suit controlled by the human brain for people suffering from quadriplegia. In: 14th Towards Autonomous Robotic Systems, TAROS 2013, St. Anne's College, Oxford, August 28-30. LNCS (LNAI), pp. 28–30. Springer (2013)