SmartBoard

DESIGN DOCUMENT (vesrsion 2)

SMART BOARD

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Table of Contents

1 Statement of Needs

This project is about combining a traditional whiteboard with a new type of smart whiteboard that pushes the physical boundaries of a traditional whiteboard. The need of this design is for it to give many digital whiteboard features, which can keep track of what is on the board, erase content and add notes. In short the white board will behave as if it has a memory of the notes. Hence even if a user erases a specific note, this note can be retrieved within a given duration of time. This sort of smart whiteboard is very useful in a teaching environment such as a university and other learning establishments. Many professors have a need for whiteboards in their offices which are able to store notes. However, a usual whiteboard can only have so many notes until the white board runs out of space and the existing notes will have to be erased to write new notes. Unlike normal whiteboards, the Smart Board is capable of keeping track of what is on the board and what was written on the board so that a specific note can be retrieved when necessary. Furthermore, erasing content and adding notes can be difficult in such a learning environment, hence the Smart Board is also capable of retrieving erased notes similar to the undo button in google docs or Microsoft word. This smart project is about combining a traditional whiteboard along with the normal whiteboard features with a new type of smart whiteboard that pushes the physical boundaries of a traditional whiteboard and gives the user multiple options of handling notes and keeping track of notes.

2 Statement of Objectives

1.Digitally record what is currently on the white board in a private and non-invasive manner. This option allows the user to be able to keep recordings of his own notes and can easily retrieve these notes when the necessity arrives.

2.Erase parts of the white board as directed through a hardware and software interface. This option of the Smart Board allows the user to erase parts of the notes he has written similar to the manner in which one would erase something on a normal whiteboard. This is done by the use of a plotting software similar to that used in touchpads.

3.Write new notes or drawings on the white board through a remote, internet enabled interface. This option allows the user to access the Smart Board user to write on the board without physically touching the board or from a distance. This in turn allows the user to write long notes more conveniently than when writing on a normal white board.

4. Something like an app, or a website that could be loaded on a tablet, or maybe even a "send a picture and have it sketch" feature. This option allows the user to send an image or sketch to the Smart Board from a remote source, and afterwards allows the user to edit this image or sketch according to as he sees fit.

2.1 Decision Matrix

Options	cost	prototyping	Collaboration	score
Weights	6	5	4	
Plotting system using gears for control.	5*6=30	3*5=15	4*4=16	61
Plotting system using Arduino	4*6=24	4*5=20	6*4=24	68

Plotting system using motor drive shield	4*6=24	6*5=30	4*4=16	70

Table 1 Decision Matrix

The below table shows the sum up of points.

Options	cost	prototyping	Collaboration	score
Weights	6	5	4	
Plotting system using gears for control.	30	15	16	61
Plotting system using Arduino	24	20	24	68
Plotting system using raspberry PI	24	30	16	70

Table 2 Sum Up of Points

2.2 House of Quality

Customer Requirement	Weight	Engineering Requirement	WiFi Operation	Accuracy	High Speed Motor	High Resolution Camera	Database Capacity	Durable	Two Dimensional	Cursor Movement Reading
Write on whiteboard	9		3	3	1			1	3	3
Erase on whiteboard	9		3	3	1			1	3	3
Remotely Use Robot	9		3			1				
Online Portal	3		3			1				
Images on whiteboard	3		3				9			
Scanning board	3			1		9				3
Cost within budget	3		1	1	1	1		3	1	1
Durable and Robust Design	1				1	1		3		1
Reliable Design	1				1	1		3		1
Absolute Technical Importance (ATI)			102	60	23	44	27	33	57	68
Relative Technical Importance (RTI)			35%	21%	8%	15%	9%	11%	20%	24%
Target ER values			24 hours	1 cm	100 rp	108MP	100G	2200 M	-	1 cm
Tolerances of Ers			5 min	0.01 cm	10 rpm	10 MP	10GB	200 M	-	0.01 cm

Figure 1 House of Quality

Above is the table for house of quality. When designing the house of quality, the engineering requirements and customer requirements were taken into consideration. As can be seen from the above table customer requirements are to the left side of the table and the engineering requirements are to the right-top edge of the table. Each corresponding box shows the relation between customer requirements and engineering requirements according to the marks that have been assigned at each box. Furthermore, this table has been designed in such a way that it has generated a priority list of engineering requirements where the most important requirement is the correct Wi-Fi operation. This is because the Wi-Fi connection need to properly function throughout the day so the user can access the Smart Board at any time. The next most useful requirement is the cursor reading as it can easily locate the exact point where the cursor is present. Next most important requirement is the movement of the cursor in the X-Y plane or the 2-D movement of cursor. This movement is to be used for writing and cleaning purposes in both the horizontal direction and vertical direction. The least important factor is motor speed as the motor speed will only affect the writing speed of the user. Also the motor speed will affect the erasing speed of written content on the Smart Board which is also the least of the concerns.

