



## BCI: Next Generation for HCI

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**Abstract**— In an era when IT and IT-devices are all around us and have taken various forms, like desktop, portable laptop, handheld mobile and PDAs, touch-screen based ATMs and tablet PCs etc, the Human Computer Interaction (HCI), the way to interact with these devices, also need to take new turns to make them successful. HCI plays a very important role because at the end it is end-user i.e. client or consumer of device who matters most and it is the HCI system which is most close to client or consumer. For IT-devices discussed above we have different types of Human Computer Interaction system e.g. keyboard, mouse, touch screen etc. While these are all traditional systems, There also exist some advance forms of HCI system which are in developing state and has a very promising features to revolutionize the IT industry by revolutionize the way we access IT-devices. Brain Computer Interface (BCI), controlling computer using brain directly, is an HCI system which is in developing state and has very promising features for revolutionizing the IT industry. With BCI we can read brain of our user and hence can develop next generation of ‘user-friendly’ system. BCI also provides possibility of connecting brains [14] like we can connect two servers. Most importantly it provides a very promising future for physically challenged who cannot access traditional computer system due to their physical disabilities. In this paper, we will discuss very brief introduction to HCI and its various forms. Then we will discuss about basics of BCI, components and structure of BCI systems, scope of applications of BCI system and related technologies. We will also look on some important research work in this field. At last we will discuss the main challenges which are need to address for making BCI a successful and consumable technology.

**Keywords**— *Computer*: any IT based device e.g. desktop, laptop, mobile, PDA, ATM, tablet PC etc  
*BCI*: Brain Computer Interface/Interaction, *HCI*: Human Computer Interaction/Interface, *EEG*: Electroencephalography

### I. INTRODUCTION

#### 1.1 Human computer Interaction (HCI)

In the area of HCI research the main focus is on defining new ways of human interaction with computer system. With the passes of time a number of inventions have been made in this field. In initial days we used only keyboards to access our computer system (e.g. in Unix Terminal). In Second phase, after invention of mouse and other pointing devices, we started using graphical user interface using pointing devices like mouse which make the use of computer more easy and comfortable. Nowadays we are using pressure-driven mechanism, i.e. touch screen, which is common at ATMs, Mobile phones and PDAs etc. Although it is not as common in daily works but the release of tablet PCs and its popularity[15] shows that the day is not much far when we wouldn't be having keyboards and mouse at all.

All of these inventions have been made for balancing the requirements of society and user. E.g. Games, Multimedia Applications etc are not possible using only-Keyboards so we need mouse driven system for such applications, similarly we cannot have large keyboard on mobile so we need a touch screen system for mobiles.

In addition to these traditional HCI models, there are some more advance HCI technology too for adding more flexibility and hence making the product more useful. E.g. swap card system at office doors for attendance and ATM-swap card for shopping. Speech processing systems are also there where we can access our computer system using our speech. Fig 1 shows most popular traditional HCI systems.



Fig.1 Different ways to interact with computer

**1.2 HCI and other Technologies**

As with all research domains, HCI is also not an independent research domain but is also influenced by other research domains. E.g. Development of GUI has given the birth to mouse and other pointing devices. Similarly popularity of web based and mobile based system given the birth to touch screen.

For Example, Think about Cloud Computing, using SaaS we need not to have a PC installed with software in our offices. We can have a centralized SaaS server and can use a low-power tablet-PC without any peripheral, 'which is very Eco friendly'. But without SaaS the use of Tablet PC is not that easy as they are not as powerful as normal PC or are not price competitive.

So, HCI is also driven by other domain of research to make them more effective and useful and vice-versa.

**1.3 Brain Computer Interface (BCI)**

In all the traditional HCI system discussed above there is one common thing in all-we use human peripheral to interact with system. As shown in fig-2, a normal or traditional human-computer interaction comprises of following five steps

1. Human brain decides the instruction for delivering to
2. this decision, from human-brain, is transfer to human peripheral(s) by nervous system
3. from human peripheral(s), this decision is transferred to computer peripheral
4. from computer peripheral the decision is (now it is computer command) transferred to computer brain i.e. CPU
5. CPU which executes the task



Fig.2 Traditional HCI system

Now imagine, wouldn't it be interesting if we skip the steps 2, 3 and 4. Additionally, as these steps requires most of the transfer time as time taken by brain to decide and CPU to execute the instruction is almost negligible, it will make the system considerably faster. And logically too it is quite

obvious as only Human brain and computer brain are the active part of this communication/interaction all are just a medium which-just bridging a gap between human thinking process and CPU understanding process. If we can somehow bridge this gap via some automatic means, as shown in fig-3, it is nothing but a brain computer interface where human brain thoughts are directly converted into computer brain instructions/program. But of course, without a doubt, this 'gap bridging' is not easy at all. It requires a number of technologies, from life science to mathematics to computer science and much more, to converge in order to make this hypothesis a reality. In this paper we will see various technologies and concepts concerned with this field and how they have made this hypothesis a reality up to some extent.

