ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2016

Analysis of Brain Activity using Cognitive Science and Machine Learning

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ABSTRACT: This research gives an insight into the thought process of the human mind using various techniques of Artificial Intelligence. Various patterns are produced in the human mind according to the various kinds of thoughts going on in the mind. Through this research work based on Cognitive Science, we have tried to analyze few of those patterns/brain-waves produced while feeling different emotions. It incorporates fetching of the EEG patterns of brain activity under various situations, gathering data on the basis of patterns, feeding that data as training data in simulator and testing new data using training set which involves Machine Learning. This research is purely hypothetical in nature but if realized in hardware, it can become useful in interrogation of criminal/terrorist to take out important information from them, to transfer confidential information safely and can also be used by dumb people to interact with others.

KEYWORDS: Brain Waves, EEG, Simbrain, Emotions, Cognitive Science, Machine Learning, Artificial Intelligence.

I. INTRODUCTION

The inner workings of the human mind are far more intricate than the most complicated systems of modern technology. For over half a century, researchers in the field of artificial intelligence (AI) have been attempting to develop programs that will enable computers to display intelligent behaviour. In the past decade, enormous strides have been made in understanding the human brain. Cognitive psychology is the science of how the mind is organized to produce intelligent thought and how the mind is realized in the brain [3], [6]. The main objective of our research is to understand how the brain functions on various levels and how it reacts under different kinds of situations by researching on Cognitive Science. Under this work, we have tried to analyse the different waves that the brain emits as well as its responses under various situations. This research work is based on software analysis of brain activity but if executed on hardware, it can become useful in interrogation of criminal/terrorist as the thoughts going on in his mind can be retrieved. In this manner, cases can be solved efficiently and in case of terrorist activity, lives of lakhs of people can be saved. In case of army or other places where confidential information is to be transmitted without the knowledge of enemy or there is a risk of leakage of information by some intruder, this system can be used to send the thoughts wirelessly to its destination where only the authorized person can have the access to that confidential information thus, increasing the security. Apart from these, this system can be used by the person who has the disability to speak (dumb) in order to communicate with the rest of the world. His/her thoughts can be displayed on a screen and in that way, communication can be made possible between them and others.

The paper presents types of brain waves in Section 2. Section 3 and 4 gives information about EEG simulator and Simbrain. Section 5 provides simulation results. Paper is concluded in section 6.

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II. BRAIN WAVES

At the root of all our thoughts, emotions and behaviours is the communication between neurons within our brains. Brainwaves are produced by synchronised electrical pulses from masses of neurons communicating with each other. Brainwaves are detected using sensors placed on the scalp [9].
The various types of waves that brain produces under different circumstances are as follows:

A. *Beta Waves*

These brain waves are of high frequencies (12Hz to 40 Hz), have low amplitude and are highly asynchronous in nature. These are mainly observed when we are awake and alert. They are responsible for our logical thinking, conscious thoughts and produce a stimulating effect on mind. Hence, having an appropriate amount of these waves can help enhance our focus, which can help us in our studies and other critical tasks. However, excess of these waves can impinge a negative effect on the human mind and may lead to problems like stress, anxiety, inability to relax, high arousal and adrenaline rush. On the other hand, a low amount of Beta waves can result in daydreaming, depression and poor cognition. The Beta activity can be increased naturally by consumption of stimulants such as caffeine or some energy drink [10].

B. *Alpha Waves*

The Alpha waves have the frequency ranging between 8Hz to 12 Hz. It helps bridge the gap between our conscious and subconscious mind. These waves are mainly observed when we are awake but in a relaxed state of mind. Too much of these waves can lead to Daydreaming or inability to focus while in scanty quantities, it may result in anxiety, high stress and insomnia. In optimum quantities, these waves produce calming effect on mind, enhance problem solving ability and induce confidence by thinking positive about everything. Alpha waves can be increased by closing your eyes and relaxing or practicing meditation and by consumption of alcohol and other relaxants [5], [10].

C. *Theta Waves*

The frequency range of Theta waves is between 4 Hz to 8 Hz. They are involved in daydreaming and sleep. Theta waves are connected to us while feeling deep and raw emotions. An excess of these waves can result in depression, hyperactivity, inattentiveness, impulsivity and may make the person “highly suggestible” based on the fact that they are in a deeply relaxed and semi-hypnotic state. In optimum quantities, it can make our mind creative, intuitive, relaxed and may help us in connecting emotionally whereas, if present in little quantities, it can cause stress, anxiety and a state of poor emotional awareness. Intake of depressants increases the proportion of Theta waves [5], [10].

