Project Closeout

Group 39 - EEG Project

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1. Design Impact Statement

This section will serve as an overview of the different societal impacts of implementing an electroencephalogram (EEG) decoding system. In the following sections we will discuss the public health, cultural, environmental, and economic impacts of this research.

1.1 Public Health, Safety, and Welfare Impacts

A notable public health impact is how this technology will disproportionately benefit traditionally privileged groups. One main application of this brain computer interface (BCI) technology will be in medical prosthetics and thus physicians will be primary actors in the diagnosis and prescription process. Implicit bias in medicine is dangerous because clinicians can, consciously or unconsciously, alter a patient's treatment based on perceptions of their ability to afford medication, their pain tolerance, or their susceptibility to addiction [1.1.1]. The technology we are researching will not be exempt from this implicit bias, but hopefully with intentional design and wise implementation some of the negative effects can be mitigated.

1.2 Cultural and Social Impacts

A vital impact of this technology will be its effect on the perception of disabeld users. In the literature, the idea of restoring a sense of normalcy to users who are otherwise unable to function “normally” is discussed at length; there is a fine line between providing useful technology for those who want it and reenforcing a false narrative of what normal is in our society. Cochlear implants are an example of medical technology that has incredible potential to improve the quality of life of its users, but members of the Deaf community have embraced their culture and sign language in a way that makes the suggestion of a need for a fix offensive [1.2.1]. There is the possibility for the technology we are researching to be misconstrued in a similar manner so we think it is vitally important to work alongside the communities that can be helped by this development to gain insight into their needs and hesitations.

1.3 Environmental Impacts

The tech industry is a notorious perpetrator of over-consumption and environmental waste. While our project does not directly include a large amount of electronics, the eventual implementation of this technology will. Globally, e-waste is a growing issue with 50 million metric tons of it being generated in 2018 alone [1.3.1]. This growing amount of waste is unsustainable and needs to be curbed by a combination of more recycling and less initial consumption. It is the responsibility of corporations, not consumers, to make a change in the industry standards to move toward more environmentally friendly practices.

1.4 Economic Factors

One economic factor that is specific to our project is the relative cost of the EEG headset that is used as the data collection device. We chose to use a low-cost EEG headset that is easily accessible in relation to other headsets to explore the idea of accurate decoding with low overhead costs [1.4.1]. Exploring low-cost alternatives will help to allow for more accessible final products which are beneficial to the general public. While storage capacity and computational power are not taken into consideration in this analysis, improvement in one aspect of the project is a positive change.

