Visual Cliffs, Virtual Reality and Movement Disorders

Rachneet Kaur, Yizhen Ding, Alex Rios | Faculty Advisors: Prof. Richard Sowers, Prof. 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,
- Unity3D (we code in C#),
- HTC Vive virtual reality headset,
- EEG cap with 64 electrodes,
- Brain Vision PyCorder for signal capturing,
- Open Vibe,
- Python 3.6,
- 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 treadmill, streaming the treadmill's motion data over the network
- One running the game software, rendering the graphics to the virtual reality headset
- One capturing the EEG signals and running Open Vibe to do data analysis in real time

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.

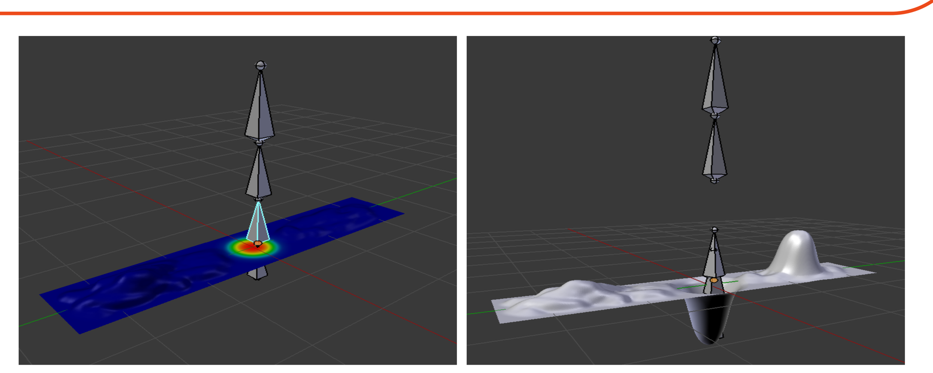


Fig 1: *A screen shot of assigning weights to terrain vertices in Blender*

Implementing Adaptive terrain

We animate the shape of the terrain to adapt to the user's anxiety:

- The terrain mesh is rigged in Blender, the way this is usually done for character animation. Vertices are set up to be influenced by controls moving along splines.
- Vertices in the terrain model are assigned different weights so that they can move with the bones proportionally to their weights.
- These files are imported into the game software, in order to vary the shape of the terrain in real-time based on data gathered from the EEG.

Data Logging

- The distance from the Player's current position to the the bottom of the terrain using Ray-casting Techniques in Unity3D.
- The real-time estimated anxiety level through EEG signal processing.

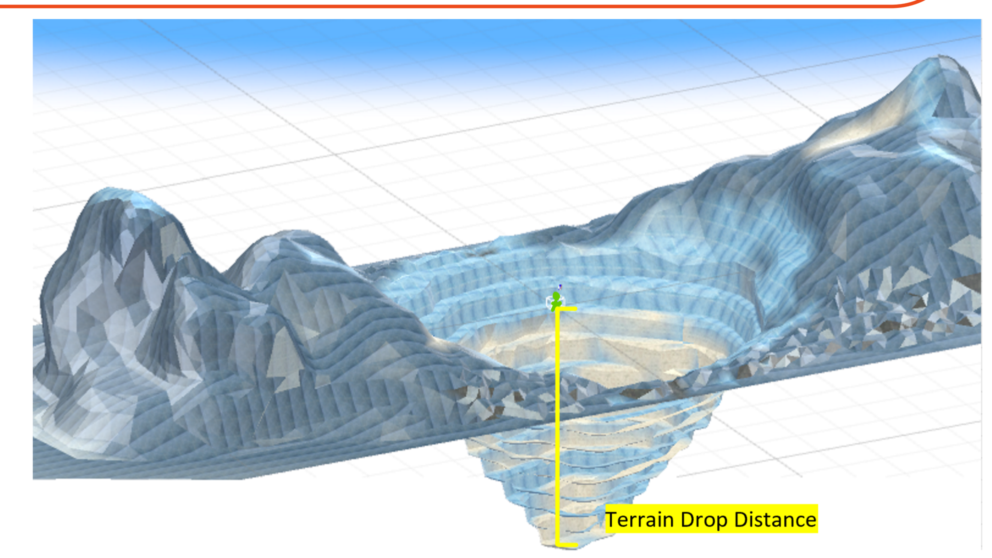


Fig 2: *A screen shot of logging the distance from the player's position to the bottom of the terrain*

