GNG2101

Design Project Progress Update

Group B05 - 05

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1 Introduction

The first client meeting helped to create a more detailed background of the problem at hand, as well as pointing us in the direction of potential solutions. During our client meet we virtually met with The Client, she suffers from limited motor function making it difficult to engage in normal everyday tasks such as painting. To prepare for our meeting we as a team developed a list of questions to ask to help us better understand the situation and needs of the client. We were able to gather information on what exactly The Client needs to best accommodate her situation. Through conversation we learned what exactly she prioritizes, and what previous products were good at and what they could not provide.

With this information we obtained from the client meet we came up with a list of client needs and restrictions, helping to develop a deeper understanding of the problem, along with a list of metrics that are to be included in our design. The team was able to use this information to start benchmarking ideas on how this device will come together along with a general idea of what will not work as possible solutions. Prior to our meeting with The Client the team had very mixed perceptions on what exactly our task would be. After meeting and talking to her we gained a better understanding of what she was seeking as our client. This document will illustrate the key information gathered through our client meet, and how our design process will begin to take place for our canvas manipulation device.

2 Business Model Canvas and DFX

2.1 Business model and sustainability report

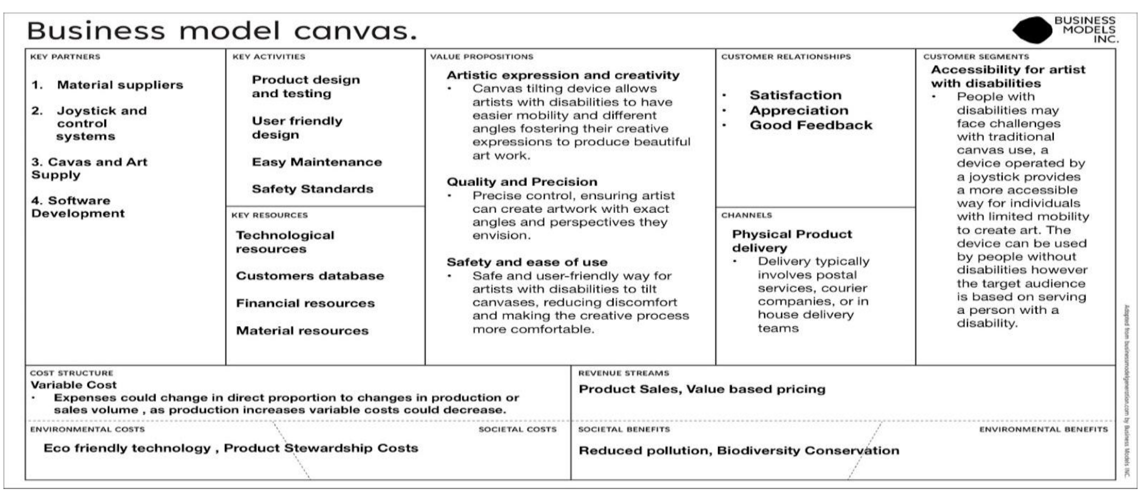
Value Proposition

Today, art is extremely important having seemingly infinite influence on history and culture, this makes it extremely important to ensure that it is as accessible as possible. This includes, but not limited to, those with limited motor function resulting in limited access to conventional methods of creating any form of art. In this case, our client has the inability to pursue the art form known as acrylic fluid painting. They require a separate device that allows for precision movement of a canvas in all dimensions to direct the flow of paint to create their desired image. Key features of this device would be full 360-degree horizontal motion, angular manipulation in the vertical, and intuitive controls/user input. As a team consisting of mechanical, electrical and software engineers' we possess the needed skills to design and build a device that possesses these needed qualities. Along with these initial requirements this product can be designed with more than one target consumer in mind. With the input method being the most optimizable and open-ended feature to enable use of the device through hands, feet, voice, and touch.

Tripple Bottom Line

The Triple Bottom Line Business Model Canvas provides a structured framework for designing a sustainable and socially responsible business model for the canvas-tilting device, by addressing the "how, what, who, and how much" aspects of the project.

Figure 1: Tripple Bottom Line Chart



Core Assumptions

Table 1: Core Assumptions

	Assumption	Feasibility Comment
Value Proposition	The product's value proposition is based on its 3D rotation and 2D spin profile features, versatility in supporting various canvas sizes and shapes, water resistance, and eco-friendliness.	The feasibility of this assumption relies on the uniqueness and effectiveness of these features in enhancing the painting experience for disabled individuals. Ensuring that the product genuinely improves their painting experience is key.
Customer Relationships	The business assumes it can build strong customer relationships by actively involving disabled customers in the product development process and addressing their specific needs.	The feasibility of this assumption depends on the company's commitment to empathic design and continuous engagement with disabled customers. Feedback-driven iterations are essential to adapt the product to their evolving requirements.
Channels	The product will be distributed through online channels, disability support organizations, and specialized assistive technology stores.	The feasibility of these distribution channels depends on their reach within the disabled community. Building partnerships with organizations that support disabled individuals can be instrumental in reaching the target audience.
Revenue Streams	Revenue will come from product sales, with pricing structured to be competitive while considering the value provided to disabled artists.	The feasibility of this assumption relies on proper pricing strategies and affordability for the target customer segment. The willingness of disabled artists to invest in such a product will determine its financial viability.
Key Resources	The business will require resources such as designers, engineers, and accessibility experts to develop and maintain the product.	The feasibility of this assumption depends on the availability of skilled resources and the ability to design and produce a user-friendly and accessible product.
Key Activities	Key activities involve product development with a focus on accessibility, continuous improvement based on user feedback, and marketing efforts targeting the disabled community.	The feasibility of these activities relies on the company's dedication to accessible design and its ability to respond to user needs promptly.
Key Partnerships	Partnerships may be formed with disability advocacy groups, rehabilitation centers, and assistive technology retailers.	The feasibility of these partnerships depends on their alignment with the product's mission and their ability to promote and distribute the product effectively
Cost Structure	The primary costs include personnel salaries, research and development costs, marketing expenses, and materials for production.	The feasibility of this cost structure depends on efficient cost management and the ability to secure funding or grants that support the

		development of assistive technology for disabled individuals.

In conclusion, the feasibility of this business model is contingent on the effectiveness of the product in meeting the unique needs of disabled artists, the affordability of the product, and the company's commitment to empathic design and continuous improvement based on customer feedback. Close collaboration with the disabled community and relevant organizations will be essential in ensuring the success of this venture.

Sustainability Report

This report examines the social, environmental, and economic implications of the painting assist device. We evaluate its impact on inclusivity and quality of life, its eco-friendliness in reducing paint wastage, and its revenue streams potential against the backdrop of research and development investments. By assessing these dimensions, we aim to guide decision-making and ensure that the device aligns with our commitment to social inclusion, environmental responsibility, and economic viability.

Table 2: Sustainability Report

Types of Impact	**Positive**	**Negative**
Social	**Accessibility**: The painting assist device provides The Client and other disabled individuals with limited motor function the opportunity to engage in art and creative expression. It promotes inclusivity and allows them to pursue a fulfilling hobby or therapeutic activity. **Quality of Life:** By enabling The Client to create acrylic fluid paintings despite her physical limitations, the device contributes to improving her overall quality of life. It enhances her sense of accomplishment and happiness.	**Cost**: Depending on the pricing strategy, the cost of the device may be a barrier for some disabled artists. Ensuring affordability while maintaining product quality will be crucial to mitigate this negative impact.
Environmental	**Eco-Friendliness:** The device's eco-friendly features, such as water resistance and potential paint/runoff collection system for recycling, contribute positively to the	**Materials:** The production of the device may require various materials, some of which might not be sustainable. To counter this, efforts

	environment by reducing paint wastage and minimizing environmental pollution.	should be made to source eco-friendly materials and explore recycling options for device components.
Economic	**Revenue Streams:** The device offers a revenue stream through product sales. Pricing it competitively while offering unique features can generate a steady income for the business.	**Research and Development Costs:** Developing and maintaining an innovative product like this may incur substantial research and development costs. Balancing these costs with pricing and ensuring profitability will be a challenge.

