

## **A Program for Brain State Analysis using Electroencephalographic Data**

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### **Abstract**

Using electroencephalographic (EEG) data, cognitive psychologists can visualize and observe correlations between idle and different active brain states. The intention of this project is to create an application that takes EEG data and exposes it to various analytical techniques so the resultant brain states can be studied and predicted. We present explanations of the design and implementation offered herein. Furthermore, a summary of the application's functionality is elucidated. Upon completion, we anticipate that this software can be used to produce important and dependable conclusions about a given subject's brain states and correlate that to an identified physical or psychological activity.

### **Introduction**

Transcendental meditation [6], a spiritual development technique, was popularized by former Hindu ascetic Maharishi Mahesh Yogi and gained popularity in the west during the 1960's [2]. The concurrent brain states associated with transcendental meditation have been viewed as something outside of the world of physical measurement and objective evaluation by most scientific communities. Scientists now have the ability to measure and register electric potential of the human brain through the use of electroencephalographic technologies.

This research is motivated by a desire to study finite differences within the minds of those practicing meditation, and those who do not. Such an endeavor is an avenue towards modeling a wide range of brain states [3]. The combination of electroencephalographic data with modeling methods in fields such as data mining and bioinformatics could be used to prove that subjects in a state of transcendental meditation are in a verifiable and observable state of mind that can be monitored and predicted [1]. The merger of these fields of study prove constructive in biometric authentication, creating better user interfaces for computers, and in the development of improved computer assisted learning systems.

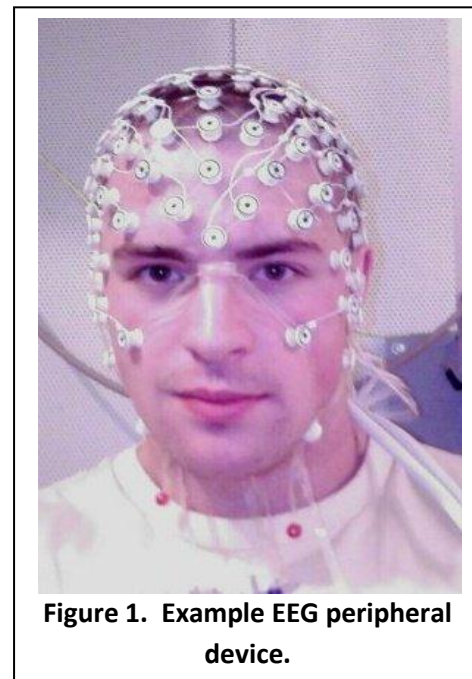
The initial approach in such study should be development of a software application that can organize and analyze that data. First, the process of loading and the analysis of the data will be explained, followed by a concise summary of the logical composition of

the application. Finally, a succinct explanation of the source and structure of the dataset used during the development process is offered.

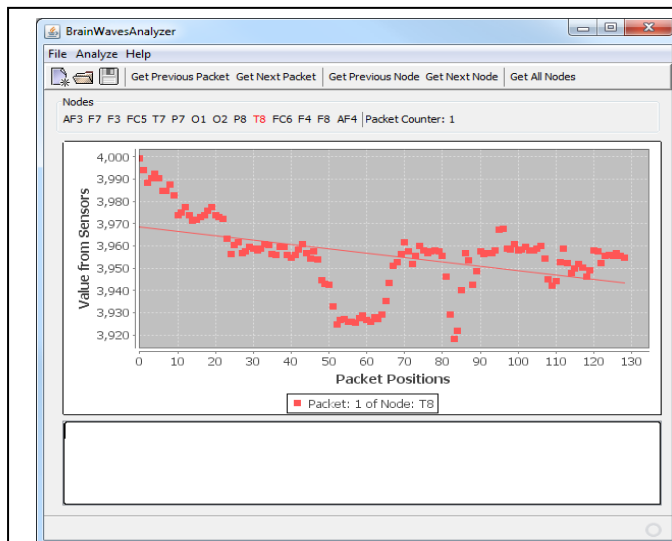
The foundational research of this article is from four studies, two of which were done by Dr. Byeongsang Oh of the Concord Hospital of the University of Sydney. Dr. Byeongsang found that patients that practiced meditation experienced higher well-being levels, better cognitive function and lower levels of inflammation than a control group [4]. The remaining studies were by the researchers Dr. Wanli Ma and Dr. Dat Tran of the University of Canberra. They studied new means of statistical modeling methods that could be applied to biometric authentication, intrusion detection, data mining and bioinformatics systems [5].

