Research Proposal for Task Classification of Electroencephalographic Data

1 Title

Task Classification through analysis of Electroencephalography.

2 Investigator

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3 Hypothesis, Research Questions, or Goals of the Project

It has already been demonstrated that EEG task classification is possible and very useful in many sectors. This technology; however, is still in its early stages of infancy with many questions unanswered. The following topics are areas of task classification research that deserve further attention.

3.1 Electrode Quantity and Positioning

Most Electroencephalographic recording devices offer the operator the choice of recording anywhere from 8 channels to 256 channels. Of course recording 256 channels gives the system the greatest flexibility, but reduces the practicality. Because of this factor, the optimal number of electrodes for task classification must be determined. Our hypothesis is that there is a specific set of electrodes that will mimic the effect of recording with 256 electrodes. By expanding on previously utilized techniques we will determine the exact number and location of this efficient electrode configuration.

In order to ensure consistency of the electrode placement for each individual a standardized system was developed. First the circumference of the test subject's head should be determined using a tape measure. This measurement will establish the cap size for the test subject. Next, a tape measure is used to measure the distance from the depression above the nose and below the forehead to the occipital protuberance (the natural bump in the back of a human head). The location of the halfway point should be noted. Next, the distance between the bottoms of each ear opening should be recorded. When taking this measurement the tape should pass over the position of the first measurement to ensure they intersect. Electrode A1 should be located at this intersection. This gives a consistent reference that is universally effective for every test subject.

In order to properly catalog electrode positions for each test subject the Patriot electrode localization system will be used. This system will allow lab members to reference electrode positions in post processing. This information may be valuable in identifying brain regions and electrode positions associated with different tasks.

3.2 Feature Extraction Techniques

Although the signals observed in the human brain are simply small differences in potential across the scalp, there are many ways to analyze them. The most common example is to observe the behavior in the frequency domain. Although not the only type of analysis, frequency seems to be the most common and useful, hence, it will be the technique discussed in this proposal. When analyzing frequency there are many factors to consider. If the entire signal was transformed to the frequency domain the time information would be lost. This is obviously not a desirable characteristic. In order to both preserve the time information and observe the frequency data, a short time Fourier Transform is used. This technique requires that the programmer selects a time window duration that optimizes the analysis of the signal. This optimized signal will allow for an efficient classification of the incoming data.

3.3 Data Classification

Most of the applications of this technology require some sort of feedback. This may be in the form of a wheelchair moving, or as simple as a light bulb turning on and off. With any method of feedback there are two basic desired attributes, speed and accuracy. These attributes are dependent on the classification algorithm. Dozens of algorithms are currently being used and modified for use, with new variations evolving all the time. Our hypothesis is that there is a specific algorithm that will provide the most time efficient and reliable classification. By utilizing several of the most popular techniques we will determine which algorithm is the most beneficial for the previously stated applications.

3.4 Data Processing

A typical EEG session produces a great deal of data in a short period of time. This is not an issue for applications that use post processing techniques. Unfortunately the most exciting and promising applications require real-time processing. As the sampling rate of the EEG signal increases the amount of data that requires processing also increases. In order to produce the previously mentioned feedback, the signal must have the features extracted and each time window must be classified. This process takes time. The main factors in determining the amount of time necessary for this processing are the speed of the computing device, the feature extraction and classification algorithms, and the amount of data to be processed. In most cases the common desktop computer will not have sufficient computing power to complete these tasks in a timely manner; hence, transmission to a capable machine is necessary. The question now becomes, what is the most efficient way to quickly transfer the data to this machine and receive the feedback after the processing is complete.

4 Background and Significance

Recent advances in feature extraction and task classification of Electroencephalographic signals have revealed a future that will give the neurologically disabled a new medium with which to communicate with the world. Though the future of this technology is very bright there is still much work to be done.

Although hundreds of research papers have been written that discuss both feature extraction and task classification many advances are still required to make the technology available to the public. Unlike many areas of academic research, this technology also has an incredible potential in the civilian sector to create an entirely new industry. This fact has led several large corporations to begin to take notice. In a research paper published by Microsoft in 2007 [a], they acknowledge the great potential for this technology while cautioning that much work needs to be done in order to deal with the noise and uncertainty that plagues the current systems. These uncertainties are exactly what we wish to deal with in this research.

One specific technique in the area of Brain Computer Interfacing is called the Steady State Visually Evoked Potential (SSVEP). This technique uses flashing lights to classify the region at which the subject is physically concentrating his/her vision. Although this technique is more simplistic and limited than some of the other techniques, it is also more realistic and reliable. In fact it is already being used at research facilities around the world to communicate with individuals who are "locked i", meaning their brains are fully functional, but they are unable to communicate with the outside world. Some systems that utilize SSVEP simply allow the user to manually spell a word. Others give the use control over a simple computer operating system. Future applications may include human control over any mechanical or electronic system in order to give the user a tactical advantage. This sort of application has obvious military application in the form of controlling advanced equipment where physical control by way of the hands and feet is not sufficient.