In summary, the painting assist device has the potential for significant positive social and environmental impacts by improving accessibility to art and promoting eco-friendliness. However, careful consideration of affordability and sustainable material choices will be necessary. Economically, it can generate revenue but may require substantial upfront investment in research and development.

2.2 Design for X

In this section, the desires of the client will be analysed and synthesized into client needs interpretations, which will later be used to craft a problem statement, and a design criterion.

Table 3: Clients Needs Statements and Interpretations.

Client’s Words	Interpretation	Priority (from most to least important - 1 to 5)
“I like to work with a variety of canvas shapes and sizes.”	The canvas clamping mechanism should be able to accommodate various shapes and sizes.	(4)
“The electronics on the device should be shielded from paint.”	The device should be water/liquid resistant,	(1)
“I had to water down my paint to get it to flow, while using the last machine.”	The device should have a larger range of motion.	(3)
“Sometimes I like to reuse the leftover paint.”	The device should have some sort of easy paint collection system.	(5)
“I can currently only use one of my hands for this activity.”	The device should have an easy user interface, and account for users with limited hand mobility/dexterity.	(2)

Ensuring that electrical components are protected from the paint is critical for this project as it ensures that the device will function and that no electronic components or moving parts will be shorted or clogged by the acrylic paint (1).

After ensuring that the electrical components can be shielded, and the product can function in regular conditions, it its important to consider the comfort of the client, as the goal is to design a product that they can comfortably use on a regular basis. Because the product will be targeted towards individuals experiencing issues with hand dexterity and motor function, usability of the product should greatly be considered during the design process (2).

Small motors limited the range of motion in the previous design for this product. As a result of the insufficient tilt range, the customer felt forced to water down her paints in order to obtain the flow effect she desired in her art. Though smaller motors can be used to create a smaller proof of concept, it is critical to create an end product that meets the needs of the consumer (3).

During the initial client meeting, our client expressed a desire to use larger paint canvases, typically larger than 12 × 12. The final design should be able accommodate a wider range of sizes, so that the client is not constrained to a particular canvas size (4).

The client also expressed her desire to create art with the paint left over from acrylic pours. Creating a system to collect the leftover paint from the pours should be a secondary design consideration, as it does not greatly affect the key functions of the device, however it still allows the user to reuse materials (5).

3 Problem Definition, Concept Development, and Project Plan

3.1 Problem Definition

In the previous section, we explored different client needs, and ranked them 1-5 based on their perceived importance during the project. In this section, we will summarize *Table 3*: *Clients Needs Statements and Interpretations* from Deliverable B, and explore the different known and unknown variables in this project.

Table 4: Clients Needs and Project Information

From Deliverable B		Project Information	
Interpretation	**Priority**	**Known Information**	**Unknown Information**
The device should be water/ liquid resistant.	1	• The client struggles with motor function on her right hand/arm. • The previous iteration did not have enough range of motion. • The client would like to be able to reuse some of the paint. • The client works with many different canvas shapes and sizes, typically over 12' x 12'.	• If The Client has a preferred sensitivity for the joystick mechanism. • Who will be cleaning the device? • Are there any extra safety features that The Client would like (i.e. fail safe button)?
The device should be user-friendly.	2		
The device should have a large tilting range of motion.	3		
The device should accommodate multiple canvas sizes.	4		
The device should have a paint collection system.	5		

The first section of the table recounts the list of clients needs, that were also touched on in the previous deliverable. The client's needs and interpretations are instruments in our product design, as they will serve as a basis for the design criteria that will be used for the remainder of the project. The ranking of the interpreted clients needs has been developed by the team. See section *2.2 Design for X* for an in depth analysis of the needs ranking.

The second section of the table establishes the known information for this project and will allow the team to develop a list of additional questions to ask the client during the next meeting.

3.2 Problem Statement

Despite the rapid growth in individuals wishing to pursue art, there are still large barriers that exist for disabled individuals, in art spaces. Our client, The Client struggles with motor function in her left arm, which prevents her from using the typical methods used in acrylic fluid painting. The Client requires an environmentally friendly device that will allow her to secure painting canvas' of various sizes, while allowing her to pivot the canvas, all while only using a single hand. This solution should be user-friendly, to ensure that The Client can comfortably use this device on a regular basis.

Need Inspired Metrics

Table 6: Need Inspired Metrics

	Metric	**Units**
Size Compatibility	Maximum and minimum canvas size and shape compatibility.	Inches or centimeters.
Rotation Angles	Degrees of rotation along three axes	Degrees (°).
Spin Profile	360-degree spin capability.	Degrees (°).
Joystick Control Sensitivity	Sensitivity levels of the joystick for precise control.	Levels (Low to High).
Weight Capacity	Maximum weight the device can support.	Pounds or kilograms.
Stability	Device stability during canvas manipulation.	Subjective rating (1 to 10).
Ease of Assembly	Time required for assembly and disassembly.	Minutes.

Table 7: *Metrics: Units and Values*

Metric	Unit	Marginal Value	Ideal Value
Total Weight	kg	< 8	6
Height	cm	< 60	45
Cost	$ (CAD)	< $100	$80
Rotation speed	rpm	1-50	0.1-50
Canvas tilt	degrees	1-45	0.1-42
Minimum motor torque	lb-in	35	50
Power type	V	10V	24 V
Footprint	m^2	< 2	1
Load bearing	g	>500	700
Comfort	hours	3	4

Table 8: *Benchmark on Metrics: Competitive Products*

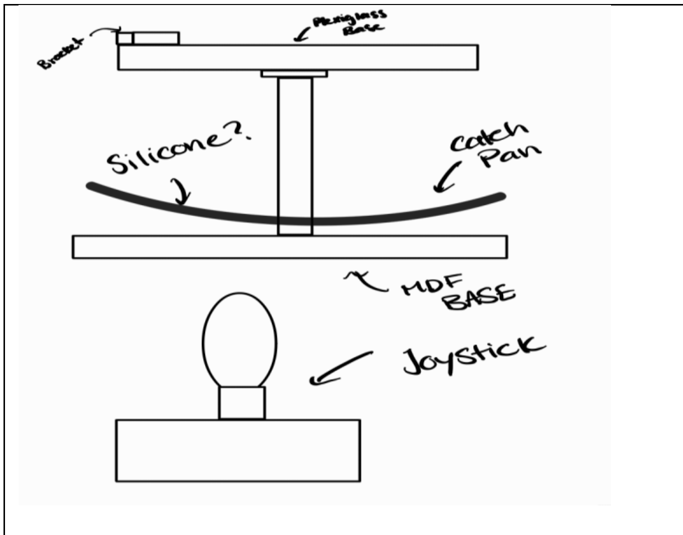
Metric #	Metric	Imp	Unit	Canvas Spinner	Motorized Canvas Spinner	Canvas Mount	Easel Canvas Mount

