The Thinking Cap Senior Design Team

Revised Project Charter

23rd December 2018

Executive Summary:

Imagine you are a child with disabilities, and it is difficult to play with most toys other kids do because of your lack of mobility. It would be hard to interact with other kids, unless…

What if there was a safe way for you to interact by just using your mind?

Our goal is to spend the Spring Semester of 2019 proving the capabilities of controlling an RC car with our minds. Through heavy data gathering with our OpenBCI EEG headset and data classification through supervised learning algorithms, we plan on turning a simple Raspberry Pi RC car into a mind-controlled rover.

Core Functionality:

Our main goal for this year is to build a brainwave-to-controller-input predictor to control an RC Car. To do this, we are gathering EEG and EMG data on ourselves while playing video games that focus on avatar movement. Our tools include using our OpenBCI Mark IV headset, running the results through organization software we wrote, and then feeding it into a supervised learning network. We are recording movement key-presses in the game, then using software we wrote to synchronize those keypresses with EEG data in a format tailored for machine learning.

After gathering many instances of brainwave data before each keypress, we will then feed the neural network a fixed amount of clips (in milliseconds) of live EEG data. The network will then output the % similarity of that EEG clip to the EEG preceding the movement actions it has been trained on. If the % similarity of that clip is above a certain threshold for one of the actions - forward, backward, left or right - that control will then be sent to the rover.

Importance of Project:

If our team successfully creates a brainwave-to-button predictive engine for RC car control, the same Mind-Controller software suite will could be used to control other machines or computers in general. This has serious applications for VR and AR control of future computers. The same software suite could also be used to control a robotic prosthetic in the future.

Project Members and Mentors

Dr. Sudeep Pasricha **Role: Machine Learning Expert** **Ph.D. Computer Science**
Responsibilities: *Advising Neural Network Training and Analysis for Real-time Systems Control.*
Katie Britt **Role: Principal Software Engineer** **Electrical Engineering Student**
Responsibilities: *Lead Embedded Systems & Validation Engineer*
Greyson Kehm **Role: Rover Controls Engineer** **Electrical Engineering Student**
Responsibilities: *Lead Electrical & Communication Signals Engineer*

Problem Statement:
We are using supervised learning to determine patterns in eight streams/electrodes of EEG and EMG data to determine what movement commands look like in the brain. We are then using our results to control the movement of an RC car controlled by a Raspberry Pi microcomputer.

The Problem We Hope to Solve in One Sentence:
We want to allow a person to control an RC Car by simply wearing an EEG headset and thinking different movement commands.

Furthermore:
In other projects we have researched online, controls are limited to 2 actions, start and stop. Projects that exist currently do not truly extract the signals for “forward” vs “backward” or “left” to “right. They map binary controls to different movements, such as “meditating” or “not meditating” to right and left. Our goal is to have greater control with pure EEG input, and to have our car move when the user is actually thinking “go left,” “go right,” “go forward,” “go back.”

We hope to demonstrate our product during the Spring 2019 E-Days by demonstrating our mind controlled rover on a small obstacle course we build.

Project Objectives

Goal 1: Gathering EEG Data on a Pertinent Videogame: Halo 1

1. EEG headsets are extremely safe as they do not induce any electromagnetic waves, but passively read the electrical signals already occurring in the brain. The Mark IV EEG/EKG/EMG headset from OpenBCI also has spring-loaded electrodes that allow for a quick and easy setup and eliminates the need for conductive gel.

2. We chose to use the free version of Halo 1 for our volunteers (and ourselves) to play while gathering EEG data and recording their key presses. This is because this game is free, has a large amount of player-created maps so that we can choose the most minimalistic version, with the user controlling a bi-pedial avatar or virtual vehicle in the game to train the network on. A player can drive an ATV, a car, or even fly an aircraft. We will limit initial data gathering on bi-pedial avatar movement or car movement initially though.

    a. **Predictable Button Presses & Data Exporting for Player Avatar Movement**
        i. Forward, Backwards, Left, Right, and even jump or throw and object. Other than the last two, these common movement options pair well with RC Car usage. The last two could be used for ancillary rover control like turning on lights or other ancillary functions.
    b. **Many different vehicles to choose from, with basic movement options**
        i. Our main priority will be to gather data on players while they control their in-game avatar and vehicles using the typical motion controls for forward, back, left, and right ("W," "A," "S," "D")
    c. **Free to play with a dedicated modding community**
        i. The free to play aspect of the game ensures that anyone at any university will be able to play the game and gather homogenous data. Also, many player-created maps exist since the game was initially launched, making it possible to use a minimalist, or potentially custom, map for our data gathering purposes.