## Methodology

The output that is generated by the headset device shown in Figure 1 is a Comma Separated Value (CSV) file, and our program is written to be able to read in the file without doing any preprocessing. When the file is opened through the open file button or menu item, a new object is instantiated that is of type ReadFile which is a custom defined class within the program that opens the file and then parses the information. When the location of the file is passed to the class a DataInputStream is instantiated that will then traverse each line of data. The file is actually read by using a special class called CSVReader that is able to handle the manipulation of CSV files. The ReadFile object first extrapolates from the data all information relevant to the 14 nodes, which are represented in the file by columns. Information that is gathered by the nodes is separated into packets,



**Figure 1. Example EEG peripheral device.**



**Figure 2. Example of visualization rendered from test data on one node.**

where each packet has 129 values. The first method that the object executes initially reads all packets of all nodes into an array, it is then from this array, called dataRead, the data is actually parsed. Since each packet contains 129 values, this allows for a consistent approach to parsing that can be applied to any file that is read from the peripheral without the need to be concerned with the file size or data length. The parsing simply

continues until the end of the file is reached. Once this parsing of information is loaded into the program, the values for each node is then passed to an object of type FileVisualizer that then actually graphs this information onto the panels to visualize the data. This is done by passing the respective node array to each object that represents a node. Figure 2 demonstrates a single graph that represents an entire packet for that node. The user is then able to traverse, via the menu bar, to whichever node they want to visualize next. Moreover, the user is also able to negotiate through packets which the program loads and repaints onto the panel, thus allowing for comparison between packets of nodes. Only after the data has been loaded, one can do some limited analysis on the data set as such as the fast Fourier transform (FFT) and Linear Regression. Defined in Figure 3, linear regression is an analytical technique that takes a set of data, often graphed as a scatter-plot, and makes one "best fit line" of that data. FFT, as shown in Figure 4, allows for the ability of noise reduction on the data set which helps eliminates any obstructions that might have been present during the use of the peripheral device such as hair or excessive movement. The algorithm that was applied is a direct implementation of the discrete Fourier transform since the data set is small enough to where efficiency isn't as pertinent.

Given functions  $f_1, \dots, f_k$ , find values of coefficients  $a_1, \dots, a_k$ , Such that the linear combination  $y = a_1 f_1(x) + \dots + a_k f_k(x)$  is the best approximation to the read data.

**Figure 3. Linear Regression**

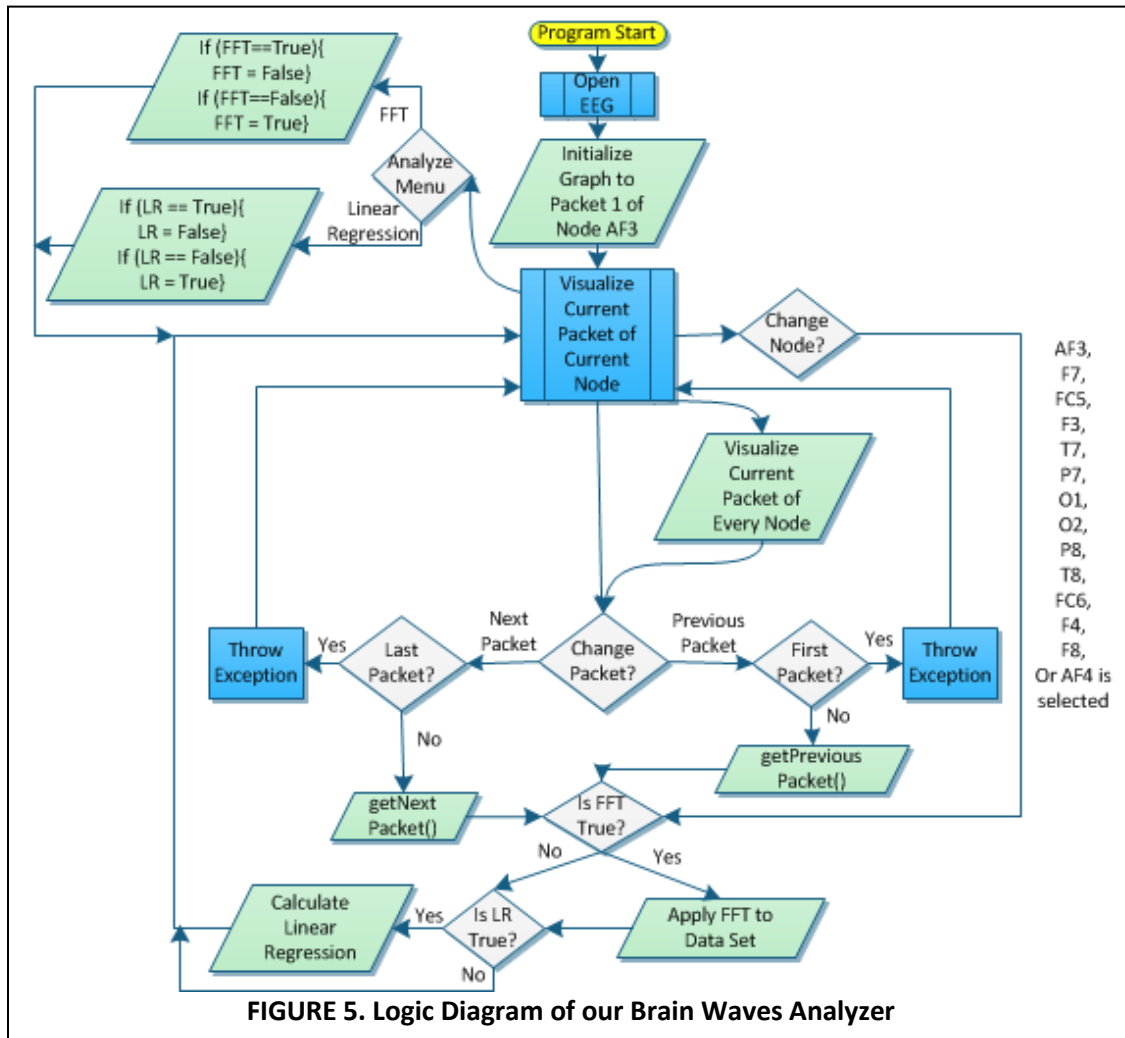
$$X_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N}nk}$$