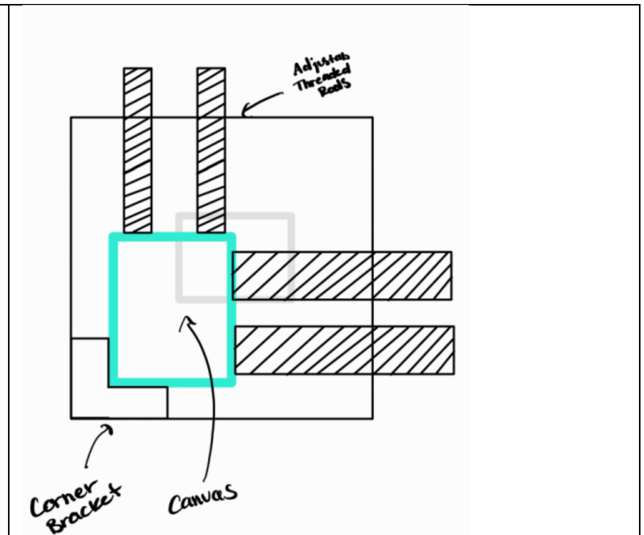
1	Weight	3	kg	N/A	N/A	N/A	N/A
2	Height	3	m	0.0762	N/A	0.2413-0.6350	0.07
3	Cost	5	CAD	31.99	545.00-573.00	20.95	33.99
4	Rotation Speed	5	rpm	Manual N/A	375	N/A	N/A
5	Tilt	5	deg.	N/A	N/A	0-90	N/A
6	Portability	1	subj.	Yes	Yes	Yes	Yes
7	Power type	2	Volts	N/A	24	N/A	N/A
8	Footprint	3	m^2	0.02129	N/A	0.04903-0.12903	0.0104
9	Load bearing	4	g	6800	N/A	N/A	N/A
10	Comfort	5	Time	N/A	N/A	N/A	N/A

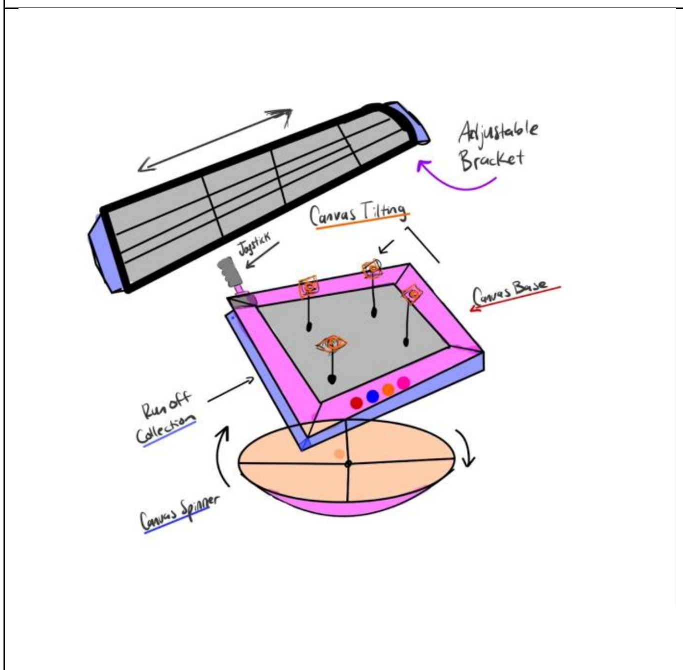
3.3 Concept development

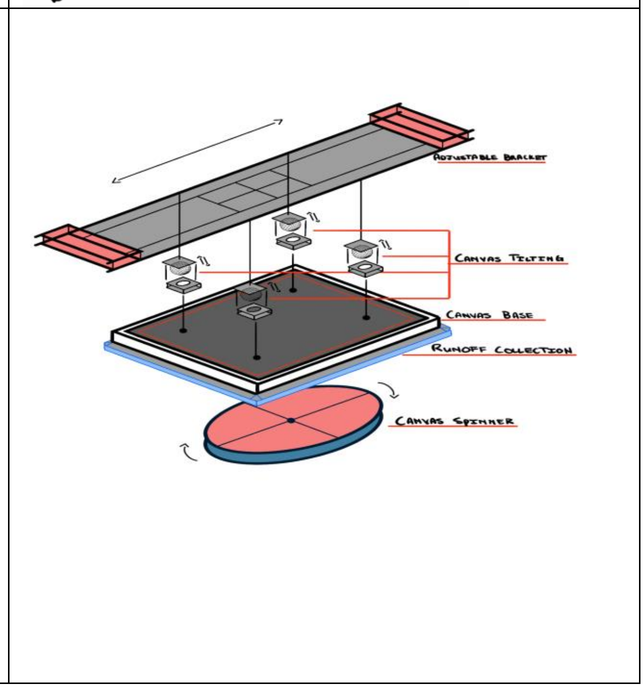
The following table illustrates the different design concepts made by each team member for the paint assist product.

Figure 1: Concept Development









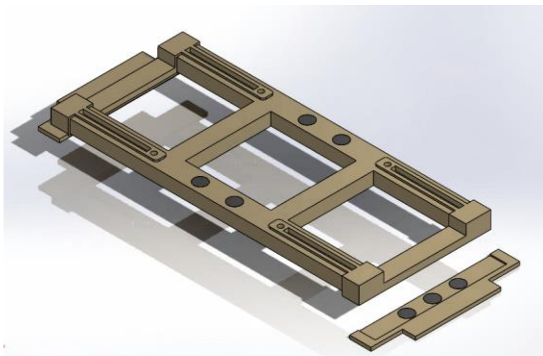
Final Concept Design

In response to the problem statement provided, we have undertaken the task of developing prototype concepts for each subsystem and an assembled system designed to address the specified problem.

Subsystems

- Clamping mechanism: For this subsystem, we have decided to use an adjustable bracket using two separate magnetic components. One component will be affixed to the back of the canvas using magnetic tape, while the other component will be integrated into a telescopic mechanism. This design not only accommodates canvases of varying sizes but also seamlessly connects with the canvas's tilting base.

Figure 2: Clamping mechanism



- Canvas Tilting: A rotation mechanism is used, which consists of two motors, two gears, and two shafts. This combination enables the canvas to rotate along the x and z-axes. while a spinner underneath provides a 360-degree rotation along the y-axis. It is shown in the following figures.

