International Journal of Information Technology and Knowledge Management
July-December 2010, Volume 2, No. 2, pp. 429-434

DEVELOPING BRAIN COMPUTER INTERFACE USING FUZZY LOGIC

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The study of Human–Computer Interfaces (HCI) provides a challenge for future interaction research and development. Brain-Computer Interfaces (BCI) is a part or a subset of Human-Computer Interaction (HCI) that involves the communication between the user and the system via brain signals. The electroencephalography (EEG) have developed into one of the most important and widely used quantitative diagnostic tools in analysis of brain signals and patterns. Various soft computing techniques are being used to recognize and classifies different brain activation patterns associated with carefully selected mental tasks like Neural Network, Fuzzy Logic etc. Fuzzy Logic is a form of algebra employing a range of values from "true" to "false" that is used in decision-making with imprecise data, as in artificial intelligence systems. The aim of this paper is to give an idea of developing an application based Brain Computer Interface (BCI) using Fuzzy Logic.

Keywords: Fuzzy Logic, Electroencephalogram (EEG), Brain Computer Interface (BCI), Human Computer Interface (HCI).

1. Introduction

Over 95% of the system software contains the excellent interface which allows the user to interact with the computer system. Brain Computer Interfaces (BCIs) are proposed to enabling people to operate electrical devices and applications by thinking process or through their mental activity. Brain–Computer Interfaces (BCIs) is the best possible way of providing the communication between the user and the system via brain signals and also it control the bypassing the classical neuromuscular communication channels [13]. So, here the main emphasize is on the brain which is the most complex organ in the body.

1.1. Brain

It is the organ that allows the person to think, have emotions, move, and even dream. The brain can be separated into various parts as shown in Fig.1. The brain and spinal cord make up the central nervous system and all of the nerves found in our body make up the peripheral nervous system. The wrinkles are called cortex and it is where the majority of brain cells or neurons reside.

The cortex can be divided into four main lobes. The frontal lobe, that evolve heavy thinking, pondering and planning our actions; temporal cortex, that process sounds and form memories; occipital cortex, that process all the things that are seen; and parietal cortex, that integrate or makes sense of all of the different bits of information that are bombarding the brain. As shown in Fig 2 the brain signals are mainly used for providing the communication between the user and the Brain computer Interface (BCI) system [26].

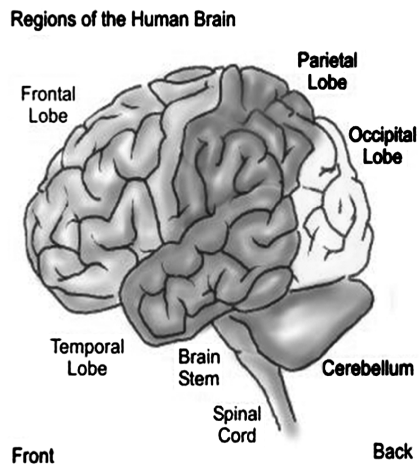

Fig. 1: Major Parts of Brain

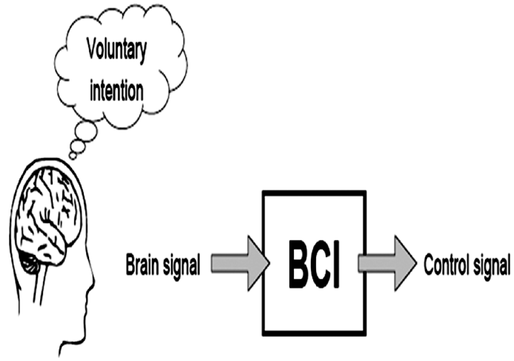

Fig. 2: General BCI

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The main advantage of Brain computer interface system is to those people who are physically disabled. In such cases, the people can express their views or desires via their brain signals just by thinking process. Sometimes, BCIs are referred to as thought-translation devices but this notion is misleading since all BCIs require the active participation of the subject. The studies by various researchers have shown that the human brain typically has some parts dealing with language processing like word production and comprehension or syntax and semantic processing [18]. Theoretically, a Brain Computer Interface could allow a person to spell words using thoughts, which could then be translated into other languages.

