Abstract Summary

The requested project involves creating research equipment for a neuroscience study at KUMC focused on reaching and grasping. The goal of reaching and grasping studies is to gain a better understanding of the neural mechanisms underlying reaching and grasping. These studies could have significant implications for individuals with neurodegenerative disorders and the development of neuro-prosthetics. This project consists of two parts: an eye tracking component to track the subject's eye movements, and a task environment. For my part of the project, we were asked to do a redesign of the task environment used in Dr. Rouse's 2015 study. The task environment will have a 3x4 grid of 12 interchangeable objects that the subjects can grasp and manipulate. The proposed design involves a wireless sensor module consisting of a microcontroller, battery, and accelerometer that will detect movement.

Background & Motivation

Previous studies on reaching and grasping have shown that the arm movement and the size of the grip used to grasp an object, while occurring simultaneously, are interdependent to an extent. In another study on reaching and grasping, the researchers focused on examining the joint angles of all five digits of the hand and the overall hand shape as they grasped various objects, but they did not consider how these changes related to the movement of the arm. Dr. Rouse's 2015 paper titled *Spatiotemporal distribution of location and object effects in reach-to-grasp kinematics* built on those previous topics by not only tracking joint angles but also tracked arm movement during reaching and grasping. They accomplished this by creating a task environment of different size, shape, texture, and colored objects that subjects manipulated. In addition to the physical appearance and makeup of the different objects, the motion required to satisfy the completion of that task also varied. Some required pulling or pushing motions, while others required a twisting motion or even a button to signal task completion. Initially the subject is given an indication to what object the subject was supposed to interact with and an indication when the subject successfully interacted with the object. During the time between the indication to interact and the actual interaction, the researchers used An 18-camera video motion analysis system that tracked various points on the hands and arms. [1]

Dr. Rouse and his associates at KU med are interested in how the brain interacts with the hand and arm during these reaching and grasping movements. Though this task on the surface seems straight forward, reaching and grasping involves coordination of various muscle groups in the arm, hand, and fingers, as well as sensory feedback. Dr. Rouse is using electrophysiology techniques in this round of research of reaching and grasping. Electrophysiology is a branch of neuroscience that deals with the electrical properties of biological cells and tissues, particularly the electrical signals produced by neurons [2]. In the context of reaching and grasping, electrophysiology is used to study the electrical activity of individual neurons as the subject performs motor tasks such as reaching and grasping. He will be using these brain sensors along with eye tracking software and the task environment to provide a high-resolution view of neural activity.

A better understanding of the neural mechanisms underlying reaching and grasping can have a significant impact on the lives of individuals with neurodegenerative disorders such as Parkinson's disease. By studying the neural circuits that control reaching and grasping, researchers can gain insights into the causes of motor impairment in these disorders and develop new treatments to improve patients' quality of life. Furthermore, advances in the field of neuro-prosthetics, which involves the development of artificial limbs and other devices that can be controlled by the brain, could also greatly benefit from a better understanding of reaching and grasping. These devices can enable individuals with limb disabilities to interact more effectively with their environment and improve their overall quality of life. [3]

Project Description

The project requested by KUMC involves making research equipment for neuroscience research involving rhesus macaque monkeys. The project is broken into two parts: eye tracking and a task environment.

The eye tracking component will track the subject's eye movements during the tasks. The task environment will be a redesign of the one used by Dr. Rouse in his 2015 paper and will feature a 3x4 grid of 12 interchangeable objects that the subject can grasp and manipulate into predetermined positions. The task environment will provide indications on which objects the subject should grasp and an indication of a successful interaction with the object.

The task environment will feature interchangeable objects, allowing researchers to easily change the objects' shape, texture, and weight. The flexibility of this tool will provide researchers with the ability to study the neural mechanisms of reaching and grasping in a variety of conditions.

System Requirements

The given points were given as requirements for the task environment.

