University of Massachusetts Lowell
EECE.4991 Capstone Project

Project Number: 20-005

UML Assistive Technology / NEEDS Center

Card Matching Activity

Final Report

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Executive Summary
Group Number: 20-005
Card Matching Activity
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The NEEDS Center works with developmentally disabled individuals of all ages. These individuals have a difficult time finding activities that promote the motor skills and hand eye-coordination that they need to live independent lives. This led to the NEEDS center proposing their dilemma to us at the University of Massachusetts Lowell.

The concept they proposed was an electronic card matching activity. The user of the device will stand upright, with their arms extended in to play. An image will be displayed, and the user will have to match the picture displayed by using a physical interface. Their students need encouragement to stay mentally and physically active in their everyday lives. So, a fun yet simple card matching activity promoting motor skill and mental training will be designed and provided to improve quality of life for the clients.

Our objective is to create this card matching activity by December 2020 with a solution that meets all their criteria. This means the system must have an upright display tall enough for the user to stand and reach outward, a power supply connected to a wall outlet, no latex, no sharp corners, and no lead. We will utilize a Raspberry Pi, an LCD screen, an analog button grid, and an AV Cart to mount everything on. The screen will display a 3x3 array of images. The image that is desired to be matched with is displayed to the left. Nine analog buttons will be mapped to the location of the nine displayed possible answers. The button board will also contain a power button and a menu button. The menu button allows you to start the game and go to a theme selection screen. At the theme selection screen, nine images representing nine different themes will be displayed. The user can choose the theme of their choice before playing the game by pressing the button that corresponds to the theme. By pressing the menu button mid-game, the user can go back to theme selection to choose a different one. The power button can be pressed at any time to turn the system on or off.

Our solution will provide the benefit of improved teaching ability of the employees at the NEEDS center, as well as improved motor skills of their students. With our design enlarged enough so that the students can stand to play, they will be engaged mentally and physically, providing the solution the NEEDS Center's problem without them having to pay for a commercially manufactured product.

Our design has been completed and can be evaluated as a success. All requirements have been met. Students at the NEEDS center will be able to use their motor skills, sharpen their image recognition skills, and exercise their ability to make choices. The system is maneuverable, sturdy, and engaging. This allows for the game to be brought to students throughout the facility. It is simple to operate, provides entertainment and education, and does not require need for heavy supervision all while being safe to use.

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Introduction

In early February 2020, the University of Massachusetts Lowell has assigned a team of four electrical engineering students whose major is Electrical Engineering to work with North East Educational and Developmental Support Center (NEEDS Center) to develop a Card matching game device. This card matching device has been developed to encourage motor skill development and hand-eye coordination for the students. This has been completed by engineering a device which utilizes an LCD Screen, an analog push button board, a Raspberry Pi and an AV cart.

This report will discuss our project from start to finish. We will discuss the project definition, including our original project concept and deliverables. Design and Analysis of our system will also be covered, including our project concepts and chosen solution. Lastly, the project evaluation will be discussed. This will be determined by satisfaction of problem and objective, project requirements, and budget.

Project Definition

Customer and Project Information

The NEEDS Center, or North East Educational and Developmental Support Center, is a 501-c-3 non-profit organization that was founded in 2012 by professionals with numerous years of experience in the field of Developmental Disabilities services and supports [1]. Individuals with disabilities are provided with education, training, and support so that they may gain more independence. Leaders at the NEEDS Center all have an extensive background in working with those that are developmentally disabled. The NEEDS Center started in April of 2014. In July 2017, NEEDS Center expanded to include a consulting division that provides behavioral and other support to children with autism and other developmental disabilities in both school and home settings. Their mission statement reads as follows: "NEEDS Center's mission is to provide education, training, and support to individuals with developmental disabilities to assist them to live as independently as possible".

Student's with intellectual disabilities often have difficulty with decision making, motor skills, quick recognition. Currently, the NEEDS center does not have an all-in-one device that can encourage the improvement of these skills. They teach in many different classrooms

throughout the day and require portable learning tools so that they may bring the device to the students rather than have the students relocate.

This led to the NEEDS center formulating the idea of an electronic card matching device that would require the user to use their motor skills and hand-eye coordination to play. Images would be displayed to the user and they would have to provide physical input to choose the images that matched. They wanted it to be portable, sturdy, safe to use, and engaging.

Original Project Concept

When the project was initially proposed to us, the NEEDS center wanted a card matching game that required users to stand upright in front of a screen. The users would be shown a set of images that represent the possible answers, and one image that represented the answer that was to be matched with. The device was to be sturdy, free of any allergens or sharp edges, and be wall outlet powered. Our initial approach was to have a screen that would display the image, a computer to process the game software, and either a touch screen or push button board to receive user input.

Original Expected Deliverables

For the originally expected deliverables, a fully functional card matching activity is to be produced. The system should be an all-in-one stand, which holds a screen at around chest level with the user. The device will include physical user input which requires the user to use their motor-skills and hand-eye coordination. A power button will be included to power the device on and off. The stand will portable, sturdy, and wall outlet powered. It must be sharp edge and corner free to prevent any potential harm. It must also be latex and lead free. A user's manual will also be delivered to the customer which will include instruction for operation and any warnings for possible hazards that are unavoidable.

Problem Statement

Caring for those with mental illness can come with many challenges. There are many forms of illness and each comes with a unique set of difficulties that require different techniques to overcome. Difficulties can come in the form of both reduced motor skills and hand-eye

coordination which can cause some people to be unable to live alone. To help a wide variety of disabilities you need many different tools. At the NEEDS center they strive to assist individuals with all sorts of disabilities to one day reach complete self-dependence. To do this they have many actives to try and help stimulate their patient's both physically and mentally. While they have some tools to accomplish this, their selection can be limited at times. So, in order for them to be able to assist their patients to a greater extent more tools are needed. They want one that encourages their patients to get up and work on both posture and motor skills while keeping them mentally stimulated. Along with keeping them active, it's also important to give them something to do that won't cause any stress because too many stimulants can also be an issue for some patients.

People with intellectual disabilities need encouragement to stay both mentally and physically active in their everyday lives. Therefore, a fun yet simple card matching activity that promotes motor skill and mental training will be provided that can help improve quality of life for the clients.

Project Objective

The purpose of the card matching game device is to assist individuals with developmental disabilities from NEEDS Center by training and practicing with the device to improve their development. The device should promote the use of their motor skills by requiring users to stand upright and reach forward to play. Using the designed system will assist them in their efforts to live as independently as possible.

The objective is to design and construct a card matching activity by December 2020 that promotes the improvement of hand-eye coordination and motor skills for individuals with developmental disabilities.

Research

Based on our customer needs, the card matching activity will require many different circuits including audio amplifiers, a touch screen, and an ac-dc converter. We will also have to make use of a microcontroller which will allow for the control of outputs when cards are matched, when to use an audio response, and when certain images should be displayed. These topics will be the subject of our research.

GPIO Pins with Push Buttons:

In order for our system to receive input from push buttons, code must be written to recognize it. A software library called RPi.GPIO allows users to reference I/O pins as board numbers and channel numbers [5]. In order to call a GPIO pin, the setmode() command must be used to determine how you would like to reference the pin. You can either write setmode(GPIO.BOARD) or setmode(GPIO.BCM) to choose which reference you choose. Once you have chosen a reference mode, you then can use the command GPIO.setup(channel, GPIO.IN) to choose the pin you want and tell the IDE to poll this pin for a logic level input. Then you can call that pin in a while loop such as "while(GPIO.input(channel) == GPIO.HIGH): print("HIGH")" to create a condition to occur when the logic level signal is sent to the pin. You can also use "== GPIO.LOW" for the opposite condition. By using this, we will be able to callout 11 different GPIO pins for the 11 different buttons to be used (button array, power, and menu buttons).

Basic Push Button Circuit:

Many Raspberry Pi sample circuits exist online for many applications. We need to design a circuit that will allow for a logical level signal through the push button to be detected at the GPIO pins. If a GPIO pin is not connected to a logic level voltage or ground, the pin will be floating between high and low which will break the application it is being used for [6]. This means a pull-up or pull-down circuit must be used to hold the voltage steady at the input pin. A GPIO pin connected to a pull up circuit will read logic level high unless the push button is pressed. Then, the while loop can be constructed to work with that behavior.

Audio Feedback:

Another feature that our customer would like to see implemented is audio feedback for right and wrong responses when attempting to match the cards. Any device that outputs audio will need an audio amplifying circuit and a speaker. There are multiple classes of audio amplifier circuits, A, B, AB, and D being a few [7]. Since the practical power efficiency of A, B, and AB type amplifiers are very low, class D amplifiers are used often. Class D amplifiers operate in switching mode, which provides lower power dissipation and performance. This is because the MOSFETs are either completely on or off, not in between. A schematic diagram with a block

level description of an audio amplifier shows that it consists of five main components (Shown at end of paragraph). These are an input, integrators and filters, a modulator, an output stage, and a lowpass filter. The output stage is sent to the low pass filter, as well as a feedback loop to the integrator and filter block. The proposed document in the research paper cited [7] utilizes a low DC voltage source to power the op-amps in the circuit, two power MOSFETs, capacitors, and resistors. There are two op-amps being utilized, one as a comparator and one as an integrator. The integrator is used to provide a closed loop feedback to improve performance and eliminate non-idealities. The low pass filter removes any undesired wave forms from the output signal that have been generated throughout the circuit.

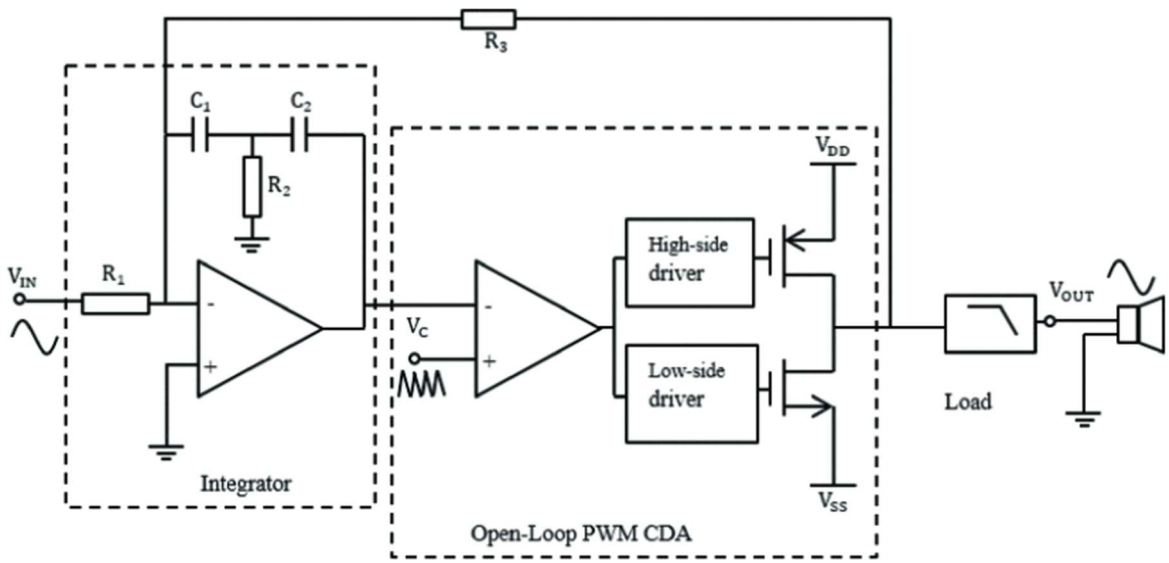

Figure 1- High Level Schematic Diagram of an Audio Amplifier Circuit.

Touchscreen:

One feature that our customer would like is for the use of a touch screen as a mode of input for the device. There are many types of touch screens used today but we will focus on resistive and capacitive touch screens. Resistive touch screens come in two main configurations 4-wire and 5-wire. 4-wire resistive touch screens use both the upper and lower layers in the touchscreen "sandwich" to determine the X and Y coordinates [8]. Voltage is applied across the screen in the Y direction which when the two layers are pressed together the position can be read by one of the X electrodes. At the point of contact there exist a voltage divider which can be used to determine the Y coordinate. This process is then repeated to retrieve the X coordinate [8]. The

big downside to a 4-wire screen is one coordinate uses the outer layer as a uniform voltage gradient and the constant flexing that occurs will eventually degrade the linearity and accuracy of whatever axis is using the outer layer [9]. 5-wire resistive touch screen have one wire going to the coversheet while the other four go to the four corners of the back layer. Then a controller applies voltage to only the top corners while grounding the bottom two to allow voltage to flow uniformly from top to bottom. This provides us with the Y voltage from the coversheet. Then the two right corners are grounded while the two left corners are supplied with voltage to obtain the X voltage [9].

One advantage of using 5-wire versus 4-wire is that it uses primarily the back layer to get all the inputs, so if the coversheet's conductivity coating cracks, there isn't as big of an issue with non-linearity of measurements. An advantage of resistive touch screens is that they tend to be more affordable and are also durable as they are not affected by outside elements such as water or dust [9]. However, they can be significantly damaged by sharp objects or scratches.