2. Project Timeline

2.1 Visual Timeline

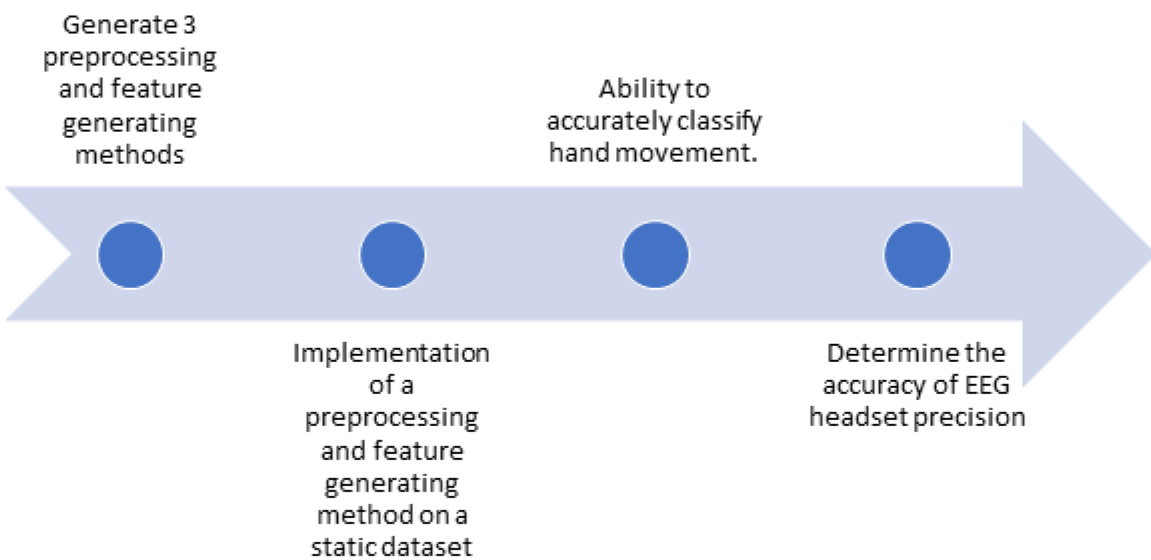

Figure 1: Fall 2020 Visual Timeline

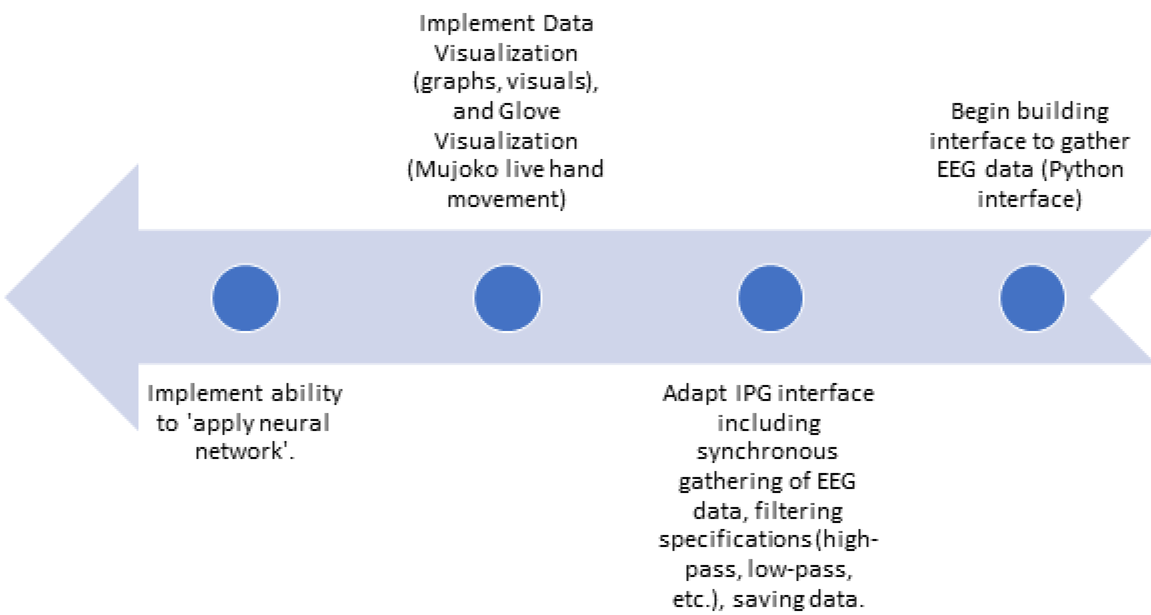

Figure 2: Winter 2021 Visual Timeline

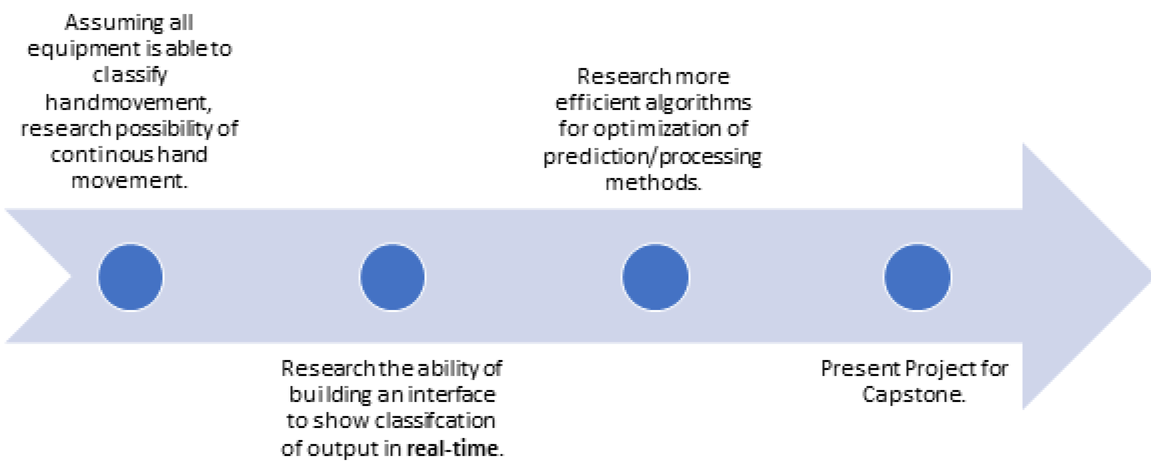

Figure 3: Spring 2021 Visual Timeline

2.2 Detailed Timeline

Fall 2020

Project Goals	**Key Benchmarks**	**Responsible**	**Deadlines, events, fixed dates**
Generate 3 preprocessing and feature generating methods	Implement Surface Laplacian, Common Average Referencing, Principal Component Analysis, and Independent Component Analysis	James, Patrick, Kristen	**11/9** for preprocessing. **11/30** for feature generating methods
Implementation of a preprocessing and feature generating method on a static dataset	Importing data collected from both Patrick and IPG group dataset to verify proper implementation of preprocessing and feature generating methods	James, Patrick, Kristen	**11/9** for preprocessing **12/7** for feature generating methods
Ability to accurately classify hand movement.	Utilizing the feature generating methods to properly classify the hand movements at a reasonable accuracy.	James, Patrick, Kristen	**12/9** for feature generating methods
Determine the accuracy of EEG headset precision	Once the hand is able to accurately classify hand movement, we need to use a verifying method of determining the accuracy of the algorithms	James, Patrick, Kristen	**12/15** for feature generating methods

Winter 2020

Project Goals	**Key Benchmarks**	**Responsible**	**Deadlines, events, fixed dates**
Begin building interface to gather EEG data (Python interface)	Interface will contain buttons for different options (filtering, data collecting, saving data, data visualization, glove visualization)	James	**12/20** but will contain more elements as the term continues. Buttons will be established.
Adapt IPG interface including synchronous gathering of EEG data, filtering specifications (high-pass, low-pass, etc.), saving data.	Button functionality. Allow functionality for low pass, band pass, notch, and high pass filters to actually be applied to the system.	Kristen	**1/15**
