User Centered Design in Brain Computer Interface using a Combined Electroencephalogram and Magneto Encephalogram Data

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Abstract
Understanding brain analysis and performance has continued to draw attention as it seems to be a major resolution of the unresolved problem in Human Computer Interaction. This paper considers the use of brain signals, the Electroencephalogram and Magneto encephalogram data, as a means of enhancing the performance of Bain Computer Interfaces by incorporating the data into the development process of the interface. Data used for experiment are simulated with the Monte Carlo simulation process and tested as available within the EEGLAB environment. Results show that the combined use is possible, though with variations and the performance on combination is well admissible with known benchmarks. The paper concludes that a synergized use of the Electroencephalogram and Magneto encephalogram data for report generation will be a further enhancement of the performance of the Brain Computer Interface.

Keywords: Bain Computer Interface, Electroencephalogram, Magneto encephalogram, EEGLAB

1. Introduction
Nowadays, many softwares are developed with a keen interest on the type of interface that runs on them, since softwares are more likely to be acceptable to users, when they are “friendly”. Being “friendly” is a function of the flexibility of the accompanying interface. This is a major requirement in end users software development process. The understanding required for this kind of process is similar to those embodied in the concept of the Brain Computer Interaction (BCI) where systems are developed to enable users perform task on computers by using the capability of their perception and cognition, depending on the performance of their brain.

A Brain–Computer Interface (BCI), often called a Mind-Machine Interface (MMI), or sometimes called a Direct Neural Interface or a Brain–Machine Interface (BMI), is a direct communication pathway between the brain and an external device. BCIs are often directed at assisting, augmenting, or repairing human cognitive or sensory-motor functions. Research on BCIs began in the 1970s at the University of California Los Angeles (UCLA) under a grant from the National Science Foundation, followed by a contract from DARPA. The papers published after this research also mark the first appearance of the expression brain–computer interface in scientific literature [1] and the functionality is primarily dependent on Electroencephalogram (EEG) and Magneto encephalogram (MEG) data.

To understand the relationship of this to the brain signal research, we consider the case of Epilepsy. Epilepsy is a disorder of humans and animals that may occur spontaneously or may be triggered by brain disease. It is characterized by an abrupt change in behavior, which corresponds to a sudden change in the electrical and chemical activity of the brain cells. Many different kinds of epileptic attacks occur, they generally last a few minutes and may consist of jerking of arms and legs with unconsciousness (major epilepsy), or simple loss of awareness without any movement (minor epilepsy). BCI has recently been used in understanding the causes of this disease and also minimize its risk. This is by understanding the changes that occur between the normal functioning of the brain and that of seizure (in which epilepsy occurs). An electroencephalogram, or EEG, is one of the available tests used to diagnose epilepsy.

EEG, measures and records the electrical activity of the neurons in the brain. An EEG discovers if there is abnormal electrical activity in the brain and, in some cases, the types of seizures that might have occurred. The seizure is a temporary seizure of the brain signals made up of both the EEG and the MEG. The interest in this paper is to further study the brain, with a view of understanding some complexity that can be related to and used for advancement in the retrieval of information about body organs and genes.
This process will involve a deeper investigation into the reading and uses of the EEG and MEG data as most of the information to be extracted from the brain use as functions of these signals. If these data are captured and modelled appropriately, it can better assist the development of a more usable BCI. The paper shall not attempt to develop a BCI for now, however attempts will be made to unify the information sources of the brain data with the view of having a well placed benchmark to which appropriate BCIs can be developed. The BCI is essentially useful in situations where the brain can process information but the user lack some physical capabilities to further utilize that process due, maybe to a level of disability. The research of BCI can be wholly tailored towards disabled persons however recently this have been extended for general usage. This way, such individual can initiate a computerization process by simply thinking about such process. This is achieved with the help of generated brain signals which are transformed into electric signals for the computer to interpret. Earlier research supports this representation as the brain has dedicated region meant for specific task as example, Broca’s area is a region of the hominid brain used for language production while cortex is used for semantics interpretation. The following section provides an overview of the human brain.

