Three-Dimensional EEG Signal Tracking for Reproducible Brain Activity Monitoring

Abenezer Wudenhe, Qinglei Meng, Fow-Sen Choa
Department of Computer Science and Electrical Engineering
University of Maryland Baltimore County
a157@umbc.edu, meng2@umbc.edu, choa@umbc.edu

Electroencephalography (EEG) monitoring methods play a highly important role in studying human brain electrical activities. Its ability to achieve millisecond scale time resolution is critical for obtaining causal relationship. However, due to the dynamic nature of brain electrical activity, the same stimuli may generate different responses at different time or different psychological setting. Time averaging and repeat testing are usually required to obtain reproducible and meaningful data that can link to behaviors. Here, we propose a new approach to link single measurement with behaviors that can monitor brain functions reproducibly without repeating measurements. The method opens doors to freely explore brain functions and responses in real time without many restrictions like, for example, doing event related potential (ERP) measurement.

Extraction EEG biomarkers and correlating them to behaviors have always been a working progress since the time the technique was discovered. Event related potential (ERP) technique has been one of the successful methods that is used to obtain reproducible brain responses to stimuli. However, ERP signals are intrinsically weak and need to average sufficiently to distinguish signals from noises. This also leads to a lack emphasis on mapping deep brain structures as well.

In this study, raw EEG data was collected from six subjects (4 males and 2 females, all aged between 18 and 30) while they were asked to do math operations, work on the formation of an emotional image, and imagine executing a motor function in their minds. A time stamp was used to mark the image formation time in recorded EEG signals. Signals within 300 ms before image formations were selected for data processing. Running independent component analysis to remove artifacts and tracing locations of the strongest brain activity for each delta (0-4Hz), theta (4-8Hz), alpha (8-13Hz) and beta (13-30Hz) waves, we found reproducible linkage of subject behaviors with tracing characteristics along the 3 categories: emotional, math and motor functions. EEG data was recorded by KT88 every 10 ms and exported as BioSemi data file for Matlab (with EEG toolbox). An independent component analysis (ICA) was added to remove artifacts as mentioned for all BioSemi datasets before being converted to a text file for sLORETA. sLORETA, an electromagnetic tomography tool, was used to apply filters from the EEG data to obtain each of the four frequencies for each subject's activity and their focus points over the 300 ms.

Each wave has its own identifiable behavior that reveal several notable characteristics of the image formation process. During activities focusing on emotional actions, Alpha waves spend a large majority of their time in the frontal lobe of the brain. Alpha waves also continued to stay in central part of the brain rather than traveling around to areas in the frontal lobe. While completing mathematical computations, Alpha waves oscillated between the frontal lobe and the back of the brain and was even spread between the right and the left hemispheres of the brain. Beta waves however oscillated between regions in the frontal lobe and the back of the brain. The beta wave mostly stay within cortex and constantly perform inquisition type of two-point back-and-forth one-time bouncing. When focusing on activates centered around motor functions, Alpha waves seemed to display favoritism between either the right hemispheric or the left hemispheric of the brain along with spending some time in the center of the brain. Beta waves oscillate between the frontal lobe and the back, visual cortex, but also show a preference in either the left and right hemisphere of the brain. Theta waves continues to show behavior of wrapping around the brain. They also show activity in the occipital lobe of the brain.

The proposed 3-D EEG tracing method has demonstrated highly reproducible brainwave characteristics and these characteristics are likely related to the fundamental activities correlated to emotion, math operation, and motor function part of brain.