Capacitive touch screens have panels coated with a material that store electric charges. Whenever it is touched, a small amount of charge is drawn to the point of contact [9]. Similar to the 5-wire resistive set up, there are circuits at each corner that measure the charge and retrieve the position. Capacitive touch screens do a good job of finding position, but one downside is that the signal can only really be obtained from a capacitive touch. Meaning, you can't use styluses or gloved hands, which isn't really a big issue for our device. Capacitive screens are also not affected by most common liquids, dirt, and grease [9]. This could be very important since one of the requests our customer has is for the device to be as durable as possible.

Graphical user interface:

In order to communicate with the user, a graphical user interface (GUI) will need to be designed into the device for both the center staff and the user to either set up the game or to play it. As Raspberry Pi is likely to be the platform as the core of the device, python3 will in term be the language used for the device.

A likely method to start the design is by importing the "App" class from the "guizero" module to create a user interface as an app [13]. Then, using this method, this may allow us to

construct a simple interface that can efficiently interact with the user through words, images, and possibly sound.

A further important point when designing the GUI is its layout's physical effect on the user. In the study "Touch Screen User Interfaces for Older Adults: Button Size and Spacing", it is suggested that a 11.43 mm square button is the acceptable minimum button size for an average reaction time of 1400 ms. A separation of between 3.17 mm to 12.7 mm of buttons is also suggested for a better reaction time [2]. Although this study is designed for a different audience, it can be deduced that a special spacing layout is extremely important to maximize the device's efficiency at performing its core function: helping the users practice their motor skills.

Games for Fine Motor Development:

Individuals with mental disabilities such as Down Syndrome, autism, and Asperger's will most often have severe motor function disabilities that require activities that will help to develop their motor skills and aid in living a less assisted life. A fine motor movement is known as the coordination of the movements of the small muscles, most commonly involving hands and fingers with the eyes (hand-eye coordination), also called dexterity. These fine motor skills will aid with the growth of intelligence of an individual as well as their self-awareness [10]. The motor skill we will focus on will be this fine motor skill, but there is another type of motor skill known as gross motor skills which primarily involves the movement and the coordination of the arms and legs, so basically any of the large body parts; and this gross motor skill is responsible in the performing of actions such as walking, jumping, and swimming.

These movements are responsible for actions like picking things up with the thumb and finger, writing, blinking [12]. The knowledge that comes with the development of motor skills is knowledge about the body, knowledge about how to perform a movement, knowledge about feelings of self-confidence, knowledge about how to think, and knowledge about skills. The games and activities used for developing these skills are all different, but all have same final objective of helping these individuals develop their fine motor skills as well as the knowledge needed to use it. These activities are of course very simple in nature and have to be due to the mental disabilities of not being able to learn a complex game; these activities include puzzles, playing catch, molding dough into balls using the palms of hands, using tweezers to pick up objects, stretching rubber bands around different sized bottles and containers, stringing beads on

string or pipe cleaners, tracing objects on paper, and even as simple as coloring in the line in coloring books. If the individual is capable of more complex tasks then simple games can be played like Operation, Hungry Hippos, Buckaroo, Lite Brite, Bed Bugs, and Connect Four [11]. Individuals with Down syndrome will have difficulty with development and the learning of skills and concepts will certainly take longer compared to what's normal for others, but with modification of the learning process these individuals will increase their abilities to be more self-sufficient and much more capable in task for living a day to day normal life.

The Raspberry Pi:

The Raspberry Pi is a microcontroller that we will utilize to code our LCD display and take input from the push button system. Our device requires images to be displayed on a screen, which means we require storage, a display port, computing, a USB port, a DC voltage supply, and audio. Our device also requires that it must be wall outlet powered. The Raspberry Pi will certainly be able to accommodate this.

The key features of the Raspberry Pi include a 2 GB LPDDR4-3200 SDRAM [13]. This means that we will have two gigabytes of low power dual data rate storage. This storage device is in communication with a Broadcom BCM2711, Quad core Cortex-A72 64-bit SoC that operates at 1.5 GHz. This will allow computations to be incredibly fast for an application like ours. The Raspberry Pi has two USB 3.0 ports that allow for the upload of images on to the device that will be used for matching. A 4-pole stereo audio port can be used in combination with the LCD screen to produce positive audio feedback when the match is made. The microcontroller has 2 micro-HDMI ports that will be used to connect to the display, which also utilizes micro-HDMI. The device is powered using a 5V DC wall adapter, allowing the device to be wall powered. Forty general purpose I/O pins are part of the board that can be utilized to take logic level voltage signals from the push button board so that the controller can recognize the user input. The I/O pins also include a 5V and 3.3V DC power supply that can be used to power the push button board itself. The Raspberry Pi also comes with a Micro-SD card slot with a Linux operating system and data storage. This will be utilized to program the software portion of the device.

Requirements

Project Specification Requirements:

1. **Device Objective** The device must display a target image and a separate array of images. Then the player must choose the image from the array that matches the target.

   Rationale: The game is meant to be an electronic card matching game that prompts users to press a button to match the target image.

2. **Theme Selection** The device must contain nine different themes of images for the user to choose from. The device must display an array of images representing a theme and the player must choose which theme they like.
   Rationale: The theme selection grants more variety and choice for the player.
3. **Device Height** The device height should be 36 – 44 inches tall.
   Rationale: The goal of the device is to be played at arm's distance so that the user must reach out to play, forcing them to use their motor skills.
4. **Device Maneuverability** The device should weigh no more than 15 lbs. to move it around the room it is in. The device must also have wheels.

   Rationale: The NEEDS Center has required the device to be portable from one area of the room to another to make sure that is not in the way for activities.

Safety and Health Requirements:

5. **No Leaded Material** No lead shall be used throughout the assembly of the device.

   Rationale: Leaded material is banned by University of Massachusetts Lowell protocol. Lead has been proven to have negative effects on human health. These affects include brain function, kidney function, and heart health.

6. **No Latex** Latex must not be used in the creation of the device.

   Rationale: Per the NEEDS Center, students that will come in contact and use the device may have latex allergies. The device should be playable for students.

7. **Max Power Cable Length** The maximum length of the power cable should not exceed three feet.

Rationale: The NEEDS Center has required a wall outlet power source with a cable no longer than three feet to avoid tripping hazards. Students using the device or in the vicinity of the device will have weak motor skills, and thus hazards should be limited.

8. **No Sharp Corners** The device casing must have rounded edges to limit safety hazards.

   Rationale: The NEEDS Center has required that there be no sharp edges on the device. The students may trip or stumble when playing due to weak motor skills, and thus, preventative measures must be taken.

Implementation and Game Play Requirements:

9. **Power Button** There must be a power button that will shut the system down.

   Rationale: The NEEDS Center requires a power button to shut down the device, so it does not need to be unplugged when it is not in use. It will also be utilized to control when the device is used by the students. A power button will also mitigate data corruption.

10. **Stability of Device** The device must be sturdy and account for pressure applied from the user leaning on the device so that it will remain upright. The device wheels must have locks. The system should not be top heavy, and exhibit well balanced weight distribution. The push button board must be mounted at an angle to lessen force applied in the x-axis by the user.

    Rationale: The NEEDS Center requires that the device be sturdy enough for the user to be able to lean on the device without it falling over. Students may lean on the device when they go to press a button. If they lose their balance, the device must not fall over in that case.

State Guidelines:

11. **Regulated Outlet Power Supply** The state requires that all devices using a wall outlet as a power source to meet all Massachusetts regulations.

Rationale: An AC-DC power supply used in the design must comply with all Massachusetts state guidelines. A power supply that is certified by Underwriters Laboratories will meet these regulations.

Technical Details and Analysis

Analysis of Multiple Design Choices

Our first solution involves one screen that can cycle between about 9 or 16 images and a matching number of pushbuttons with the images attached to the device. The push-buttons would be arranged in either a 3x3 or 4x4 array. In this set up the images on the buttons are always mapped to one specific image each. This limits the number of games the device would be able to run. The images are all preselected and the program would just use a random number generator to pick one image out of the bank of images to select and display. In order to check for correctness each input would be attached to a Raspberry Pi and when the system receives the correct input there would either be a light or sound to let the user know it was correct. Once the system receives the correct input it would then cycle to another random picture from the ones saved on the program. To start and stop the program there would be an on and off switch or button that allows the user to end the game whenever they want.

The second solution involves a large LCD screen displaying one large image and 9-16 smaller images with a matching number of buttons towards the bottom of the device. This setup is similar in look to an old cellphone but on a larger scale. In this setup the topmost, standalone image is what was chosen as the correct image and the smaller images are going to be randomly selected from a large library of images. A copy of the correct image included within the small images will then be displayed in a 3x3 or 4x4 array. It can use a Raspberry Pi to run a program which will read the input from the buttons and output whether the answer is correct or incorrect and then cycles to the next array of images. In order to display that the answer is correct we plan to have an on-screen prompt which lets the user know if their response was right or wrong.

While most of the hardware being used to make the system will differ, thr function remains the same between two housing unit design concepts. The first design is kiosk style structure made from wood that will contain a Raspberry Pi inside and an outward facing button

board in front of a screen. The device would stand at 4ft high with the monitor and buttons in one large box by the top with a thin stand attaching them to a large, rounded base to keep the system stable. The second design was brought up to us by our Mentor, Frank Rene, and involves attaching a button board and monitor onto the top of an AV Cart. This design allows for the client to move the device around more freely and increases the overall stability of the system.

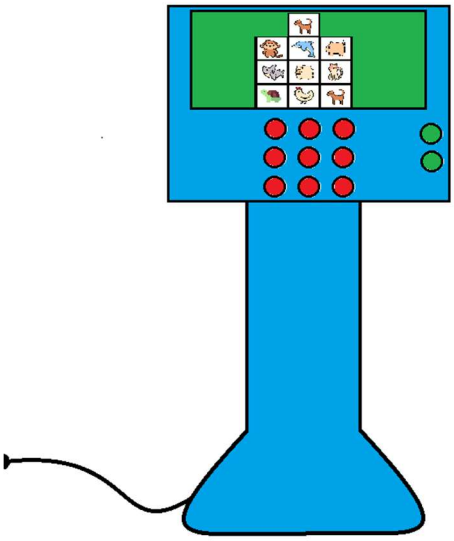

Figure 2- Original design concept for the physical system. This design shows off the second software design option with all images being displayed on screen instead of the buttons and the kiosk stand design mentioned above. A major flaw in this design was it's lack in mobility.

The biggest difference between the general solutions for our system is how the software functions. For the first solution we would just need a program which essentially loops pictures when a button is pressed but with a random selection process. Each image would be associated with a different input signal and when the program received that input signal it would move onto the next image. So, the simplicity of this method is what stands out about it the most. The second solution's program requires a few more steps for it to achieve the desired outcome. First, we need a function which loops pictures when a button is pressed with a random selection process but in addition we need to add a function which then takes that image and 8 other random images and displays them in random spots on a 3x3 array. Once the program receives a correct input it must change the correct image and reshuffle the array with new images. An advantage to this

program is that it allows for more randomness between the games, so it serves as a better motor control training tool. It also allows for different themes of images to be used, which will provide more choice and freshness to the game. This design is a better product for the consumer. However, for a team without someone who has a lot of programming experience, it may present some difficulties.

Chosen Solution

Even with these difficulties in mind we have chosen to go with the second solution for our product because it is a superior training tool for someone who wishes to improve their hand eye coordination and fine motor skills. As for the housing unit we decided that the AV Cart would give the client a lot more flexibility with the device, so it was chosen for the final design. An LCD monitor will be displayed above an arcade push button box in the form of an enclosed ramp. The push button board will contain a 3x3 array of buttons on the top, with a menu/start button on one side and an on/off button on the other. The Raspberry Pi and wiring will be contained inside the box. Both the box and the monitor will be mounted down using bolts to the cart to ensure that it is secure. It will be around 3.5ft tall and be powered from a wall outlet.

The student will either sit or stand based on the instruction of the teacher while playing. The power button will be pressed to launch the game. They will be given different themes of images for the user to decide on. They will provide the theme choice with a push button on the top and the game will begin. They will then have to match an image using the push button grid. They can return to the theme menu at any time using the menu button or turn it off at any time using the power button.

Design and Analysis

The button box which will contain the 3x3 button board array. Each of the buttons will represent a different image on the screen and when the correct button is pressed the next image appears on top. On the flat top there also will be a button which will control the power of the system and a button to control the menu. The device is power via a wall outlet and power strip

attached to the AV Cart. Connected to the cart's power strip is an IEC cable to power the monitor and an AC/DC External Wall Adapter connected to a Raspberry Pi via USB-C. At the core of the system there will be a Raspberry Pi which reads the inputs from the buttons and runs the program. Each button will be connected by the GPIOs on the Raspberry Pi.