Heart Rate Monitoring

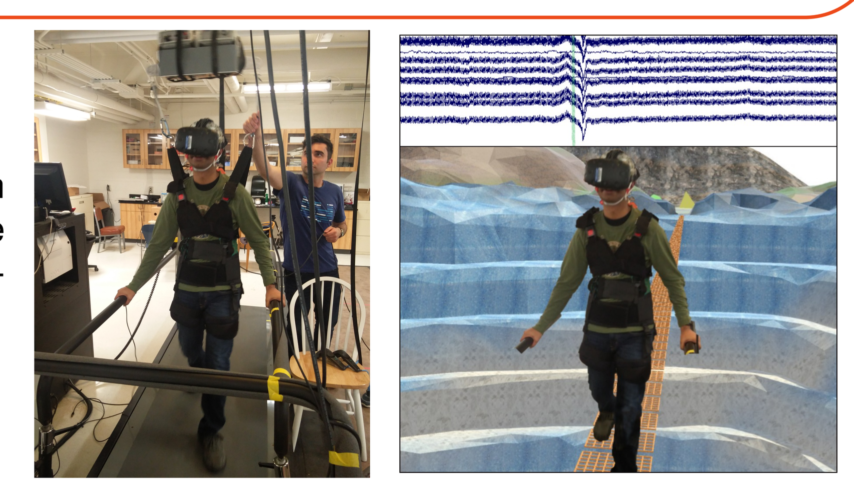
- Implemented real-time communication between C# and heart rate monitor
- Constructed graphical user interface to display real-time heart rate
- Implemented real-time adjustment on the "scary-level" of terrains according to user's base heart rate

EEG Analysis

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

- Refine the signals using a bandpass least squares filter
- Filtered data is epoched. Reject artifacts in the signals.
- Independent Component Analysis (ICA) is performed on the epoched dataset.
- The selected good components are back projected to extract features.

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



Finite Impulse Response Filter

- To get rid of environmental factors, FIR filtering is performed.
- Signals with frequency between 1Hz and 45Hz are filtered out from setting band pass in fast Fourier transformation.

Independent Component Analysis

- Input: signals which are combination of 64 components
- Effect: Extract 64 independent components from mixing signals, and get weighted matrix
- $s_k = (w^{(T)} * x)$ where w is the weight matrix