2. THE BRAIN

Brain is the boss of the body and runs the whole show. The human brain contains about 10 billion nerve cells, or neurons. On average, each neuron is connected to other neurons through about 10 000 synapses. (The actual figures vary greatly, depending on the local neuroanatomy.) The brain's network of neurons forms a massively parallel information processing system. This contrasts with conventional computers, in which a single processor executes a single series of instructions. The brain is the center of the nervous system in all vertebrate and most invertebrate animals—only a few invertebrates such as sponges, jellyfish, adult sea squirts and starfish do not have one, even if diffuse neural tissue is present. It is located in the head, usually close to the primary sensory organs for such senses as vision, hearing, balance, taste, and smell.

The brain is the most complex organ in a vertebrate's body. In a typical human the cerebral cortex (the largest part) is estimated to contain 15–33 billion neurons,[2] each connected by synapses to several thousand other neuron.[3] The brain is not homogeneous, at the largest anatomical scale, we distinguish cortex, midbrain, brainstem, and cerebellum. Each of these can be hierarchically subdivided into many regions, and areas within each region, either according to the anatomical structure of the neural networks within it, or according to the function performed by them.

The overall pattern of projections (bundles of neural connections) between areas is extremely complex, and only partially known. From what we know of neuronal structures, one way brains learn is by altering the strengths of connections between neurons, and by adding or deleting connections between neurons. Furthermore, they learn "on-line", based on experience, and typically without the benefit of a benevolent teacher. The efficacy of a synapse can change as a result of experience, providing both memory and learning through long-term potentiating which is done through the release of more neurotransmitters. Many other changes may also be involved. The brain performs an incredible number of tasks including the following: It controls body temperature, blood pressure, heart rate and breathing. It accepts a flood of information about the world around human from various senses (seeing, hearing, smelling, tasting and touching). The brain handles your physical movement when walking, talking, standing or sitting. It lets you think, dream, reason and experience emotions. All of these tasks are coordinated, controlled and regulated by an organ that is about the size of a small head of cauliflower. Figures 1, 2 and 3 shows the human brain with appropriate labels:

Figure 1: Brain with emphasis on the lobes
The approach in the generalized Brain Computer Interaction (BCI) research is to improve the understanding of the brain and its waves with the aim of using modern machine learning processes and algorithms to perform usable analysis on the brain. In this way, we can generate an artificial clone of the brain waves signals. Such technology will require the use of modern sensor systems. Being a research that has been introduced more than a decade ago, recent approaches has been transgressed from the initial teaching of this subject area so much that it has exceeded the development of a simple cursor control/movement paradigm to increasingly involve the use of real life applications such as program development, robot operational, wheel chair control, enhanced door control system amongst others. This will help disabled people to perform activity in a better way than what it used to be. Such application requires highly reliable environment to achieve performance. This is a major task in a domain that has not recorded many major successes. The current day BCI offers low throughout information and are insufficient for these complex applications [4].

3. BRAIN COMPUTER INTERFACE

3.1 Electroencephalogram (EEG)
The electroencephalogram also called the EEG has been mentioned earlier but for its importance in this research, we further discuss it elaborately. It is a process used for major achievements and results obtained in the BCI. The EEG formulates the methodology for measuring brain waves. The measure in this regard is associated with a process of knowing the signal generating rate. Over time, it has been shown to be a method for providing evidence of how the brain functions. The processes involved include the use of electrical currents within the brain. The measure is carried out by attaching electrodes to the scalp with an extension of the electrode wire attached to the machine. The output is displayed on the EEG. In the last 15 years, it has been used in the evaluation processes of brain disorder. It helps to understand the type and the location of an activity during brain hold-up. This makes it adequate to evaluate human with brain related challenges. These challenges include but not limited to coma, tumors, confusions, depression, strokes amongst others.