The final design of the program runs by bouncing in and out of 3 core game loops. When the game begins the system is in the "Start Menu" loop this refreshes the press start image every second while waiting to receive an input from the menu button. If nothing is pressed the game will stay on this menu. Once the system receives an input from the menu button it goes into the "Theme Selection" loop. This loop begins by taking the Theme image array and putting it through our themeSelect function. The themeSelect function takes each value in an image array and displays them on screen at specific X and Y coordinates based on the size of the display and the size of the image. It is written to go through three different X coordinates and increment the Y and reset the X every 3 images. This lets us make sure all the images are lines up properly in a 3x3 array no matter the image. The loop then checks the value of the variable S to see if it matches one of 9 preset values and if it does not match any the system simply displays the image array. The variable S was initiated with the value 10 at the start of the program and whenever a button is pressed the value of S is changed to match the number of the button and the theme associated with that button is moved into the variable array. Array is then run through the shufflearray function, which takes all the inputs in an array and randomly shuffles their order and saved into the variable draw. Whenever the value of S goes below the value 10 the program moves into the main game loop.

The main game loop begins by displaying the image prompt on the top left corner of the screen. It achieves this by taking the variable prompt, which contains a randomly generated number made at the beginning of the program and displaying the image at value prompt of the image array. Once the prompt is loaded onto the screen the draw variable from the previous loop is run through the drawIcons function which goes through the same process of displaying the icons at specific X and Y variables as the themeSelect function from before. The only difference between these two functions is that the game array is shifted very slightly to the right to make more space for the prompt. Once the array is set up the loop checks to see if any of the buttons are pressed. If any of the buttons on the array are pressed the game sets the variable select equal

to the number of the button and runs the checkAnswer function. This function takes the value of select and prompt and checks to see if they are equal. If the values are equal the function returns a 1 and a checkmark is displayed on the center of the screen, the draw variable is reshuffled so that the image array is different and a new random number is generated for prompt. If the values are not equal a red X is displayed on screen and the array is left the same. Whenever the main loop detects an input from the menu button is breaks out of the main game loop and goes back up to the Theme Selection loop. If the user ever pressed the off button the entire system will be shut down and power will be cut to the Pi.

For the electronic wiring, ten pull up circuits were wired to ten arcade push buttons. Nine were for the 3x3 push button array. The tenth was used for the start/menu button. This pull up circuit functions so that when a button has not been pressed, the GPIO pin reads logic level high. When the button is pressed, the GPIO pin reads logic level low, the triggering condition in the code to register that a selection has been made. This circuit was constructed using the Raspberry Pi's 3.3V supply pin, a 1k ohm resistor, a 10k ohm resistor, a push button, and a GPIO pin per instance the circuit was repeated. Another small electrical circuit used was simply wiring one terminal of a push button to ground and one to a GPIO pin. This circuit is for the power button. When the power button is pressed, the software written to constantly check for a logic level low signal. For a full electrical schematic, see appendix D.

The final hardware of the product looks like an arcade cabinet on wheels. It is around 3.5 to 4 feet tall depending on where the user chooses to set the height. One piece of plywood with the dimensions of 0.25" x 2' x 4' (thickness x width x height) was used to construct the push button ramp. The top of the box was cut to have the dimensions of 17.5" x 18" (width x length), with 1" diameter holes drilled to fit the push buttons. Each push-button hole center is spaced 5" apart from the neighboring push-button holes in both the x and y direction. The two side panels of the box have the dimensions of 17" x 6.5" with a hypotenuse of 18". The rear panel that finishes the encasing of the box has the dimension of 17.5" x 6.5". A small notch was cut on the bottom edge of the rear panel to feed the HDMI cord and LCD screen power cord from inside the box to the connections on the monitor. Inside the ramp it is re-enforced with 0.5" x 1" moldings that match the length of the wood they re-enforce. By adding these moldings, the panels can be wood glued together. These moldings also allow for four screws to be drilled through the bottom

of the av cart and into the molding. One screw is placed in each corner of the box to mount it to the cart. The rear panel is the only portion not glued. Instead, four screws are used to fasten it to the box, one in each corner, which will allow for removal in case any maintenance must be done. The LCD screen is mounted to a wooden pedestal by 4 bolts. The wooden pedestal has dimensions of 8.5” x 4.5” x 2.5” (length x width x height). The length and width of the monitor stand that mounts to the pedestal has the same dimensions. The wooden pedestal is then mounted to the AV cart by four screws from underneath. The whole push button box was then sanded to round all edges and corners. It was spray painted black to match the cart. A 1” diameter hole was then drilled through the AV cart under the push button box to feed the power cables of the Raspberry Pi and LCD screen through the bottom. Excess cable was coiled and stored in the box.

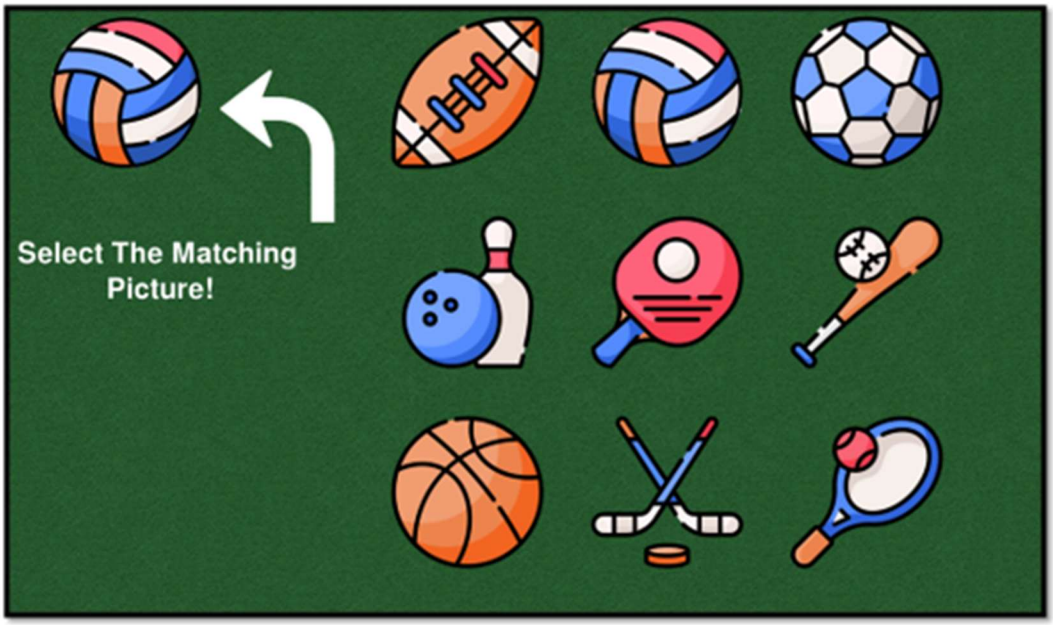

Figure 3-Screenshot from final version of the game. While we had originally planned for the answer prompt to be over the image array, we decided by setting it off to the side we can more clearly separate it as a prompt. This also allows for the images to all be large which increases visibility for the user. Whenever a correct answer is chosen the image on the left is randomly changed and the array is shuffled.

Figure 4-The final physical system design. The AV Cart design presented more benefits to our clients such as extra mobility and additional space to bring other activities to train the students. The cart is also height adjustable which meets one of the requirements from our sponsor. In order to make sure nothing falls everything will be mounted onto the cart.

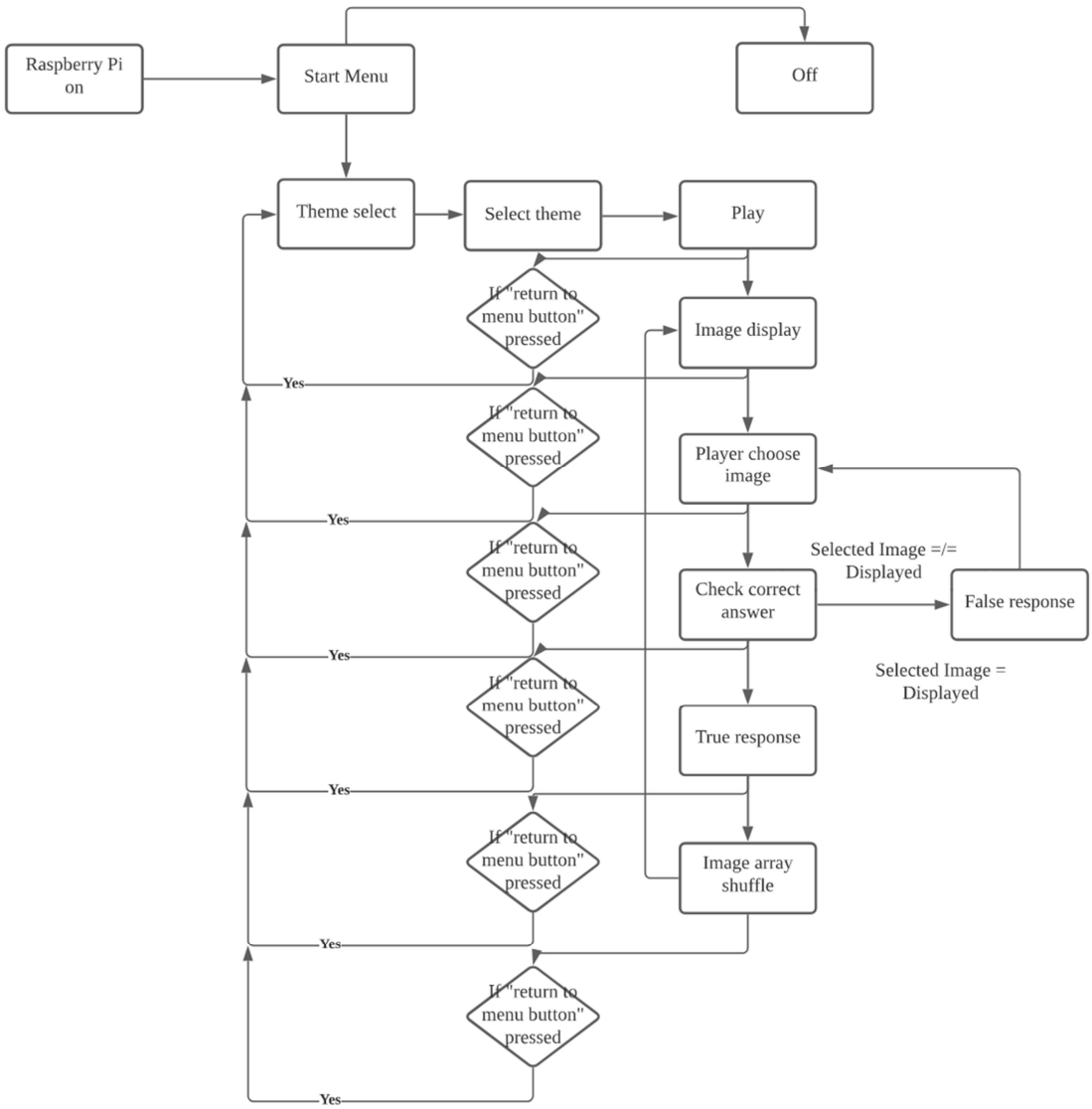

Figure 5- Our program runs is written in Python and runs off a Raspberry Pi. A large majority of the software is written using the Pygames module with some help from the RPI.GPIO to handle the input detection. The Pi boots up into the start menu of the game. Once the menu button is pressed theme selection begins. After picking a theme the game begins and the program waits for an input from the user. If the user inputs a correct response the game will reshuffle the array and wait for another input. At any time, the user can press the menu button to back out into the theme selection and if the off button is pressed the system will shut down.

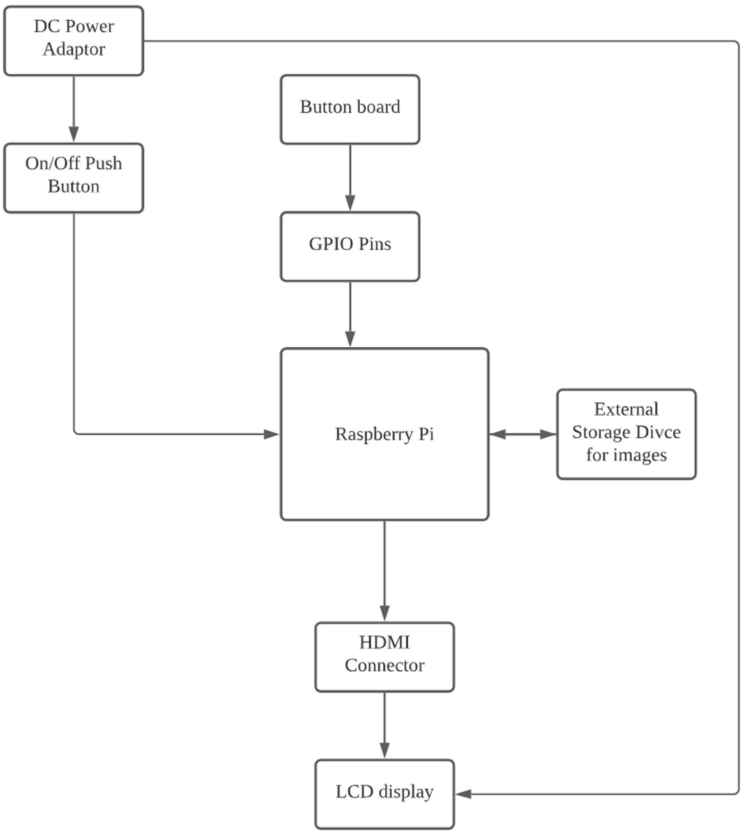

Figure 6- Hardware Diagram of the final system. The entire system is connected to an wall outlet via the built in power strip on the AV Cart. Connected to this power strip is an IEC cable that powers the monitor. A *5.1V 15W AC/DC External Wall Mount Adapter attaches to the Raspberry Pi via a USB-C connector. The monitor is connected to the Pi via the HDMI connector and the button board is connected to the GPIO pins. The OS and our program assets are all saved on an attached SD card on the bottom of the Pi.*

Disclosure of non-original design content

All of the images used in our game were acquired online from Flaticon which is owned by Freepik Company. Many of the images came from Freepik themselves but the sports, and fruit themes were created by Warangkhana Sookruay and Icongeek26. Since our system is for personal noncommercial use, we are allowed to freely use the images in our product. The code for the on and off switch was retrieved from Howchoo's text guide and GitHub repository which is included in our references section. The rest of the code for our system is entirely original. All the hardware designs used in our system were original designs.