1.2. Brain Computer Interface

The Brain-Computer Interfaces (BCI) technology provides the capabilities to the user by enabling interaction with computers through a conscious and spontaneous modulation of the brainwaves after a short training period. By analyzing brain electrical activity online, several groups have designed brain-actuated devices that provide alternative channels for communication, entertainment and control. With BCI, now the subjects can operate simple computer games, or brain games, and interact with educational software. Work with humans has shown that it is possible for them to move a cursor and even to drive a wheelchair [30]. Invasive BCIs, almost exclusively investigated in animal models using implanted electrodes in brain tissue, and non-invasive BCIs using electrophysiological recordings in humans are described [28]. Basically, a Brain-Computer Interface (BCI) is a communication system in which messages or commands that a user wishes to convey pass not through the brain's normal output pathways to the muscles but are instead extracted directly from brain signals [24].

1.3. Electroencephalography (EEG)

A Brain Computer Interface (BCI) can also be implemented using inexpensive general purpose clinical EEG acquisition hardware as the base unit, a synchronisation module was constructed to allow the EEG hardware to be operated precisely in time to allow for recording of automatically time stamped EEG signals. Also, Brain-computer interfaces (BCIs) can be used for communication in writing without muscular activity or learning to control seizures by voluntary regulation of brain signals such as the electroencephalogram (EEG) [11].

1.4. Fuzzy Logic

FL is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. Fuzzy Logic's approach to control problems mimics how a person would make decisions, only much faster [20].

Basic Concepts in Fuzzy Logic

There are two basic concepts in fuzzy logic. They are linguistic variable and fuzzy if-then rule or fuzzy rule.

Linguistic Variable

It is a variable whose values are words rather than numbers. Its use is closer to the tolerance for imprecision and thereby lowers the cost of solution. It encapsulates the properties of approximate or imprecise concepts in a systematic and computationally useful way. It also reduces the apparent complexity of describing a system.

In 1973, Professor Lotfi Zadeh proposed the concept of linguistic or "fuzzy" variables. We can think of them as linguistic objects or words, rather than numbers. The sensor input is a noun, e.g. "temperature", "displacement", "velocity", "flow", "pressure", etc. Since error is just the difference, it can be thought of the same way. The fuzzy variables themselves are adjectives that modify the variable (e.g. "large positive" error, "small positive" error, "zero" error, "small negative" error, and "large negative" error). As a minimum, one could simply have "positive", "zero", and "negative" variables for each of the parameters. Additional ranges such as "very large" and "very small" could also be added to extend the responsiveness to exceptional or very nonlinear conditions, but aren't necessary in a basic system [43] [21].

Fuzzy IF- THEN Rule

IF -THEN rule statements are used to formulate the conditional statements that comprise fuzzy logic. A single IF - THEN rule assumes the form where A and B are linguistic values defined by fuzzy sets on the ranges (universe of discourse) X and Y, respectively. The IF part of the rule "x is A" is called the antecedent or premise, while the THEN part of the rule "y is B" is called the consequent or conclusion.

Additional benefits of fuzzy logic include its simplicity and its flexibility. Fuzzy logic can handle problems with imprecise and incomplete data.

2. RELATED WORK

The brain signals can be acquired in various ways. The initial work with Electrodes (pre-1965) is given below:

Hess (1932) - first to implant electrodes in diencephalon of cat

- Fischer (1957): Various metals/insulators used as single wire electrodes; 1-2 mm injury around tract.
- Collias (1957): Histopathological analysis; evolving response; astrocyte capsule formation by 1 mo.; FBR to electrode
- Delgado (1961).
- Robinson and Johnson (1961): Reinforced histological findings.

Then there was an evolution of Electrode Designs as given below:

Microwires

- Salcman and Bak (1973) - Record with parylene-coated microwires;
- Woodward and Chapin (1980s) - Developed multi-wire arrays.

Silicon Microelectrode Arrays

- Wise and Angell (1970, 1975) - Use IC technology to develop microelectrodes;
- BeMent (1986) - Developed first multi-site electrode from Si (Michigan-style electrode);
- Campbell (1991) - Developed first monolithic multi-shank electrode from Si (Utah Electrode Array).

