Visual Cliffs, Virtual Reality and Movement Disorders

Rachneet Kaur, Daan Michiels | Faculty Advisors: Dr. Richard Sowers, Dr. Manuel Hernandez

Department of Industrial and Enterprise Systems Engineering, University of Illinois at Urbana Champaign

Introduction

Goal

Our goal is to explore a Brain Computer Interface (BCI) approach to examining changes in anxiety while walking in a vast virtual world. We are creating virtual reality (VR) components of a testbed for understanding responses to visual stimuli and their relation to movement disorders such as Parkinson's disease.

Materials and Methods

Setup

Our experiment uses the following equipment and software:

- Motek C-MILL Treadmill,
- Unity 5.5 (We code in C#),
- HTC Vive virtual reality headset,
- EEG cap with 64 electrodes,
- BrainVisison PyCorder for signal capturing,
- MATLAB and the open source EEGLAB and BCILAB toolboxes for data processing.
- Zephyr hxm bt wireless as the heart rate monitor

Network Layout

Our experiments are run in a lab in Freer Hall. We use several computers, connected over a local network:

- One connected to the treadmill, which streams the treadmill's motion data over the network
- One running the game software, which receives the treadmill's data, simulates the treadmill's movement in the virtual world, and renders the graphics to the virtual reality headset
- One capturing the EEG signals, saving the signals to disk
- One running MATLAB to do data analysis after the experiment

Virtual World

We designed the virtual world in Blender, an open source 3D modeling program. The world consists of separate slices, each slice 100 meters long. The software allows one to create world from pre-made slices by selecting them and putting them in order. The building of the world is done in virtual reality, with the designer grabbing and positioning the slices using an HTC Vive controller.

During the experiment, the user walks through the world that was built. An infinitely extending bridge, consisting of pieces that mimic a metal grid, form the surface that the user walks on. Depending on the shape of the terrain the user is walking on, this bridge may float just above the ground, or high up above.

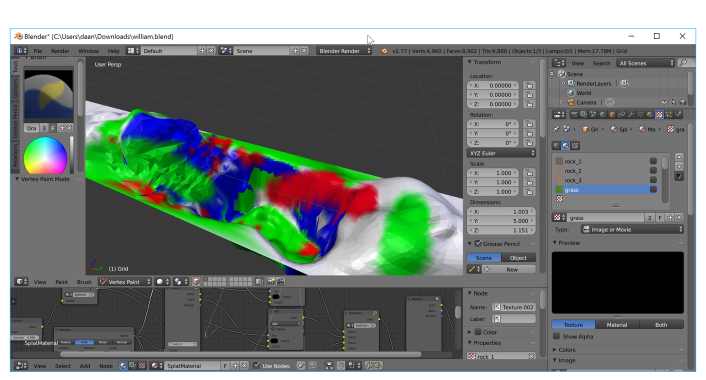

Fig 1: *A screenshot of the world being designed in Blender. The colors indicate different materials such as grass, rock, or sand.*

Heart Rate monitor

- Implemented real-time communication between C# and heart rate monitor through multi-threading
- Constructed graphical user interface for displaying the real-time heart rate
- Built a heart rate measuring system to measure user's heart rate before experiments when he is calm
- Implemented real-time adjustment on the "scary-level" of terrains according to user's base heart rate

EEG Analysis

The following steps constitute processing of the recorded raw EEG signals:

- The recorded signals are refined using a bandpass least squares filter
- Filtered data is epoched through EEGLAB. Standard methods are used to reject artifacts in the signals.
- Independent Component Analysis (ICA) is performed on the epoched dataset thus obtaining and selecting good ICs by visual inspection.
- The processed datasets corresponding to baseline and anxiety are merged into a matrix and fed to BCILAB for the feature extraction.