Project Evaluation

Satisfaction of Problem and Objective

The problem for the NEEDS center was a lack of a device that helped their students with hand-eye development to improve their motor skills function. Our project solved this problem because the game we created allowed for the students to be able to play the game while standing and press buttons straight out in front of them, this forced them to use their hand-eye coordination to play the game, so it helped them work on their motor skill while having a fun time. The game also uses the student's memory by forcing them to look at an image and remember it so they can then choose the correct answer from the list of nine images that correlate to the buttons below, this helped the students with development of their short-term memory. All the needs of our client were meet, they were primarily focused on wanting a game that easily playable as to not over stimulate their students, and most importantly being safe so that it was not to cause harm to anyone. After multiple conversations with the client during the decision making and building of the system as well as after completion of the final product they were thrilled with the results and its completion; so overall it can be said that we solved our clients problem and meet the objective.

Satisfaction of Project Requirements

There were eleven different requirements for our project that we needed to satisfy, beginning with the device objective requirement which was that the device must display a target image and an array of images and the player must choose the correct image from the array that

matches the target. This requirement was meet because the completed game plays exactly as described, the buttons are correlated to the array above and when the correct button is matched to the image a green check is displayed and the array and target are shuffled.

The theme selection requirement is that the device must contain nine different themes of images for the user to choose from and the device must display an array of images representing a theme and the player must choose which theme they like. This requirement was meet because the theme selection menu works as intended, all nine themes are individually unique and grants more variety and choice for the player so the game stays feeling unique.

The device height requirement was that the devices height needed to be 36 inches to 44 inches tall. The device needs to be this height so it can be played at arm's distance so that the user must reach out to play, forcing them to use their motor skills. This requirement was meet because the cart is 41 inches tall and is adjustable, so its base height is 41 inches but by removing the top pegs it can lowered to 35 inches, and if the additional peg is added it becomes 47 inches tall.

The device maneuverability requirement is that the device should weigh no more than 15 pounds so that it can easily move around the room it is in. The device must also have wheels. This needs to be met so that the device stays portable enough to be moved from one area of the room to another to make sure that is not in the way for other activities. This requirement was met because the device is under 15 pounds and since the entire system is housed on an AV cart it has wheels and a handle, so it is easily rollable.

There was specific requirement that the team had to meet regarding safety and health requirement, one of these being using no leaded material. No lead can be used throughout the construction of the device because leaded material is banned by University of Massachusetts Lowell protocol. This is due to lead being proven to have negative effects on human health, such effects include damage to brain function, kidney function, and heart health. This requirement was accomplished by purchasing and using no equipment that contained led, including the solder used on the PCB board.

Using no latex was a requirement in which latex must not be used in any part of the creation of the device. This requirement is per the NEEDS Center because concern that students that will come in contact and use the device may have latex allergies, and the device should be

playable for all students. This requirement was accomplished by purchasing and using no equipment or material that contained latex.

Max power cable length was a requirement ensuring that the maximum length of the power cable should not exceed three feet. This was a concern expressed by the NEEDS Center because of concern that a wall outlet power source with a cable longer than three feet would create tripping hazard, and students using the device or within the vicinity of the device with weak motor skills would be at most risk of this threat. This requirement was not accomplished because using the power cord attached to the AV cart was the only option and it measures at 15 feet. This problem was addressed with the NEEDS center and has been approved and solved by simply wrapping the cord around the included cable management on the cart to reduce the cord to the desired length.

No Sharp Corners was a requirement that the device must have no sharp edges or corners, the edges must be rounded to limit safety hazards. This requirement was expressed by the NEEDS Center over concern that the students may intentionally attempt to injure themselves on the device or may trip or stumble when playing due to weak motor skills, and thus, preventative measures must be taken. This requirement was accomplished by ensuring that all of the edges and corners of the device were rounded out smooth and checked for jagged pieces, also the wooden board was sanded smooth and coated as to avoid splinters.

There were also requirements regarding the implementation and the game play of the device, such as the power button requirement that there must be a power button that will easily allow the system to shut down. This requirement was expressed by the NEEDS Center so that the device does not need to be unplugged when it is not in use. It will also be utilized to control when the device is used by the students with permission from the teacher, also a power button will greatly mitigate data corruption of the system. This requirement was met by adding a button to the right side of the device that when pressed will boot the system down and turn off the device.

The stability of device requirement is that the device must be sturdy and account for the pressure being applied to it from the user leaning on the device so that it will remain upright. The device wheels must have lock and the system should not be top heavy so that it exhibits a well-balanced weight distribution, also, the push button board must be mounted at an angle to

lessen force applied in the x-axis by the user. This requirement was presented by the NEEDS Center over concern that the device will be sturdy enough for the user to lean on the device without it falling over because it is highly likely that the students may lean on the device when playing; and if this were to occur the device must not fall over. This requirement was achieved by choosing a cart that is wide enough to be balanced and support the components being attached to it, the cart also has wheels with locks on them for added stability when stationary. Since construction it was confirmed that the cart was not top heavy and the unit was well balanced and will not be easily tipped, the button board is also mounted to the cart at approximately 45 degrees angle and is reinforced to handle additional weight from the user.

Requirements involving state guidelines were also implemented, such as integration of a regulated outlet power supply which the state of Massachusetts requires that all devices using a wall outlet as a power source must meet all Massachusetts AC-DC regulations accordingly. This requirement was accomplished by using a power supply that is certified by Underwriters Laboratories that meet these regulations, this power supply is what is used for the device's AV cart.

Budget / Finances

The fabrication of the system included use of only a few materials; a 22in LCD monitor, a Raspberry Pi 4 model B, push buttons constructed out of plastic, a button board made out of birch plywood, and lastly a utility AV cart with power strip constructed out of some sort of polymer. The electrical components from this set of materials are the 22in LCD monitor, the Raspberry Pi 4, and the push buttons. The mechanical components from the set of materials is the plywood button board, and the plastic utility AV cart. The electrical components were used to form the games hardware subsystem, and the mechanical components were used to for the housing unit to hold the hardware.

For the entire construction of our system, it only required the five main components. All of these components the team ordered through the school's budget. All the other miscellaneous pieces such as the wires, screws, and extra wood were already on hand and available to use without additional purchases, so there was nothing else purchased for the system besides the five main components. This resulted in a grand total of the entire system costing $330.72, this was

below our estimated budget of around $100 per teammate, so roughly $400 for the team; $69.28 below budget.

Hierarchal Designator	Parts Designator	Part Description	Manufacturer	Model Number	Source	Price	Quantity
1	Monitor	22in LCD	HP	2QU11AA#ABA	Newegg	$89.99	1
2	Raspberry Pi 4	Model B Desktop Kit (2GB)	Raspberry Pi	C1214-C1207_2GB	Chicago Electronic Distributors	$100.00	1
3	Buttons	Arcade Push-Button	Uxcell	A19062000ux0456	Amazon	$31.18	2
4	Button Board	Birch Plywood (1/4 in. x 2 ft X 4-1/12 ft)	Home Depot	154146	Home Depot	$14.41	1
5	Cart	Plastic Utility AV Cart with Power Strip	Norwood Commercial Furniture	NOR-OUG1042-SO	Amazon	$95.14	1

Project Reflection

Challenges and Critical Issues

Since our team has no one with a lot of programming experience many of the challenges we faced were from writing the program. The first set of challenges we faced were from designing the initial image array. When we initially designed the array, it was just a set of 9 static images and one static image prompt. Once we started working on the randomization function, we ran into a few issues. The first issue was that the system was not waiting for any input before shuffling the array. The array was randomizing every second which gave it an almost slot machine like appearance. As we looked through the code to figure out the problem, we came to

the realization that this was being caused by the randomization function being inside of the main game loop. The way we had the randomization function set up it would take the original image array and then shuffle the inputs into a random order and output this as the new array. While the function itself was correct by being inside of the game loop it was updating the image array every second and redisplaying the new shuffled array. By moving the initialization of the function outside of the main loop the array was able to remain static and only changed when it needed to. The same issue was present with the answer prompt since the number that was being randomly generated to select and answer was changing every second. Once it was moved outside of the main loop it too functioned properly.

Another issue faced when designing the program was getting the AutoStart function on the Pi to work with the game. When doing research on how to make the Pi boot into an application we found many solutions but many of them did not seem to be working. At best the system would boot up and the window would open and immediately close. The thing that many of these methods had in common was that they execute the program from the terminal, so we did some testing to see what was causing the error. We discovered that the way our images were loaded into the program was working when we ran the program through the IDE but not in the terminal. The specific line of code for loading in the images simply look for the images name since the IDE defaults to searching for files in the same place as the program. When programs run in the terminal however the default location that it searches for files is in a completely different directory. This problem was fixed by making our program call the images by their absolute path so the terminal would know exactly where to look for the images when loading them in. Once the code was rewritten with this in mind the AutoStart function started to function as expected.

Some challenges that the team faced while constructing the button board box included making sure all of the wooden panels where cut evenly, with each angle being 90 degrees. To achieve this, a square tool and a table saw were used. Making sure the holes for the buttons came out smooth and uniform was also a challenge. A 1” hole saw was used to drill through the board and a square tool was used to make uniform markings in a 3x3 array so that the grid was neatly finished. Building the monitor stand proved to be a challenge since we wanted the monitor to sit

at an angle while facing the user. To achieve this, a power sander needed to be used to shave the bottom of the pedestal at a proper angle.

Hazards to Team / Safety

When designing and testing the operation of our device, there will be no hazards to the team. When the final edition of the device is being constructed, soldering the device will be a hazard that is present. Proper eye protection must be used. No lead solder will be used in the design. The person soldering must be attentive to the hot iron and fresh solder joints. Do not place the iron on the table, rather you should place it on the rack as intended. A clamp to suspend the device being soldered in the air will make sure that the person soldering is not burned when adding a joint. Along with soldering when constructing the button board ramp for the device multiple dangerous tools must be used in the process. Proper protective gear must be worn, and extra precaution must be used when cutting the wooden used for constructing the button board. Safety goggles must be worn during all drilling, sawing, and sanding.

Customer Perspective / Hazards to End User

This device benefits the customer by providing them a safe, maneuverable, and easy to operate learning activity. The game can be played both while standing and sitting, while maintaining an arm's length of distance between the buttons and the user. This creates the hand-eye coordination and motor-skill improvement that the NEEDS center is looking for. For use, the user simply has to plug in the AV cart to a wall outlet and hit the white power button on the push button box. For more details on proper setup, operation, and support please see the user's manual located in appendix B.

Once the device is delivered to the client, there will be minor hazards that are present to the user. The AV cart has a long power cord that is coiled around the cart handle. Only the needed amount of cord should be used to avoid tripping hazards. Another hazard is that since the cart has wheels, it can move when leaned on. During operation of the device, the wheel locks should be locked, and the cart should be up against a wall. The corners of the board are rounded and sanded, but still blunt. Any tripping hazards in the environment around the device should be removed so that nobody trips into the device.

Standards Utilized

Both the LCD monitor and Raspberry Pi used on the device both have been certified to be within the standards required for hold a CE mark. The US Standard System of Measurement was used for all measurements of this device. HDMI is the chosen medium of communication between the Raspberry Pi and the Monitor. Finally, the American Wire Gauge code was used for all wiring completed in the system.