Using EEG in order to construct a reliable Brain Computer Interface is a difficult task due to the fact that EEG only collects information from the surface of the scalp. Using more sophisticated systems such as a Magneto Encephalography (MEG) allows the operator to locate the exact source of each electrical impulse within the brain. Further research proved that this source location of the brain activity was extremely valuable when creating a brain computer interface. The problem with using an MEG to construct a brain computer interface is both the cost and size of the required equipment. Even if a patient was able to afford the equipment, it would not be portable, which would defeat the purpose entirely. One way to utilize source localization in a practical way is to develop an algorithm that will determine the source of the brain activity while only observing the activity at the surface of the scalp. A discovery in this area would immediately make the brain computer interface a reality. In order to develop an algorithm that would be capable of this reconstruction of the brain's electrical activity, researchers at the Biomedical Imaging Lab at the University of Texas at El Paso are attempting to adapt similar algorithms used to reconstruct two dimensional images. In the two dimensional case the algorithm extracts more information from a decimated image and reconstructs an image with more detail. Just as it did with the two dimensional image, this algorithm may be able to reconstruct the electrical activity within the brain.

Another factor, discussed earlier [LT06], is the problem of noise. This is due to the fact that although the subject may be concentrating on a specific task to the best of his/her ability, there is still a great deal of activity taking place in the brain. Dealing with this noise is not a popular area of research in the Brain Computer Interface community. Research performed outside the BCI community shows that the human brain has a significant reaction to audible stimulus. One theory is that this reaction may be utilized to control the noise that detracts from the performance of a classification algorithm by injecting artificial noise audibly and then filtering in back out. If this theory is correct the result would be a clean signal, therefore improving the success of the classification algorithm.

5 Research Method, Design and Proposed Statistical Analysis:

In order to determine the most efficient feature extraction and task classification algorithms a great deal of data is required. This data will be recorded from volunteer test subjects via an Electroencephalography. This device records the normal electrical activity occurring in the brain. This activity must then be manipulated for classification in a process called feature extraction.

Once the features are extracted, the data is ready to be classified.

Once the data has been collected it may be analyzed an infinite number of times using the 146 GFLOPS computer cluster available through the UTEP Distributed Computing Lab. Each variation of feature extraction and classification algorithm will be tested analyzed for performance. Because this is a "post processing" technique there is no restriction on the complexity or computational requirement for the given algorithms.

Because most of the real world applications for this technology would require a real-time system, more refinement will be required in order to make the proper algorithms function more efficiently.

Statistical analysis will be fairly simple for this experiment due to the fact that the classification would either be correct or erroneous, making the classification binary. The comparison of algorithms will be as simple as comparing the percentage of correct and incorrect classifications over the same data for the same time window.

6 Human Subject Interactions

Human subject interaction in this experiment is absolutely fundamental to the research being conducted. Sixteen human subjects will participate in this study. The test subjects must be English speaking adults above the age 18. Because age and sex should not be a factor in the results of this type of research, there is no reason to recruit minors for the research. The human subject will be asked to assist to only one experimental session that will last about 3 hours.

6.1 Procedures for the recruitment of the participants

Recruiting poster and advertisements will not be necessary in the case of this experiment. The majority of the test subjects are students that are already involved in the research. These students have already expressed a willingness to participate as test subjects as well as assistant investigators.

6.2 Procedure for obtaining informed consent

Potential test subjects will be given an electronic (e-mail) copy of the informed consent prior to their participation in the experiment. They will be encouraged to review it in advance of the experiment. In the event that they do not wish to participate in the experiment due to a procedure or requirement they may withdraw without inquiry from the research team.

6.3 Research protocol

1. A schedule for each test subject will be established based on their availability. This schedule should be posted to the website so that both test subjects and test administrators have access to the schedule as it changes in real time. Also, the other students and faculty who utilize the lab should be notified at least one week in advance of each experiment.

2. A consent letter must be provided to the test subject at least one week in advance of the experiment that includes details such as the recommended amount of sleep before the experiment, and prohibited drugs or stimulants, such as caffeine.

3. Before the test subject arrives at the lab, the Biosemi equipment should be pre-positioned and ready to record and the room should be arranged in the manner outlined in the IRB. The stimulation software should be queued and ready to play. These steps will avoid last minute distractions that may elevate the stress level of the test subject (**15 min)**.

4. At this time at least two test administrators should be present in the lab, and should remain there for the duration of the test. In the case of a female test subject at least one of the test administrators should also be female.

5. Once the test subject arrives he/she will be required to sign the consent letter that was ptovide to him/her.

6. In order to ensure the integrity of the collected data some basic information will be required from each test subject. This questionnaire will include the following Yes/No questions **(5 min)**.