2.3 General System Description

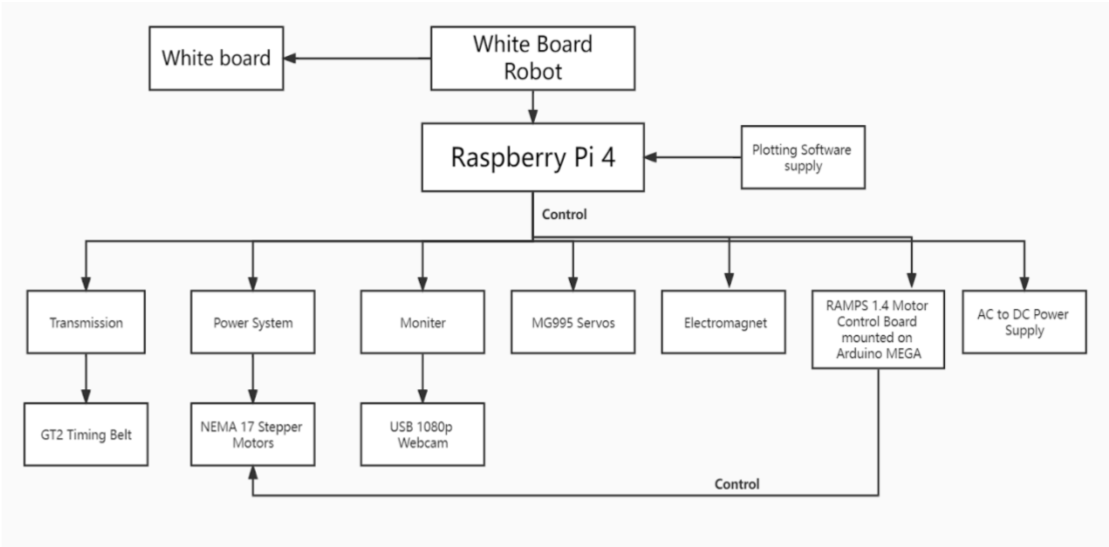

Figure 2 General System Description

The general system has many subsystems that each perform their respective tasks in order to function as an overall system. The general system consists of a white board that is basically connected to the whiteboard robot. The whiteboard robot is able to carry out tasks mentioned previously in this document. These tasks include digitally recording what is currently on the white board so that this content can be retrieved on a later time, erase parts of the white board as directed through a hardware and software interface, Write new notes or drawings on the white board through a remote, internet enabled interface, and also has the option allows the user to send an image or sketch to the Smart Board from a remote source, and afterwards allows the user to edit this image or sketch according to as he sees fit. The Smart Board consists of Raspberry pi as the control unit, while also being connected to a plotting software that gives the X-Y or 2-d coordinates for the Smart Board to write. We initially thought of using an Arduino for the control unit, however due to better power management and faster clock speed of the raspberry pi we decided to use raspberry pi as our control unit. The raspberry pi is further in control of various other subsystems. These include the transmission system, the power system , the monitor, MG995 servos, electromagnet, and AC to DC power supply. The raspberry PI further controls the RAMPS 1.4 motor control board mounted on Arduino mega. Next the above mentioned subsystems are connected to other smaller subsystems. The RAMPS 1.4 motor control board mounted on Arduino mega is connected to the NEMA 17 stepper motors that are used to control the plotter coordinates. The power system is also connected to the NEMA 17 motors. The monitor is connected to the USB 1080P Webcam. The transmission subsystem is connected to the GT2 timing belt. The general system layout can be seen below. A pen will be connected to the servo motors in order to plot on the Smart Board.

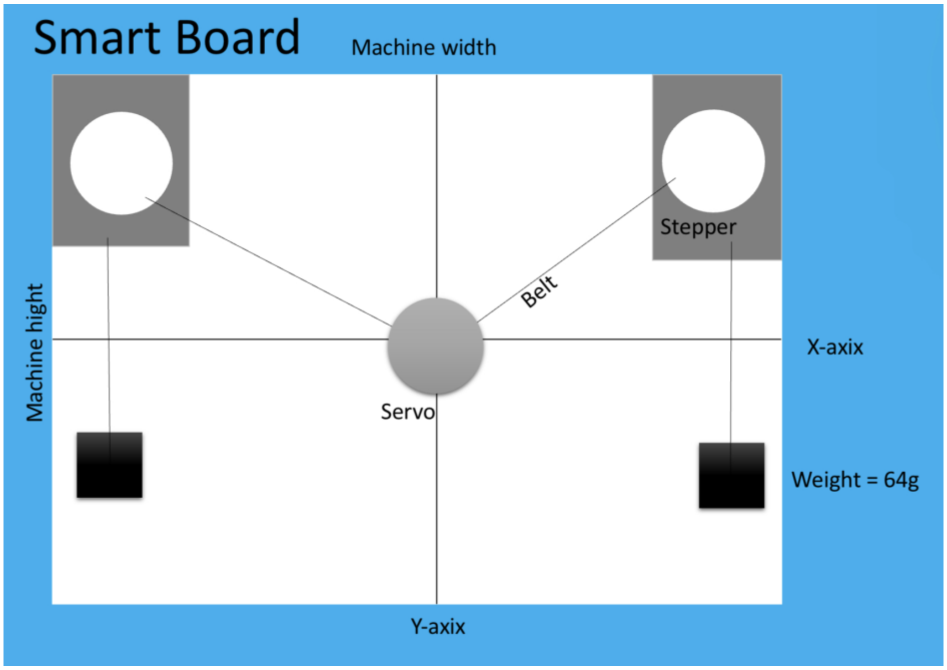

Figure 3 Dimensional Design Drawings We create this figure by inspiring some ideas from [5]

As can be seen above the large rectangle represents the white board, and the top two edges is where the NEMA 17 stepper motors would fit.