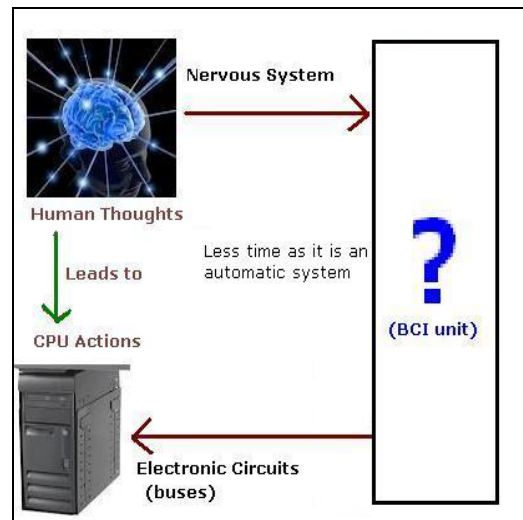


Fig.3 BCI based HCI system

**1.4 Scope of BCI Applications**

As discussed above, using BCI as human computer interaction technique we can have fastest computer system than we ever had because BCI does not contains manual information transfer at all. So, being the fastest interface, this interaction is promising to all domains but there are some specific domains where this interface is specifically very important. Firstly, Computer Games can be made more useful, effective and attractive using BCI. Similarly, using BCI in operating machines, e.g. Honda ATR are using it[21], and embedded system is also another potential field where BCI can be used. Besides this it has a medical industry as a biggest area of application [19] [20].

**1.5 Technologies Concerned with BCI**

In section-2 when we shall discuss BCI structure and all, we would be encountering various concepts and technologies. Following list gives a brief introduction to all these related technologies and their prime applications in BCI.

1. **Biology/Neurology**  
We use various concepts of Neurology for studying the structure of brain, neuron etc as it is very important for implementing BCI for any application.
2. **Electroencephalography (EEG)**

EEG [24] is the technique of reading brain. It is the prime method which facilitates conversion of human thoughts into digital signals.

3. Pattern Analysis and Recognition  
Once we have digital signal we need to analyze and recognize them for understanding what the brain is thinking.
4. Artificial Intelligence and Artificial neural network  
Although we have several alternatives for pattern analysis and recognition, Artificial Intelligence and Artificial Neural Network provides very effective and useful algorithms for this.

## II. MECHANISM OF BCI

### 2.1 Architecture of Brain

As per Neurology, science related to brain structure and other aspects of brain, our brain contains special types of cells called neurons. We have intelligence due to specific arrangement of neurons in our brain. The main aspects of neurons, we are mainly concerned with, are

1. They are in very excessively huge count (80-120 billion[1][2])
2. One neuron is connected to other several neuron and the degree of connectivity is quite high (for an adult around 100 to 500 trillion[3])
3. Each neuron has some potential(in mV) and this potential varies with our thoughts/brain state (e.g. sleeping).It means when we think something a particular patterns of potential in developed in brain neurons. This potential is also a mean via which a neuron communicates to other neuron(s).
4. Neurons can be clustered, i.e. all 80-120 billion neurons can be divided into few numbers of clusters (depends upon application and design topology). Clustering of neurons makes it easy to analyze the pattern as it is easy to analyze few cluster patterns as compared to analyzing pattern for all 80-120 billion individual neurons.

### 2.2 Reading brain using Electroencephalography (EEG)

EEG, study of brain signals, is a technique which makes us capable to read the potential pattern develops in our brain. As discussed above when we think something a particular neuron potential pattern is developed in our brain across different neurons. With EEG equipment (fig 3) we can read this pattern and hence can interpret the brain thought/state (up to some extent only). So in short, EEG is used to read our brain (of course up to certain extent only). Once we know what is there in brain we can develop computer instruction for doing the required task. And Hence EEG is the core technique behind BCI.

Like EEG, there are other technologies for reading brain e.g. MRI, fMRI etc. Reference [4] shows a comparison between all these techniques and their potential application areas.