Implement Data Visualization (graphs, visuals), and Glove Visualization (Mujoko live hand movement)	Button functionality. Allow functionality for raw(untouched) stream across each EEG channel. Frequency band visual (alpha, beta, delta) aggregated across all channels.	James	**1/25**
Implement ability to 'apply neural network'.	Train a model in real-time, save its predictions on an API that shows different body movements (Mujoco), enable MLP training (multi-layer perceptron), be able to load an existing model via. UI	Patrick	**2/10**

Spring 2020

Project Goals	**Key Benchmarks**	**Responsible**	**Deadlines, events, fixed dates**
Assuming all equipment is able to classify hand movement, research possibility of continuous hand movement.	Data will be statically collected using IPG group data, examine graphs over time of signals or features to ensure they are computing properly	Patrick	**3/1**

Research the ability of building an interface to show classification of output in **real-time**.	Ensuring that the real-time has no more than 1-2 ms of delay when reacting to the glove and outputting data.	James, Patrick, Kristen	**4/1**
Research more efficient algorithms for optimization of prediction/processing methods.	Ensuring that there is relevance of the respective preprocessing/feature generating graph based on their MLP performance. Hand labels being in the range of -1 to 1, squared standard error will be used instead of accuracy, and 2 hidden layers will be utilized.	James, Patrick, Kristen	**5/10**
Complete project	Presenting the project for review.	James, Patrick, Kristen	**5/17**

2.3 Updates and Suggestions for Timeline

An addition to this timeline that would have been helpful for our project would have been designated reflection points. A challenge we faced with this research project was a constant change in scope as we discovered what was possible and what was unrealistic, and our engineering scope and testing procedures failed to change at the same pace. Implementing scope reflection times, for example one a month, would have allowed us to align the project goals with our progress more seamlessly.