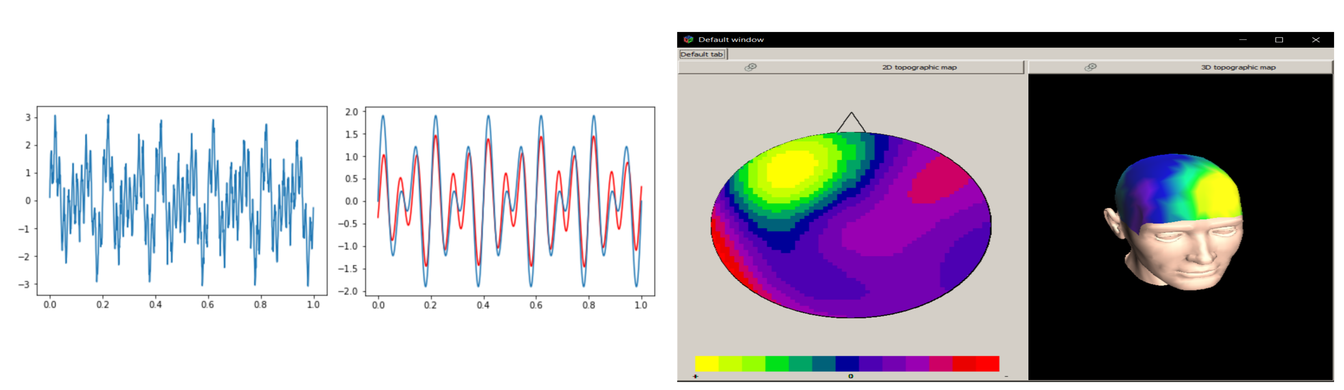


Fig 3: Left: Filtering of the raw data
Right: ICA of the mixed signal

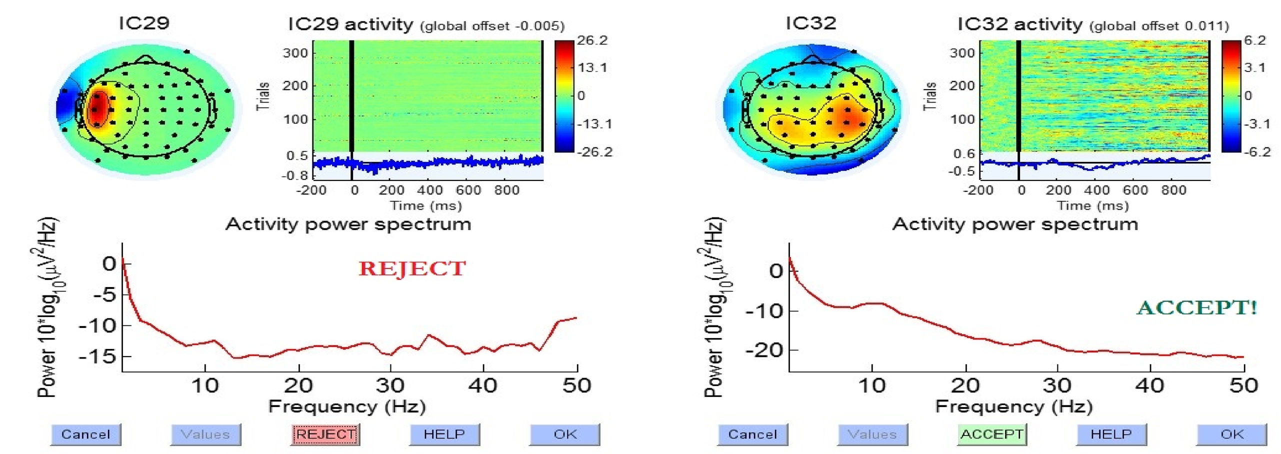


Fig 3: Left: Noisy power spectrum plot suggests no evident activity in 8-12 Hz Frequency range. **Right:** Heat map indicates even concentration from all channels. The spectrum plot is smooth and shows a jump at 10Hz, followed by a steady decay. These are strong signals to include it in the EEG analysis.

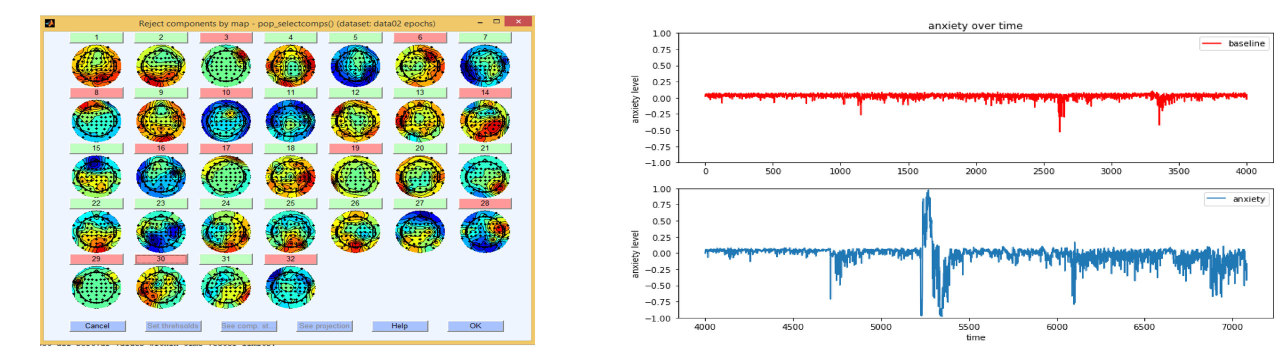


Figure 3: *Left: An overview of individual channel components rejected by their map.,* ***Right:****Power spectrum plot for channel F3 and F4*

Results and Discussion

- Rigged a terrain in Blender to be able to adjust its shape in real-time, in order to adjust to the user's anxiety.
- Used background thread to communicate with a server over TCP to gather anxiety information.
- Established network communication between the VR software and the signal processing software over UDP.
- Demonstrated the feasibility of identifying changes due to anxiety from high density EEG data while subject walks in a virtually infinite world.
- Built data pipeline between virtual reality side and signal processing side

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
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.*

Future Research

Extensions

- Dynamically vary several terrain parameters based on anxiety predictions through EEG and physical signals like heart rate.
- Adaptation of the virtual world to the user's anxiety level leading to decrease in their anxiety levels in balance demanding walking conditions.
- Efficient and proper data normalization of the anxiety feedback values since it may vary significantly among different users.

Acknowledgements

Support for this project was provided by the Illinois Geometry Lab, Department of Mathematics, UIUC. We would like to thank the Mobility and Fall Prevention Research Laboratory for their support.