---

1. Research reported in this publication by the National Science Foundation under award no. ECCS-1631820.

Three-Dimensional EEG Signal Tracking for Reproducible Brain Activity Monitoring

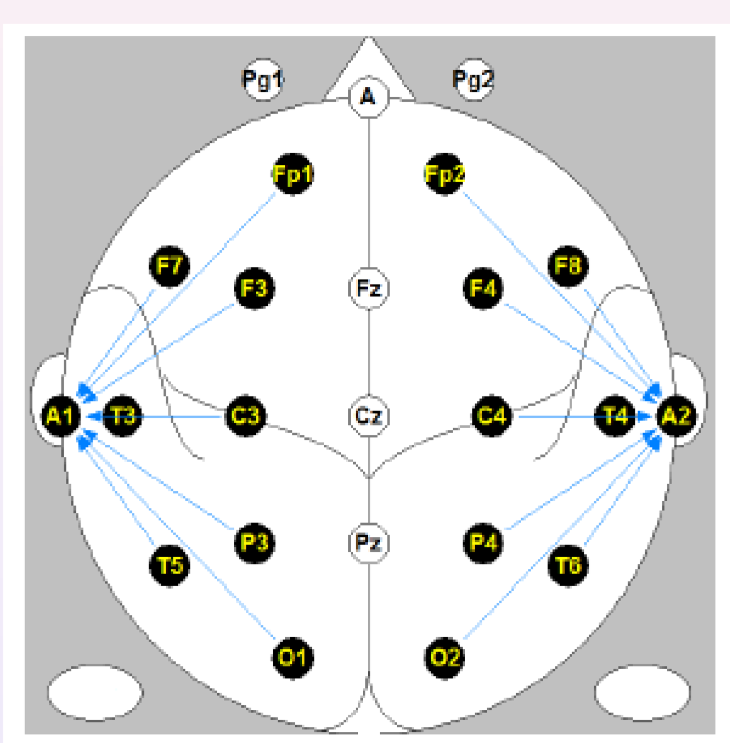
Abenezer Wudenhe[1], Qinglei Meng[1]
Faculty mentor: Fow-Sen Choa[1]
[1]Computer Science & Electrical Engineering, University of Maryland Baltimore County

Objective

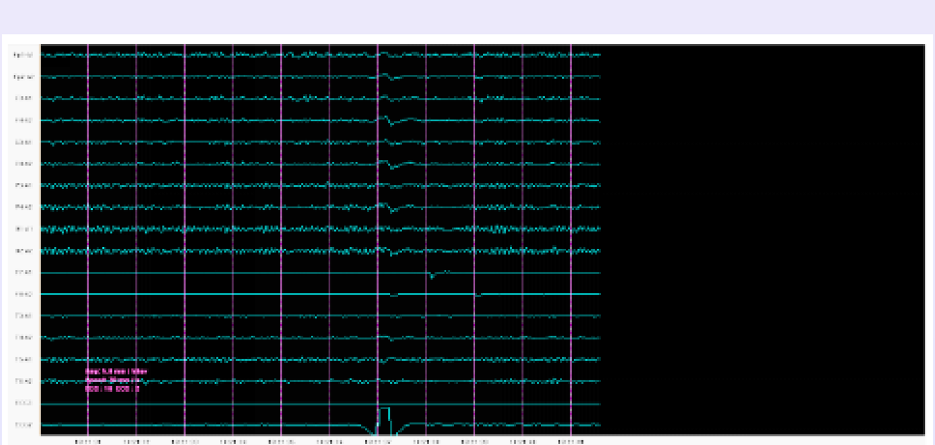
Electroencephalography (EEG) monitoring methods play a highly important role in studying human brain electrical activities. However, time averaging and repeat testing are usually required to obtain reproducible and meaningful data that can link to behaviors. Here, we propose a new approach to link single measurement with behaviors that can monitor brain functions reproducibly without repeating measurements.

EEG Extraction

Six participants (4 males and 2 females, all aged between 18 and 30) were fitted with a 16-channel EEG system as shown below.