Environmental Impact and Considerations

There is almost no direct impact on the environment that has come from the construction of the device or from using the device. The system operates using electricity provided through an AC/DC wall outlet. While for the most part this is environmentally friendly, there is still negative impacts to the environment to get that electricity to the wall outlet for use, resulting in an indirect impact from the team's project. There was no direct impact on the environment from the creation of the device as it was all just simply plugged in, screwed, and glued together. However, to get the individual part to the team, such as the five main components for construction for the majority of the system, there was a negative impact to the environment caused by the need to have those items shipped to the team resulting in an indirect impact. There would also be a negative impact to the environment if the device were to be disposed of. This is due to what the system is constructed of. The monitor, Raspberry Pi, wires, and buttons would become landfill as they are most likely not recyclable. The AV cart may be recyclable due to it being made out of a plastic polymer, and the wood used for construction of the button board is easily recyclable or could be repurposed.

Societal Impact

The society at large is not greatly impacted by the team's project. This is due to the device being mostly isolated to only the exposure of the NEEDS center and its students. The biggest impact that the device can make on society is certainly involving future work and research because there is potentially opportunity for research to be done with continued use of the game. It is very possible that the students will see an increase to their memory and especially a large improvement to their hand-eye coordination/motor skills. Eventually then the game and

its system can be greatly improved on to further the benefit and development in a larger range of disabled individuals. This not only benefits our client but opens the opportunity for this to be mass produced for not only an economical benefit, but to improve the lives of the disabled across the world.

Ethical Consideration

During the design process, members of the design operated well within the rules stated in IEEE's Code of Conduct. Members were respectful, and all non-original designs have been credited to its original creator.

Safety of the student and staff of the NEEDS Center was paramount during the design process of the device. All corners of the device were smoothed, and all internal wiring were organized to prevent them from being a hazard to the facility's students. When choosing components for the system the team made sure to consider what would provide the simplest experience and most accessibility for the user. Finally, the project requirements provided by the project sponsor has been met.

Teamwork

The different parts of the project were divided amongst the team equally. Every team member was responsible for their own hands-on part of the project as well as all working together on the parts of the project as well. The writing, editing, and correcting of the assignment were equally divided amongst the team members. One team member was responsible for a majority of writing the code, another was responsible for the implementation of the boot and start screen, another was responsible for the design and assembly of the PCB board for controlling the button board, and the last was responsible for the construction of the final housing unit. The biggest issue with teamwork that the group encountered was the decision making for the final design of the project. Every team member had a strong opinion about how the system should look and function. This debate was primarily around the style/appearance of the game and the design of the housing unit. The team overcame this difficulty by incorporating the best ideas from each of the team members such that everyone agreed, and the project developed into its best possible form by having all the best ideas incorporated.

The team's relationship with the mentor can be easily described as excellent. We kept a consistent relationship with our mentor. During our weekly Thursday meetings, he expressed how well the team was doing with completing the projects deadlines, completing team goals, and constructing a system that looks and works like a professional system. He was proud of the team's accomplishments and also expressed that this team was one of the best, if not the best, teams that he has had the pleasure of mentoring.

Technical Communication Skills

The team communicated with one another through multiple different platforms. For general daily communication Facebook Messenger was the tool of choice. For meeting face-to-face (virtually) to share and compare work, they used Microsoft Teams which allowed them to screenshare to work together more efficiently as they could all be viewing the same thing at the same time. This also allowed the use of camera to show the progress on the system. The team communicated with the mentor every week on Thursday at 5pm using Zoom to simulate a face-to-face meeting as best as possible. This also allowed the team to use the screensharing to show the code and the camera to show the progress of the system. Zoom was also used to contact our sponsor, the NEEDS center, for the same reason as for the mentor. This was mostly to ask them for their opinions/approval of the direction of the project as well as show them the current status.

Multidisciplinary Issues

As the design team was not multidisciplinary, there was no major multidisciplinary issues. There was, however, some questions raised by the team on the topic of development support and its elements that needs to be considered within the design. Those questions are quickly answered by Ms. Karyn Brown from The NEEDS Center through video conference.

Future Direction of Project

The project points to a potentially fruitful line of research. With continued use of the game it is very possible that the students will see an increase to their memory and a large improvement to their hand-eye coordination/motor skills. If after a period of time this is proven to be true, there is a massive opportunity for games like this to be studied to discover additional benefits to the development of disabled students. The game and its system can then be improved

on to greater further benefits and development. If the team had additional time to work on the project the biggest change that would be made is to include the addition of more game modes and more themes. This wouldn't improve the game, but it would improve the versality to the user. It would give them more options to possibly make the game more enjoyable over the long term in an attempt to keep the game from becoming boring. If this system were to be made into a commercialized product the biggest change would be to the computer. The Raspberry Pi would be switched out with a cheaper computer and its board would be designed entirely custom for this system. Then, everything else would just need to be integrated better so that the monitor and button board would be part of the cart. This would realistically be very simple to implement into a production unit.

The work could be expanded to help our company in the future by continuing to provide other games that will encourage and engage students to continue with their development as well and stimulate them. Since the team used a Raspberry Pi for the system, others could write more software for other games and install it on to the Raspberry Pi as to take advantage of the already constructed game hardware. Also, something as simple as new images could be added to increase the number of images within each theme as well as add entirely new themes to the game for the students at the NEEDS center.

Project Completion Plan

Our project completion plan was centered around three main subsystems. These were the software, the hardware, and the housing unit of the device. The software was broken up into small, easy to manage tasks with a fair amount of time budgeted to complete them. These tasks were distributed amongst the group evenly based on programming capability. Hardware tasks were also broken up into time manageable chunks. These tasks were mostly distributed between two group members, as seen in Appendix B under the RACI Chart. Finally, the housing unit of the device was solely distributed between three group members. This can also be seen in the RACI chart.

The specific work breakdown and all of the dependencies of each step can be seen in the Gantt Chart located in Appendix B. The RACI chart shows who was accountable, responsible,

consulted, and informed of each task. The Gantt chart includes all timelines that were followed for the completion of the project.

In terms of fulfilling our schedule, everything went smoothly. Each task was completed in a timely fashion and no task went unfinished. The system is complete and on time.

Summary

In summary, this is a team of four students completing a capstone project who will be working with the North East Educational and Developmental Support Center to develop what was described as a "Card matching device". The main purpose of this device is to provide developmental training through consistent practice which applies motor skills and hand-eye coordination. Repetition of using their motor skills will assist them to live as close to fully independent as possible. The NEEDS Center is a non-profit organization founded in 2012 and works with developmental disabilities individuals. These individuals are provided with education, training, and support for them to improve their independence and hopefully eventually be fully self-dependent, or at least more so. The NEEDS Center has asked the team to address the problem that they do not have enough stimulation for the individuals in their program. They do not have enough games or tools that allow them to use their full range of motion and to be actively engaged as well as mentally stimulated. This is the problem that has led to their need for a device to solve this issue. The request was then delivered for the development of this card matching game. Its main function is as an exercise for posture and to improve hand-eye coordination.

From discussion with the client, the final design for the device was determined. The initial goal of the device was to be a small display with a 4ft stand and button setup of 9 total buttons. This was altered to become a larger display mounted onto an AV cart with a 9-button board ramp. The device is portable and height adjustable. The game was made on a Raspberry Pi with Python with primarily the Pygames module. We were able to include a total of 9 different image themes which the user can chose for the game. The game uses 9 images in that theme and creates a 3x3 array and prompts the user to match a prompt image from the ones in the array. Whenever the user is correct the system randomizes the position of the images on the array and prompts the user to identify a different image. This creates a better motor and mental skill trainer

for the user since both the prompt and answer location can be moved to any spot. All in all, this makes the system portable, safe, easy to use, and a good training exercise for the students at the NEEDS Center accomplishing all the goals set by our sponsor and ourselves.

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Appendix A – RACI and Gantt Charts

		Frank Rene	Davey Agrinsoni	Joshua Joseph	Sean Leonard	Kwun Yin Low	Dr. John Palma
1	**Software**	I	R/A	R	R	R	I
1.1	Installing Pygames	I	R/ A	C	C	C	I
1.2	Generate an Image to the screen	I	R/ A	C	C	C	I
1.3	Generate an array of images	I	R/ A	C	C	C	I
1.4	Map the correct image to the goal image	I	R/ A	C	C	C	I
1.5	Map buttons to images	I	C	R/A	R	C	I
1.6	Test outcomes of buttons	I	C	R/A	R	C	I
1.6.1	Outcome for correct response	I	C	R/A	R	C	I
1.6.1.1	Code to Display Correct Screen	I	C	C	R	R/A	I
1.6.2	Outcome of incorrect response	I	C	R	R/A	R	I
1.6.2.1	Code to do nothing (maybe negative feedback sound)	I	C	R	R/A	R	I
1.7	Create Random Photo Array Selection	I	R/A	C	C	C	I
1.7.1	Create Multiple Arrays of Images	I	R/A	C	C	R	I
1.7.2	Create Random number generator	I	C	C	C	R/A	I
1.7.3	Verify that user input is still mapped properly to correct answer	I	C	C	C	R/A	I
1.8	Create power on routine to automatically launch game when powered on	I	C	C	C	R/A	I
1.9	Create power off routine to ensure game is not corrupted after shut off	I	C	C	C	R/A	I
1.10.	Optimization of system (extra leeway for above tasks)	I	R	R/A	R	R	I
1.10.1	Better randomization of images (randomly from bank of images rather than preset)	I	R/A	R	R	R	I
1.10.2	Timed mode selection	I	R	R	R	R/A	I
1.10.3	Audio feedback	I	R	R/A	R	R	I
1.10.4	Smoothing out presentation of display	I	R	R	R/A	R	I
1.11	Debug issues as they come	I	R/A	R	R	R	I
2	**Hardware**	I	C	R/A	R	C	I
2.1	Create Push Button Board	I	C	R/A	R	C	I
2.1.1	Wire Push Button Circuit (buttons, resistor, power, GPIO Pins, test LED)	I	C	R/A	R	C	I
2.1.2	Attach covers to the border to hide circuitry and make buttons easier to push	I	C	R/A	R	C	I
2.2	Monitor Setup and Raspberry Pi Setup	I	R/A	R	R	C	I
2.2.1	Connect Power Suppy to Raspberry Pi and Monitor	I	R/A	R	R	C	I
2.2.2	Connect HDMI between monitor and Raspberry Pi	I	R/A	R	R	C	I
2.3	Place Hardware in Housing Unit	I	C	R/A	R	C	I
3	**Housing Unit**	I	R	R	R/A	R	I
3.1	Cart Setup	I	C	R	R/A	R	I
3.1.1	Order Cart and Ship it	I	C	R	R/A	R	I
3.1.2	Cart Assembly	I	C	R	R/A	R	I
3.2	Saw four wooden panels for push button board and pedestal for monitor stand	I	C	R	R/A	R	I
3.3	Drill Push Button Holes into side and top panels	I	C	R/A	R	R	I
3.4	Sand Wood	I	C	R	R/A	R	I
3.5	Paint Wood	I	C	R	R/A	R	I
3.6	Wood Glue all panels (except rear) and inner molding to form the box	I	C	R	R/A	R	I
3.7	Screw together back panel of the box	I	C	R/A	R	R	I
3.8	Mount push button box and monitor pedestal to cart	I	C	R	R/A	R	I

Figure 6- This is the RACI chart for this project. Tasks were evenly distributed amongst team members. Each member was labeled as responsible, accountable, or consulted. Our mentor and professor were to be informed of any tasks progress when deemed necessary.

