The Potential of Brain Computer Interfacing for Sustainable Development

S. R. Liyanage

Faculty of Computing and Technology, University of Kelaniya, Kelaniya, Sri Lanka.; sidath@kln.ac.lk

Abstract

A Brain-Computer Interface (BCI) is a communication system which enables its users to send commands to a computer using only brain activities. These brain activities are generally measured by ElectroEncephaloGraphy (EEG), and processed by a system using machine learning algorithms to recognize patterns in EEG data. In the next few years, BCIs will be more flexible and powerful, and much easier to use with little or no support. BCIs will be the more practical tools for severely disabled users, and will gain increasing adoption, catalyzing a synergistic feedback effect. As BCIs become cheaper, easier to use, and better publicized, more people may wish to purchase BCIs, leading to further advances.

BCIs may be invasive or non-invasive. Invasive BCIs require surgery to implant the necessary sensors, whereas non-invasive BCIs do not. More than 80 percent of BCIs are non-invasive systems, like the EEG that measures electrical activity associated with mental tasks. All BCIs require four components: methods to acquire, process, implement, and manage relevant brain and/or other signals. Rapid progress is being made in all four components. New sensors are being developed that do not require electrode gel, which reduces preparation time and hassle and makes BCIs more accessible to new users. Dry sensors over the forehead can acquire not only brain signals, but also other relevant signals such as electrooculogram (EOG) and facial electromyography (EMG). Improved sensors for invasive BCIs could provide a better picture of brain activity while reducing the cost, time, and surgery.

Invasive BCIs have shown they can provide reliable control years after implantation, helping to address concerns about long term reliability. "Hybrid" BCIs combine a BCI with another means of sending information, such as another BCI or assistive technology, or a conventional interface like a keyboard or mouse. The additional communication system could improve bandwidth, confirm selections, turn the primary channel on or off, provide a backup if the user is fatigued, or yield other benefits. A whole new category of BCI applications is being explored—devices for disorder rehabilitation, rather than simple communication and control.

The aim of this paper is to explore the potential of BCI research, some of which is carried out in Sri Lanka from different perspectives. As an emerging market South Asian region has a huge potential to develop effective and sustainable BCI systems in the future. Collaborative integrated research in medicine and engineering in neuroscience, signal processing and pattern recognition are required to make any significant advancement at this stage.

Introduction

A Brain-Computer Interface (BCI) is a communication system which enables its users to send commands to a computer using only brain activities. These brain activities are generally measured by ElectroEncephaloGraphy (EEG), and processed by a system using machine learning algorithms to recognize patterns in the EEG data. The brain-computer interface (BCI) field is one such technology which shows great promise. The World Economic forum has identified BCI as one of the top emerging technologies.

BCI research is gaining attention from various groups, including commercial companies, academics, funding agencies, and potential new users. This new found interest has facilitated considerable progress in each of the four component areas defining BCIs. In thenext few years, BCIs will become more flexible and powerful, and much easier to use with little or no support. BCIs will be more practical tools for the severely disabled, and will gain increasing adoption among other groups. Increasing adoption could catalyze asynergistic feedback effect. As BCIs become cheaper, easier to use, and better publicized, more people may wish to purchase BCIs, leading to further advances.

BCIs may be invasive or non-invasive. Invasive BCIs require surgery to implant the necessary sensors, whereasnon-invasive BCIs do not. More than 80 percent of BCIs are non-invasive systems, such as the electroencephalogram (EEG) that measures the electrical activity associated with mental tasks. All BCIs require four components: methods to acquire, process, implement, and manage relevant brain and/or other signals. Rapid progress is being made in all four components. New sensors are being developed that do not require electrode gel, which reduces preparation time and hassle and makes BCIs more accessible to new users. Dry sensors over the forehead can acquire not only brain signals, but also other relevant signals such as electrooculogram (EOG) and facial electromyography (EMG). Companies like Quasar, Emotiv,and NeuroSky have heavily advertised dry electrode systems for gaming and other goals. The ENOBIO dry electrode system developed by Starlab is currently available, with Starlab working on numerous improvements. Twente Medical Systems (TMSi) has a different type of practical electrode that relies on water instead of gel. Other means of detecting brain activity such as functional Magnetic Resonance Imaging (fMRI) and Near Infrared Spectroscopy (NIRS) are also being explored in the BCI research community, although fMRI and NIRS are overrated for most BCI applications and have yet to provide any real benefit over EEG and. Improved sensors for invasive BCIs could provide a better picture of brain activity in many ways while reducing cost, time, and the inconvenience of surgery.