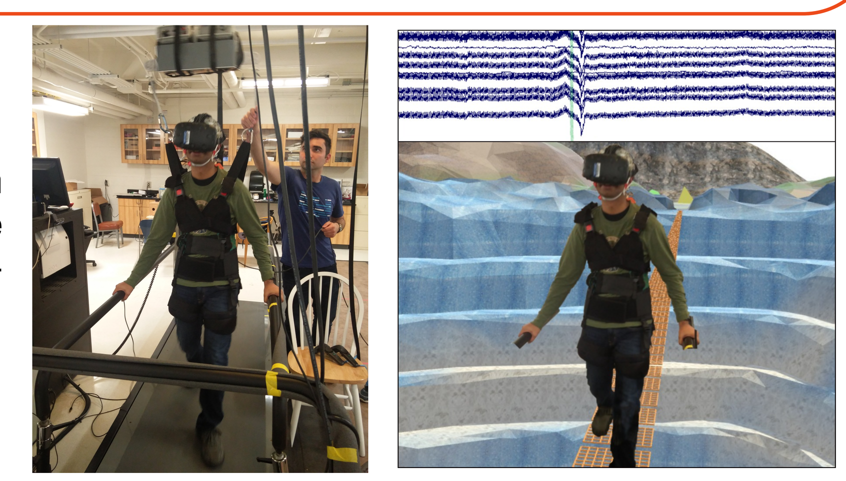

Fig 2: A team member walking on treadmill with VR headset while we record EEG data, possibly anxiety-correlated electrical activity

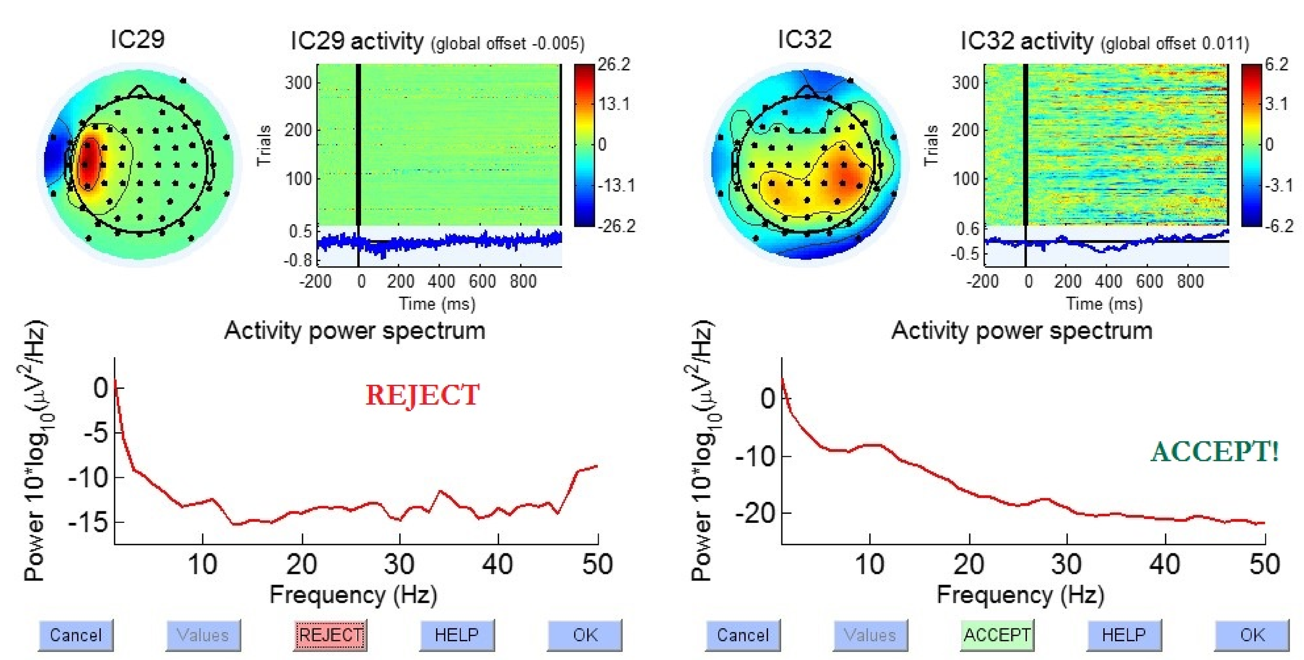

Fig 3: Two different Independent Components. **Left:** Very localized activity in the heat map, which likely indicates an artifact from the side of his head. The power spectrum plot is very noisy and has no evident activity in 8-12 Hz Frequency range. It is a very obvious rejection. **Right:** Heat map indicates even concentration from all the channels. The spectrum plot is smooth and shows a jump at 10Hz, followed by a steady decay. These are strong signals to include it in the EEG analysis.

Results and Discussion

Approximately half of the team focused on the gaming aspect, which included designing the virtual world, interfacing with the headset, interfacing with the treadmill. A large part of our efforts were directed at learning the various pieces of software. We managed to communicate with the treadmill over TCP, using a background thread. In addition, we learned a lot about Unity and Blender interfaces.

One other task that the team accomplished was calibrating the coordinates in the virtual world relative to the physical world. We recorded measurements of the Vive controllers' positions to correctly calibrate the positions of the treadmill's safety rails. This is to ensure that the rails can be seen by the user in the virtual world.