Figure 3: Canvas Tilting – Side and front view

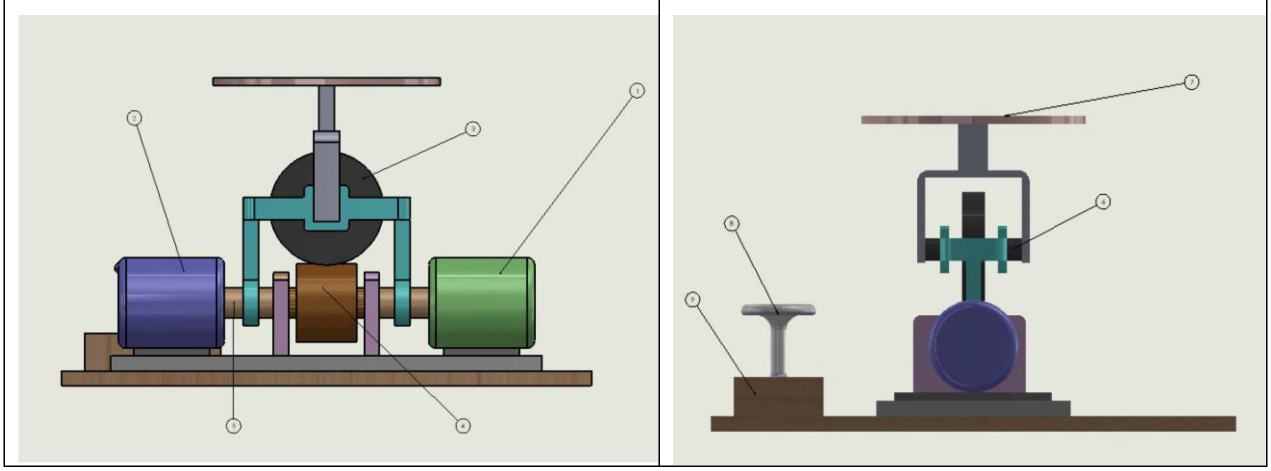


Table 3: List of Parts

Numbers	Description
1	Motor for rotation along x-axis
2	Motor for rotation along z-axis
3	Spur Gear
4	Worm Gear
5	X-axis Shaft
6	Z-axis Shaft
7	Mounting Bracket
8	Joystick
9	Control box

Figure 4: Canvas Tilting assembly

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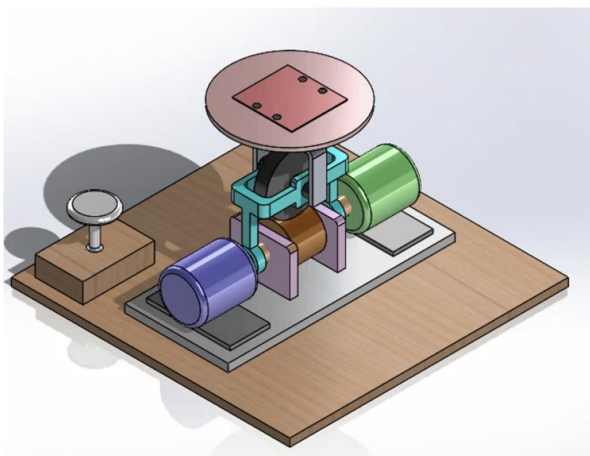


- Runoff Collection: The runoff collection tray is a shallow, concave structure securely attached to the bottom of the canvas tilting mechanism. This tray is positioned directly beneath the canvas to collect any paint runoff. It is made from a durable, easy-to-clean material such as acrylic or plastic. At one end of the collection tray, there is a small drainage hole with a valve or plug mechanism. This allows collected paint to be drained into a separate container or reused. The tray is generously sized to accommodate even the largest canvas sizes, ensuring it remains effective.

Figure 5: Runoff Collection

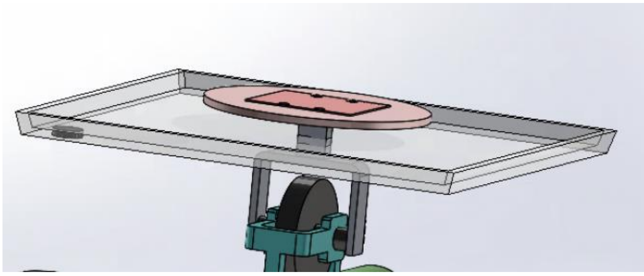
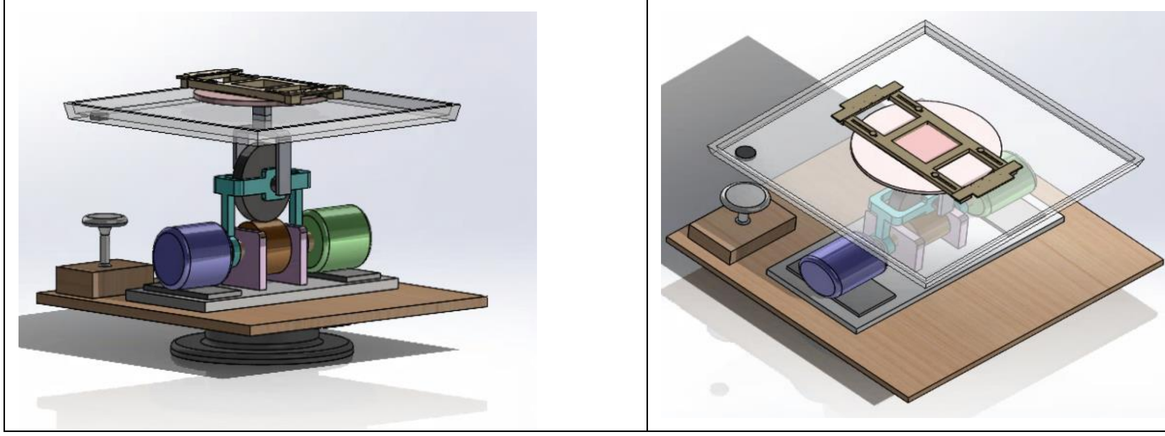


Figure 6: Assembled system



3.4 Project plan

In this section, we will systematically analyze and evaluate various design concepts against the defined target specifications.

Table 8: Analysing Target Specifications

Target Specifications	Evaluation	Calculations
Size Compatibility • The device must support canvases	This requirement can be met by designing an adjustable platform that can be extended or retracted as needed. The maximum canvas size can be	• Calculate the dimensions of the adjustable platform:

Target Specifications	Evaluation	Calculations
from 6x6 inches to 36x48 inches.	accommodated by a 36x48-inch platform.	○ Minimum canvas size: 6x6 inches ○ Maximum canvas size: 36x48 inches
Rotation Angles • The device should tilt from 0 to 90 degrees on two axes and offer 0 to 360 degrees on the third axis.	To achieve this, we can use a combination of two motors for the two-axis tilting and a rotational motor for the third axis. Calculations for motor specifications and gear mechanisms will be needed to ensure precise control.	. • Calculate the range of motion for each axis: ○ Two-axis tilt: 0 to 90 degrees ○ Third-axis rotation: 0 to 360 degrees
Spin Profile • Full 360-degree rotation capability is required.	This can be achieved by incorporating a high-torque rotational motor with proper gearing.	• No additional calculation is needed; this requirement simply specifies a full 360-degree rotation.
Joystick Control Sensitivity • Highly sensitive joystick control is necessary for precise canvas manipulation.	Use of high-quality and responsive joystick components along with adjustable sensitivity settings can fulfill this requirement.	The sensitivity of a joystick can be measured in terms of the number of steps or values it can provide. • For example, a joystick with 12-bit resolution can provide 4096 different values for sensitivity.
Weight Capacity • The device must support a weight capacity of 20 pounds.	Calculate the motor and structural specifications to ensure it can safely handle this load without compromising stability.	Calculate the torque required to support 20 pounds of weight when fully extended to 90 degrees. The formula is: • Torque (Nm) = Force (N) x Lever Arm Length (m)

Table 9: Target Specifications

Target Specifications	Evaluations	Calculations
Stability • The stability is rated at 8 out of 10.	This can be achieved by designing a sturdy and well-balanced base with anti-vibration measures and using high-quality components.	Stability can be subjective, but you can quantify it by specifying maximum allowable vibration or oscillation amplitude or acceleration in your design criteria.
Ease of Assembly • Assembly should take under 10 minutes.	Ensure that the device is designed with user-friendly connectors, clear instructions, and minimal tools required for assembly.	Calculate the number of components, connectors, and steps involved in assembly to estimate the assembly time
Durability • The device should last for 7 years.	Select materials and components known for their durability, and consider providing maintenance guidelines to the user.	Durability can be calculated based on the expected duty cycle and the lifespan of key components (motors, gears, etc.)