Fig.4 EEG Equipment

### 2.3 Abstract view of BCI system

As shown in fig-5 a BCI system comprises of following components

1. Thinking in Brain  
Whenever something is to be done a 'thought' is developed in our brain which leads to development of a neuron potential pattern.
2. Reading Brain by EEG  
The developed potential pattern is read by EEG (or other similar techniques) to transform into an analyzable signal patterns. This is also known as EEG spectrum.
3. Analysis of EEG spectrum  
The signal pattern developed by EEG equipment is analyzed using various pattern analysis techniques.
4. Recognizing EEG spectrum  
Based on the signal analysis we recognize what task brain wants to get from computer or what the brain is thinking of.
5. Converting into suitable computer signal  
Once we know the task to be done we can easily determine proper computer command (or sequence of command i.e. program) to get the task from computer
6. Sending the signals to computer system  
Once we finish discovering the required command/program, send the same to CPU which then carries out the required task.
7. Feedback to User  
After CPU accepts the input it carries out the operation and sends the feedback to user in various feedback-forms e.g. video, audio etc. In [5] a study is done regarding various effective feedback methods for BCI systems.



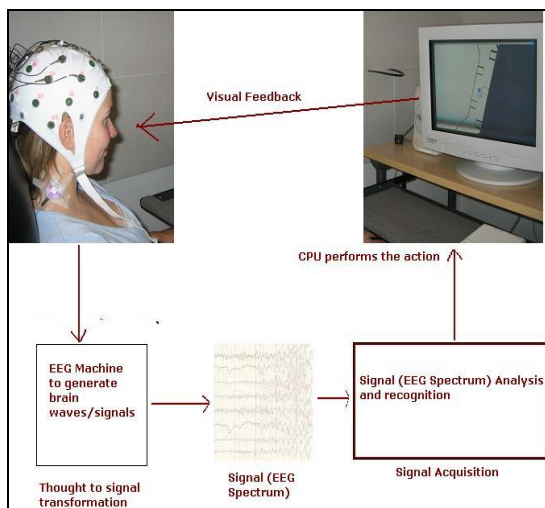


Fig.5 Components of a BCI system

Exploring the complete organization of above discussed BCI system, we have following important points:

- As far as first-point is concerned we need to cluster all the neurons into appropriate number of clusters and according to part of brain which is more important for a particular problem.
- The 2<sup>nd</sup> point is merely an EEG step. As we already have very sophisticated EEG equipment we can easily carry out second step.
- Regarding 3<sup>rd</sup> and 4<sup>th</sup> point we will discuss in Section-2.4. These are two main fields requiring lot efforts for making BCI a properly implementable technology.
- Again fifth and sixth points are also not much difficult to deal because once we know the task we can issue proper command corresponding to that.
- Regarding seventh point we have a detailed discussion on various feedback methods in [5].

So the main challenges is to analyze and recognize EEG spectrum (point 3<sup>rd</sup> and 4<sup>th</sup>). In the next section we will see some tools and techniques for Analyzing and Recognizing EEG spectrum.

#### 2.4 Techniques for EEG spectrum Analysis and Recognition

In broad terms, EEG spectrum analysis and recognition is merely a highly complex pattern analysis and recognition problem. So any technique for pattern analysis and recognition can use here provided it can handle such a complex and large patterns. Some possible techniques for pattern analysis are: Artificial Neural Network [16], Genetic Algorithms [17], Support Vector machine [18] and many more.

### III. RELATED RESEARCH WORK

Despite the fact that BCI is very complex process because of complexity of human brain, there are several successful implementation of BCI. Moreover, although, it's a new field a vast range of research has been done in this field. In [6] a

theoretical approach for designing a BCI system has been discussed. In this the uncertainty of neural signals and sensory feedback is also discussed. In [7] a study has been discuss for comparing BCI system based on various interface types (ABC interface vs. frequency-based interface) and screen size i.e. , on computer monitor, GPS device and mobile device. In this, study has been done for comparing user performance based on various matrices taking both physically challenged and normal users into account. A P300 [8] based BCI application for spelling prediction has been discussed in [9]. A BCI system for virtual reality has been discussed in [10]. NeoPhone [11] discuss the design of a brain controlled mobile phone. As in BCI we directly interact with user's brain we can easily read user's brain for increasing system's design and interface as discussed in [12]. In [13] a common framework (model) has been discussed for developing, evaluating and comparing BCI systems.

### IV. SIGNIFICANCE AND RELEVANCE OF BCI TECHNOLOGY

In this section we shall discuss impact of BCI on other technologies, IT-industry and our society.