Where the NEMA 17 stepper motors would fit.

2.4 System Capabilities, Conditions, and Constraints

The Smart Board is a system that is capable of combining traditional whiteboard technology with modern robotics and microcontroller technology. It is capable of using a gondola equipped with a marker that is controlled by a combination of an Arduino and Raspberry Pi. The movement of the gondola is accomplished through the use of stepper and servo motors, which are programmed to move the marker in a polar plotter fashion to create drawings and writing on the whiteboard surface. The system is capable of digitally recording what is currently on the white board in a private and non-invasive manner. This capability is offered to the Smart Board through the participation of the plotter software system that is connected to the raspberry pi.

The system is also capable of erasing parts or small portions of the white board as directed through the hardware and software interface by the user. This option is made usable by the help of the plotter software system connected to the raspberry pi. The system is also capable of writing new notes or drawings on the white board through a remote, internet enabled interface. This option is to be allowed in the future. At the current stage of design this feature is not available. However, we plant to add this feature and improve the overall system in the future.

The system is capable of movement control using the operation of NEMA 17 stepper motors. This component is responsible for controlling the movement of the gondola and marker. It receives input from the user and uses algorithms and software to control the stepper and servo motors to achieve the desired movement. Using controls, the stepper motors rotate clockwise or counterclockwise which will in turn allow the movement of the gondola. This rotational behavior of the stepper motors also allows the user to control the position of the gondola in the X-Y plane or the 2-D plane. Below is the image of the NEMA 17 stepper motor used.

Figure 4 Stepper Motor

The system is capable of efficient power management by using the power Supply. This power subsystem is capable of providing power to the various components of the robot, including the microcontrollers, motors, and any other electronics that allow the robot to function efficiently. The power system has a constraint which is lack of power. At times there are times at which the stepper motors face trouble when rotating due to power being distributed to other subsystems that also function simultaneously. Below is an image of the power supply that was used:

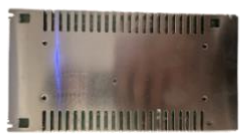

Figure 5 Power Supply

The system is capable of using sensors to detect and measure. The sensor component includes any sensor or device which is used to detect and measure environmental variables that may influence the behavior of the robot. For example, this may include sensors to detect the position of the marker or the whiteboard surface. The sensor subsystem needs to be improved as the sensor system has constraints such as lack of sensitivity of sensors when detecting the position of the plotter. Below is an image of the sensor used:

Figure 6 Camera

3 Implementation

3.1 General Overview

The Smart Board is a ground-breaking solution that combines conventional whiteboard technology with the most recent developments in robotics and microcontroller technology. It comprises of a gondola with a marker that is managed by an Arduino. Stepper and servo motors are used to move the gondola, and they are programmed to move the marker like such a polar plotter to produce writing and drawings on the whiteboard surface.

This project overcomes the physical constraints of a conventional whiteboard while adding several digital features, making it a significant advancement in whiteboard technology. The Smart Board provides users new opportunities for creativity and collaboration in both personal and professional situations thanks to its capacity to write and draw on the whiteboard surface. The Smart Board offers a special and adaptable way to record and share ideas, whether you're a student, teacher, artist, or business expert.

A new development in whiteboard technology is the Smart Board. It stands out from the competition thanks to its unique design, which combines the greatest features of conventional whiteboards with cutting-edge microcontroller technology. It is an essential tool for anyone wishing to increase their creativity and productivity.

3.2 Behavior Analysis

A scientific method for examining both human and animal behavior is behavior analysis. In this area, conduct is understood to be a collection of discernible activities that come about because of a person's interactions with their surroundings. Behavior analysis is to pinpoint the external factors that affect behavior and then use that knowledge to help people behave better.

When applied to the Smart Board, behavior analysis can be used to understand the behavior of the robot and identify any potential issues or areas for improvement. To accomplish this, behavior analysts may employ strategies including direct observation, experiments, and data analysis to comprehend the interaction between the robot's behavior and its surroundings. This may entail examining the robot's movements, the precision of its writing and drawings, and any other pertinent elements that might affect its behavior.

The first strategy of the Smart Board is perception. The Smart Board is equipped with sensors that allow it to perceive the input from users. The sensors detect other input devices, such as pens and styluses, enabling the board to detect the type of input. The perception strategy helps the Smart Board to interpret user input accurately.

The second strategy of the Smart Board is planning. After perceiving the input from users, the Smart Board plans the appropriate action. The planning involves determining the appropriate response to the input, such as drawing, erasing, or modifying. The board also plans the appropriate size and color of the input, ensuring it matches the user's intentions. The planning strategy helps the Smart Board to organize the drawing process and ensure accurate input.