- Objects of different size, shape, and weight must be able to be disconnected from the activity board allowing different task environments.
- Rods must be able support objects of different size, shape, and weight.
- The activity board must support 12 objects in a 4 x 3 grid in about an area of about 18 x 12 in.
- The objects need to be anchored to a rod or support, so they stay at a fixed location. Although design should allow for future flexibility with freely movable objects
    - Accelerometers would allow for wireless motion detection.
    - must detect motion in one dimension.
    - Noise from the accelerometer must not be interpreted as an interaction from the monkey.

  - The motion sensor package must be wirelessly attached to the end of the rod with the object.
- The board must lay on a flat surface or mounted vertically
- There should be a LED indication of what object to be manipulated and only one object should be illuminated at a time.
- The LED should turn on for a duration set by the user.
- The user must be able to plan an experiment by determining the LED sequence and timing durations.
- Timing resolution must be accurate to the scale 1 ms.
- The software must store the time the LED turns on and off, time when the monkey interacts with the object, and how long the object is interacted with.
- The software must determine if a trial was successful (the correct object was manipulated) or a failure (no object or the incorrect object was manipulated).
- The task board needs to allow for swapping objects so researchers can dissociate between movements to a location versus grasping a particular object in different blocks of trials.
- A task will consist of 30-50 trials and then the location of objects will be adjusted. This would repeat 8-10 times per day.
- The apparatus should allow for easy cleaning.
- Creation of a task software to control what object is instructed and then determine if the correct object was manipulated.