#### 4.1 BCI and Web Technology

Nowadays, after introduction of web technologies like Cloud Computing, most of the business is done by web-applications (or web services). A very prominent benefit of a web-application over a desktop application is that it is platform as well as devices independent. Here device independent means we can access the system from various types of devices like desktop, laptop, mobiles, PDAs, tablet PC. Moreover, the handheld device market is also increasing as it is easy to use a portable PDA or mobile as compared to desktop. Advance web technologies like Cloud Computing in conjunction with Mobile technology has potential to change the shape of our work place from desktop based to web and mobile based. But as mobiles has limited physical dimension it's not feasible to have a complete keyboard on it. And thus we need some other method of interacting with such portable, smaller size devices. The problem has been addressed up to certain level by introducing touch screen. Another approach i.e. BCI is also a very promising candidate for solving this problem.

#### 4.2 BCI vs. Eco friendly IT

As we saw in previous section that a BCI system facilitates operating of a computer system without having a large number of accessories it makes a computer system very highly Eco-friendly. For a BCI system we need a mobile pr PDA or any type of computer or IT device and a BCI suite. And after the advancement nowadays we have a complete BCI suite even in brief case size box (fig 4).

#### 4.3 BCI in Medical Science

As discussed in various literatures e.g. [19] [20], BCI has a large range of applications in medical science ranging from brain treatment to neuroprosthesis. With the help of BCI we can diagnose various brain related and physical disability

related problems. We can also diagnose psychological problems with BCI. Neuroprosthesis, replacing a natural part by artificial one, is a sub-domain of BCI which deals with developing artificial body part which can be controlled directly with brain signals.

#### 4.4 BCI and Society

BCI has a very promising future for those who cannot use computer system due to their physical limitation or they are not able to understand the terminology. Since BCI does not require any physical connection, a person having physical disability can use a BCI enabled system easily. Moreover, since in BCI we are not using keyboard etc a person who do not know the typing can also use the system by just thinking.

### V. CHALLENGES FOR BCI

Although, BCI is successful in some areas but has not been accepted as consumable technology because of some limitations and difficulties which are need to address. In this section we shall look over such some difficulty in implementing a BCI system for making BCI a successful technique.

#### 1. Noise Filtering

At any moment generally we have multiple thinking in our brain. So when we generate wave for a particular thought we also get some waves corresponding to other unnecessary thoughts, these waves act as noise for original waves. For handling these noise-waves we need to increase our concentration during process. But it is not possible to concentrate fully on a particular thought, nor is it practical. For handling this we need some Noise-Filtering mechanism that can detect the unrelated spectrum so we can filter them out.

Design of Noise-Filters requires some situation and application specific knowledge accompanied by some knowledge from neurology. First we study the situation/application then identify which part of brain will deal with it. And then we carry-out some close-to-ideal situation where user (called subject) tries to concentrate fully on the application. We carry out some such experiment for finding out the pattern of the signals and on the basis of this we prepare and calibrate our Noise-Filter. As process shows it very difficult problem and requires a lot of time (generally in months).

#### 2. Clustering of Neuron

As discussed in Section 2.1 point-4, we divide 80-120 billion brain-neurons into few clusters. But the question is – on what basis we should divide the neurons? The answer is –on the basis of application/situation and experimentation only. So, there exists no standard way define the exact clustering perfect for all situation. But still we have some standard e.g. 10-20 system [22] which is very suitable for large number of problem but still a lot of research is required in this field for automatic clustering of neurons.

#### 3. Signal Acquisition

The biggest challenge for BCI is-how to analyze and recognize the brain-waves or EEG spectrum. Very deep research has been done in this field to find new techniques for this and problem has been solved up to a considerable extent. But still we need to make it further effective, accurate and faster for making a BCI system useful. It is very crucial part of BCI system as the main delay is caused at this level only. So as fast we can this system so the total BCI system.

#### 4. User Interface Design

Nowadays we have very complex GUIs for our web/desktop applications because we can easily move the pointer using mouse. But when coming to BCI, we need to control pointer movement from our thinking and hence we must have a GUI which can easily be accessed and controlled by brain. A very simple and working GUI is described in [23]. Two very interesting videos are also available at [www.youtube.com/watch?v=ykEerBqHbbo](http://www.youtube.com/watch?v=ykEerBqHbbo) and [www.youtube.com/watch?v=5fZER3ykaJs](http://www.youtube.com/watch?v=5fZER3ykaJs) in which a BCI system is use to access mail and twitter.

### VI. CONCLUSION

In this paper we discussed about various aspects of BCI system inclusion its structure, applications and promises to IT world. We also look various challenges which need to address for making BCI a successful and consumable technology. The main motivation of the paper is to bring this new emerging technology to the front.

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