The third strategy of the Smart Board is execution. After planning the appropriate action, the Smart Board executes the plan. The execution involves controlling the display to show the input and providing feedback to the user. The board also checks its progress against the plan, adjusting where necessary. The execution strategy enables the Smart Board to perform the input accurately and efficiently.

The fourth strategy of the Smart Board is feedback. The Smart Board is designed to provide feedback on the input process. The feedback includes information about the progress of the input, the errors detected, and the completion of the input. The board provides visual and auditory feedback, which helps the user to monitor the progress of the input process. The feedback strategy enhances the user experience and ensures the user is aware of the progress of the input.

Once the behavior of the robot has been analyzed, behavior analysts can then develop and implement interventions to improve its performance. These interventions could entail adjusting the robot's hardware or software, altering the environment in which it functions, or giving the robot more instruction and feedback. Improving the functionality, dependability, and general efficacy of the Smart Board is the goal of behavior analysis in this context.

In conclusion, behavior analysis is a useful tool for comprehending and enhancing the Smart Board's behavior. The functionality and performance of the robot can be improved by implementing successful interventions after behavior analysts have examined the robot's behavior and how it interacts with its surroundings.

3.2.1 State Diagram

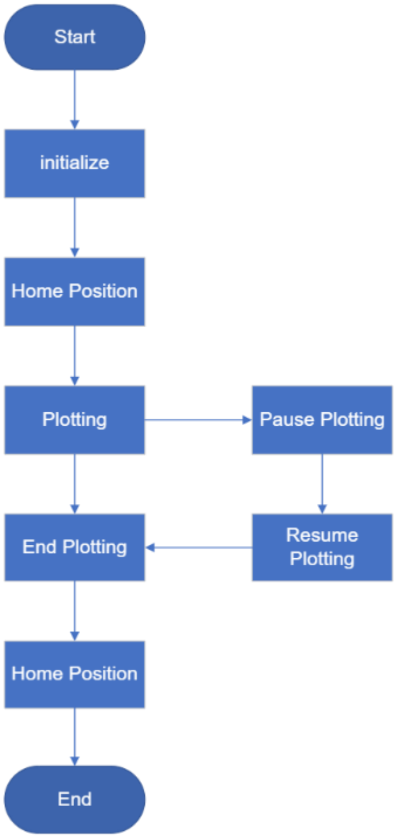

Figure 7 State Diagram

Explanation：

1. Start: This state represents the start of the plotting process.

2. Initialize: In this state, the system initializes all the required components, including the stepper and servo motors.

3. Home Position: In this state, the gondola is moved to the home position where the marker is ready to start the plotting.

4. Plotting: In this state, the marker is moved according to the programmed instructions to produce writing and drawings on the whiteboard surface.

5. Pause Plotting: In this state, the plotting process can be paused if needed.

6. Resume Plotting: In this state, the plotting process can be resumed after being paused.

7. End Plotting: In this state, the plotting process is completed.

8. Home Position: After the end of the plotting process, the gondola is moved to the home position.

9. End: The process ends.

3.2.2 Flowcharts

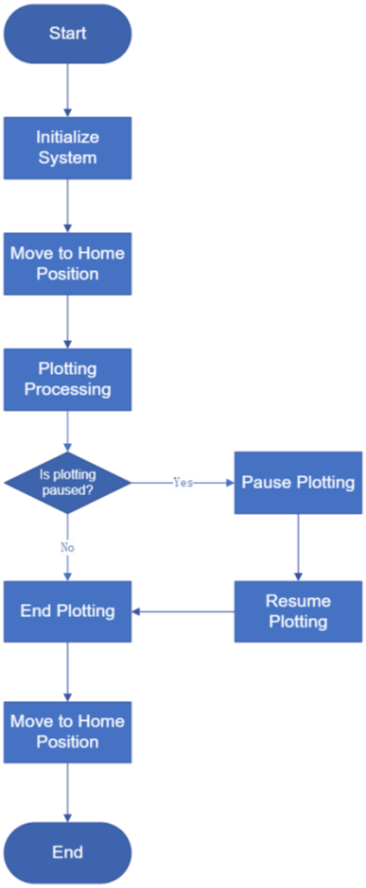

Figure 8 Flowcharts

3.2.3 Entity Relationship Diagram

Entity Set (left)	Relationship	Entity Set (right)
Gondola	Carries	Marker

Arduino	Controls	Stepper Motor
Arduino	Controls	Servo Motor
Power	Supplies	Arduino
Marker	Draws on	Whiteboard
Stepper Motor	Drives	Gondola
Servo Motor	Drives	Gondola

Table 3 Entity Relationship Diagram

3.3 Functional Analysis

The Smart Board is a novel solution that combines traditional whiteboard technology with modern robotics and microcontroller technology. It consists of a gondola equipped with a marker that is controlled by an Arduino. The movement of the gondola is accomplished through the use of stepper and servo motors, which are programmed to move the marker in a polar plotter fashion to create drawings and writing on the whiteboard surface.