Additional Considerations:

- Paint Protection:
  - To protect the device from paint, consider adding a cover or enclosure around the moving parts, making it easy to clean and maintain.
- Accommodating Canvas Shapes:
  - Ensure that the platform design allows for different canvas shapes by providing adjustable clamps or supports.

Concept Relationship to Target Specifications:

The concept development aligns closely with the target specifications, aiming to create a user-friendly [painting assist system. Here's how the concept relates to the target specifications, along with its benefits and drawbacks:

Size Compatibility:
Concept: Accommodates canvases from 6x6 inches to 36x48 inches. Ideal range matches, and marginally acceptable range partially matches.
Benefit: Wide canvas size compatibility caters to a broad range of artistic needs.
Drawback: May not be suitable for extremely large canvases outside the 36x48-inch limit in the ideal range.

Rotation Angles and Spin Profile:
Concept: Provides 0 to 90 degrees on two axes and full 360-degree rotation on the third axis. Ideal values match perfectly, and marginally acceptable values offer reduced flexibility.
Benefit: Ideal rotation angles allow artists to work at any angle, offering maximum creative freedom.
Drawback: Marginally acceptable values limit rotation, potentially constraining artistic expression.

Joystick Control Sensitivity:
Concept: Offers highly sensitive joystick control. Matches the ideal sensitivity.
Benefit: Precise control aids artists, especially those with limited mobility, in achieving fine details.
Drawback: May require a learning curve for users who are not accustomed to highly sensitive controls.

Weight Capacity:
Concept: Supports up to 20 pounds. Matches the ideal weight capacity.
Benefit: Can accommodate a wide range of canvas weights, ensuring versatility.
Drawback: None concerning weight capacity.

Stability:
Concept: Rated 8 out of 10 for stability. Ideal stability rating matches.
Benefit: High stability ensures safe and smooth canvas manipulation during artistic processes.
Drawback: None concerning stability.

Ease of Assembly:
Concept: Assembly takes under 10 minutes. Matches the ideal assembly time.
Benefit: Quick and hassle-free assembly enhances user convenience.
Drawback: None concerning ease of assembly.

Durability:
Concept: Designed for a lifespan of 7 years. Matches the ideal durability.
Benefit: Longevity assures a reliable and long-lasting product.
Drawback: None concerning durability.

Wrike Snapshot:

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4 Detailed Design and BOM

After the second client meeting, the team debriefed, and used all the information gathered to update the previous design concept. The Client, our client, expressed some concern about the ability of the previous design to shield the moving mechanical parts from the paint, and its ability to withstand a maximum weight of 5 pounds. After receiving this feedback, the design team determined that a detachable silicone draping would be added to the product. Additionally, tests will be conducted to determine if the product will withstand a weight of 5 pounds.

4.1 Detailed design

Mechanical Subsystem

The mechanical subsystem of the canvas tilting mechanism is a robust assembly engineered to support and maneuver a canvas with precision. Incorporating gears, shafts, and a unique adjustable bracket offers artists a dynamic range of motion for their canvas while maintaining stability, even under varying weights and rotational demands.

Materials:

- Aluminum or Steel Framework: Provides structural integrity and can support the weight of heavy canvases. Aluminum is lightweight and corrosion-resistant, while steel offers higher strength.

- Silicone Draping: Used as a protective shield against paint splatter, ensuring the mechanical components remain clean. Silicone is flexible, durable, and easy to clean.

- Wooden Canvas Base: Offers a sturdy platform for the canvas while providing a natural aesthetic.

Components:

- Worm and Spur Gear Mechanism: For smooth and controlled tilting of the canvas.

- Shafts: These will be made of hardened steel for durability and strength. They connect to the motors and gears to transfer motion.

- Motors: High torque motors for tilting the canvas, ensuring smooth operation even with heavy canvases.

- Adjustable Bracket with Clips: Allows for securing the canvas in place. Clips provide an easier attachment mechanism compared to magnets (client feedback).

- 360-degree Rotating Base: Allows for full rotation of the canvas along the y-axis. This could be facilitated using a ball-bearing mechanism.

- Runoff Collection Tray: Made of plastic or acrylic, this tray collects any runoff, keeping the workspace clean.

Manufacturing Process:

1. CAD Design: Initial design is made using SolidWorks to visualize and test the system virtually.

2. Prototyping: Initial prototypes can be made using 3D printing or basic workshop tools to test the feasibility.

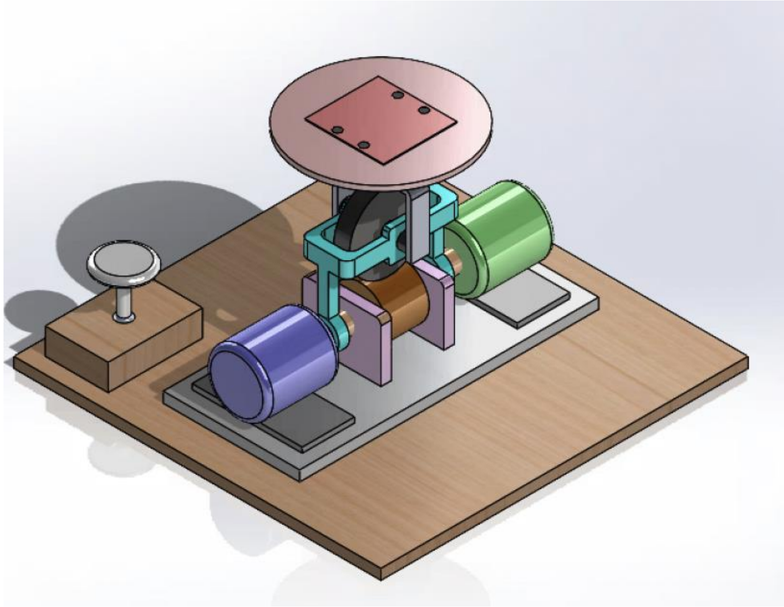
3. Material Sourcing: Once the design is finalized, bulk materials like aluminum, steel, and silicone will be sourced.

4. Machining: Components such as gears, shafts, and the framework will be machined using machines for precision or will easily be bought from McMaster-Carr if the budget allows.

5. Assembly: Components will be assembled, with electrical and software systems integrated.

6. Testing: The final product will undergo rigorous testing for stability, load-bearing capacity, and functionality.

Figure 7: Detailed Design



Software Subsystems

The software subsystem of the paint assist device serves as the brain, translating user inputs into precise movements of the canvas holder. It includes algorithms for interpreting joystick inputs, controlling the motors or actuators responsible for rotation, and ensuring a smooth and responsive user experience. Key functions of the software include:

1. **User Input Interpretation:**
The software interprets signals from the joystick to understand the user's desired movements. It analyzes the direction, speed, and intensity of joystick movements.
2. **Motor Control Algorithms:**
Algorithms are implemented to control the rotation motors or actuators. These algorithms ensure that the canvas holder moves accurately to the desired angles based on user input.
3. **Safety and Error Handling:**
The software incorporates safety features to prevent abrupt movements that could damage the device or artwork. It also includes error handling routines to address issues such as motor jams or communication failures.

4. **Calibration and Customization:**

Calibration routines allow users to set the device's initial positions and sensitivity levels according to their preferences. Customization features might include adjustable speed settings and sensitivity controls.