**Figure 4. Discrete Fourier Transform**

## Logic Flow

Figure 5 is a visual representation of the flow of logic for our program. When the program is run, an EEG file in CSV format must first be parsed before anything can be visualized. Upon opening a valid file, the first node visualized is always packet 1 of node AF3. From there, the user has the choice of enabling MultiView, changing analysis options in the toolbar, selecting a next or previous packet, or changing the node. We can traverse the next or previous node by physical location (starting at AF3 and moving counterclockwise around the brain) or by simple selecting any desired node. Once a node is selected, we run a quick check to see if the user has enabled linear regression or fast Fourier transform. All choices are then applied to the data set and the current packet of the current node is drawn. If MultiView is selected, a chart, such as in Figure 9, will be visualized showing each nodes brainwaves with respect to every other one. Before being drawn, it will perform the same checks for linear regression and FFT as picking any desired node would. From the Analysis menu, linear regression and FFT can be enabled or disabled by simply clicking on them. When clicked on, the state is toggled (if linear regression or FFT is false, make it true, if it is true, make it false). Next and previous

packets can be traversed, with a simple check to disallow moving forwards or backwards if we are at the first or last packet, respectively.



## Data analysis and results

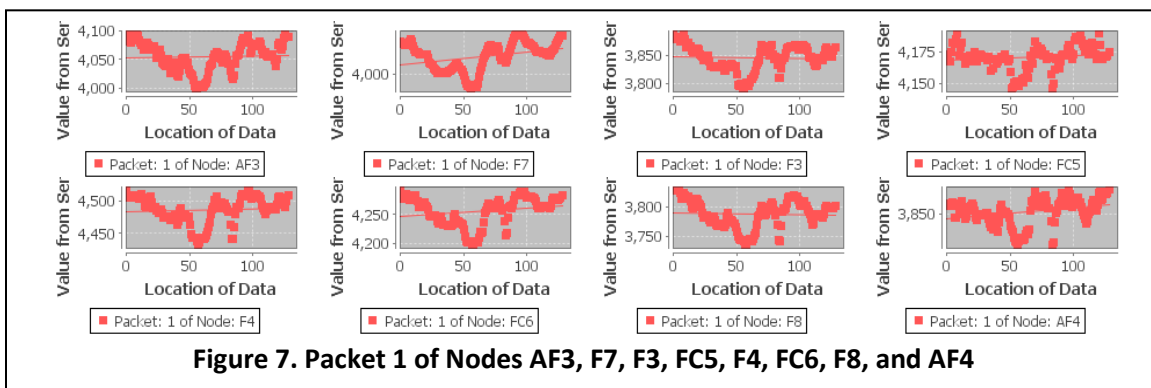
The data set analyzed comes from a study in which a candidate performed the tasks in Figure 6. The individual alternated between idle activity, reading news headlines, and participating in a mathematics exam limited to basic algebra every 60 seconds for 20 minutes.