Now days, to acquire these signals, a set of electrodes is used, most of the times attached to a brain cap. Several brain cap designs have been presented, as well many different electrodes. So far, all the brain caps are difficult and uncomfortable to wear. Moreover, the electrodes, wet or dry, are also difficult to place. To overcome these two main problems BCI offers a wearable cap which is useful for disabled and healthy people. A wearable brain cap has the ability to measure the required EEG signals without requiring any electrical contact with the head. The wearable cap is obtained using a flexible polymeric material, with new integrated contact less electrodes. The electrodes may be obtained using a new electroactive gel, which is used to read the EEG signals [19].

2.1. Current Work

Brain-based communication depends on accurate measurement and interpretation of brain function where a “thought” refers to the computer-aided interpretation of neuronal activities of the user. Neuronal activities may be recorded either at certain extremities of the human (arms, legs, etc.) or at the brain itself by analyzing brain waves. In principle, this approach is not limited to input into the computer but moreover may include methods for the computer to give feedback to the user by directly stimulating neurons. Here this small subset of HCI put an emphasis on Brain-Computer- Interaction (BCI).

Signal Acquisition Technologies

Majority of BCI science in North America involves “invasive” technologies, i.e., multi- electrode recordings from arrays of electrodes implanted directly into brain. However, certain BCI sites in Europe are capable of providing technologies that could aid in the advancement of “invasive” sensor technologies. The majority of BCI science in Europe involves “noninvasive” technologies, i.e., multi-electrode recordings from arrays of electrodes mounted onto the surface of the skull.

Recent advances in Brain-Computer Interface (BCI) technology indicate that there is potential for a new type of human-computer interaction: a user transmitting thoughts directly to a computer as shown in Table 1. The goal of this concept would be to extract as much entropy as possible from a user’s brain signals upon “transmitting” a thought. Provided that these brain signals can be recorded and processed in an accurate and repeatable way, a pass thought system might provide a quasi two-factor, changeable, authentication method resistant to shoulder-surfing.

Table 1
Current Work in BCI

S.	Name and affiliation	Name of work	Brief Description
1.	A Ferreira, R L Silva, W C Celeste, T F Bastos Filho* and M Sarcinelli Filho Federal University of Espirito Santo (UFES), Av. Fernando Ferrari, Brazil. (16th Argentine Bioengineering Congress and the 5th Conference of Clinical Engineering, Journal of Physics: Conference Series 90 (2007) 012094)	Human-Machine Interface Based on Muscular and Brain Signals Applied to a Robotic Wheelchair	This paper presents a Human-Machine Interface (HMI) based on the signals generated by eye blinks or brain activity. The system involves signal acquisition, processing, feature extraction and classification. The command options, which are going to be sent to the commanded device, are presented to the user in the screen of a PDA (Personal Digital Assistant). Here a robotic wheelchair is used as the device being commanded.

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S.	Name and affiliation	Name of work	Brief Description
2.	Dr. Andrzej Cichocki Head, Laboratory for Advanced Brain Signal Processing (Brain Science Institute , RIKEN, Nov. 2003)	Human/Brain Computer Interfaces: Challenging puzzles to solve	Using more general human computer interface (HCI) devices that integrate biofeedback from different aspects of the body, human commands can be conveyed to the computers not only by pre-processed brain signals but also by free speech, gaze- and head tracking, and gesture recognition. EEG signals, or some other electrophysiological signals, might provide a new way to communicate with the external world and control remote devices and computers.
3.	Matthew Middendorf, Grant McMillan, Gloria Calhoun, and Keith S. Jones (IEEE TRANSACTIONS ON REHABILITATION ENGINEERING, VOL. 8, NO. 2, JUNE 2000)	Brain-Computer Interfaces Based on the Steady-State Visual-Evoked Response	In this work, the Air Force Research Laboratory has implemented and evaluated two brain-computer interfaces (BCI's) that translate the steadystate visual evoked response into a control signal for operating a physical device or computer program. In one approach, operators self-regulate the brain response; the other approach uses multiple evoked responses.
4.	Richard A Andersen, Sam Musallam and Bijan Pesaran	Selecting the signals for a brain-machine interface	Brain-machine interfaces are being developed to assist paralyzed patients by enabling them to operate machines with recordings of their own neural activity. Recent studies show that motor parameters, such as hand trajectory, and cognitive parameters, such as the goal and predicted value of an action, can be decoded from the recorded activity to provide control signals.
5.	Anand Kulkarni Kevin Simler Alex Storer Maryam Vareth And University of California, Berkeley	Technology-Mediated Telepathy: A Natural Language Brain-Computer Interface	The research involves reading the motor signals generated by the human brain while communicating naturally and translating them in real-time into verbal speech. The work was chosen with sign language for the purpose of easily reading signals, but this work serves as a proof-of-concept for motors signals from any language provided sufficiently high imaging resolution is obtained.