5. **User Feedback:**

The software provides feedback to the user, indicating the current position of the canvas holder or any error conditions. This feedback could be visual (LED indicators) or auditory (beeps) to enhance the user experience.

6. **Communication Protocols:**

If your device incorporates wireless connectivity or IoT capabilities, the software subsystem manages communication protocols for remote control or data logging purposes.

Technology for Software Subsystems

Microcontroller/Embedded Systems:

Description: Microcontrollers like Arduino or Raspberry Pi can be programmed using languages like C/C++ or Python to control motor movements based on joystick inputs.
Advantages: Cost-effective, widely supported, and suitable for real-time control applications.

PID Control:

Description: Proportional-Integral-Derivative (PID) control algorithms can be implemented to achieve precise and stable control of motors.
Advantages: PID control provides accurate and smooth movements, compensating for errors and disturbances.

Bluetooth/Wi-Fi Connectivity:

Description: Implement Bluetooth or Wi-Fi modules to enable wireless control of the device via smartphone apps or computer interfaces.
Advantages: Allows for remote control and enhances user convenience.

Sensor Integration:

Description: Use sensors like accelerometers or gyroscopes to detect the device's orientation, providing feedback for automatic calibration or stability control.
Advantages: Enhances device stability and user experience by adjusting motor movements based on the device's orientation.

Graphical User Interface (GUI) Development:

Description: Develop a user-friendly GUI using frameworks like PyQt (Python) or JavaFX (Java) for desktop applications, or frameworks like React Native for mobile applications.
Advantages: Provides an intuitive interface for users to calibrate settings and monitor the device's status.

Firmware Development:

Description: Write firmware code that directly interfaces with hardware components, ensuring efficient and optimized control of motors and sensors.
Advantages: Offers low-level control, maximizing the performance of the device.

Table 10: Arduino - Pros & Cons

Pros	Cons
Easy to Learn and Use:	Limited Processing Power and Memory
Real-time Control:	Limited Connectivity Options (No Built-in Wi-Fi/Bluetooth)
Low Cost:	Limited Multitasking Capability
Extensive Community Support:	Limited Graphics and User Interface Capabilities
Wide Range of Compatible Sensors and Shields:	Limited Storage Capacity
Suitable for Real-time Applications:	Limited Operating System Capabilities (No OS)

Table 11: Raspberry Pi - Pros & Cons

Pros	Cons
Powerful Processing:	More Complex to Set Up and Configure
Linux-based OS:	Limited Real-time Control (Not Suitable for Hard RT)
Extensive Connectivity:	Higher Power Consumption
Multimedia Support:	Higher Cost Compared to Arduino
Rich Graphics and User Interface Capabilities:	Limited Analog Inputs (Requires ADC)
Multitasking Capability:	May Require Cooling Systems for Intensive Applications
Large Community and Documentation:	Not as Power-Efficient as Microcontrollers

Product Assumptions

Here, we will define any other product assumptions that could affect the ability to implement the design.

Table 12 – Product Assumptions

What could affect the implementation of the design	Product Assumptions
Control Systems	The device should be equipped with a precise and responsive control system driven by a joystick
Customizable Tilt Angles	Might require an adjustable mechanical design as well as corresponding electrical controls
Materials and Components	Ensure that the electrical components and materials used are durable, reliable, and readily available
Paint Protection:	Device must protect against paint spillage.
Environmental Conditions	Ensure the electrical subsystem can withstand temperature variations, humidity, and other environmental factors

Additional assumptions include:

1. **Tilt Angle Range:** Acceptable range of tilt angles, e.g., -360 degrees to +360 degrees, to accommodate different artistic needs. The device should reliably tilt within this range.
2. **Maximum Canvas Weight**: Acceptable maximum canvas weight, e.g., 50 kilograms, which the device should be able to support without compromising safety or stability.
3. **Joystick Sensitivity:** Acceptable sensitivity levels for the joystick, ensuring that it provides precise control over the tilt angle. For instance, a sensitivity of ±1 degree for fine control.
4. **Power Source Voltage:** voltage of the power source, e.g., 110-120VAC or 220-240VAC, depending on the region where the device will be used.

Electrical Subsystem

The electrical subsystem of a canvas tilting device plays a critical role in controlling and powering the various components needed to tilt the platform, ensuring user safety, providing and enabling easy maintenance. Here's how the electrical subsystem would work in such a device:

- **Power Supply:** The electrical subsystem starts with a power supply system, typically connected to a standard electrical outlet. The power supply provides the necessary electrical energy to operate the device. Depending on the device's design and capacity, this can range from a regular 110-120VAC or 220-240VAC supply to a dedicated power source, such as a battery system for more portability.

- **Joystick Control:** The user interface of the device is typically a joystick, which allows the artist to control the platform's tilt in various directions. The joystick is connected to a control unit within the electrical subsystem.

- **Control Unit:** The control unit is the brain of the electrical subsystem. It processes the input from the joystick and converts it into commands for the actuation system (e.g., motor or actuator) to tilt the platform. It also manages safety interlocks and other critical functions.

- **Actuation System:** The actuation system, which can be a motor or an actuator, is responsible for physically tilting the platform. It receives commands from the control unit and adjusts the platform's position accordingly. The actuation system should be powerful enough to handle the weight of the canvas and platform.

- **Safety Interlocks:** Safety interlocks are crucial components within the electrical subsystem. These include limit switches, emergency stop buttons, and overload protection mechanisms. If the device reaches unsafe angles or encounters issues, these safety interlocks can trigger an emergency stop to prevent accidents.

- **Customizable Tilt Angles:** The control unit is programmed to allow for customizable tilt angles, accommodating different artistic needs. The artist can input specific angles or use presets to achieve desired positions.

- **Maintenance and Calibration:** The electrical subsystem is designed for ease of maintenance and calibration. If sensors drift or components need adjustment, the system should allow for straightforward access and calibration procedures.

- **Paint Protection and Electrical Isolation**: To prevent paint from reaching and damaging sensitive electrical components, the electrical subsystem should be designed with protective covers and barriers. Electrical isolation measures, such as sealing and insulating components, are also employed.

- **Emergency Procedures**: The electrical subsystem is equipped with protocols for handling emergency situations. This includes how the device responds to power failures, system malfunctions, or activation of the emergency stop.

4.2 BOM

The following tables organize all the materials and equipment required by the team to produce the designed solution. The team is aware that these tables are tentative and subject to change.