Activity	Start	End	Comment
Idle	0:00	1:00	Trial candidate does nothing
News Headline	1:00	2:00	<a href="http://www.slashdot.org">http://www.slashdot.org</a>
Idle	2:00	3:00	Trial candidate does nothing
Math Test	3:00	4:00	<a href="http://www.freemathtest.com/Pre-Algebra/FindTheAverage/">http://www.freemathtest.com/Pre-Algebra/FindTheAverage/</a>
Idle	4:00	5:00	Trial candidate does nothing
News Headline	5:00	6:00	<a href="http://www.slashdot.org">http://www.slashdot.org</a>
Idle	6:00	7:00	Trial candidate does nothing
Math Test	7:00	8:00	<a href="http://www.freemathtest.com/Pre-Algebra/FindTheAverage/">http://www.freemathtest.com/Pre-Algebra/FindTheAverage/</a>
Idle	8:00	9:00	Trial candidate does nothing
News Headline	9:00	10:00	<a href="http://www.slashdot.org">http://www.slashdot.org</a>
Idle	10:00	11:00	Trial candidate does nothing
Math Test	11:00	12:00	<a href="http://www.freemathtest.com/Pre-Algebra/FindTheAverage/">http://www.freemathtest.com/Pre-Algebra/FindTheAverage/</a>
Idle	12:00	13:00	Trial candidate does nothing
News Headline	13:00	14:00	<a href="http://www.slashdot.org">http://www.slashdot.org</a>
Idle	14:00	15:00	Trial candidate does nothing
Math Test	15:00	16:00	<a href="http://www.freemathtest.com/Pre-Algebra/FindTheAverage/">http://www.freemathtest.com/Pre-Algebra/FindTheAverage/</a>
Idle	16:00	17:00	Trial candidate does nothing
News Headline	17:00	18:00	<a href="http://www.slashdot.org">http://www.slashdot.org</a>
Idle	18:00	19:00	Trial candidate does nothing
Math Test	19:00	20:00	<a href="http://www.freemathtest.com/Pre-Algebra/FindTheAverage/">http://www.freemathtest.com/Pre-Algebra/FindTheAverage/</a>

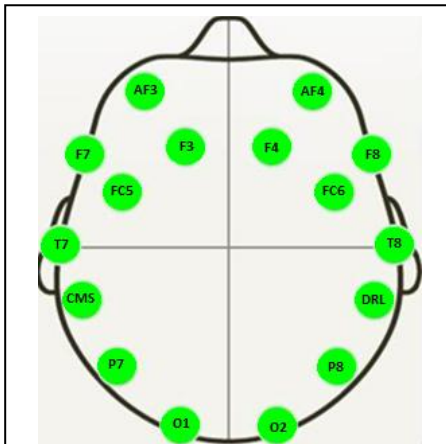
**Figure 6. The data we are parsing comes from this case study.**

Recording this data resulted in 123001 values for all 20 minutes. With 129 values per packet we have approximately 953 packets per node. We can assume that this leaves approximately 47 packets per node per minute.

Upon running the software, we are presented a graph of the current packet of the current node. When we apply linear regression to the generated scatter-plot, the positive or negative slope correlates to an increase or decrease in brain activity for the entire packet of said node.