D. *Delta Waves*

The frequency range of Delta waves is between 0 Hz to 4 Hz. These are the slowest brain waves in human beings and highly synchronous in nature. These waves are mainly found in infants and as they age, the level of Delta being produced drops down. They are associated with the deepest levels of relaxation and restorative, healing sleep when produced in optimum quantities. They are also involved in unconscious bodily functions such as regulating heart beat and digestion. Too much of these waves may cause brain injuries, inability to think and learning issues. On the other hand, if they are less in number, it will have a negative impact on the body as the brain will not be able to rest and sleep properly. Depressants and deep sleep can increase the Delta waves [10].

III. EEG SIMULATION

The scalp and cortex lie like pages of an open book on which the cortex enciphers vast quantities of information and knowledge. They are recorded and analysed as temporal and spatial patterns in the electroencephalogram and electrocorticogram [2], [4]. Electroencephalography (EEG) is practiced by neurologists, cognitive neuroscientists, and others interested in functional brain imaging. Electrical potentials on the scalp exhibit spatial and temporal patterns that depend on the nature and location of the sources and the way that currents and fields spread through tissue [1]. Special sensors (electrodes) are attached to the head and hooked by wires to a computer as shown in Figure 1. The computer records the brain's electrical activity on the screen or on paper as wavy lines [11].

Scalp EEG software was used to simulate EEG output in our research. Scalp EEG is a tool for measuring electrical activity generated within the brain. EEG serves an important role in localization of ictal and interictal sources.

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Localization is guided by analysis of phase reversals and fields of spikes and sharp waves. Knowledge of typical and atypical patterns of spike fields is necessary for accurate EEG interpretation. This interactive model is primarily designed as a teaching tool for aiding EEG analysis. The model does not explain source location within the brain, but instead generates predicted EEG patterns given a scalp potential distribution as input [7].

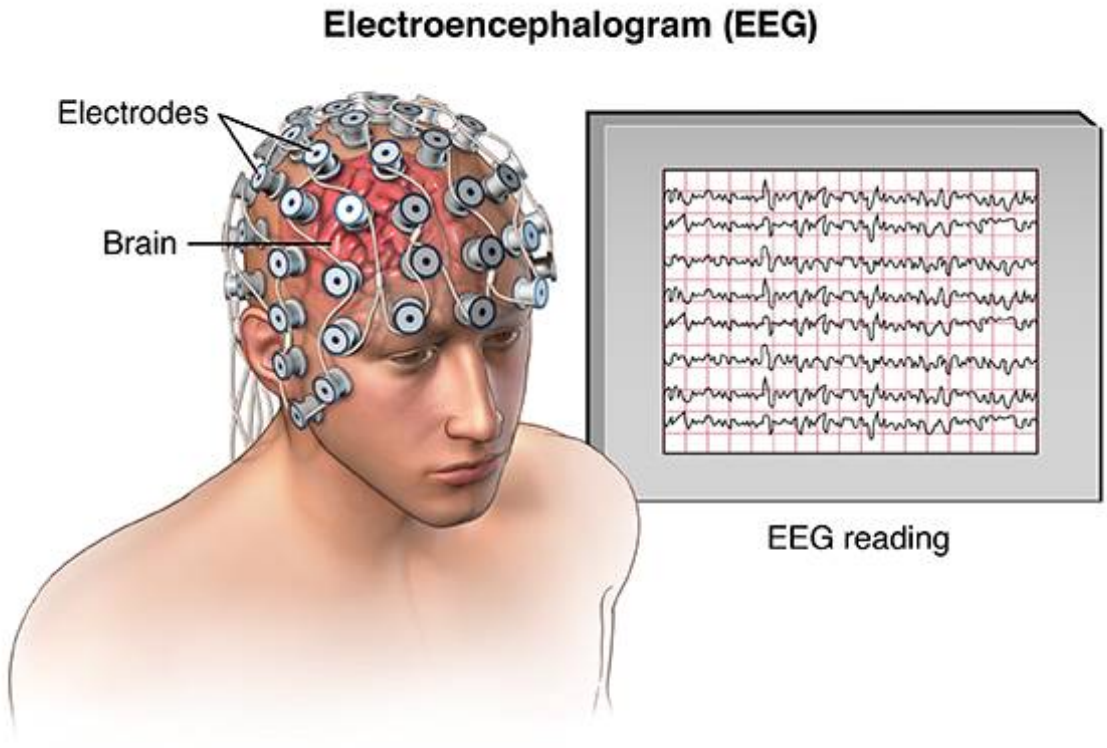

Figure 1. Electroencephalogram [12]

IV. SIMBRAIN

Output from Scalp EEG was given as input to the data world component of Simbrain. SIMBRAIN is an open source tool for building, running, and analyzing neural-networks (computer simulations of brain circuitry). Simbrain aims to be as visual and easy-to-use tool as possible. Unique features of Simbrain include its integrated "world components" and its ability to represent a network's state space. Simbrain is written in Java and runs on Windows, Mac OS X, and Linux [8]. Our final output was obtained from the Display component in SIMBRAIN [8].