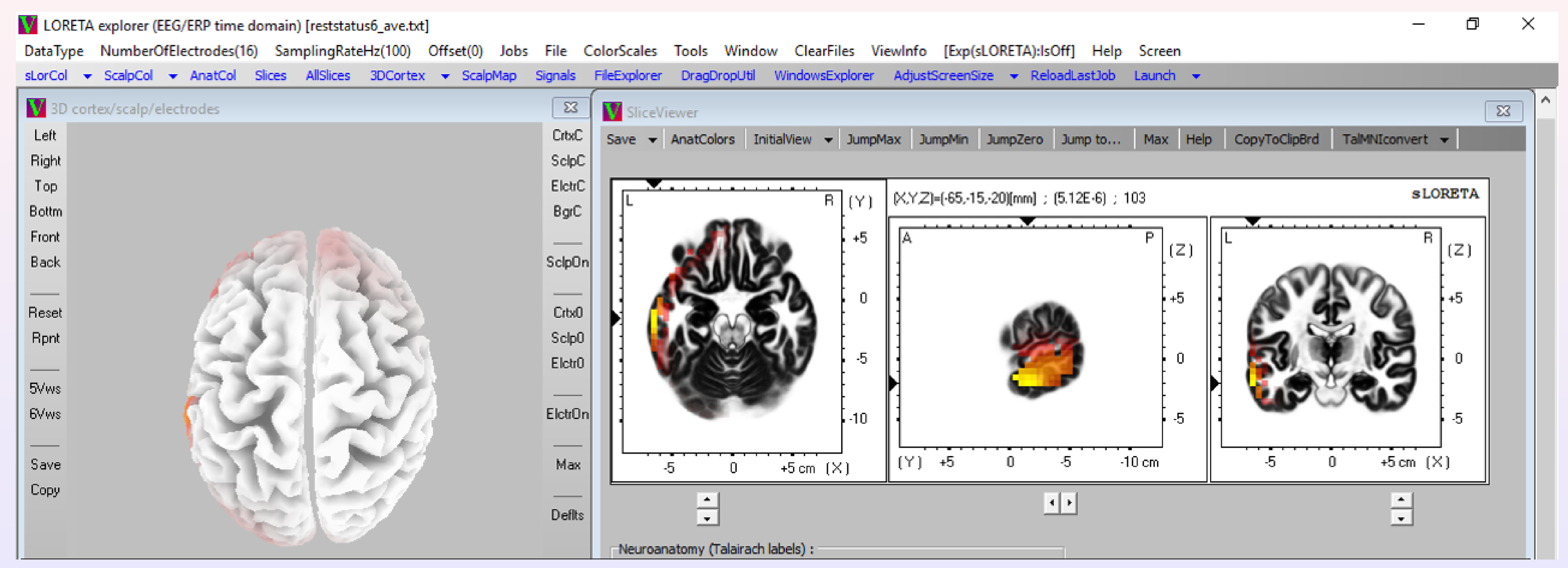


16-channel EEG system



Real-time EEG signal on KT88

Signal Analysis



sLORETA brain activity map and focus point.