In the event of death, the implication is that the EEG has stopped working. The EEG can also been used to determine the survival chances of patients with serious life-threatening alignment or those on life support. The EEG technology cannot be seen as a new technology, though not earlier used in human, brain waves were first recorded in 1912 in dogs. In 1924 in Jena, German psychiatrist Hans Bergers recorded the first electric field of the human brain.
He named it electroencephalogram now commonly abbreviated as EEG over a period of 9 years (1929 – 1938) [5]. The amplitude of the EEG is about 100μV when measured on the scalp and about 1-2mV when measured on the brain surface. It has a bandwidth usually of between 1Hz to about 50Hz. On the average, the brain has an estimated total of 10^10 nerve cells covered with about 1,000 – 100,000 synapses [6]. The amplitude last about 1ms. In research associated with the BCI, EEG acquisition hardware are used as base unit to allow for automated EEG readings. Since the BCI, in this regard, can help in performing task without necessary muscular inclusion, the voluntary modulation of the brain signal such as the electroencephalogram (EEG) can be determined [7]. The processes have been used to operate small modes of computer games and also tested for online collaboration.

This technology is desired majorly by disabled persons, since it will enable such persons to express their desire by simply thinking about it. Furthermore, this paper is concerned with the understanding of the ways by which the EEG and other associated data, like the MEG data, can be combined in order to improve the performances of interfaces such as the BCI. The BCI being a subset of the HCI has all its major intent inherent in the later. The successes achieved has shown tremendous acceptability as demonstrated by the massive interaction modality of user performance as reported in [8].

3.2 Magnetoencephalography

In addition to measuring the electric field directly via electrodes placed over the skull, it is possible to measure the magnetic field that the brain generates using a method known as magneto encephalography (MEG). It is a functional neuroimaging technique for mapping brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain, using very sensitive magnetometers. This technique also has good temporal resolution like EEG but with much better spatial resolution. The greatest disadvantage of MEG is that, because the magnetic fields generated by neural activity are very subtle, the neural activity must be relatively close to the surface of the brain to detect its magnetic field. Arrays of SQUIDs (Superconducting Quantum Interference Devices) are currently the most common magnetometer, and SERF being investigated for future machines. Applications of MEG include basic research into perceptual and cognitive brain processes, localizing regions affected by pathology before surgical removal, determining the function of various parts of the brain, and neurofeedback.

As of today, MEGs can only detect the magnetic signatures of neurons located in the depths of cortical folds (sulci) that have dendrites oriented in a way that produces a usable field. MEG signals were first measured by University of Illinois physicist David Cohen in 1968 [9]. Recent studies have reported successful classification of patients with multiple sclerosis, Alzheimer's disease, schizophrenia, Sjogren's syndrome, chronic alcoholism, among others. MEG can be used to distinguish these patients from healthy control subjects, suggesting a future role of MEG in diagnostics [10].

4. RESEARCH QUESTIONS

Literature has shown that the independent use of the EEG and the MEG to achieve several results have been published in this research area. Though, the EEG and the MEG results are combined to define a holistic framework, the need for advancement beyond the present successes of the BCI research has motivated the need for this extension. This is aimed paper at presenting the possibility of the combined use of the EEG and MEG data (signals) as a simultaneous singular process. Even as most labs have been dedicated to EEG studies, the data used for experimental observations are both. (MEG–Magnetoencephalography and EEG – eletroencephalography). We attempt to investigate how the combined use of EEG and MEG can enhance the performance of the Brain Computer Interface. They are used to reveal cognitive process such as language understanding auditory/visual perception and decision making simultaneous use of the EEG and MEG [11].