Furthermore, many invasive BCIs have shown they can provide reliable control years after implantation, which helps to address concerns about long term reliability. “Hybrid” BCIs combine a BCI with another means of sending information, such as another BCI or another assistive technology, or conventional interface like a keyboard or mouse. The additional communication system could improve bandwidth, confirm selections, turn the primary channel on or off, provide a backup if the user is fatigued, or yield other benefits.Hybrid BCI research is beginning to explore BCIs as multimodal interfaces in which users can interact, in an intuitive and natural way, using BCIs as one of the communication channels. “Passive” BCI systems could augment our interactions with computers and other devices by assessing alertness, anticipation, recognition, or other mental states based on activity from the brain, eyes, muscles, heart, or other sources. New signal processing approaches have reduced training time for some BCI approaches and improved accuracyand reliability. Progress is alsoapparent in BCI signals that are not acquired directly from the brain, both alone and in combination with EEG activity. Although the prospect of combining different signal types has been validated, many resulting challenges in signal fusion remain unexplored, due largely to inadequate communication and networking among relevant stakeholders in both the sensor and signal processing communities. Many new BCI devices and applications have recently been developed for such purposes as control of smart homes or other virtual environments, games, prosthetic devices such as artificial limbs, wheelchairs, and other robotic devices. A whole new category of BCI applications is being explored—devices for rehabilitation of disorders, rather than simple communication and control.

Recent accomplishments include BCIs as a communication channel using advanced virtual environments, which reduce training time while improving accuracy, performance, and user satisfaction. While research in human computer interaction (HCI) has definitely shown that well designed, user centered interfaces yield many benefits, many fundamental design and validation principles in HCI and assistive technology (AT) are still ignored in the BCI community. To integrate BCIs into the HCI framework, designers must also consider fundamental interface issue such as whether a BCI is synchronous or asynchronous, how to handle the “No Control State” in which the user does not wish to convey information,and both how and when to present feedback. User-centered design is critical, and testing with healthy usersmay be inadequate. Healthy users and designers may have trouble appreciating issues unique to a severely disabled user. Consider a patient with ALS (LouGehrig’s disease), who cannot move or blink, and may have spasms, neuropsychiatric disorders, and very different goals, abilities, and expectations.Tasks such as mounting a cap and later washing the hair, which may seem trivial for healthy persons, can be much more burdensome for disabled personsand their caretakers.

Recently there has been exploratory research on the uses of BCI for inducing or facilitating recovery of motor, cognitive, or emotional function. There is opportunity to research into the use of BCI as an therapeutic tools to restore more normal motor control and more normal cognitive and emotional function for people with disabilities. This is an important endeavor because conventional

