Modeling Context for Enhanced Brain Signal Interpretation

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Abstract— **In recent years, there have been significant advances in Brain Computer Interface (BCI) devices and brain signal interpretation. The increased availability of inexpensive tools to measure brain events, such as standard electroencephalography (EEG) technology, has led to a significant increase in research in brain signal interpretation. In this paper, we propose a new way to enhance brain signal interpretation by applying models of context constructed using semantic technology. While we didn't find an immediate compelling reason to use semantics specifically, we did find that application of context will be useful, perhaps essential, in brain signal interpretation. We also present a novel mechanism for control of infrared (IR) devices in which brain signals are interpreted through semantic models and translated to speech. The speech is interpreted using software on a handheld device and successfully transformed into IR signals for control of a household device, namely, a television.**

Index Terms—Virtual Reality, Brain Modeling, Brain Computer Integration, Knowledge Representation.

I. Introduction

Event-related potentials (ERPs) are electrical signals produced in the brain in response to specific sensory stimuli. These signals provide measures of cognitive and facial muscular activity. Measured at the scalp using standard electroencephalography (EEG) and other technology, event related potentials are displayed as wave-like lines and measured according to their amplitude and elapsed time following a stimulus [1]. It has been shown that cognitive-evoked event related potential signals can be obtained and used reliably through EEG [2], as well as electrooculography (EOG) and electromyography (EMG) [3]. It has also been suggested that context be used in conjunction with Brain Computer Interface (BCI) signals to enhance interpretation [2]. Recent research has shown that EEG signals can be used to navigate virtual environments [4] [5]. To our knowledge, no models exist to represent and support BCIs and there has been no attempt to apply neither context nor semantic models to enhance the interpretation of brain events. In this paper, we propose a new approach to interpreting brain signals. We show how context and semantics can be used to interpret a brain event for control of a household device, a television. With this research, we pose the following question:

Can brain signal interpretation be enhanced using semantic models of thought and context?

To answer this question, this paper first provides background on brain signal technology and the tools we used in the research. We also provide background on context, semantic technology and ontologies. Next, we discuss the overall design and implementation of our application called VirtualContext. We provide findings and conclude with ideas on how this work should continue.

II. Background

For this research, we used the Cyberlink Brainfingers application [3] which provides hands-free control of a personal computer by recording and responding to electrical signals from facial muscles, eye movements, and brainwaves. Brainfingers records three primary signals as follows.

1. Electroiculographic or EOG signal. This is the lowest frequency channel that measures the forehead bio-potential and is responsive primarily to eye movements. Therefore, in Brainfingers, the EOG signal is typically used to detect left and right eye motion [3].

2. Electromyographic or EMG signal. The EMG signal primarily indicates facial muscle activity.

3. The Electroencephalographic or EEG signal. This is also referred to as the Brain-Body signal. The frequencies of this signal reflect internal mental/brainwave activity as well as subtle facial muscle activity. A wide range of facial muscles affect these frequency bands including those muscles used to raise eyebrows, clench teeth, etc. [3].

In all cases, we found that facial events were reflected across all three signal types. We found that EMG was the easiest to interpret since the signals more finely reflected the brain event. This is discussed in more detail in Section IV and is shown in Appendix A.

III. Concept and Design

We envisioned using a brain signal recording device, such as Cyberlink Brainfingers, in conjunction with a tracker, such as Polhemus. With both inputs, context can be applied for enhanced interpretation of brain events. There are numerous potential applications for this technology, including but not limited to, the following.

1. Control of household devices
2. Control of a car
3. Control of a computer
4. Interaction with virtual reality environments and games
5. Response to events in battle

We constructed a subset of this vision in a prototype called VirtualContext. This is a Java-based web application that reads pre-recorded brain signals and interprets these signals using semantic context. We could not find an obvious application of the model of thought, but did find the context of the individual situation essential in interpreting the signals.

Based on the context and simulated position of the individual, VirtualContext interprets the brain signals and transforms the interpretation to a command using text to speech. The speech is then recognized by software on a handheld device, which in turn transforms the command into the appropriate IR signal. For demonstration purposes, we built the application to control a Sony television set. This approach is novel in that it offers wireless control of a common household device using an application that can be accessed over the World Wide Web.

IV. Recorded brain events

Cyberlink Brainfingers does not support transmission of real time brain events, so we pre-recorded events for processing by VirtualContext. We recorded 10 events covering a variety of brain events, such as moving eyes from left to right, raising eyebrows, clenching teeth, etc. The recordings, made every 0.01 second by Brainfingers, include EOG, EMG and EEG signals. The files recorded and graphs of the data will be provided in the full paper.

V. Findings

During the course of this work, we found that brain signal measurements are still much too course for meaningful interpretation. We expect that tools to record brain events will continue to improve over time and we hope to gain access to tools that allow for finer recording in the future. Our research into previous work on brain signal interpretation suggests that successful brain interpretation to date has relied on pre-recorded signal patterns of known events for interpretation of future events. Other successful applications have operated within very specific domains using signal spikes within an implicit (assumed) context. Intrusive devices are required to obtain the finer signals. We did not find work that was able to interpret brain signals in general, but instead most approaches rely heavily on calibration. Therefore, we believe that the field of brain signal interpretation is in its infancy. We assert that progress in brain interpretation will depend on a number of factors, including the following.

- Enhanced measurement with more robust tools
- More in-depth understanding of process of thought
- Accounting for difference in individual signal patterns

We are disappointed to note that we did not find a compelling case for expression of context using semantic technology. It appears that a simple XML schema may suffice. As discussed in Section II, semantics would offer inherent extensibility, but it is not clear if the additional benefit of extensibility justifies the increased complexity of applied ontologies. However, we believe that with access to finer brain signal recordings and a better understanding of the thought process, cases that would benefit from applied semantics may emerge.

VI. Conclusions

In this work, we propose a new way to enhance brain signal interpretation by applying context modeled using semantic technology. While we didn't find an immediate compelling reason to use semantics specifically, we did find that application of context will be essential in brain signal interpretation. We also demonstrate a mechanism for control of IR devices in which brain signals can be translated to speech, which in turn can be recognized and transformed into IR signals for household devices. We built some of the mechanics for interpreting brain signals using semantic context and identify compelling use cases for enhanced brain signal interpretation. We also constructed simple ontologies built for context and thought, though we only ended up using the model of context in this first version of the prototype VirtualContext.

Despite the challenges, brain signal interpretation will advance and will benefit a number of fields, including health care applications, games and defense intelligence. The future of this field has unlimited potential and we should seek opportunities to continue this very important work.

VII. Future work

As we continue this research, we should obtain finer brain signals via other measurement techniques. We need to study the neuroscience, including theories of interpretation; we should seek to develop new theories of how thought operates. We should investigate further if more compelling use cases for the application of semantic models to brain signal enhancement, as we are not yet convinced we have exhausted the possibilities. From this result, we may seek to extend the ontologies of thought and context. We should investigate brain signal interfaces to other devices and to 3D environments such as Maya. Related but perhaps separate research would involve development of a computational model of consciousness. It would be interesting to investigate consciousness as an emergent property of the thought process.

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