The first function of the Smart Board is input. The robot is designed to receive input from users, such as commands, gestures, and other input devices. The Smart Board's input function includes sensors that detect the user's input, allowing the robot to determine the location, type, and size of the input. The input function enables the robot to interact with users in real-time, making it an effective tool for collaboration and teaching.

The second function of the Smart Board is processing. The robot is designed to process the user's input and execute the appropriate action, such as drawing, erasing, or modifying. The processing function involves the robot's software and hardware, which work together to process the input accurately and efficiently.

One of the key features of the Smart Board's processing function is smart algorithms. The robot's software includes algorithms that enable the robot to process the user's input accurately and efficiently. The smart algorithms feature enhances the user experience and makes the robot an efficient tool for presentations and teaching.

The third function of the Smart Board is output. The robot is designed to draw on the whiteboard, displaying the user's input in real-time. The output function includes the robot's drawing belt and pen, which enable the robot to draw on the whiteboard accurately and efficiently.

One of the key features of the Smart Board's output function is fine motor control. The robot's drawing belt is designed to provide precise and accurate movements, enabling the robot to draw on the whiteboard accurately and efficiently. The fine motor control feature enhances the user experience and makes the robot an efficient tool for presentations and teaching.

3.3.1 Functional Decomposition

The Smart Board can be decomposed into several key functional components, each of which is responsible for a specific aspect of its operation. These components include:

1. Movement Control: This component is responsible for controlling the movement of the gondola and marker. It receives input from the user and uses algorithms and software to control the stepper and servo motors to achieve the desired movement.

2. User Interface: This component provides a means for the user to interact with the robot. This may include a graphical user interface, touch screen, or physical buttons. The user interface component is responsible for receiving input from the user, processing it, and transmitting the necessary instructions to the movement control component.

3. Power Supply: This component provides power to the various components of the robot, including the microcontrollers, motors, and any other electronics.

4. Sensors: This component includes any sensors or devices used to detect and measure environmental variables that may influence the behavior of the robot. For example, this may include sensors to detect the position of the marker or the whiteboard surface.

5. Microcontrollers: The Arduino control the operation of the robot. The microcontrollers are responsible for executing algorithms, processing sensor data, and transmitting instructions to the movement control component.

3.3.2 Functional Coupling

The functional components of the Smart Board are coupled, or connected, in a specific way to achieve its overall behavior. The coupling between the components can be described as follows:

1. Movement Control: This component is coupled to the microcontrollers, which provide the necessary algorithms and software to control the motors. The movement control component is also coupled to the sensors, which provide data on the environment that may influence the behavior of the robot.

2. User Interface: This component is coupled to the microcontrollers, which receive input from the user and process it to generate the necessary instructions for the movement control component.

3. Power Supply: This component is coupled to all other components of the robot, providing power to the microcontrollers, motors, and sensors.

4. Sensors: This component is coupled to the microcontrollers, which process the data from the sensors to generate the necessary instructions for the movement control component.

5. Microcontrollers: This component is coupled to all other components of the robot, including the user interface, movement control, sensors, and power supply. The microcontrollers are responsible for coordinating the behavior of the robot and ensuring that all components work together to achieve its desired behavior.

In conclusion, the Smart Board can be analyzed from a functional perspective by decomposing it into its constituent components and understanding the coupling between these components. This functional analysis provides a comprehensive understanding of the behavior of the robot and can be used to identify potential areas for improvement or to develop new functionality. The functional decomposition and coupling described in this analysis provide a foundation for further development and optimization of the Smart Board.

4 Testing Strategies

4.1 Motor Test

1: Test before not connected to the power supply

Resistance Test: Measure the resistance of each coil in the stepper motor using a multimeter. The resistance should be within the range specified in the motor data sheet. If the resistance is significantly different, the motor may be damaged.

Continuity Test: Use a multimeter to check for continuity between the wires of each coil. There should be continuity, and the resistance should be consistent with the resistance test.

2: Connect the stepper motor to a power supply and control board: Connect the stepper motor wires to the control board, and connect the control board to a power supply. Make sure the wiring is correct and the connections are secure.

Power up the system: Turn on the power supply and control board.

Check for proper operation: Observe the stepper motor shaft and listen for any unusual noises. The shaft should rotate smoothly in precise steps, without any grinding or skipping.

Perform a full-step test: Send commands to the control board to make the stepper motor perform a full-step movement, which rotates the shaft by a full step. Observe the shaft and make sure it rotates smoothly and accurately.

Perform a half-step test: Send commands to the control board to make the stepper motor perform a half-step movement, which rotates the shaft by half a step. Observe the shaft and make sure it rotates smoothly and accurately.

Repeat the tests: Repeat the full-step and half-step tests several times to make sure the stepper motor is functioning properly and consistently.

If the stepper motor is not functioning as expected, Use a multimeter to check the resistance of the coils and make sure they are within the expected range specified in the data sheet.

3: Test the speed of the step motor:

Power up the system: Turn on the power supply and control board.