Outlin Numb	Task Name	Duration	Start	Finish
1	**Software**	**46 days**	**Wed 9/16/2**	**Wed 11/18/20**
1.1	Installing Pygames	1 day	Thu 9/17/20	Thu 9/17/20
1.2	Generate an Image to the screen	1 day	Fri 9/18/20	Fri 9/18/20
1.3	Generate an array of images	1 day	Mon 9/21/2	Mon 9/21/20
1.4	Map the correct image to the goal image	2 days	Tue 9/22/20	Wed 9/23/20
1.5	Map Images to inputs	1 day	Tue 9/22/20	Tue 9/22/20
1.6	Map buttons to images	1 day	Wed 9/23/2	Wed 9/23/20
1.7	**Test outcomes of buttons**	**2 days**	**Thu 9/24/20**	**Fri 9/25/20**
1.7.1	**Outcome for correct response**	**1 day**	**Thu 9/24/20**	**Thu 9/24/20**
1.7.1.1	Code to Display Correct Screen	1 day	Thu 9/24/20	Thu 9/24/20
1.7.2	**Outcome of incorrect response**	**1 day**	**Fri 9/25/20**	**Fri 9/25/20**
1.7.2.1	Make sure system does nothing if an incorrect response	1 day	Fri 9/25/20	Fri 9/25/20
1.8	**Create Random Photo Array Selection**	**7 days**	**Wed 9/23/2**	**Thu 10/1/20**
1.8.1	Create Multiple Arrays of Images	2 days	Wed 9/23/2	Thu 9/24/20
1.8.2	Create Random number generator	2 days	Wed 9/30/2	Thu 10/1/20
1.8.3	Verify that user input is still mapped properly to correct answer	2 days	Wed 9/23/20	Thu 9/24/20
1.9	**Create Start Menu**	**2 days**	**Wed 9/16/2**	**Thu 9/17/20**
1.9.1	Design Starting Screen for the game	1 day	Wed 9/16/2	Wed 9/16/20
1.9.2	Map user input to begin the game	1 day	Thu 9/17/20	Thu 9/17/20
1.10	**Create Theme Selection**	**8 days**	**Tue 10/27/2**	**Thu 11/5/20**
1.10.1	Contact Sponser for theme request	1 day	Tue 10/27/2	Tue 10/27/20
1.10.2	Gather Images for each theme	1 day	Wed 10/28/:	Wed 10/28/20
1.10.3	Create an Array to represent each theme	2 days	Thu 10/29/2	Fri 10/30/20
1.10.4	Create new loop to allow user to choose the theme for the game	2 days	Sat 10/31/20	Mon 11/2/20
1.10.5	Allow for the user to change theme after having selected one	2 days	Tue 11/3/20	Wed 11/4/20
1.11	Create power on routine to automatically launch game when powered on	3 days	Wed 11/4/20	Fri 11/6/20
1.12	Create power off routine to ensure game is not corrupted after shut off	2 days	Tue 11/17/20	Wed 11/18/20
1.13	Better randomization of images (randomly from bank of images rather than preset)	4 days	Tue 10/6/20	Fri 10/9/20
1.14	Smoothing out presentation of display	4 days	Tue 10/20/2	Fri 10/23/20
2	**Hardware**	**37 days**	**Thu 9/10/20**	**Fri 10/30/20**
2.1	**Create Push Button Board**	**37 days**	**Thu 9/10/20**	**Fri 10/30/20**
2.1.1	Ordering button board components and shipping	7 days	Thu 9/10/20	Fri 9/18/20
2.1.2	Wire Push Button Circuit (buttons, resistor, power, GPIO Pins, test LED)	3 days	Fri 9/18/20	Tue 9/22/20
2.1.3	Make cardboard prototype of the button for use of game testing	6 days	Fri 10/2/20	Fri 10/9/20
2.1.4	Attach covers to the border to hide circuitry and make buttons easier to	16 days	Fri 10/9/20	Fri 10/30/20
2.2	**Monitor Setup and Raspberry Pi Setup**	**5 days**	**Thu 9/10/20**	**Wed 9/16/20**
2.2.1	Purchase Monitor and Raspberry P	4 days	Thu 9/10/20	Tue 9/15/20
2.2.2	Connect Power Suppy to Raspberry Pi and Monitor	0.5 days	Wed 9/16/20	Wed 9/16/20
2.2.3	Connect HDMI between monitor and Ras	0.5 days	Wed 9/16/2	Wed 9/16/20
3	**Housing Unit and Cart**	**18 days**	**Wed 11/11/:**	**Fri 12/4/20**
3.1	**Cart Setup**	**14 days**	**Wed 11/11/:**	**Mon 11/30/20**
3.1.1	Ordering cart and Shipping	13 days	Wed 11/11/:	Fri 11/27/20
3.1.2	Cart assembly	1 day	Mon 11/30/:	Mon 11/30/20
3.2	Saw four wooden panels for push button board and pedestal for monitor stand	2 days	Fri 11/27/20	Sun 11/29/20
3.3	Drill push button holes into side and top pa	1 day	Mon 11/30/:	Mon 11/30/20
3.4	Sand Wood	1 day	Tue 12/1/20	Tue 12/1/20
3.5	Paint Wood	1 day	Wed 12/2/2	Wed 12/2/20
3.6	Wood glue all panels (except rear) and inner molding to the box	1 day	Thu 12/3/20	Thu 12/3/20
3.7	Screw together back panel of box	0.5 days	Fri 12/4/20	Fri 12/4/20
3.8	Mount Push Button Box and monitor pedestal to cart	0.5 days	Fri 12/4/20	Fri 12/4/20

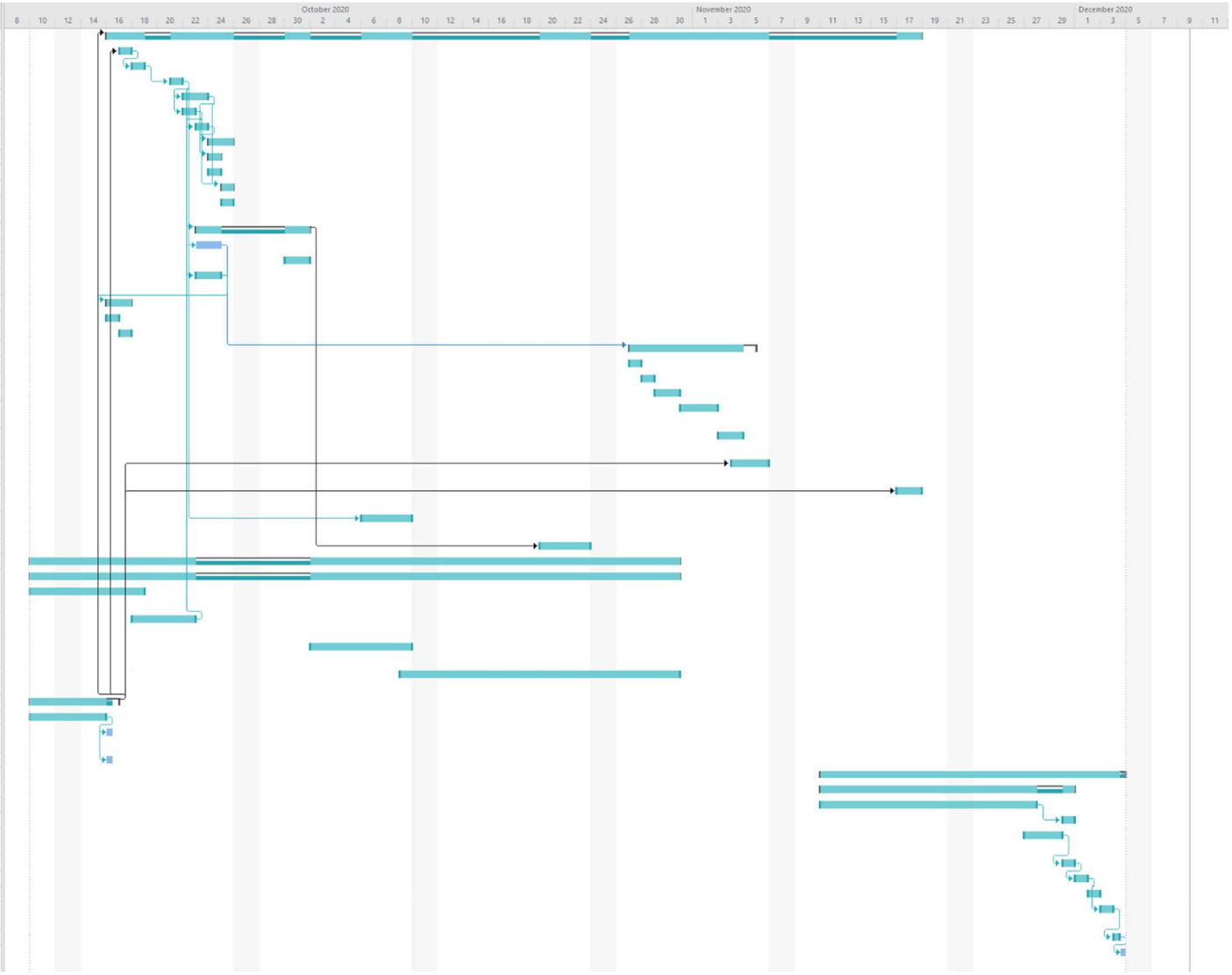

Figure 7- This is the Gantt chart for this project. Tasks were corrected to include time of ordering and shipping and time spent on work was edited to match real time.

Appendix B – User's Manual

Matching Game Device

User Manual

Version 1.0

Group 20-005

12/10/2020

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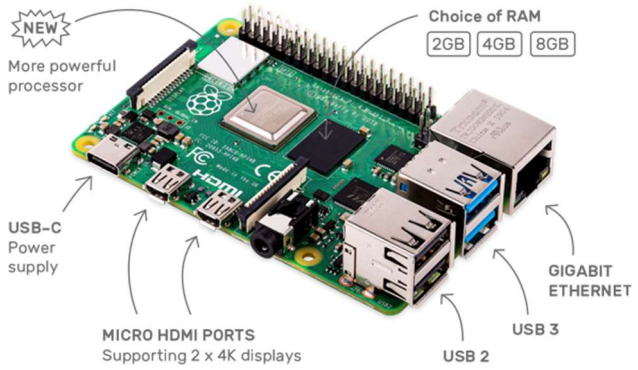
Introduction

This User Manual provides the information necessary for users with all levels of software and electrical understanding to effectively use the Matching Game Device. Topics covered throughout include things to consider before starting the system, how to use the device to play the game, how to shut down the device safely and properly, and ways to fix any possible issues that may occur during long term use. All the important hardware of the device and their uses to the system will be outlined. Although the Raspberry Pi has the ability to be used outside of the game, these functionalities will not be covered in this user manual as it does not pertain to our system in particular.

Overview

Four Electrical Engineers from the University of Massachusetts Lowell were tasked with designing and building a matching game device for the North East Educational and Developmental Support Center (NEEDS Center). This matching game device has been developed to encourage motor skill development and hand-eye coordination for the students. This has been completed by engineering a device which utilizes an LCD Screen, an analog push button board, a Raspberry Pi and an AV cart. The device runs a python program off a Raspberry Pi which prompts the user to match an image prompt with an array of images on screen using a 3x3 button board on the device.

Included Hardware to Note



Raspberry Pi 4 Model B

The Raspberry Pi is located inside the push button box. The image above shows the USB connections used for the mouse and keyboard, the USB-C power supply port, and the Micro HDMI ports used to display the game to a monitor.

Micro HDMI to HDMI Cable

The image above shows the Micro HDMI to HDMI cable. This cable is used to connect the Raspberry Pi to its display. The Micro HDMI input goes to the Raspberry Pi and the HDMI input goes to the display.

5.1V 15W AC/DC External Wall Mount Adapter

This AC/DC External Wall Mount Adapter is used to power the Raspberry Pi. The USB-C input is plugged into the Raspberry Pi while the outlet prongs are plugged into any basic outlet.

Raspberry Pi Keyboard and Mouse

The keyboard and mouse can be used to control the Raspberry Pi outside of the game for general purpose or maintenance. The USB cables connect to the ports on the Raspberry Pi. The keyboard cable has a Micro USB input that is plugged into the back of the keyboard. The keyboard cable and mouse are stored in a cubby below the top shelf of the device.

Norwood Plastic Utility AV Cart with Power Strip

This AV Cart has a long power cable looped around the handle of the cart. This power cable is plugged into any three-prong wall outlet. This powers the AV cart power strip. This power strip is used to power the monitor and the Raspberry Pi.

HP 22YH 22" Full HD 1920 x 1080 LCD Monitor

This LCD monitor displays the game. It is powered using an IEC power cable, which plugs directly into the monitor.

IEC Power Cable

This power cable is used to power the LCD monitor. The three-prong input is plugged into the AV cart power strip. The other end is plugged into the monitor.

Getting Started

Set-up Considerations

In order to make sure the device is used in the safest way possible, the user should make sure all the listed tasks are accomplished before using the device. All cable connections are already made prior to first time operation other than plugging the AV Cart power cable into the wall.

1. Make sure only the necessary length of power cable is uncoiled from the cart to avoid tripping hazards.
2. The wheels on the cart should be locked in place and the cart should be placed against a wall to avoid any operational hazards.
3. Before connecting the cart into a wall outlet all connections on the system must be secured.
    a. The Raspberry Pi Power Adapter must be connected to the cart's power strip and the USB-C Port on the Pi.
    b. The IEC monitor power cable should be securely connected to both the power strip on the cart and the monitor.
    c. The HDMI cable must be connected to the HDMI mini port on the Raspberry PI and HDMI port of the monitor.

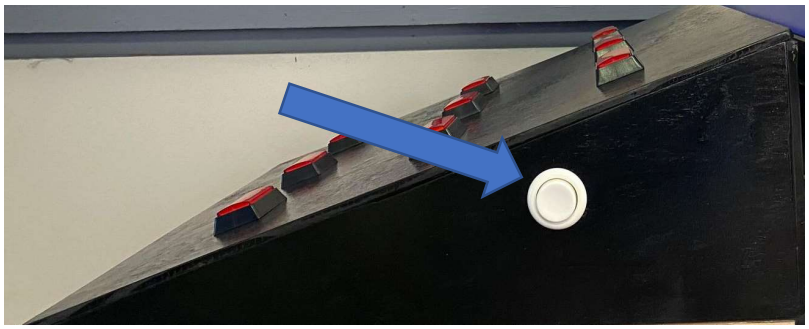
Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the Matching Game Device

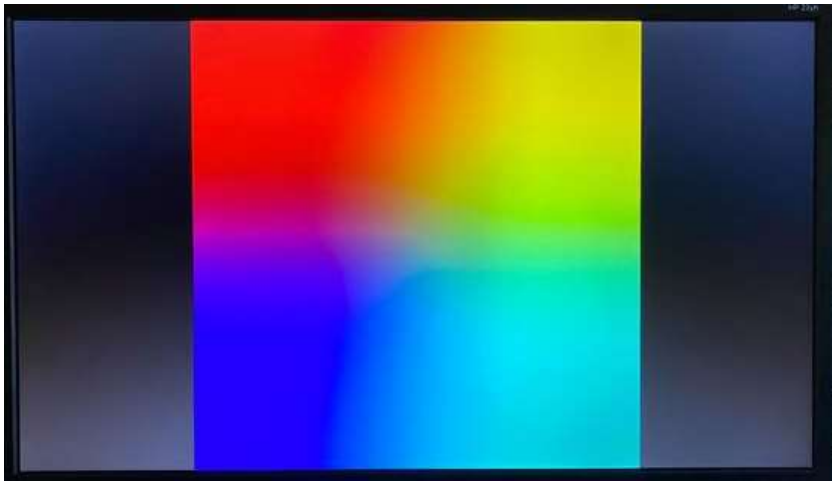
Starting

The user may plug in the cart to a wall outlet once all other cable connections have been found to be secure.