5. APPROACH

Signals generated from the brain are either electrical or magnetic, these signals forms the basis of all data analysis in the BCI research. Research has revealed that the signal has differential responses [12]. Since the actual behaviour of the EEG and MEG pattern has not been fully investigated in terms of its gradient direction[13], it is necessary to develop a simultaneous system that can be used to analyze the data and get a reliable estimate of a generalized pattern. Such combined analysis can form a basis for new solution to the emerging problem of containment (pattern containment) of the EEG and MEG data set. In the following section, we present a method for the proposed simultaneous analysis. The advantage of the method is that it allows the generalized least square method to account for observed undulations. The processes are expected to exist in a more understandable pattern such that an algorithm can be used to predict the patterns. The paper further intends to understand the interdependence of the bioelectric and biomagnetic data with strong factors.
This will allow us to understand and present a probable solution to the emerging problem inherent in Independent Component Analysis, ICA. The solution will provide a suitable method for developing an appropriate algorithm since the ICA problem is principally to separate a set of N independent inputs which has N linearly mixed output. This is always done without further knowledge about their distribution and their dynamics. The earliest well published approach of the ICA to EEG is at the Denur meeting[14]. Our interest in the ICA is in its assumption that EEG is a linear mixture of underlying brain data sources. This assumption is largely due to the fact that the mixing of brain fields at the scalp electrodes is basically linear. Scalp EEG signals are produced by partial synchronization of neural scale field potential across cm² scale or larger areas of the cortex. This synchronization optimizes relation between spike mediated top–down and bottom-up communication both within and between brain area. This fundamentals are used in formulating the following approach.

We apply a regression analysis with the following generalized model:

\[
\begin{pmatrix}
  y_n \\
  y_w \\
  y_{Rn}
\end{pmatrix} = \begin{pmatrix}
  \mathbf{x}_n \\
  \mathbf{x}_w \\
  \mathbf{x}_{Rn}
\end{pmatrix} \boldsymbol{\beta} + \begin{pmatrix}
  \varepsilon_n \\
  \varepsilon_w \\
  \varepsilon_{Rn}
\end{pmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)
\]

5.1 Model Discussion
The model is formulated in such a way that the subscript represent the undulating (differencing) values in EEG and MEG where y is measurement on a given sensor (N), P is the non linear MEG or EEG in concentric sphere, \(X\) and q are sensor location and orientation respectively. \(\mathbf{x}, \beta\) and \(\varepsilon\) are used as radii, conductivities and distributed noise respectively. MEG is given by \(b(Vn, Td, d) \cdot Zn / (Z'n Zn)^{1/2}, \) in dipole where \(b(Xn, Td, Ed)\) is a vector, essentially, a valued magnetic vector [15].

This model is available as used in [16],[17]. We can generalize that, applying multiple regressions, EEG and MEG data will produce an output in form of the solution b of the linear equation

\[y = xb, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)\]

where y are the data, x is the matrix and b contains the regression coefficient.

5.2 Reading the EEG/MEG data
We lay emphasis on the importance of the EEG in this paper, as a depiction of the electric activity occurring at the surface of the brain. Physically, the performance of the EEG appears on an interface of the monitoring machine. It exists as a wave function with varying frequencies. Generally, the amplitude is taken as a measure of voltage. Frequency (Hertz) or \(\text{Hz}\) has been attributed to be a major characteristics used in understanding the pattern of the brain signals.

This is necessary as a form of reminder into the peculiarity and importance of the EEG and MEG data. Usually, data from EEG readings had been used to make decisions, though MEG data are essential, but they are also very expensive, this is because they are more difficult to analyze than the EEG data. In taking these data, the Event Related Potential (ERP), Event Related Magnetic Field (ERM), oscillation, power and phase, sources localization and topological map are some of the major factors that are being considered. To achieve the aim of this paper, a stimulated experiment using base line data is adopted.
5.3 Experimental Set up
In setting up the experiment for this research, the EGGLAB 7.1.3 .13b is used as the analyzing platform while the dataset used is the EEG recording available at the EEGlab stimulation centre. This is used in testing models upon registration and approval. EEG lab is an open source for electrophysiological signal processing application which has been tested for reliability over the years. It is an interactive MATLAB tool for processing continuous and event related EEG, MEG and other electrophysiological data incorporating Independent component analysis. The software runs on matlab v5 and higher. Linux, Unix, Window and MAC OS. EGGLAB provides several ways of visualizing and modeling brain wave changes. Such is admissible to individual dataset or a collection of dataset.