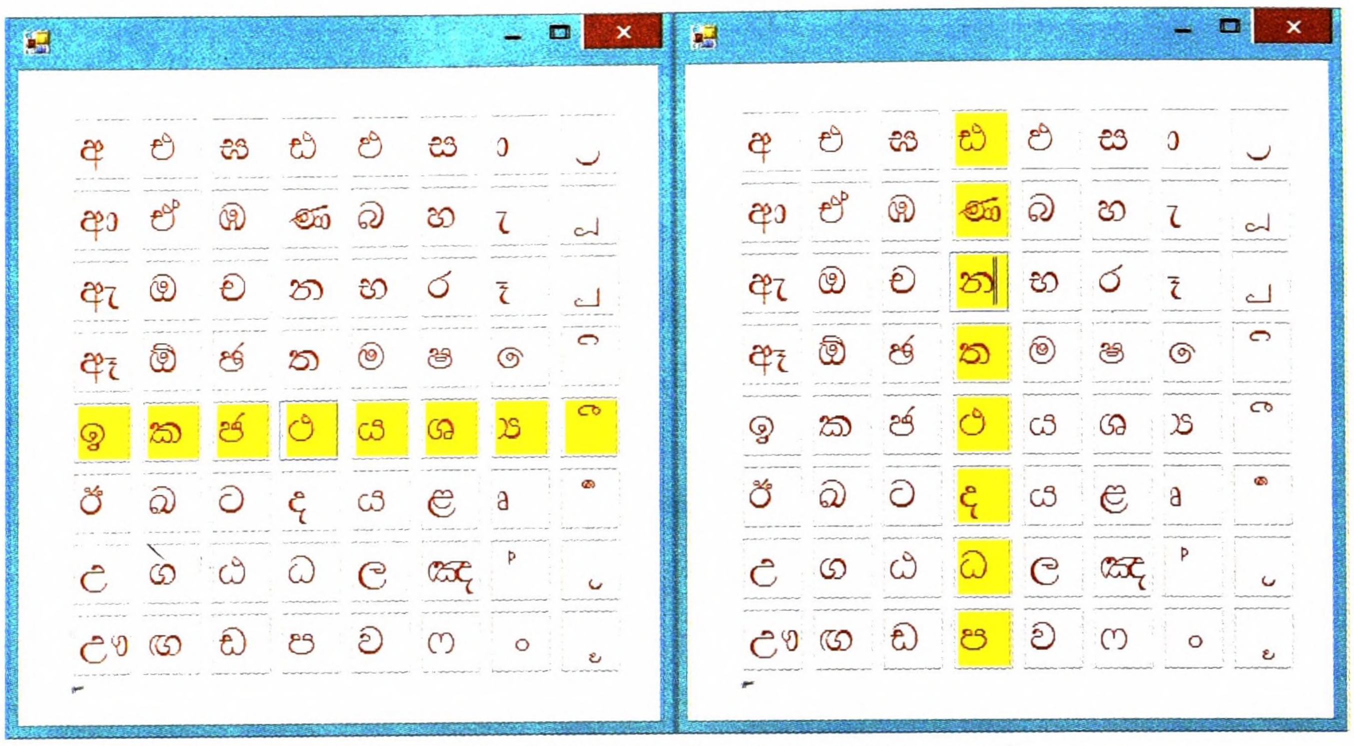

Fig. 1. User Interface for a Sinhala BCI Communicator

rehabilitation methods are often ineffective, or only minimally effective in restoring these functions to people with neurological injury or disease. BCIs for therapeutic purposes make use of feedback signals designed to modify brain activity in order to improve some aspect of motor or cognitive function, either by altering ongoing brain activity and/or by inducing and guiding long-term plasticity. Central nervous system (CNS) plasticity involves the structural and functional neuronal and synaptic changes that occur during learning of new information and during acquisition of new cognitive or motor skills.These changes can occur anywhere in the CNS, from the cortex to the spinalcord. Such plasticity occurs during development and throughout life induced and guided by CNS activities.

BCI Research in Sri Lanka

BCI research has grown dramatically over the past few years, but no effort is being made to ensure efficient communication and collaboration among key stakeholders and researchers in Sri Lanka. A few engineers and computer scientists are pursuing BCI research in Sri Lanka from different perspectives,. The aim of this article is to explore the potential of integrated research in BCI.

P300 Based Sinhala Communicator

Among the BCI applications, one of the most popular technologies is the P300 BCI, a BCI that primarily utilizes the P300 wave of the brain event-related potentials (ERPs). This BCI presents the user with a screen on which visual events, used as stimuli, appear at distinct locations. The user attends one of these locations and silentlycounts the events (e.g., flashes) that occur there. The counted or otherwise-attended event (the target event) can be detectedbecause this event is followed by a higher amplitude P300 than unattended (non-target) events. A command associated with this location is executed.