1. In order to begin using the system, the white power button on the right-hand side must be pressed.



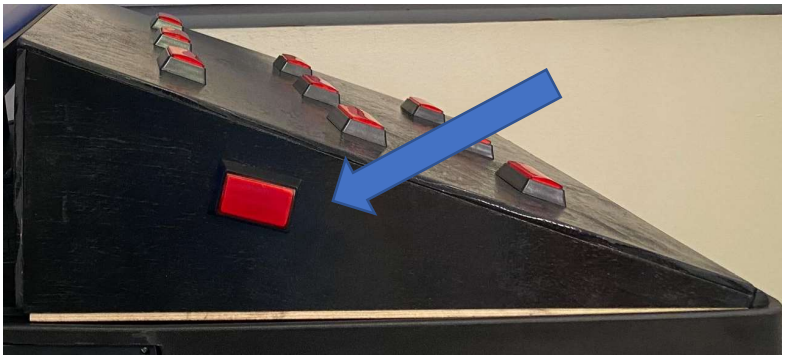
2. Once the system is powered on the user will be greeted by the following screen:



There will be multiple black screens that appear while the system is powering on. Please refrain from pressing anything until the system is complete with its power on sequence.

3. Once the following screen appears the user may start interacting with the system using either the button board or a keyboard and mouse.

4. In order to begin the game, the user must press the red rectangular menu button located on the left side of the button board. This will bring the user to the theme selection portion of the game.



5. If the user wishes to instead access other features of the Raspberry Pi, the game can be closed by using the mouse to click the X icon located on the top right corner of the game AFTER pressing the menu button once.

Theme Selection

1. After having pressed the Menu button the user will be presented with the Theme Selection screen.

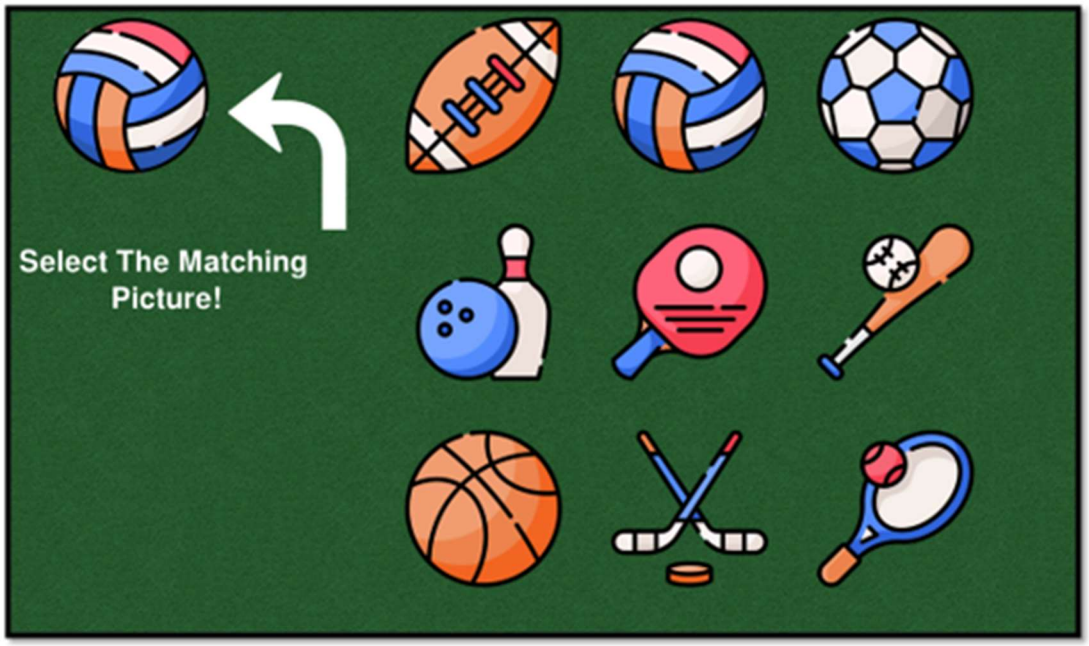
Each image corresponds with different image packs that follow a different theme. The themes included in the game are as follows: Fruit, Animals, Dinosaurs, Sports, Clothing, Everyday Items, Road Signs, Vehicles and Weather.

2. In order to select a theme, the user must press the button located on the same position as the onscreen images. For example, if the user wishes to select the fruit theme, they must press the button located on the top left of the board as seen in the image below.

3. Once a theme is selected the game will begin

Playing the game

1. After selecting a theme, the game will open to this screen:



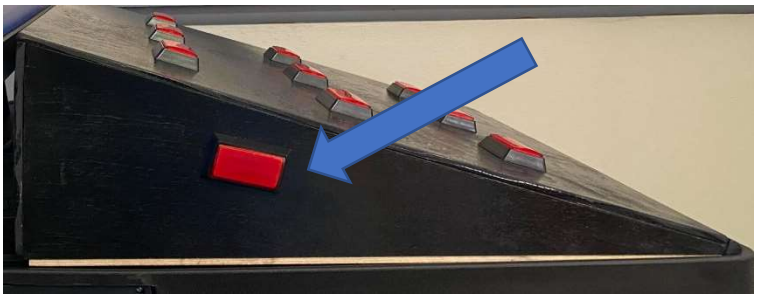
On the left side of this screen there is an image prompt, and on the right, there is an image array. The user must attempt to press the button which matches the location of the image in the image array. In the above example the user would have to press the top middle button of the button board.

2. Upon selecting a correct response, the user should see a green check mark appear on screen indicating a successful match as follows:

a. If it is a successful match the image array will be shuffled around with the same images and a new prompt will be chosen. The system will continually provide random arrays and new prompts for as long as the user inputs correct responses.
b. If the chosen image is not a match with the prompt the system will display a large red X over the screen.

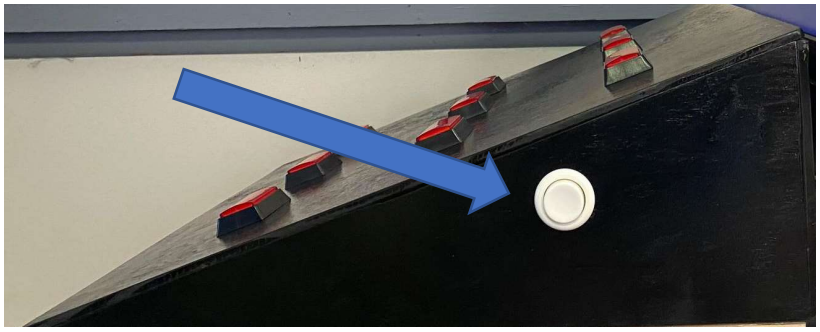
c. The array and prompt will remain the same until the user inputs a correct response.

3. If the user wishes to return to the theme selection menu this can be achieved at any moment by simply pressing the menu button located on the right of the button ramp.



Shutting Off the System

1. If the user ever wishes to shut off the system, they must press the white circular power button located on the right side of the button ramp.

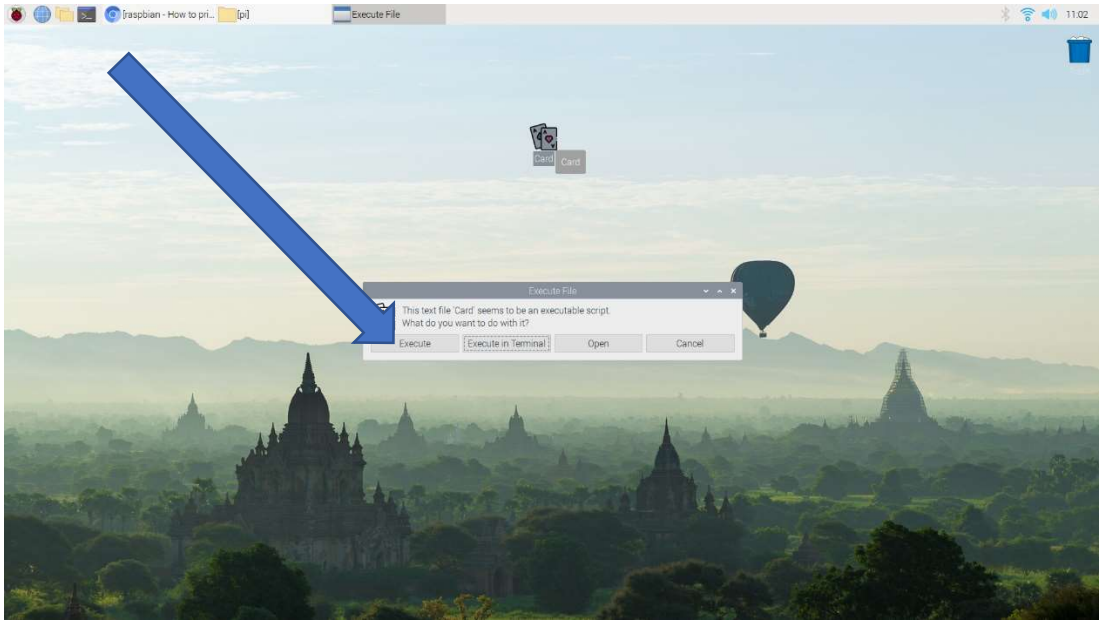


Troubleshooting & Support

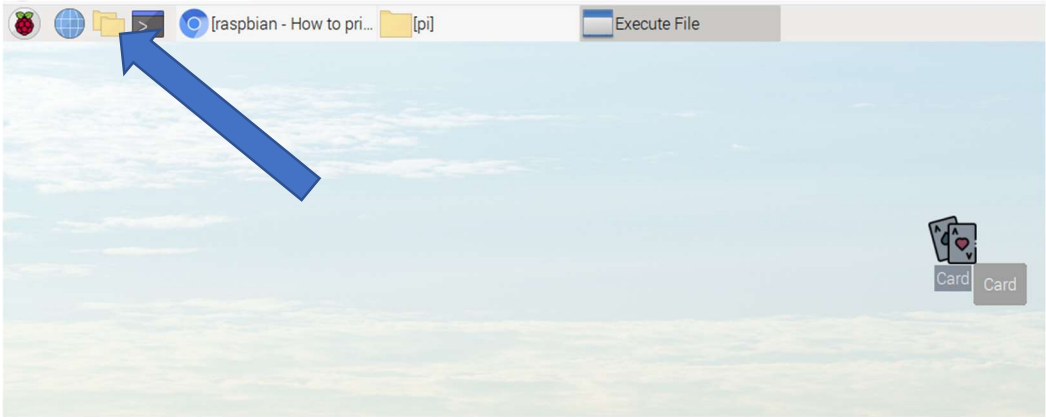
Troubleshooting when Game Closes Without Intention

If the game ever closes without an input from the user, follow these steps to restore the game.