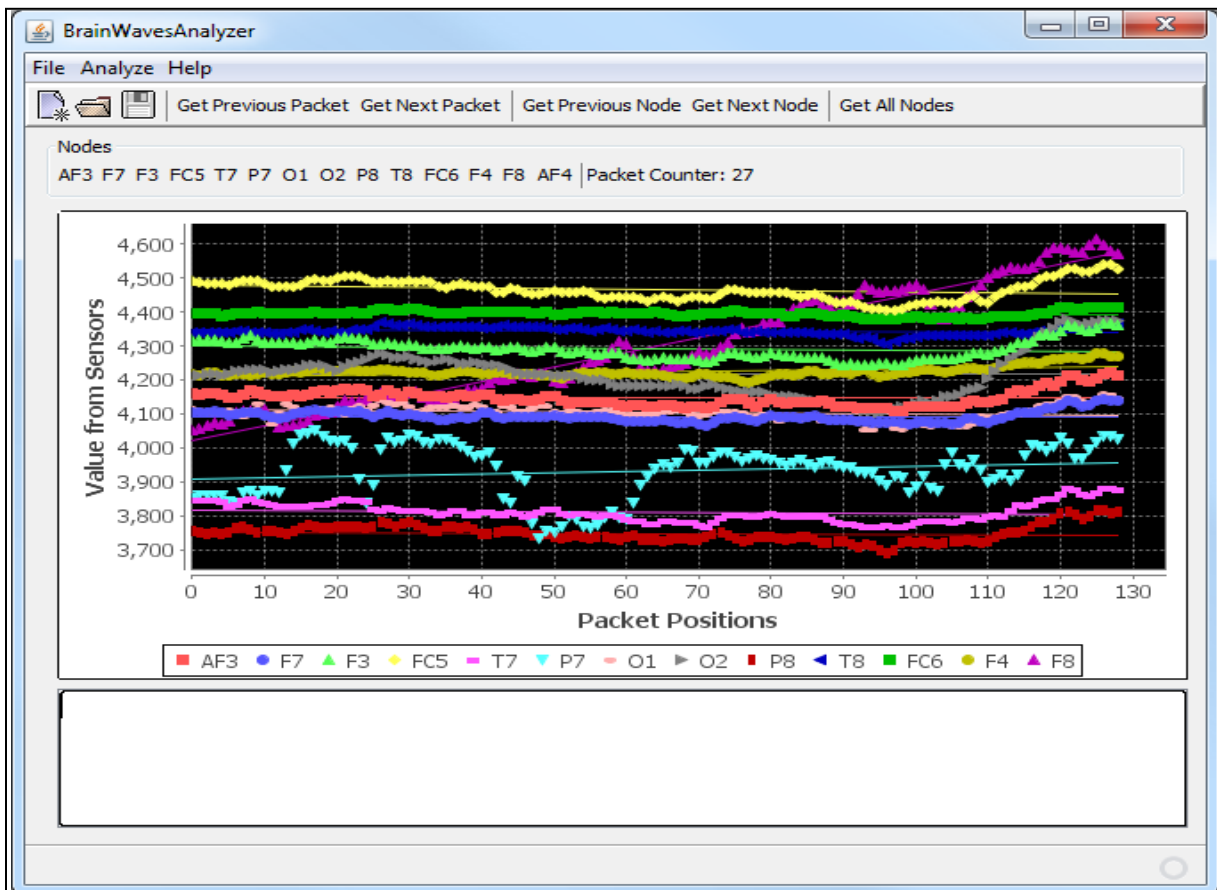


**Figure 7. Packet 1 of Nodes AF3, F7, F3, FC5, F4, FC6, F8, and AF4**



**Figure 8. Nodes AF3 through AF4(read counterclockwise) are where sensors were placed for the EEG data.**

In the first packet of our data set, we notice correlations between two sets of four nodes ({AF3 F3 FC5 F7} and {AF4 F8 FC6 F4} respectively). By cross examining node position from Figure 8 with the first packet of each node in Figure 7, we can observe similar scatter-plots that are geometrically symmetric when referencing nodes regarding both left and right hemispheres of the frontal lobe. This tells us that {AF3 F3 FC5 F7} and {AF4 F8 FC6 F4} are sections of the brain that work together when the user is in an idle brain state. We can use our MultiView functionality to observe where each node is active with respect to each other, as seen in Figure 8. Our efforts are currently invested into recognizing repeatable patterns throughout the packets. We believe that it may be possible to determine sets of packets that belong to each of the idle, news headline, and mathematics test states if they have repeatable characteristics.



**Figure 9. MultiView**

## Conclusion

We have created visualization software that can parse and visualize EEG data, with the hopes of being able to find correlations between brain states both numerically and by observations of graph behavior. We calculate and draw linear regression against the data sets to see if, over a certain amount of time, total brain activity increases or decreases.

Furthermore, a fast Fourier transform can be applied to the EEG data sets in an attempt to correct signal noise, caused by the incorrect placement of electrodes to the scalp of the subject, or by interference from hair or lesions in the electrodes attachment area. Some devotees to the practices of transcendental meditation have shown the ability to control these brain states. We want to numerically prove or disprove this assumption; The analysis of these states could be the first step in a process to first predict and later allow individuals to control these states.

## Acknowledgements

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