V. SIMULATION RESULTS

This research gives an insight into the thought process of human mind using various techniques of Artificial Intelligence. Various patterns are produced in the human mind according to the various kinds of thoughts going on in the mind. Through this research work based on Cognitive Science, we have tried to analyse few of those patterns or brain waves produced while feeling different kinds of emotions.

As shown in Figure 2, first of all we obtained different patterns based on different feelings by simulating brain waves in various parts of brain using the EEG Scalp Potential Simulator made available by University of Pennsylvania. These patterns were then fed as training set data input into Simbrain Simulator and corresponding thoughts or feelings were stored in the memory. The data was obtained by converting amplitude of brain waves into numeric data. New patterns and their data were tested using the training set input and if detected, the corresponding thought or feeling was displayed on the screen. This phenomenon of feeding training data set and analysing the test data using the already

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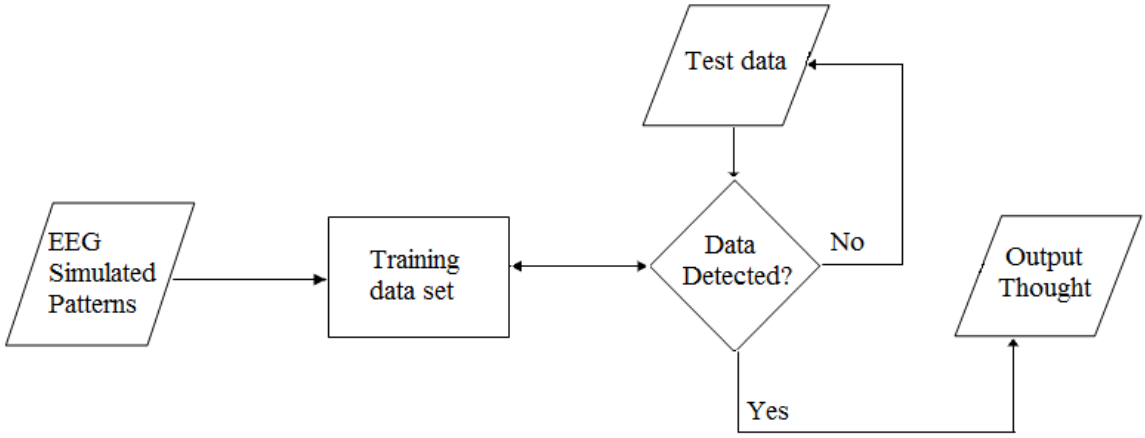

Figure 2. System Architecture

defined training data set is based on Machine Learning where the machine analyses the test data using the training set and increases its training data set after testing data each time. For future analysis, the new updated training data set is considered and the cycle goes on.

Figure 3 and Figure 4 shows EEG simulation results and corresponding Simbrain simulation output respectively. Figure 3 shows the brain waves produced when the human mind is most attentive. For example, while chatting or socializing, the mind is most attentive and produces the beta waves which are of high frequency and are highly asynchronous.