Goal 2: Training the Supervised Learning Network on EEG Data

1. We have written scripts for both logging key presses and for organizing our EEG data into matrices for our network to train on. The latter script works by parsing both json formatted files of key presses and 8 electrodes of EEG data, and then captures the EEG data that occurs at the timestamps of pertinent key presses (such as "W," "A," "S," and "D," for forward, back, left, and right). This will help us organize our data before sending it into the network to train.

2. We chose to use a supervised learning network over the various other machine learning options due to its ability to learn from past input data and predict future input data.
    a. Supervised learning networks have very specific class definitions, it is possible to specify the number of classes (directions of movement in our case), and it keeps

the decision boundary as a mathematical equation. These different classes (w,a,s and d) will be produced from our automated control to EEG synchronization script.

Goal 3: Controlling an RC Car With our EEG Headset

1. Once we have Objectives 1 and 2 completed, we will construct a Raspberry Pi RC car kit and interface the controller with our EEG headset and supervised learning network.
    a. The kit we plan to use is available on Amazon and is called the "SunFounder Model Car Kit Smart Robot Toys with Video Camera for Raspberry Pi 3 Model B+ B 2B, RC Servo Motor Remote Control Robotics and Tutorial."
    b. It includes a Raspberry Pi microcontroller, a tutorial, and all the required components for power control to the servos via the board.
2. We learned from our first semester that it is best to get results from our prototype quickly so we can refine it, rather than wasting time building something difficult that we will have to change again later anyway. Using a simple RC Car kit will be best because of this, and we have prior experience programming Raspberry Pi's.

Design Constraints and Final Design Information:

Data Gathering:

Considering controls in our experimental data gathering of EEG data on people, we are having volunteers meditate for 5 minutes prior to data gathering and having them fill out questionnaires about certain metrics like sleep or caffeination. We hope to eliminate as many distractions as possible by using a minimalistic map in Halo, and having our volunteers simply use the movement keys to navigate the virtual world while we gather data on them. Keeping a consistent environment with low amounts of noise or distractions is also helpful.

Machine Learning:

We are using a supervised machine learning network, as discussed before, and feeding in our raw EEG data for classification and training. A great thing about machine learning is that it does best with unfiltered EEG data, and so we will not be using any forms of digital filtering on our data. Reasons for using a supervised learning network were discussed in the "Project Objectives" Section above.

RC Car:

An existing RC Car kit will save us time, and using one that is controlled with a Raspberry Pi microcontroller allows for easy modification for interfacing with our headset. We have experience working with these microcontrollers as well.

Estimated Budget

Current Sources of Funding:

Personal Contributions amounting to an initial investment: CSU's Default Senior Design Team Funding for two members:	$1000 $400
Total:	**$1,400**

Currently the team has already acquired an OpenBCI, 8 electrode, headset for $524.20 using their own funding and a discount with OpenBCI. We currently need to purchase the RC Car Raspberry Pi kit.

Current Itemized Budget:

OpenBCI Mark IV headset with all peripherals: An Intel NUC Computer for Homogenous Software Launch: RC Car Raspberry Pi Kit:	$600 $300 $100
Total:	**$1000**

Careful consideration has been taken by the student team to try and ensure that total costs for the entire setup process are kept to a minimum - while still ensuring homogeneity of data gathered for the tests.

Timeline:

Acronyms:	Finals Week	WB1	WB2	WB3	WB4	WB5
WB: Winter Break	Reconsider Project Goals: Write out revised project charter and annotate code from semester; send to Professor Pasricha for approval. ✓			Gather data on ourselves	Gather data on ourselves	Gather data on ourselves
SP: Spring * numbers indicate work week number	✓ Fix written report for Olivera and send to her by Sunday	✓ Gather data on ourselves	Gather data on ourselves ✓ Begin test-feeding data through organization algorithm we wrote ✓	Build Supervised Learning Network	Train Network	Train Network
	✓ Gain a solid idea of what to pour our energy into over break by the end of Finals Week!	✓ Decide on RC Car Design and Control Specifics (if approved)		Order/purchase supplies for RC car and begin assembly and design process? (If approved)		
	SP18	**SP19**	**SP20**	**SP21**	**SP22**	**SP23**
	Have first functional Machine Learning Network to demo to Professor Pasricha	Continue training network	Continue training network	Continue training network	Continue training network	Have a solid machine learning network
	continue training Network	gather data from other volunteers	gather data from other volunteers	gather data from other volunteers	gather data from other volunteers	gather data from other volunteers
	Work on track/obstacle course design for RC car	Work on track/obstacle course design for RC car	Begin interfacing car with headset output	Work on interfacing car with headset	Work on interfacing car with headset	*Try moving car with headset ourselves*
	SP24	**Spring Break**	**SP26**	**SP27**	**SP28**	**SP29**
	Make sure RC car design is perfected		Have volunteers try to move car with headset controls	Have volunteers try to move car with headset controls	Have volunteers try to move car with headset controls	Have volunteers try to move car with headset controls
	Make sure all scripts/software have been organized, commented, and have documentation		Troubleshoot movement and time delays so that it has an acceptable delay/response time and operates smoothly	Troubleshoot movement and time delays so that it has an acceptable delay/response time and operates smoothly	Troubleshoot movement and time delays so that it has an acceptable delay/response time and operates smoothly	Troubleshoot movement and time delays so that it has an acceptable delay/response time and operates smoothly
	Try moving car with headset ourselves	BUFFER ZONE!				
	SP30	**SP31**	**FINALS WEEK**			
	BUFFER ZONE!		graduation!			