Send a step command: Send a command to the control board to make the stepper motor rotate a specified number of steps.

Measure the time: Use a stopwatch or other timing device to measure the time it takes for the stepper motor to complete the specified number of steps.

Calculate the speed: Divide the number of steps by the time in seconds to calculate the speed of the stepper motor in steps per second.

Repeat the test: Repeat the test several times to get an average speed.

Compare with specifications: Compare the calculated speed with the specifications of the stepper motor to make sure it is operating within its specified range.

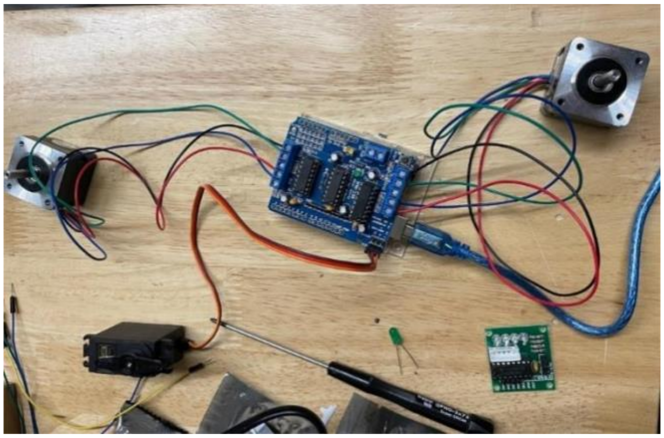

Figure 9 Motor Test

(The way we distinguish the wiring representing AB phase in the stepper motor: We by any combination of two wiring in series on a LED, manually turn the stepper motor, if the light is on represents the same phase A, -A or B, -B)

4.2 Power Supply Test

Testing a power supply involves verifying that it is able to deliver the correct voltage and current to the devices connected to it.

Connect the power supply: Connect the power supply to a power source, such as a wall outlet, and turn it on.

Measure the voltage: Set the multimeter to measure DC voltage and place the probes on the power supply's output terminals. The voltage should be within the specified range listed in the power supply's specifications.

Measure the current: Set the multimeter to measure DC current, and place one probe on the positive output terminal and the other probe on the ground terminal. The current should be within the specified range listed in the power supply's specifications. Repeat the test on all outputs: Repeat the voltage and current tests on all the output terminals, if the power supply has multiple outputs.