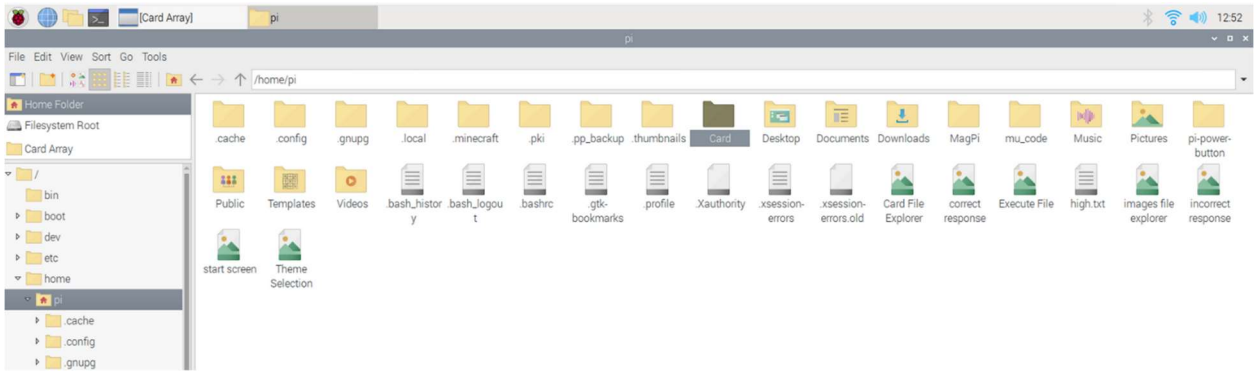
1. Make sure the mouse is plugged into the system and remove it from its compartment.
2. On the desktop of the Raspberry Pi there is an icon with the name Card and when clicked the follow message will appear:



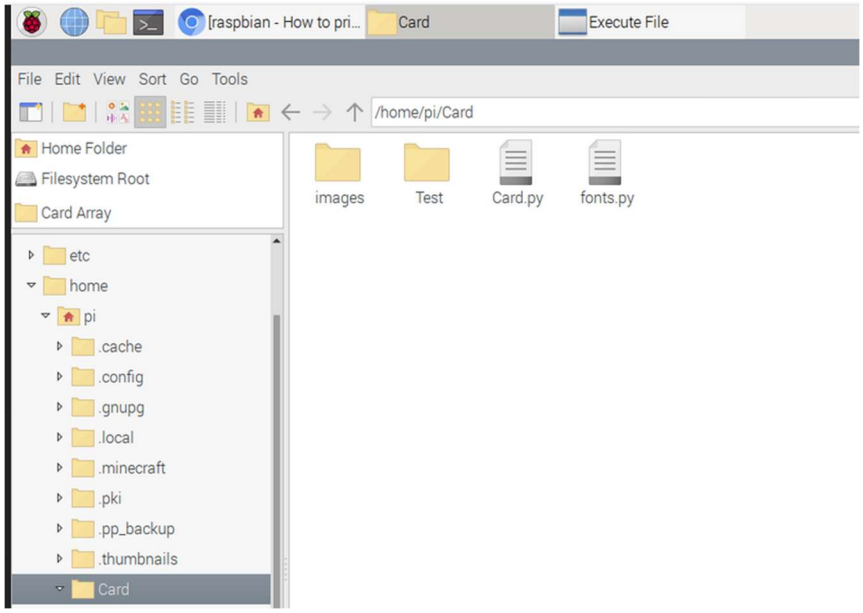
3. Click “Execute” and the game should relaunch.
4. If this is unsuccessful, use the mouse to click and open the file explorer located near the top left corner of the screen symbolized by an icon of two folders.



5. Once opened, locate the Card folder in the Home section and open the folder.

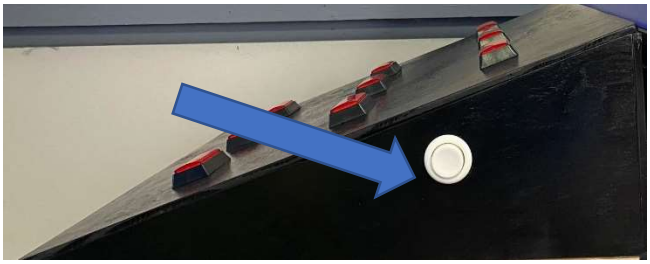


6. Inside of the folder there will be a file by the name of Card.Py. Clicking this file will bring up another window asking if the file should be Executed or Executed in Terminal.



7. Click Execute and the game should now be running.

8. If this fails, you must restart the system by pressing the power button located on the right side of the button ramp to turn off the system. Once the system is off press it again to restart the device.

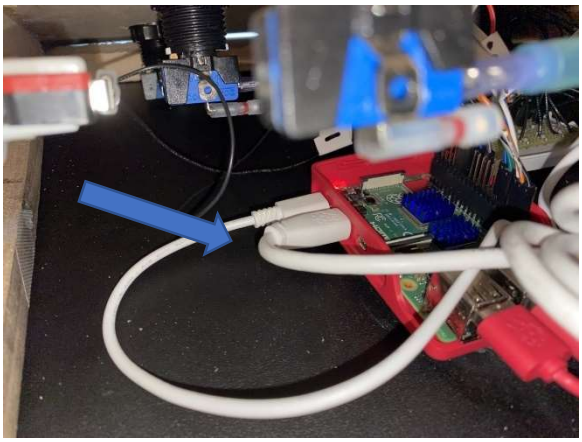


Troubleshooting When Push Button Input is not Recognized

1. Restart the system by pressing the white power button located on the right-hand side. This will reset the program on the Raspberry Pi and the issue may be resolved.
2. If step 1 does not work, check to see if the push button makes a clicking noise when it is pressed down.
    a. If the push button does not click, the internal push button connection may have fallen out. Contact support.
    b. If the push button does click, there may be something wrong with the electrical wiring connections (Pin Connections, Push Button Connections, and Power/Ground Connections). Contact support.

Troubleshooting When There is No Display on Monitor

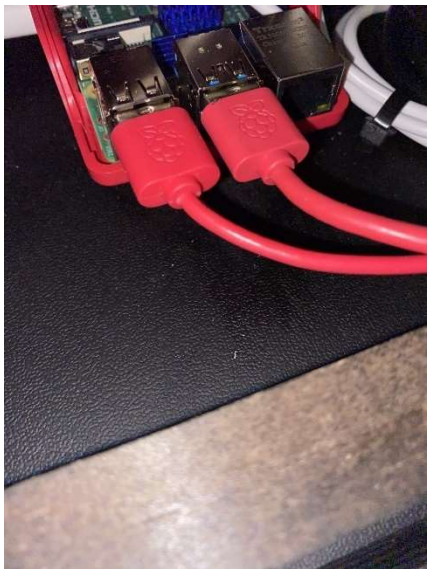
1. Make sure the AV cart is securely plugged into the wall outlet.
2. Check to make sure the HDMI Cable and LCD Screen power cable are securely plugged into the monitor.
3. Check to make sure the Raspberry Pi power cable and monitor power cable are securely plugged into the AV Cart power strip located under the top shelf of the cart. (Only proceed with steps 4 and beyond if necessary).
4. Follow the procedure for "5.5 Accessing the Push Button Internals".
5. Check to see if the mini-HDMI cable and USB-C power cables are securely connected to the Raspberry Pi as shown in the picture below:



6. If the device does not display after these connections are checked and securely plugged in, contact support.

Troubleshooting Keyboard and Mouse Not Functioning

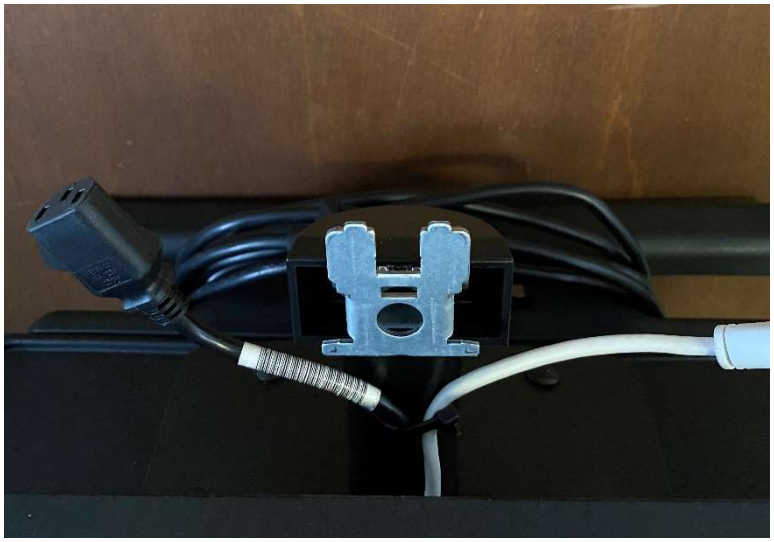
1. Check to make sure the Micro-USB for the keyboard cord is connected to the keyboard.
2. Follow the procedure for "5.5 Accessing the Push Button Internals".
3. Check to see that the keyboard and mouse USB connections are securely plugged into the Raspberry Pi as shown below:



Accessing the Push Button Internals

1. Remove the LCD monitor screen by pressing the small black button located just under the screen and on the neck of the stand. This is pictured below:

2. Once the button has been pressed, remove the connected cables from the monitor. Hold the neck of the stand with one hand and pull the monitor up and off with the other. DO NOT USE EXCESSIVE FORCE. The device stand will appear as shown:



3. Once the monitor is removed, the back panel of the push button box can be accessed. Using a T20 torque screwdriver, remove the four torque screws gently from the back panel. Remove the panel. The back panel appears as pictured below:

Support

Table 1 - Support Points of Contact

Contact	Organization	Phone	Email	Role
John Palma	*University of Massachusetts Lowell*	*n/a*	*john_palma@uml.edu*	*Professor*
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Joshua Joseph	*University of Massachusetts Lowell*	*774-258-2339*	*Joshua_Joseph@student.uml.edu*	*Design Engineer*
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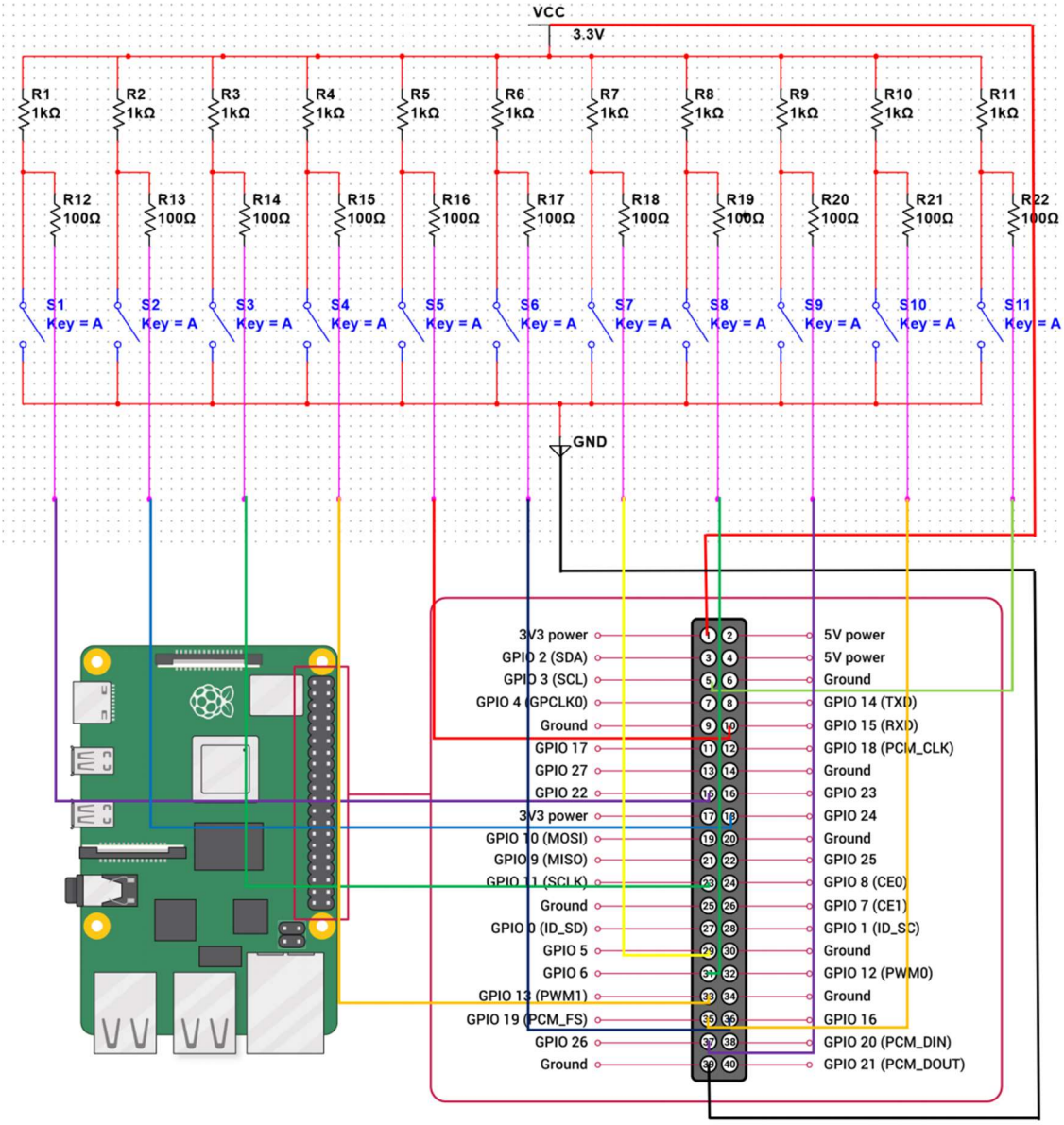
Appendix C- Electrical Schematic



This is the entire electrical schematic for the PCB board and the buttons. All of the 1k resistors are powered by pin 1 (+3.3V) shown as VCC. The switches are the buttons, the positive lead going into the button is connected to its positive terminal (labeled on the button as “POS +”). The negative lead of the button (labeled on the button as “COMM”) is connected to pin 39 (ground) shown as GND. Lastly the board and its buttons are connected to the GPIO pins through the 100Ω resistor leading directly to the GPIO pin associated with that button.