Walter Piper - Capstone 3 Project Proposal

Problem Statement Formulation:

Brain Computer Interfacing (BCI) has tremendous potential for real-time use cases for consumer applications, but it is heavily dependent on advanced signal processing techniques and domain knowledge. For computers to take electroencephalography (EEG) as input commands, machine learning algorithms and feature sets must be responsive to mental control. The time scale for real-time applications using non-invasive BCI is typically on the order of hundreds of milliseconds to several seconds. Thus, appropriate metrics/features, algorithms, and datasets with distinct temporal markers must be generated.

I will use a Muse EEG headband to collect data with self-experimentation, seeking to identify mental actions and behaviors that can be reliably classified in a time scale appropriate for real-time applications.

Context:

Brain Computer Interfaces (BCI's) constitute a major area of neuroscience research that is beginning to break into the consumer electronics market. Non-invasive interfaces using electroencephalography (EEG) have been miniaturized and paired with bluetooth technology for integration with standard consumer electronics. However, the real-time consumer applications are still in early phases. Due to the tremendous complexity and low signal-to-noise ratio of EEG, advanced machine learning and rigorous feature engineering are required for practical value.

Two main types of use cases apply to EEG. Neurofeedback involves a computer telling a person what state their brain is in. Brain-computer interfacing involves a computer accepting a person's brain state as a control command, similar to a mouse click. Both of these use cases typically involve classifiers.

Criteria for Success:

Machine learning models should identify user-intended input within 2 seconds. Ideally, multiple types of inputs could be distinguished.

Scope of Solution Space:

Find supervised learning algorithms that can score new test data in real-time. This will be done using data I collect from myself.

There is also a data engineering component. The data must be delivered from a proprietary Muse headband device. Fortunately, a 3rd party app called Mind Monitor is available to forward the data from the proprietary setup to either .csv files or as real-time data streams with the OSC network protocol.

The deliverables will consist of modeling notebooks, a written report, a powerpoint slide deck. It may also include software for real-time implementation of optimized models.

Constraints within Solution Space:
For maximum flexibility in pursuing novel goals, I will collect data myself. Furthermore, the solution must operate quickly enough for real-time implementation on standard consumer-level computers.

Stakeholders
While I am the primary stakeholder in this endeavor, it is similar to the mission of several startups such as Neurable.

Any open-source software that comes out of this may be of interest to many people who own Muse meditation headbands.

There are also books with information about the academic history of this field, which goes back roughly 3 decades.
Books:
Brain-Computer Interfacing: An Introduction by Rajesh P. N. Rao
Analyzing Neural Time Series Data: Theory and Practice by Mike X. Cohen

Key Data Sources:
My own Muse headband. In addition, the 3rd party Mind Monitor app has the capability to manually add time markers that can be used for time windowing and supervised learning.