Figure 10 Power Supply

4.3 Work Breakdown Structure

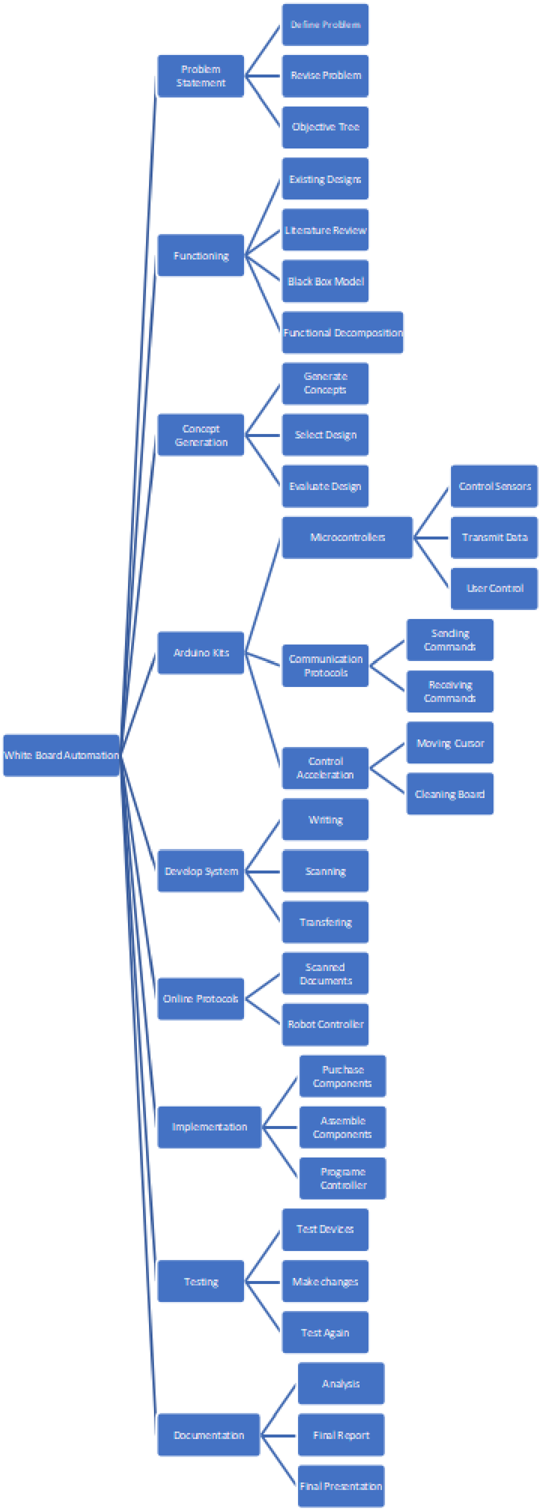

Figure 11 Work Breakdown Structure

4.4 PERT Network

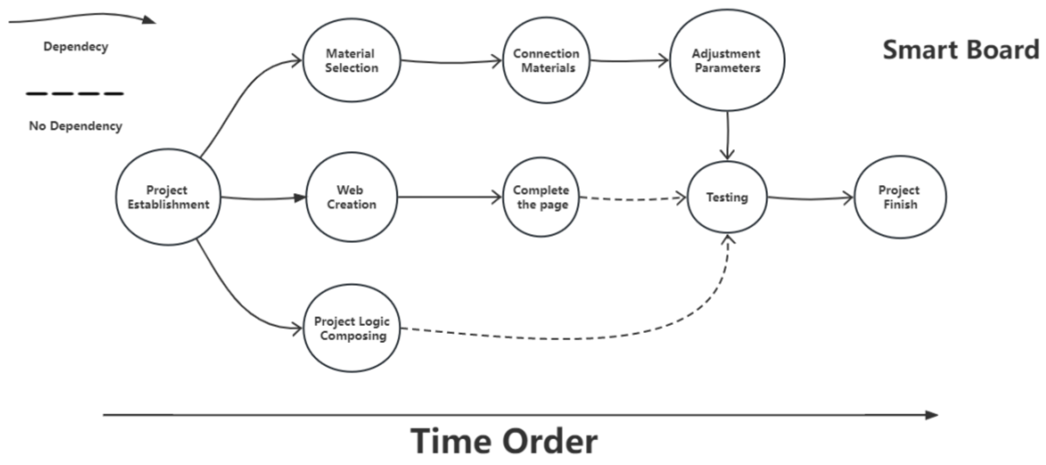

Figure 12 PERT Network

4.5 Gantt Chart

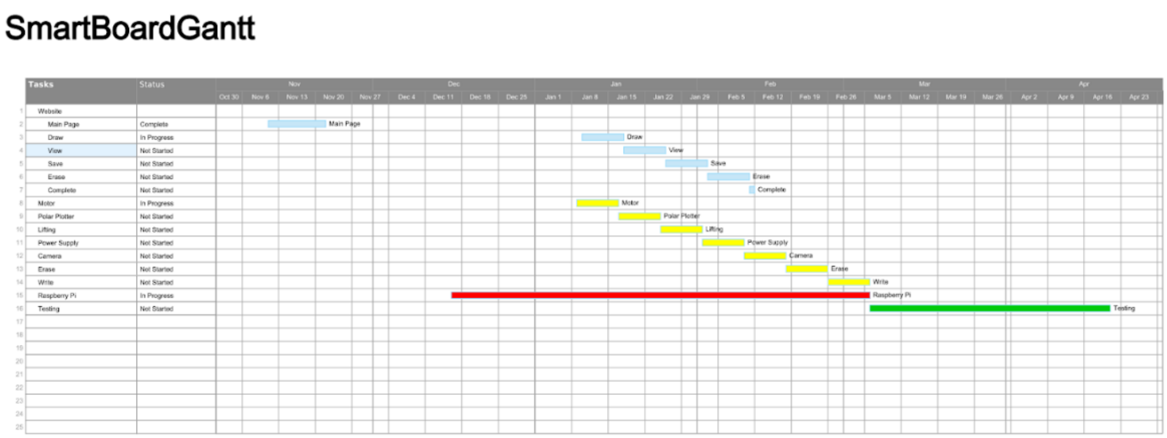

Figure 13 Gantt Chart

5 Financial Analysis

5.1 Cost

Arduino Board	$ 13.99
L293D Motor Shield	$ 3.99
L293D Motor IC*2	$ 7.99*2
Step Motor*2	$ 5.99*2
Servo Motor	$ 14.99
GT2 Pulley 16 Teeth Set	$ 5.99
Power Supply	$ 24.99
Mark PEN	$ 2.99
Cable	$ 6.99
Total	$ 101.89
Average Market Price	$ 248.7