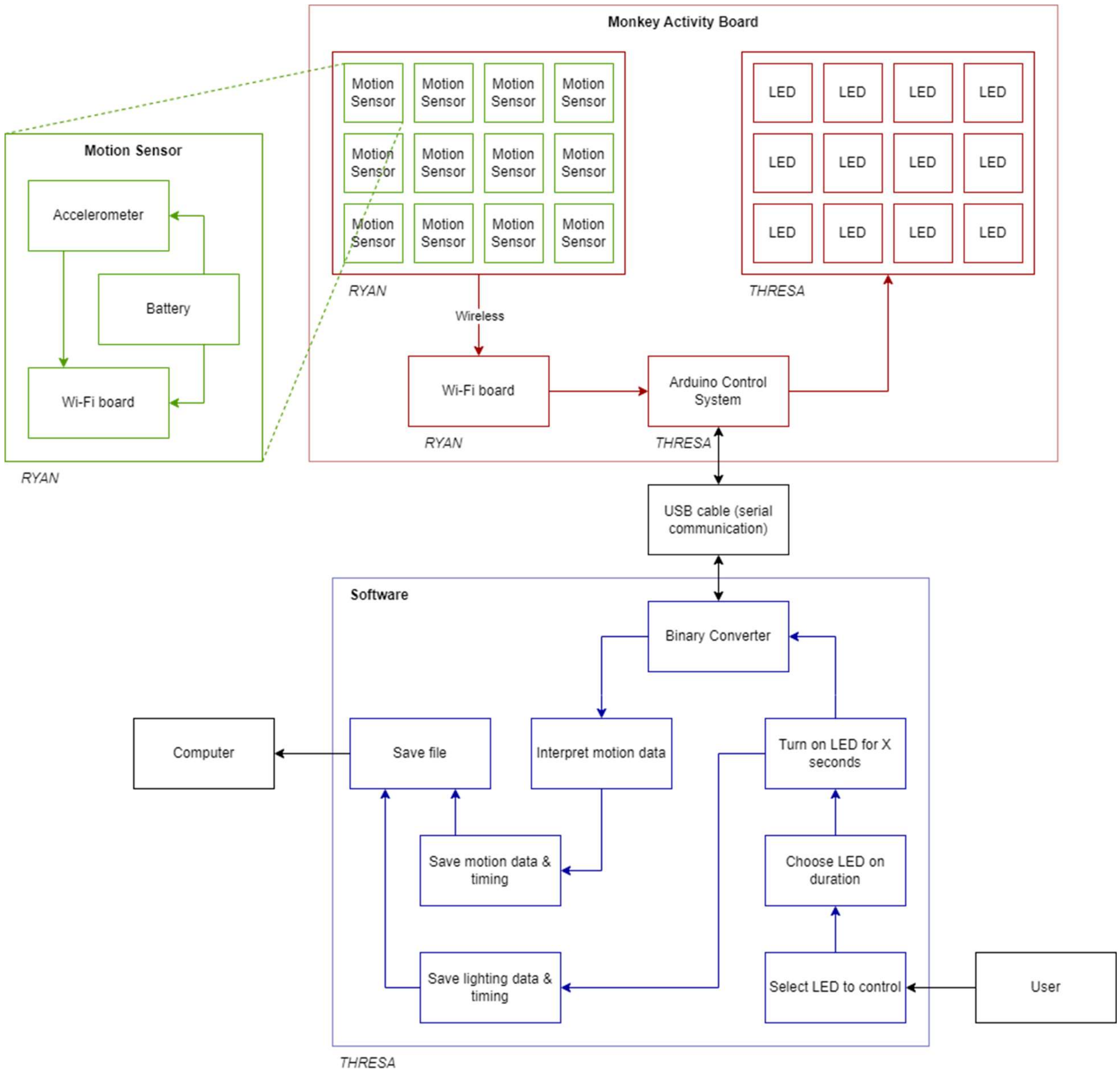
Design Proposal

overview: The task environment is divided into two sections: the board that holds the microcontroller and lights, and the sensor module that attaches to the board with mounting rods. These two sections are divided between myself and my teammate. My responsibility will be the manufacturing of the senser module that consists of a D1 mini development board, battery and accelerometer in a 3D printed case that will be able to be screwed onto mounting rods. The sensor module is either embedded or attached to the object that the researchers wish for the subject to grasp. The D1 mini is a compact development board based on the ESP8266 microcontroller. The small size, an integrated Wi-Fi module and low power consumption makes it a perfect candidate for the sensor module. Since the goal is for a wireless setup, the sensor module will be battery powered. To detect motion, the sensor module will use a 6 axis accelerometer (translation and rotation). Through testing, a minimum acceleration threshold will be determined to correctly detect movement and filter out noise. In this first iteration, the sensor will only be expected to detect 1D translational motion, but the 6 axis accelerometer will allow for future iterations to detect motions in other ways. After the accelerometer detects motion above a threshold value, the sensor module sends a notification through ESP-NOW protocols to the board's microcontroller. ESP-NOW is a protocol developed by Espressif, which enables multiple devices to send small data packets (less than 250 bytes) with one another using low-power 2.4GHz wireless connectivity.[4]

The rods the sensor modules are attached to are what determines the type of motion of the sensor module detects. For the first iteration, we will have a 1D translation motion caused by the subject pulling or pushing on the object. Rod will only allow movement along a prescribed distance under spring tension. After the object is released by the subject, the spring will cause the object/sensor module to better itself back to the starting location.

Battery Considerations: Since the sensor module is battery powered, the choice of battery is of importance. The board operates at a voltage of 3.3V, with a minimum voltage of 2.6V [5]. Conventional batteries, such as zinc-carbon and alkaline, have a nominal voltage of 1.5 Volts, so two batteries are required. Based on a comparison of voltage versus time graphs for alkaline, zinc-carbon, and lithium batteries, it is notable that zinc-carbon batteries only utilize about 25% of their capacity before needing replacement, while alkaline batteries show a slight improvement at 30%. Lithium batteries provide the best performance, with an estimated 70% usage before recharging. Given the repetitive nature of the trials, it would be more cost-effective to opt for the higher upfront cost of Lithium batteries instead of purchasing 30 conventional batteries for 15 sensors (12 to be used and 3 as backup) every time batties die. It should be noted that 3 conventional batteries could be used in conjunction of a voltage regulator, allowing for a longer runtime before replacement. There is also a devilment board available that allows for easy recharging of Lithium batteries via a micro USB port. [6]

Accelerometer Considerations: For our purposes we will use a 6 axis accelerometer that runs of a MPU-650 chip. That will let us get the desired 1D of motion detection but also allows for future expansion for detections of other movements. Other accelerometers like BN055 allows for a 9 DOF capability and internally combines data from an accelerometer, gyroscope and magnetometer that allows for true 3D space orientation. The data fusion allowed by the board allows it to give its position in euler angles and vectors. This may be of interest in future iterations where how the object is manipulated in 3D space based on finger movements is of importance. This higher capability would come with an increased cost per chip but uses the same I2C connects, so switching between the MPH6050 and BN055 would require minimal modifications.



