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,
• BrainVision PyCorder for signal capturing,
• MATLAB and the open source EEGLAB and BCILAB toolboxes for data processing.

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 slope just above the ground, or high up above.

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.

Results and Discussion
Approximately half of the team focused on the gaming aspect, which included designing the virtual world, interacting 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.

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. Also, the virtual world is relatively empty right now, and adding more elements such as trees or animals would make the experiments more interesting.

Right now, the terrains don’t vary with different runs of the software. While we did some preliminary work to test varying terrain, it has not been implemented. In the future, we would like to dynamically vary several terrain parameters.

A higher-end graphics card will allow us to smoothly run more complicated scenes with trees, grass, and even airplanes.

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 Python as well.

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