Table 4 Cost

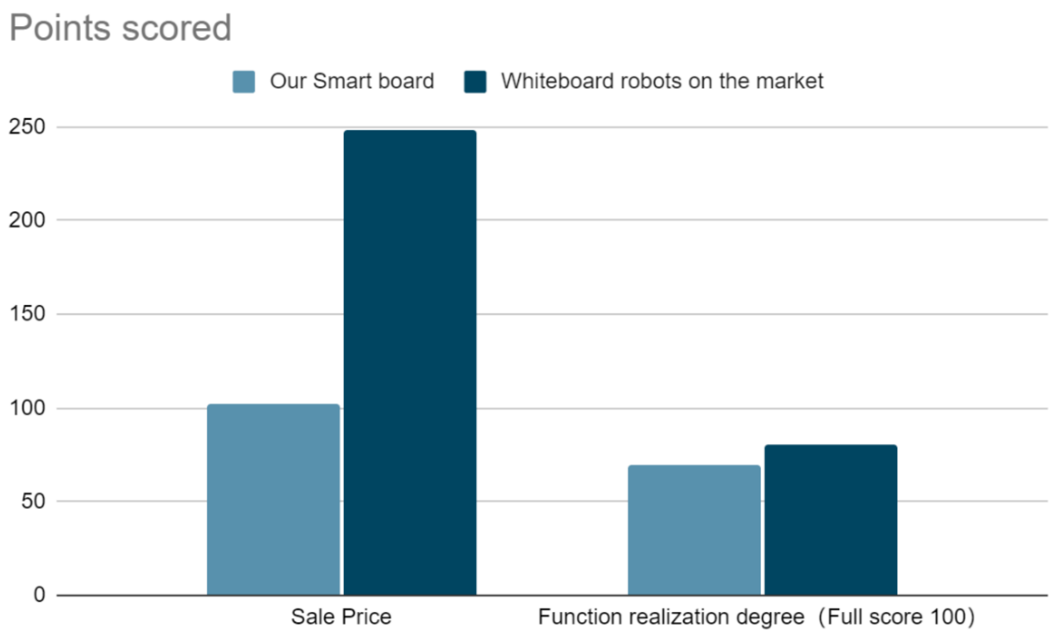

Figure 14 Points Scored

5.2 Marketing Research

5.2.1 Development prospects

Whiteboard robots, also known as interactive whiteboard robots, have shown good market prospects in recent years. Increasing adoption of technology in the education sector and the need for better engagement and interaction tools in the classroom has contributed to the growth of the whiteboard robot market.

In addition, the massive popularity of COVID has accelerated the shift to distance learning and online classrooms, creating a new market for remote whiteboard solutions. The demand for whiteboard robots is expected to grow as schools and universities continue to invest in technology to enhance the virtual learning experience.

Overall, the market outlook for whiteboard robots remains positive, and the industry is expected to continue to grow in the coming years.

5.2.2 Revenue, Break-even Point

Expected Offer Price：200$

（Monthly basis）   500/Monthly production

	Labor ($)	Raw Material ($)	Site Rental ($)	Advertising ($)	Total ($)
Cost	10000	50945	2000	500	63445
Revenue（Include Tax）					100000
Expected breakeven point					300/month

Table 5 Revenue, Break-even Point

In the initial stage of product investment, we envisage that all profits from the product will be used for promotion and publicity and the establishment of some experience stores, focusing on promoting the product concept to the campus, and we are ready to establish cooperation with educational institutions to implement the product experience program, giving our products to the institutions for free for three months.

5.3 Return on Investment

Because of the initial investment in promotion, we expect to start making profits one year after the product is put into operation, and dividends will be paid at the rate of ten percent of the investment amount each year.

6 Conclusion

Whiteboard robot is a robotic device designed to simulate the experience of writing or drawing on a whiteboard. This type of robot is typically mounted on a wheeled base and equipped with a pen or marker that can be used to write or draw on a whiteboard or other flat surface. Whiteboard robots can be controlled manually or programmed to perform specific tasks, such as drawing diagrams, writing equations, or generating graphs.

Whiteboard robots are commonly used in educational and business settings, where they can be used to demonstrate concepts, present information, and collaborate with others. They can also be used in manufacturing and design processes, where they can be programmed to create prototypes, mark materials, or perform other tasks that would typically be done by hand.

Overall, whiteboard robots are a useful tool for creating interactive and dynamic presentations, and they can help to improve collaboration and productivity in various settings.

Our team is committed to the development and input of the whiteboard robot and has invested a lot of energy and time in the project, with a special thanks to our mentors Carlo R daCunha and Kyle. Winfree and teaching assistants Jordan Beverly at the end. We hope our whiteboard robot is not only limited to whiteboard, because of our remote-control feature, we want to use the product in the future for building facade renovation, or parking space renovation, more development needs to be explored continuously!

Reference

[1] "XY Plotter Drawing Robot using Arduino Polargraph," Instructables, 2021. [Online]. Available: https://www.instructables.com/XY-Plotter-Drawing-Robot- Arduino-Polargraph/. [Accessed: May 10, 2023].

[2] "Whiteboard Drawing Robot," Thingiverse, 2014. [Online]. Available: https://www.thingiverse.com/thing:575487. [Accessed: May 10, 2023].

[3]Yao Cai, Qiang Zhan, M. Ceccarelli, G. Carbone, Shuangji Yao and Zhen Lu, "Design and simulation of a DSP controller for a LARM Hand," 2010 2nd International Asia Conference on Informatics in Control, Automation and Robotics (CAR 2010), Wuhan, 2010, pp. 361-364, doi: 10.1109/CAR.2010.5456824.

[4]MertArduino. "Make Arduino XY Plotter Drawing Robot (Polargraph)." Hackster.io. [Online]. Available: https://www.hackster.io/mertarduino/make- arduino-xy-plotter-drawing-robot-polargraph-b4fe36 [Accessed: May 10, 2023].

[5]Hackster.io. "A 3D Printed Whiteboard Robot That You Can Build Yourself." [Online]. Available: https://www.hackster.io/news/a-3d-printed-whiteboard-robot- that-you-can-build-yourself-c368a49e037f. [Accessed: May. 10, 2023].