The setup consist of the following, 170MEG and 170 EEG data adopted from the EGGLAB reading set 1. We use the same set to analyze the effect of the combined data (EEG+MEG). A failing tolerance of 80EEG and 80MEG is used to accommodate non-transcending data from the generalized sample. In section 2, we noted that noise is an essential factor in the process of analyzing both the EEG and the MEG data thus we attribute the EEG and the MEG noise standard deviation to 8% of maximum MEG and EEG signal generated. Normally, a corresponding eccentricity of 0.8 on the 170 EEG and MEG data consideration is used. In MATLAB, the associated data structure is given as follows.

```
EEG
ALL EEG
CURRENTSET
LASTCOM
ALLCOM
```

This complete data structure is available on the matlab documentation (ref). We adopt the commonly used stimulation method for the EEG research, the Monte Carlo stimulation technique because it has underlying advantages. In the MCS method, the real head model is usually rating into account and the process remove the consequences of forward model errors, though theoretically, it compares the use of EEG alone MEG alone and the combined EEG/MEG as a separate data set. The result of the stimulation process with error consideration will be based on the following category of analysis: the location error, the average Euclidean distance (for estimation location vector); the moment error for the ED between the true and estimated moment vector. This method assures us of the typical nature of the frequency range of these activities, (the electric and magnetic field of the brain).

The activity was related to the Maxwell equation which permit the formulation of the EEG recording as inner relationship with other generated symbol of the brain which can be expressed as:

\[ P = q + m \]  

where \( P \) is the vector of the EEG/MEG recording, \( q \) is the acquired matrix (with each column specifying the electrical magnetic (or/and) solution of the component and \( m \) is the vector representing any occurring noise.

6. FINDINGS

The findings in this paper reveals the diverse differences in the EEG and the MEG dataset. This is well supported by the performance of the EEG and the MEG data available at the EEG lab data set. The first major finding is the differences are in terms of the location direction where the most suitable for EEG is Longitudinal and that of MEG is Traverse. This is further explained by the diagram below:

![Diagram showing Transverse and Longitudinal Location](image)

**Figure 3: Transverse and Longitudinal Location supporting EEG and MEG respectively**

Observation based on the earlier defined scale shows that the accuracy is highly affected in MEG parameters unlike the case of EEG where just little differences is observed. Furthermore, the observation shows that a stable eccentricity is achieved in MEG than EEG. On the moment, the EGGLAB analyzer report shows that EEG moment are better and more reliable than the MEG moment about at 72% of the time. Now, the combination of the EEG and MEG result seems suitable and of balancing status because the traverse location is balanced by the MEG while the longitudinal location is balanced due in the EEG. This makes the 170EEG + 170MEG a useful consideration for the combined of the EEG and MEG data set which satisfies the purpose of this paper.
7. CONCLUSION

Since the activity and the performance of BCI is majorly dependent on the generated signals of the EEG and the MEG, it becomes necessary to present a method for synergizing the data of these signals, as this will help in improving the performance of the BCI. To achieve this, the paper presented the advantages of combined use of the EEG and MEG data as a means of improving the development of a more flexible BCI. This paper does not only show the advantages with of some experimental framework, the EEG and the MEG as signals obtained from the brain in form of a review. We later show the possibility of extending a linear framework based on the use Monte Carlo stimulation method. We propose that the linearity be explored for a combined data set, such that an appropriate distribution of noise error can be isolated from the data set using the Gaussian technique. EEGLAB and its corresponding dataset were used in testing the suitability of the proposed framework and results show that a combined use of EEG and MEG will provide a better framework for an enhanced BCI.

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REFERENCES


Author’s Brief

Enikuomehin, A. Oluватoyin is a Lecturer at the Department of Computer Science, Lagos State University and the Head, Application Development and Data Services Unit of the University's External System. His current research is concerned at developing applications for modelling emotions in information retrieval, search space reduction softwares, biologically inspired search engines and methods in software engineering. He is a member of several reputable associations like the British Computer Society, America Association of Artificial Intelligence, Nigeria Computer Professional Association, and Nigeria Association of Mathematical Physicist amongst others. Enikuomehin obtained his PhD in Computer Science from the University of Ilorin, Ilorin.