   - Have you been able to get an adequate amount of sleep over the past week?
   - Are you currently under the influence of any substance that may affect this experiment?
   - Have you consumed any Caffeine over the past 6 hours?
   - Have you ever been tested for epilepsy or any other sort of neurological disorder?
   - Is there any reason that you will not be able to focus for the duration of this experiment?

7. The test administrator will explain the experiment to the test subject. This explanation should include, but is not limited to:

   - The function of the EEG.
   - The duration and nature of each segment of the experiment.
   - The environmental conditions (light level, sounds, etc.)
   - The function of the recording cap and the electrolytic gel.

   The test subject should be instructed not to touch or scratch the recording cap during an experiment **(10 min)**.

8. The test subject should be seated in a comfortable, stationary (no wheels, or telescopic function) chair. He/She should be asked if they are comfortable and if they believe that they will be capable of remaining seated in this position for the duration of the experiment. **This is the last chance to use the restroom before the experiment is completed! (1 min)**.

9. Measurements of the circumference of the head should be taken in order to determine the correct cap size for the test subject. Also, a measurement from the base of the ear opening to the other base of the ear opening, and from the External occipital protuberance to the Internasal structure, must be taken in order to determine the proper location for the center of the cap **(2 min)**.

10. Once the cap has been properly placed on the head the test subject should be asked about the comfort of the cap. The Velcro strap beneath the chin should be adjusted accordingly **(1 min)**.

11. Measurements of the circumference of the test subject's head should be taken in order to determine the correct cap size. Also, a measurement from the base of the ear opening to the other base of the ear opening, and from the external occipital protuberance to the internasal structure, must be taken in order to determine the proper center location of the cap **(2 min)**.

12. Once the cap has been properly placed on the test subject's head, the test subject should be asked about the comfort of the cap. The Velcro strap beneath the chin should be adjusted accordingly **(1 min)**.

13. Recordings of the electrode position will be made after the cap is place on the test subject, using the Patriot tracking system **(15 min)**.

14. The electrolytic gel should be applied using the plastic syringes (not invasive) provided in the lab. This step requires practice; refer to experienced test administrators for further guidance. Once all of the plastic caps have been filled with gel, each electrode should be installed in the proper location on the recording cap. In order to reduce the strain on the electrode wires, each bundle should be fastened to the back of the test subject's chair using adhesive tape **(40 min)**.

15. The test subject should now be positioned to observe the desired monitor (21" color), or other visual or audible stimulus. The frequency range of the audible stimulus is from 20Hz to 20kHz at a level not to exceed 70dB. Once again, the test subject should be made aware of the sequence of the test, in order that there are no surprises that will adversely affect the recording **(2 min)**.

The experiment will be divided into two distinct parts. The first part will be the classification of three distinct tasks. The second will be the classification of three distinct frequencies.

6.4 Post-experiment

1. Remove the recording cap from the test subject head**(1 min)**.

2. Dismiss the test subject so that he/she may rinse his/her hair. A Neutral, hypoallergenic shampoo and a clean towel will be provided for the test subject to use if he/she wishes **(10 min)**.

3. Once the test subject returns ask him/her to complete a questionnaire. This questionnaire will include the following questions **(5 min)**:

    - In a scale of 1 to 5, 1 being poor and 5 being excellent, what level of comfort would you give to the experiment session?

- What could we have done to make your experience more comfortable?
- Were you able to concentrate on each segment of the test, or were you distracted? Could you explain why?

4. Once the test subject has completed the questionnaire he/she may be dismissed.
5. Test administrators should ensure that the equipment is properly stored in the designated containers. The recording cap should be thoroughly cleaned so that no recording gel residue remains on the cap **(30 min)**.

6.5 Privacy and confidentiality of participants?

Due to the fact that the demographics of the test subject will have little bearing on the actual research only the principal investigator will have access to this information. The students performing the data analysis will only have access to a numeric designator for each test subject and will not be able to associate this designator to any specific test subject. The personal information only accessible by the principle investigator will be stored electronically and digitally encrypted. This electronic storage will be in the form of an isolated external hard drive which will remain secured in the investigator's office.

6.6 Confidentiality of the research data

Each subject will be assigned a numeric designator in order to easily identify their collected data. This numeric designator will allow the researchers to analyze the data without identifying the test subject specifically. In the case of this experiment the collected data will be in the form of Electroencephalographic signals, which are not demographically identifiable by themselves; therefore, the confidentiality of the recorded data will be intact.

7 Potential risks

At this time no physical or psychological risks have been identified with this research.

8 Potential benefits

Each participant will receive a Biomedical Imaging Laboratory coffee mug as well as the satisfaction of participation in valuable research.

9 Sites or agencies involved in the research project

At this time there are no other agencies involved with this research besides the University of Texas at El Paso.

References

[LT06] J. Lee and D. Tan. Using a low-cost electroencephalograph for task classification in HCI research. *Association for Computing Machinery*, 2006.