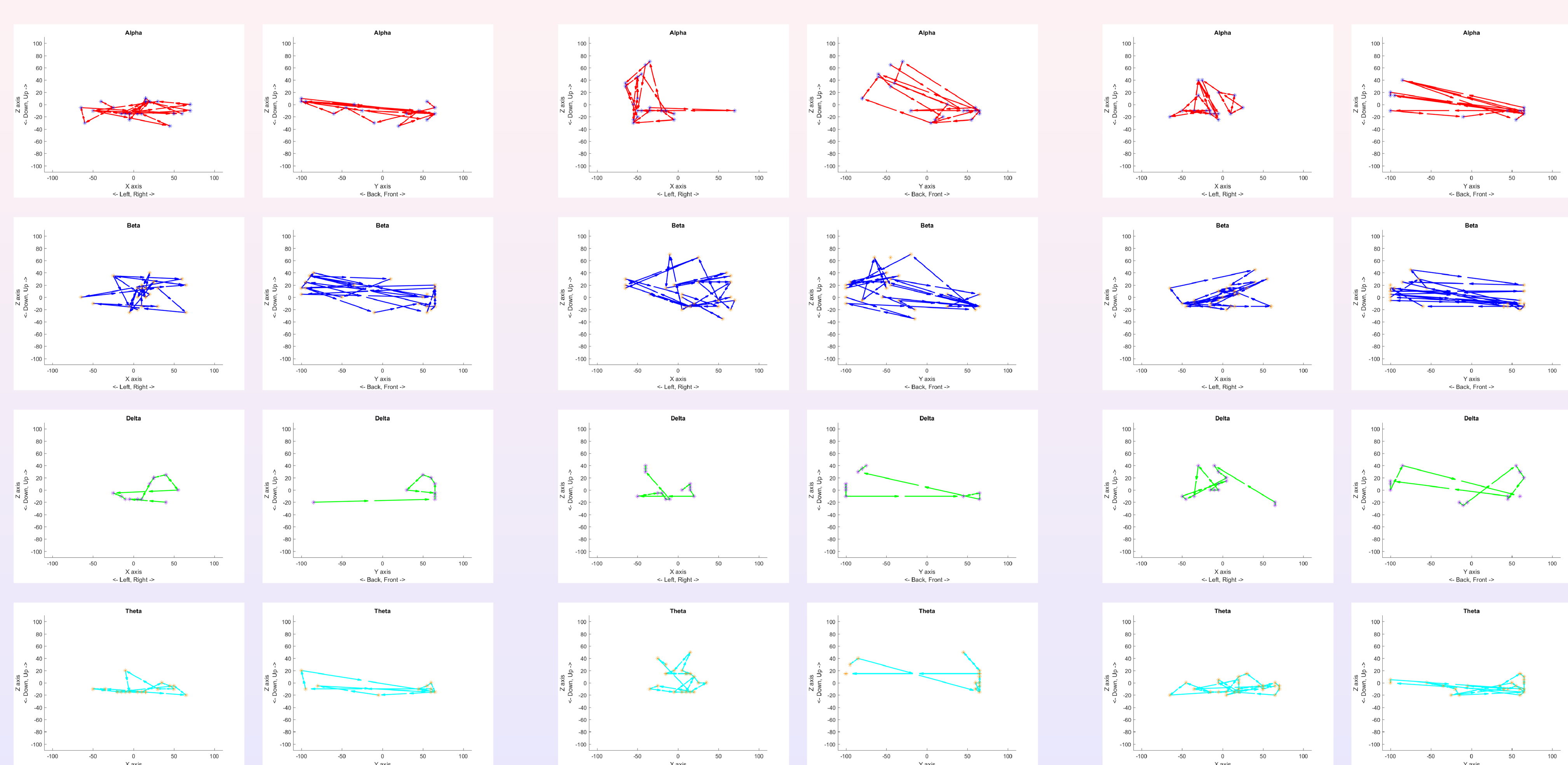
Procedure

The participants were asked to:

1. Think about the faces of the people that they loved/hate the most.
2. Do mathematical calculation in mind (15*18 and 1543-344).
3. Think about some parts of their body

Once they had mentaly completed the instructed task, they were instructed to immediately make contact to the channel and mark a time stamp. Running ICA to remove artifacts and tracing locations of the strongest brain activity for each delta (0-4Hz), theta (4-8Hz), alpha (8-13Hz) and beta (13-30Hz) waves.

3D Mapping



Performance of Alpha, Beta, Delta, and Theta wave across the brain along the 3 categories; emotional, math and motor functions.

Equipment

EEG data was recorded by KT88 every 10 ms and exported as BioSemi data file for Matlab. An independent component analysis (ICA) was added to remove artifacts before being converted to a text file for sLORETA. sLORETA, an electromagnetic tomography tool, was used to apply filters from the EEG data to obtain four particular frequencies.

Findings

Each wave has its own identifiable behavior that reveal several notable characteristics of the image formation process. Behaviors appeare for each individual wave and each measured categories. The proposed 3-D EEG tracing method has demonstrated highly reproducible brainwave characteristics and these characteristics are likely related to the fundamental activities correlated to emotion, math operation, and motor function part of brain.

Acknowledgments

- Research reported in this publication by the National Science Foundation under award no. ECCS-1631820.
- NSF, UMBC