3. PROPOSED WORK

The working of a general BCI can be explained with the help of a block diagram as shown in Fig 3. The general BCI system can have 4 main components:

- Signal Acquisition;
- Signal Processing;
- Classification and;
- Application.

As it is known that the BCI is a direct interface between a user's brain and a computer. In the first step, the brain signals are acquired through invasive or non-invasive methods. After, the signals are amplified and sampled. Once the signals are acquired, it is necessary to clean or removing the noise so to improve the accuracy of the signal.

After then the brain signals are classified to find out which kind of the mental task the subject is performing. And then the classified signals are used according to the specified application.

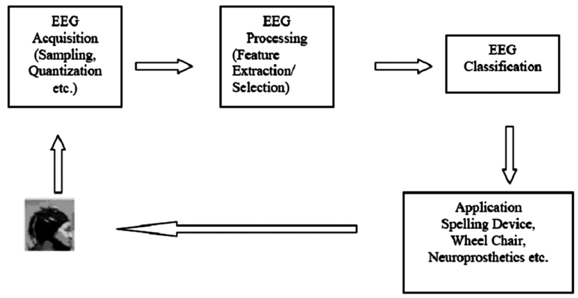

Fig. 3: Brain Computer Interface

The application can involves a spelling device, Neuroprosthetics, Wheelchair, recognition of human or subject's operations, feelings or emotions, etc. The application also generates feedback to inform the subject about the outcome of classification [24].

Based on the measures of the electrical activity of the brain i.e. EEG signals, the basic idea is to tap the user's thoughts in order to develop another communication way or interface between a human and a machine for spell words, identifying emotions or feelings etc. The emotion is one form of the state of human's mind. Basically, emotions are unconscious mechanisms controlling behaviour and Feelings are unconscious or conscious representations of emotions that are more detailed and larger in number. There are two basic reaction patterns:

- Approach: love, joy – influenced by positive emotions;
- Avoidance: sorrow, fear – influenced by negative emotions.

There are 4 different approaches to the measurement of emotions:

1. fMRI (functional Magnetic Resonance Imaging);
2. Other tests: eye measurements, galvanic skin response, EEG, heart rate, etc.;
3. Facial expressions;
4. Responses to feelings words.

The study of emotion (as one form of the state of mind) started more than a century ago, and today, much has been learned about the physiological and psychological aspects of emotion. The introduction of signal processing techniques for more quantitative emotion studies started more recently.

4. CONCLUSION AND FUTURE SCOPE

The history of Brain-Computer-Interfaces (BCI) starts with Hans Berger's discovery of the electrical activity of human brain and the development of electroencephalograpy (EEG). The Electroencephalogram (EEG) is one of the useful bio-signals to detect the human emotions. With EEG-based emotion recognition, the computer can actually take a look inside the user's head to observe their mental state. While brain-based spelling is a reality today, unfortunately, it is rather slow. Thought to text translation is typically at the rate of less than ten characters per minute. Thus, it seems that practical application of BCI technology in the area of translation would require a dramatic increase in this communication rate. Along with the spelling of words using brain signals the Identifying, recognizing emotions or feelings through brain signals is the next big thing.

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