In the most typical application, the P300 Speller, the main part of the visual display is a matrix consisting of letters of the alphabet. To accelerate letter selection, rows and columns of letters are flashed rather than single cells. The order of the stimuli is random, which is important to elicit the P300. In most cases, each stimulus is presented at least several times (often more than ten) to improve the signal-to-noise ratio using separate averaging of the data related to each row and column. Preprocessingand feature extraction are applied to the EEG epochstime-locked to the stimuli, and the feature vectors corresponding to known stimuli are then submitted to the classifier. Before actual use of the BCI, the classifier is trained using feature vectors labeled as "target" and "non-target." To obtain these vectors, a calibration session, in which the user attends the predefined locations, should be completed. After the classifier is trained, its output indicates the row and column in which flashes were followed by a brain response best resembling the response to a target stimulus. The letter found at their intersection is then typed.

On-going research on Brain Computer Interfacing carried out at the University of Kelaniya, Sri Lanka includes the development of a prototype BCI for Sinhala language. The user-interface developed for an Emotiv Epoc+ system is shown in Fig, 1. The final analysis of the proposed system is yet to be completed.

There is a need for collaboration in the areas of Neuroscience and Psychology if BCI research is to be effectively used for real world applications.

Economic Viability of BCI Based Systems

Several sources indicate that commercial interest in BCI research is increasing. Within the business community, there has been a dramatic rise in non-invasive BCI sales. Thomas Sullivan from NeuroSky expounds in a March 2011 email, "We do say publicly that we have shipped over 1 million integrated circuits that process EEG signals.This is not just in our own headsets,but in the headsets of our partners like Mattel." The dry sensors have led to simple games based on head-mounted sensors that did not exist a few years ago. Users might levitate a rock or car by focusing attention on a target object and trying to relax. Other manufacturers of BCI products for both laboratories and end users are also thriving. Edlinger from Guger Technologies reports that g.tec had an increase in annual sales of BCI equipment of about 35 percent per annum since 2005. Since Starlab's ENOBIO system was launched in late 2009, 75 percent of all ENOBIO sales have been for BCI applications. Two high-profile U.S. companies devoted to invasive BCIs have been less successful.

One such company, Cyberkinetics, ceased operations in 2009, although it had some excellent people, solid publications, and impressive BCIs. Many small to medium companies such as TMSi, Starlab, and Quasarhave focusing heavily on developing improved sensors for BCI systems over the past few years. Huge companies like Philips have some projects involving BCIs and similar systems. Enthusiasm for BCI research is also apparent through funding decisions by the European Commission (EC) and national funding entities. BCI research also can be funded through the US government's Brain Research through Advancing Innovative Neurotechnologies (BRAIN) inidicating which is aimed at revolutionizing the understanding of the human brain.

BCIs are suddenly gaining widespread attention in the popular media. Popular print publicationshave featured cover stories about BCI research recently, including *Scientific American*, *Scientific American Mind*, *Discover*, *Popular Science*, and *Wired*. Members of the Future BCI project have presented BCI research twice each on CNN, Fox, and 3SAT, as well as the Discovery Channel, WDR, and other networks. Other major networks like ABC, NBC, CBS, NPR, and BBC News have also highlighted BCI. research. BCIs have also been plot elements in many mainstream movies and TV shows, such as all six televised "Star Trek" series, "House,""Surrogates," "The Matrix" trilogy, and"X-Men" film series.

As an emerging market South Asian region has a huge potential to develop effective and sustainable BCI systems in the future. Integrative research combining medical and engineering communities in neuroscience, signal processing and pattern recognition are required to make any significant advancement at this stage. Therefore, collaborative research at this juncture could yield high quality publications and commercialization in near future.

Financial support from the University of Kelaniya Research Grant (RP/03/02/08/01/2015) is gratefully acknowledged.

References

1. Z. Sakkaff, and A. Nanayakkara. New set of cognitive tasks in EEG based Brain Computer Interface. *2010 Fifth Intnl. Conf. on Information and Automation for Sustainability.*
2. S. E. A. Kodagoda, S. S. M. Hemachandra, P. A. A. R. Pannipitiya, L. S. Bartholomeuz, and A. A. Pasqual. Minimal Invasive Headband for Brain Computer Interfacing and Analysis. *Information and Automation, 2006. Intl. Conf.* 109-114. IEEE, 2006.