3. Scope and Engineering Requirements Summary

Name	Customer Requirement	Engineering Requirement
1. Collecting Data from Glove and Headset	The system can get data from the glove and headset.	The system is able to sample EEG readings from the 16 EEG channels on the BCI Headset and sample finger movements from the glove circuit at sampling rates of between 990-1000Hz and between 33-34Hz, respectively.
2. Analysis of Processing Methods	Research and choose signal processing methods that are effective for EEG signal analysis	Provide evidence of thorough research for the chosen processing methods and analyze the accuracy rate of the respective processing methods as approved by the Project Partner.
3. Data Visualization	The system has a data-visualization tool to see the streaming EEG signals.	The system displays graphs of the 16 incoming EEG channel readings in both time and frequency domains with a time delay of less than 0.5 +- 0.1 seconds.
4. Hand Visualization	The system is able to display the current and predicted hand position.	The system will display the current position of the user's hand within a 1 second lag, and the system is able to overlay the visual with the system's predicted output of the hand movement based on EEG readings within 5 second of the associated EEG readings.
5. Generate and Utilize Features	The system is able to generate and utilize different features that help predict hand movement.	The system will have the option of generating and utilizing 3 different features generating methods. each able to classify hand movement with at least an accuracy of 60% over a span of one minute of hand movement.

6. Saving EEG and Glove Data	The user can save up to 5 minutes worth of EEG and hand-movement data from the system.	The system allows the user to choose when to start recording the incoming data, when to stop recording the data, and an option to save the data as a JSON file.
7. Saving and training the Machine Learning model	A neural network can be trained and saved from the incoming stream of recorded EEG and hand-movement data.	The system allows the user to choose when to start training the neural network, when to stop training the neural network, and an option to save the neural network as file if it trained over less than 5 minutes worth of data.
8. Analyze and Inform Client on Viability for Continuous Hand Movement	Inform whether it is viable to predict hand movement with this system.	A final analysis paper of the system's ability to predict hand movement with the given equipment is produced and is approved by the Project partner.

4. Risk Register

4.1 Risk Table

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact	Performance Indicator	Responsible Party	Action Plan
R1	Team loses access to OSU lab space due to COVID restrictions	External, Safety	35%	M	OSU closes campus buildings and restricts student access	Kristen	Retain: keep a watchful eye on policies and act proactively if there is an issue.
R2	The technology we have access to does not have the sensitivity needed to record detailed signals.	Internal, Technical	40%	H	The clarity of the signals following the preprocessing stages is not adequate to identify features from.	Patrick	Transfer: communicate issues we face with our project partner
R3	Team does not eliminate all uncertainties in the project soon enough.	Program Management, Time	40%	L	By the end of fall term there are still aspects of scope that are undecided	James	Reduce: use a timeline to plan when decisions need to be made to stay on track
R4	Project Partner does not approve of the progress we are making and/or the methods we have chosen	Internal, Communication	15%	H	Feedback on our weekly updates indicate that our project partner is expecting more than we are providing or achieving	Patrick	Avoid: clearly communicate our progress and ideas to avoid conflict and confusion between our team and the project partner
R5	The chosen and implemented preprocessing methods are insufficient.	Internal, Technical	30%	H	The implemented methods are time-delayed or do not filter out enough unwanted signals	James	Reduce: periodically check in with our team and analyze as a group whether our chosen methods are worth pursuing further

4.2 Risk Reflection

Reflecting on our project cycle and the risks we faced, our risk register proved to be an accurate representation of our experience. The most pressing risk we dealt with was not eliminating uncertainties in the project early enough in the timeline and while we weren't able to avoid this risk entirely, our strategy of reducing its impact by using an evolving timeline helped us stay aware of our progress and areas of need. In all, having taken the time to brainstorm and compile a list of likely risks along with plans of action for them benefited our team greatly because it reduced the amount of time spent addressing these issues during the design and implementation portion of the project.