FMEA:

TASK	POTENTIAL FAILURE MODE	POTENTIAL FAILURE EFFECT	SEVERITY (SEV)	POTENTIAL CAUSES	OCCURRENCE (OCC)	CURRENT PROCESS CONTROLS	DETECTION (DET)	RISK PRIORITY NUMBER: RPN (SEV*OCC*DET)	RECOMMENDED ACTION
Gathering and storing EEG data on individuals	*student requesting deletion of user data	*dissatisfied test subject	2	*student changes their mind about participating in our data gathering after they already signed the consent waiver	1	*we will encrypt all personal data of user; they cannot request for it to be deleted before the waiver specifies *only storing the information as long as we need it and using it only for the specified purpose (which is training neural networks for our senior design project)	9	18	*verify they signed the waiver and communicate with them; consult with Student Legal Services if problem persists.
	*student claims they did not provide official consent to their data gathering	*potential legal implications if we cannot prove they signed a waiver	8	*student misunderstanding their agreement when signing the waiver	1	*having people sign waivers approved by CSU Student Legal Services to ensure consent and describe how we will use their data before they ever put on the EEG headset; storing waivers somewhere very safe	9	72	*verify they signed the waiver and communicate with them; consult with Student Legal Services if problem persists.
	*student is worried their data is public	*privacy violations	5	*student did not read that we will encrypt their data and only use it for our project; all data is on a private database for our project's use only	2	*protecting the data we capture in a secure database; all our software will be open-source but our data will not be accessable to the public	9	45	*verify they signed the waiver and communicate with them; consult with Student Legal Services if problem persists.
Malfunctioning of EEG headset	*3D printed structure breaks	*cannot place headset on head	3	*was not careful with transportation and/or use of headset	4	*safe carrying case for transportation of EEG headset, and careful use when installing on students	10	120	*use epoxy if break is small. Reprint on 3D printer if break is more severe.
	*electrodes malfunction	*incorrect data gathering	7	*not used correctly or manufacturer error	2	*calibrating the electrodes every time before gathering data, and ensuring the data streams look feasable before use in gathering data; can also contact OpenBCI if problem persists to check warranty if we need replacement. We do have extra electrodes that the kit came with as well.	7	98	*try using replacement electrodes we already have; contact OpenBCI if problem persists
	*wires disconnect	*missing electrode data or other malfunctions	2	*did not inspect headset before use	7	*inspecting the headset before use each time and taking extra care when handling	5	90	*plug wires back in following the OpenBCI tutorial for constructing the headset
	*software issues	*issues gathering data	4	*did not install or use correctly; software has a bug	5	*ability to reinstall and/or debug software as computer and electrical engineers	7	180	*reinstall the software; follow a tutorial if necessary; debug ourselves if it is software we wrote

Risk Analysis:

Event	Likelihood (a)	Impact (b)	Risk Factor (axb)
Headset breaks	0.5	0.9	0.45
server with all our data crashes	0.3	0.7	0.21
Need to redelegate tasks because someone isn't happy with their part of the project	0.4	0.2	0.08
We need to change the videogame we have chosen for testing	0.5	0.3	0.15
We decide we need to add more team members in the Spring semester	0.3	0.2	0.06
Our budget runs out	0.1	0.5	0.05
Machine learning algorithm has trouble detecting patterns in our data	0.6	0.9	0.54
We over or under-train our deep learning network and get odd results	0.7	0.4	0.28
Information from EEG varies drastically from person to person and needs to be individualized or normalized somehow	0.6	0.7	0.42
We lose software due to lack of committing our changes to the drive	0.2	0.7	0.14
The headset does not physically fit all individuals' heads	0.9	0.1	0.09