Testing

Since this equipment will be used in a laboratory setting it, the software and physical components will need to be tested for robustness. On the software side of things, that means trying to break the code or interfere with the wireless communications of the sensor modules and ensure that failsafes prevent any loss of usefulness. We may need to also provide continual data backups locally in the advent of power loss to the device. Testing will also need to be accomplished to ensure noise isn't being pick up from the sensors or if multiple sensors were manipulated that it wont have undesirable effects. Additionally stress testing will be accomplished to ensure that the materials used will stand up to rough handling by the subjects. We will also want to get a baseline battery consumption rates and life expectancy and make modifications to the final battery selection.

Resources

Below is a table of required equipment to be purchased. It should be noted that the 3d print times provided are rough estimates based on similar sized objects that were quickly CAD and sent through a slicer program. Times will vary rapidly based on the required detail in the final product as well as the printer used and the choice of filament used in the printer. Additional equipment required (voltmeters calipers etc.) will be provided by the group's personal equipment inventory. Rob Young, the Senior Engineer at the instrumentation Design Laboratory has offered us to use his 3D printer if we supply the materials. A spool of PLA runs about $20/kg.

	Number of parts	Cost per part	Total Cost	Vender
MPU6050: Accelerometer (comes in packs of 3)	5	$9.99	$49.95	Amazon
RGB LED (Pk 100)	1	$8.99	$8.99	Amazon
D1 Mini (comes in pack of 5)	3	$15.99	$47.97	Amazon
D1 LiPo Battery Charger (Pk 4)	4	$11.99	$47.96	Amazon
3.7V Lipo (1000 mah) (pk of 4)	4	$28.99	$115.96	Amazon
Arduino (Planning on UNO but may require a mega depending on flash memory requirements). Does not need to be purchased right away.	1	$27.60	$27.60	Arduino
Micro USB Charging Cord	3	$7.00	$21.00	Amazon
Senser Case (3D Print Time in hours)	30	$0.00	$0.00	
Activity Board (3D Print Time in hours)	75	$0.00	$0.00	
1D mounting Rods (3D Print time in hours)	30	$0.00	$0.00	
Total			$319.43	

Timeline

Task	Jan 17-20	Jan 23-27	Jan 30- Feb 3	Feb 6-10	Feb 13-17	Feb 20-24	Feb 27 – Mar 3	Mar 6-10	Mar 20 -24	Mar 27 - 31	Apr. 3-7	Apr. 10-14	Apr 17-21	Apr 24-28	May 1-5
Deadline	Hwk 1	Hwk 2	Proposal due Fe	Hwk 3	Hwk 4	Progress report	Hwk 5	Hwk 6	Progress Report	Initial demo	Hwk 7	Hwk 8	Progress Report	Nothing due	
Other															
Choose parts										x					
Order parts				Does not need to purchase alll items at this time				Order Remaining Parts		x					
										x					
Hardware															
Bread Board Version										x					
Code & Assemble V1 x 2										x					
Bench Test For Desired Results & Tune										x					
Cad Sensor Case, Submit For Print										x					
CAD Atachment Rod fpr 1D motion										x					
Modifications Week										x					
Produce Rest of Sensor Cubes x 13										x					
CAD Board Mount										x					
Board Assembily										x					
										x					
Software															
Setup Qt										x					
Create and test simple software file										x					
Paper draft all UI designs										x					
UI to simulate activity board										x					
UI for creating LED sequence										x					
Writing data to hardware										x					
Reading data from hardware										x					
UI to visualize motion data										x					
UI to ask user for experiment details										x					
Designing structure for save file										x					
Saving experiment data to file										x					
UI for chosing save file										x					

References:

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