5. Future Recommendations

	Recommendation	Reasoning	Next Steps
FR1	When drafting the initial timeline, include suggested meeting agendas to plan check-points in advance.	With the nature of our research topic, our team had difficulties identifying beneficial points of agenda during our meetings. Given the additional challenges that working remotely presented, taking time at the beginning of the project to set clear expectations and predicted agenda points for meetings would be valuable.	During the first two weeks of the project, draft a list of action items that the team wants to complete or discuss during each scheduled meeting for the term.
FR2	Wait until after the initial research phase of the project to identify accuracy goals.	Our system identified a desired accuracy level of 60% for the pre-processing and feature generating methods implemented by the team. This number was chosen based on our perception of success rather than our understanding of the methods we were implementing, so allowing for dedicated research time before choosing an accuracy goal would reverse the motivation.	Identify a date, approximately five weeks into the project, for the team to meet and propose accuracy levels that they think they can achieve with the researched methods.
FR3	Schedule meetings once a term to explicitly discuss expectations with the project partner.	Our team had difficulties staying up to date with our research advances and the development of our project partner's interests, so scheduling dedicated meetings each term to touch base on the relevancy of the engineering requirements and projected goals would help focus the project successfully.	In the first week of the project, plan a meeting each term with the project partner to discuss the project and any desired change of scope that they have.
FR4	Identify in the testing procedures that the system will be tested with both verified data and live data.	To isolate the performance of the pre-processing and feature generating methods, it is necessary to test the methods with both static data and live data. The static data test allows for the algorithm to be verified while the live data test would prove its functionality within the system. Functionality in both settings is important and having separate	For each requirement that identifies an accuracy rating, specify expectations for testing it with a static, verified set of data as well as with live data collected by the system.

		tests for both is valuable for research in the future.	
FR5	Broaden the scope of the initial research of pre-processing and feature generating methods before choosing methods to implement.	Dedicating more time to identifying the most promising pre-processing and feature generating methods will allow for the team to make a more educated decision on which method to implement. The team would be able to say with confidence that the methods chosen would be most valuable to dedicate time to.	Identify a set number of methods to research, say 3 per group member, and formulate a set of standards to rank them by.
FR6	Extend the maximum time frame of data collection and machine learning model training.	Our system identified a 5 minute limit for data collection for training and this limit ended up being unnecessary for our purposes. The time restraint did not benefit any aspect of the research and it hindered our ability to achieve higher accuracy values.	Start the project without a time limit and reassess at the end of the 1st term meeting with the project partner to decide whether a limit should be imposed.
FR7	Extend the testing scenarios to include testing each pre-processing method with each feature generating method.	We limited our testing processes to one pre-processing method with one feature generating method but expanding upon the combinations could lead to more optimal combinations. Dedicating more time to optimizing the processing methods through research and implementation will produce more robust and accurate answers to the initial research question.	Clearly identify the needed inputs and outputs for each method to map a plan to interconnect each method.
FR8	Add a section to the analysis component that compares the benefit of using trained methods with the benefits of using untrained methods.	Adding this additional comparison point will paint a more accurate picture as to whether training a method is correlated to better performance. There are subcategories of trained and untrained feature generating methods and isolating which provides better results can help narrow future research topics.	Compare and contrast the performance of trained methods and untrained methods in the final analysis paper.

References

[Section#.Subsection#.Reference#]

[1.1.1] I. Blair, J.Steiner, E. Havranek, "Unconscious (Implicit) Bias and Health Disparities: Where Do We Go from Here?" *The Permanente Journal, vol. 15, no. 2, pp. 71-78, 2011.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3140753/ [Accessed March 3, 2021]

[1.2.1] S. Byrd, et al, "The right to not hear: the ethics of parental refusal of hearing rehabilitation." *The Laryngoscope, vol. 121, no. 8, pp.1800-1804,* 2011. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4493436/#:~:text=Like%20many%20members%20of%20the,with%20an%20appropriate%20communication%20environment. [Accessed April 12, 2021]

[1.3.1] A. Beardmore, "Uncovering the Environmental Impact of Cloud Computing." *Earth.org*, Oct 12, 2020. https://earth.org/environmental-impact-of-cloud-computing/ [Accessed April 12, 2021]

[1.4.1] "Ultracortex Mark IV." OpenBCI Documentation. https://docs.openbci.com/docs/04AddOns/01-Headwear/MarkIV [Accessed Feb 11, 2021].