Table 10: Software Components - BOM

TECH	Description	SHOP (link)	Price Range
Arduino UNO R4 (WIFI)	The Arduino UNO R4 Wi-Fi merges the RA4M1 microprocessor from Renesas with the ESP32-S3 from Espressif, creating an all-in-one tool for makers with enhanced processing power and a diverse array of new peripherals. With its built-in Wi-Fi and Bluetooth capabilities, the UNO R4 WiFi enables makers to venture into boundless creative possibilities. Furthermore, this versatile board boasts a convenient on-board 12x8 LED matrix and a QWIIC connector, offering ample space for innovation and unleashing creativity.	Link: Amazon	$50 - $70

ELEGOO UNO R3	• Clear prints on the female header connector, more precise and easier to use the wire. • The ELEGOO UNO R3 BOARD now uses an 16U2 instead of the ATMega8U2 chip. Faster transfer rates and more memory. • Control using ATMEL ATMEGA+328P chip(the same with Arduino UNO R3) • 100% compatible with the Arduino IDE and RoHS Compliant.	Link: Amazon	\$24 - \$35
Joystick	Robojax Game Joystick and Keypad Module and Shield for Arduino • Joystick and Keypad can be used as profile changers. • 2 extra Push buttons	LINK: Amazon	\$20 - \$30
Raspberry Pi 4	**Raspberry SC15184 Pi 4** • Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1. 5GHz • 2. 4 GHz and 5. 0 GHz IEEE 802. 11b/g/n/ac wireless LAN, Bluetooth 5. 0, BLE • 2 × USB 3. 0 ports, 2 x USB 2. 0 Ports • Your tiny, dual-display, desktop computer and robot brains, smart home hub, media centre, networked AI core, factory controller, and much more with Raspberry Pi 4.	Link: Amazon	\$100 - \$130

Table 11: Mechanical Components - BOM

TECH	Description	SHOP (link)	Price Range
Worm and Spur Gear	Metal Gear - 20 Degree Pressure Angle Round Bore, 48 Pitch, 48 Teeth, ¼’’ Diameter.	McMaster-Carr https://www.mcmaster.com/products/worm-gears/	$40-$100
Bearing	Ultra-Low-Friction Oil-Embedded Thrust Bearing for 1/4" Shaft Diameter, 5/8" OD, 1/16" Thick	McMaster-Carr https://www.mcmaster.com/7421k1/	$1 /each
Shaft	1045 Carbon Steel Tapped Rotary Shaft, Tapped End x Straight End, 1/4" Diameter, 19.5’’ length. Thread size:10-32 (0.38’’)	McMaster-Carr https://www.mcmaster.com/products/shafts/tapped-rotary-shafts/end-type~tapped/diameter~1-4/	$15-$70
Knob	Black Phenolic Plastic Knob **Ribbed Grip, 10-32 Thread**	McMaster-Carr https://www.mcmaster.com/6479K69/	$1 /each

List of Skills and Resources

Table 12: Skills and Resources

Subsystems	Skills and Resources:
Mechanical:	**Skills**: CAD design, fabrication, understanding of motorized mechanisms. **Resources**: Access to fabrication tools like 3D printers, lathes, milling machines, and materials (aluminum, steel, plastics).
Software:	**Skills**: Programming microcontrollers (like Arduino), user interface design for joystick control.
Electrical:	**Skills**: Circuit design, understanding of motors and power systems. **Resources**: Motors, batteries, power management systems, joystick module.

Time Assessment for Implementing the Design

1. Mechanical:

Design (2 days, 16 hours):

- CAD design: 10 hours
- Design reviews and modifications: 6 hours

Fabrication (5 days, 40 hours):

- Sourcing materials: 4 hours
- Cutting/shaping materials: 16 hours
- Joining/assembling parts: 12 hours
- Quality checks: 8 hours
-

2. Software:

- Design and Development (4 days, 32 hours):
- Requirement gathering: 4 hours.
- Programming joystick controls: 12 hours
- Initial testing and debugging: 8 hours.
- Integration and Testing (3 days, 24 hours):
- Hardware-software integration: 8 hours
- Real-world testing with the device: 12 hours
- Refinements and bug fixing: 4 hours.

3. Electrical:

- Circuit Design (3 days, 24 hours):
- Motor circuit design: 8 hours
- Power system design (battery management): 8 hours
- Joystick control circuit design: 8 hours
- Implementation and Testing (4 days, 32 hours):
- Soldering and setting up circuits: 16 hours
- Integrated circuit testing with software: 8 hours

Weekly Breakdown:

Week 1:

Mechanical: CAD design and begin material sourcing (12 hours)
Software: Requirement gathering and architecture design (12 hours)
Electrical: Initial motor circuit and power system design (16 hours)

Week 2:

Mechanical: Finish material sourcing and begin fabrication (20 hours)
Software: Start programming joystick controls (10 hours)
Electrical: Finish circuit designs and start setting up circuits (10 hours)

Week 3:

Mechanical: Complete fabrication and start assembly (20 hours)
Software: Finish joystick programming and start testing (10 hours)
Electrical: Continue soldering and testing circuits (10 hours)

Week 4:

Mechanical: Finish assembly (10 hours)
Software: Integrate with hardware and begin real-world testing (20 hours)
Electrical: Integrated circuit testing with software (10 hours)

Week 5:

Mechanical: Quality checks and refinements (10 hours)
Software: Refinements, bug fixing, and user trials (20 hours)
Electrical: Final tweaks based on software feedback (10 hours)

Week 6:

All teams: Final testing, adjustments, and documentation.

4.3 Project plan update

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=Ql1jny73HMQ5F49Ti9rcITbyqycqAgFu%7CIE2DSNZVHA2DELSTGIYA

5 Design Constraints and Prototype 1

5.1 Design constraints

1. Weight: The rotational mechanism must accommodate canvases weighing up to 5lb. This involves ensuring the strength of the bracket, the durability of the gears, and the power of the motors are sufficient to manage this weight.

2. Shape of the wooden Base: Following feedback, the shape of the base has been redesigned. At first, the spinner underneath was designed to turn 360 deg automatically, however, the budget won't allow it. Right now, the primary goal is to allow the client to rotate the canvas along the y-axis easily. The new design must be ergonomic, fitting comfortably into a user's hand, and intuitive to manipulate.

3. Power System Analysis: The choice of motors must be validated by their capacity to handle the operational load of the mechanism. Calculations must be performed to determine the torque required to rotate a canvas of maximum weight, and the motors chosen must match or exceed this requirement. Additionally, the power consumption of these motors must be assessed, especially if battery-operated, to ensure adequate operational time.

4. Budget: All components, from mechanical parts like gears and shafts to electronic components like microcontrollers and motors, must not exceed a total cost of $100. This may necessitate the sourcing of cost-effective yet durable materials and components.

5. Ease of Assembly: Given the feedback about potential difficulty in assembly, design simplifications or clear assembly instructions should be included. The clip and spring mechanism decided upon should be easily manageable by the client.

6. Flexibility: The bracket must adjust to various canvas sizes, both in terms of weight and dimensions. It is essential to consider this when designing the brackets.

7. Safety: All moving parts, especially the rotational mechanism, must be shielded or designed in a way to prevent any harm to the user. The design must also ensure the canvas remains secure during all movements.

8. Maintenance: The paint collection tray and other components should be easy to clean and maintain. The design should facilitate easy disassembly for cleaning and reassembly afterward.