The other half of the team focused on data analysis. Several approaches were used on training data, which resulted in the following classification performance of anxiety versus baseline conditions. The tabulated results are based on processed training data for one subject which excludes muscle, eye movements and other artifacts.

This work demonstrates the feasibility of identifying changes due to anxiety from high density EEG data collected while a subject walks in a virtually infinite world that is synchronized to the movement of the subject.

Real-time communication between C# and the heart rate monitor were implemented through multi-threading and graphical user interface for configuring the Serial Port class and displaying the real-time heart rate were completed.

True Positive	True Negative	False Positive	False Negative	Error
1.000 ± 0.000	0.971 ± 0.050	0.029 ± 0.050	0.000 ± 0.000	0.013 ± 0.030
0.952 ± 0.082	1.000 ± 0.000	0.000 ± 0.000	0.048 ± 0.082	0.007 ± 0.015
0.952 ± 0.082	1.000 ± 0.000	0.000 ± 0.000	0.048 ± 0.082	0.007 ± 0.015
1.000 ± 0.000	0.971 ± 0.050	0.029 ± 0.050	0.000 ± 0.000	0.013 ± 0.030
0.553 ± 0.062	0.452 ± 0.188	0.548 ± 0.188	0.447 ± 0.062	0.503 ± 0.108

Table 1: *Results for five different approaches. In order, they are: Log Bandpower, Common Spatial Patterns (CSP), Filter-Bank CSP, Spectrally weighted CSP, Windowed Means.*

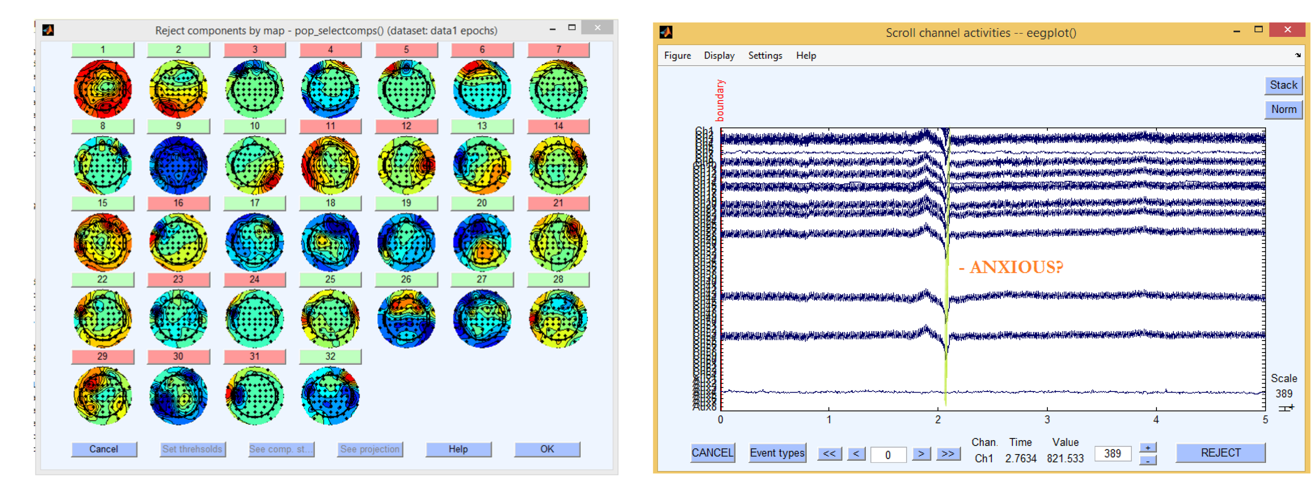

Fig 4: Left: An overview of individual channel components rejected by their map. While 64 electrodes are used to record EEG, only the first 32 are considered for analysis. **Right:** Brain waves recorded in lab while walking on treadmill show a sharp dip. This reaction may indicate an increase in anxiety when crossing the chasm.

Future Directions

Future work will consist of integration of real time EEG processing and classification while walking in an immersive VR environment and addition of subjects with and without movement disorders like Parkinson's disease.

In the future, we want to add more types of terrain to the game software.

We aim to dynamically vary several terrain parameters based on anxiety predictions through EEG and physical signals like heart rate.

We aim to process the EEG data in real time. The current workflow requires that the brain waves are saved to file. Real-time processing would allow interesting further applications, such as the adaptation of the virtual world to the user's anxiety level in order to decrease their anxiety levels in balance demanding walking conditions. We are working to convert MATLAB codes to open source softwares OpenViBE and Python as well.

Acknowledgements

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