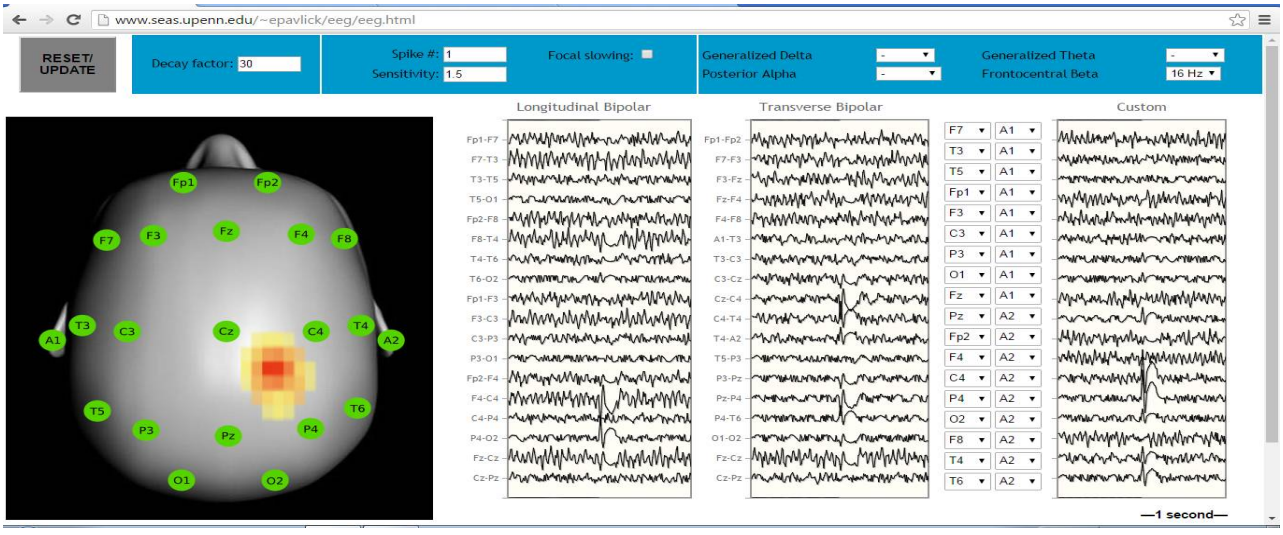

Figure 3. EEG Simulation

Figure 3 shows the brain waves produced when the human mind is most attentive. For example, while chatting or socializing, the mind is most attentive and produces the beta waves which are of high frequency and are highly asynchronous. The data corresponding to these brain waves is shown in Figure 4 in the Data World Window in Simbrain while brain waves are shown in Vision World Window. When the simulation is run, the Display Window shows the output in the form of a thought related to the kind of brain activity taking place at that particular instant. The output is displayed in the format “Emotion/Type of Brain Activity: Related Thought” i.e “Chatting: How you doin’?”.

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Various types of emotions or scenarios that were tested using the above procedure were happy, depressed, angry, attentive, loved and relaxed.

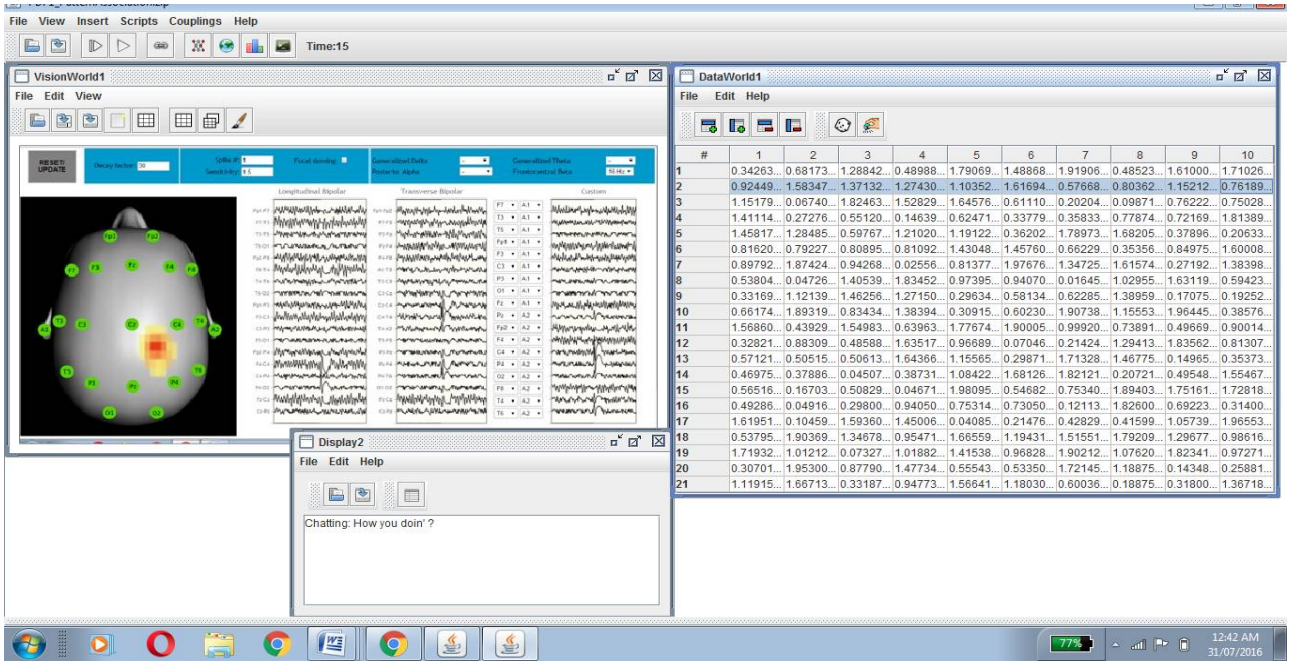

Figure 4. Simbrain Final Output

The above research is purely hypothetical in nature. The hardware results may vary according to the frequency of brain waves and age of the person being tested. Future work in this field may include simulation of various images produced in the mind while thinking or dreaming.

VI. CONCLUSION

We have designed and simulated a system which can analyze the brain activity and show what the person is thinking or feeling. Our design successfully predicted the emotions or thoughts going on in the human mind 70% of the times. As the training data set increased after adding values of each test data to it, the probability and accuracy of getting the correct output increased. We have tested various patterns relative to various emotions and situations and have successfully obtained the results in the form of thoughts conveying those feelings. Thus, by testing more and more times, the accuracy of the system can be increased.

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BIOGRAPHY

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