5.2 Prototype 1

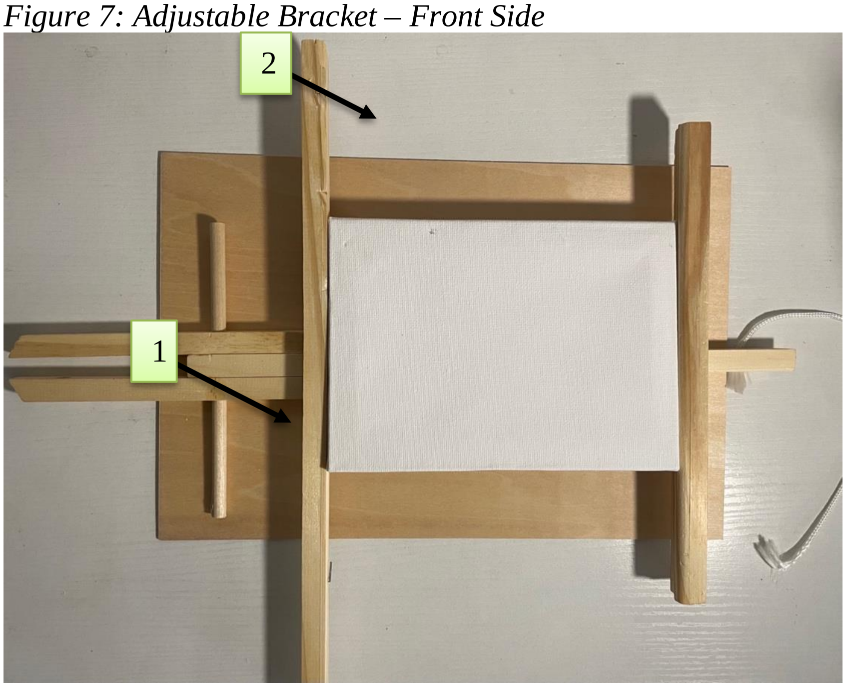
Mechanical subsystem

Clamping – Adjustable Bracket

At first, for the initial design, there was an adjustable bracket that was connected to both the canvas and the tiling mechanism by magnets, but after the meeting we had with our client, the possibility of difficult assembly for her and considering the budget, it was decided that in the next design, the clip and the spring are used.

To adjust the canvas, we were inspired by the painting tripod itself; however, it has some changes, and it is in this way that several holes are made in the middle piece of wood according to the standard sizes of the canvas or cut through the middle of the piece for any size (No. 1). For the demo, only two different sizes can be seen in the figures below. Also, a wooden nut is placed on a piece of wood number 2 to go into the holes and prevent the canvas from moving along the X-axis, and we can tighten the nut with a screw or lock the nut perpendicular to wood number 2.

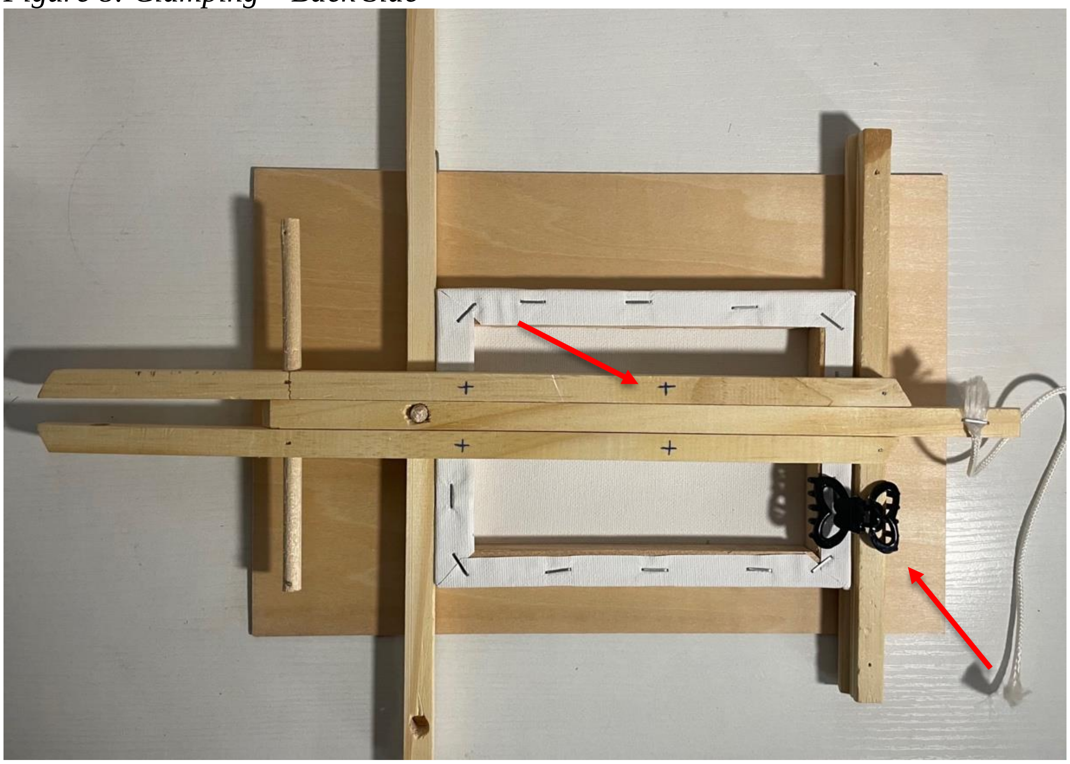
Figure 7: Adjustable Bracket – Front Side



To prevent the movement of the Z axis, we can use both a spring and a simple clip like the one shown in the picture so that it fits completely in the inner part of the canvas; thus, the canvas is adjusted from all directions.

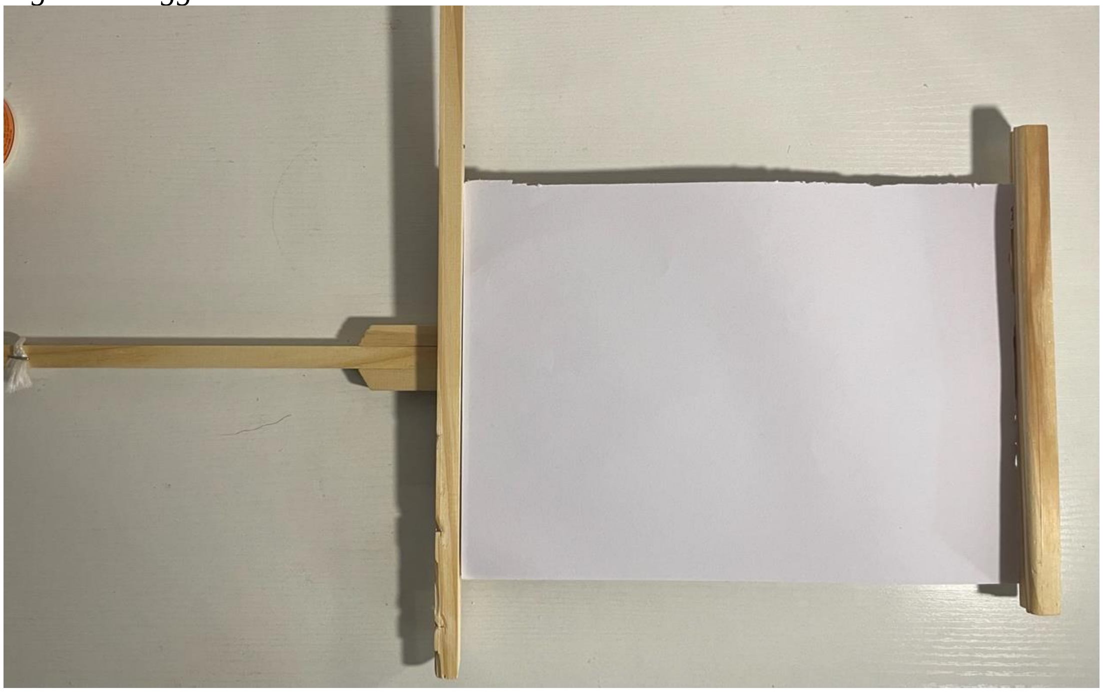
In addition, by using a similar mechanism, this bracket can be connected to its lower base, painting collection, so that instead of the positive signs seen in Figure X, a nut is connected, and on the base, four holes are made to hold the bracket and canvas.

Figure 8: Clamping – Back Side



For larger sizes, wood number 2 is opened from the opposite side as much as its own length, and again, the holes should be used to adapt to the size of the canvases (as seen in Figure X).

Figure 9: Bigger Size Canvas

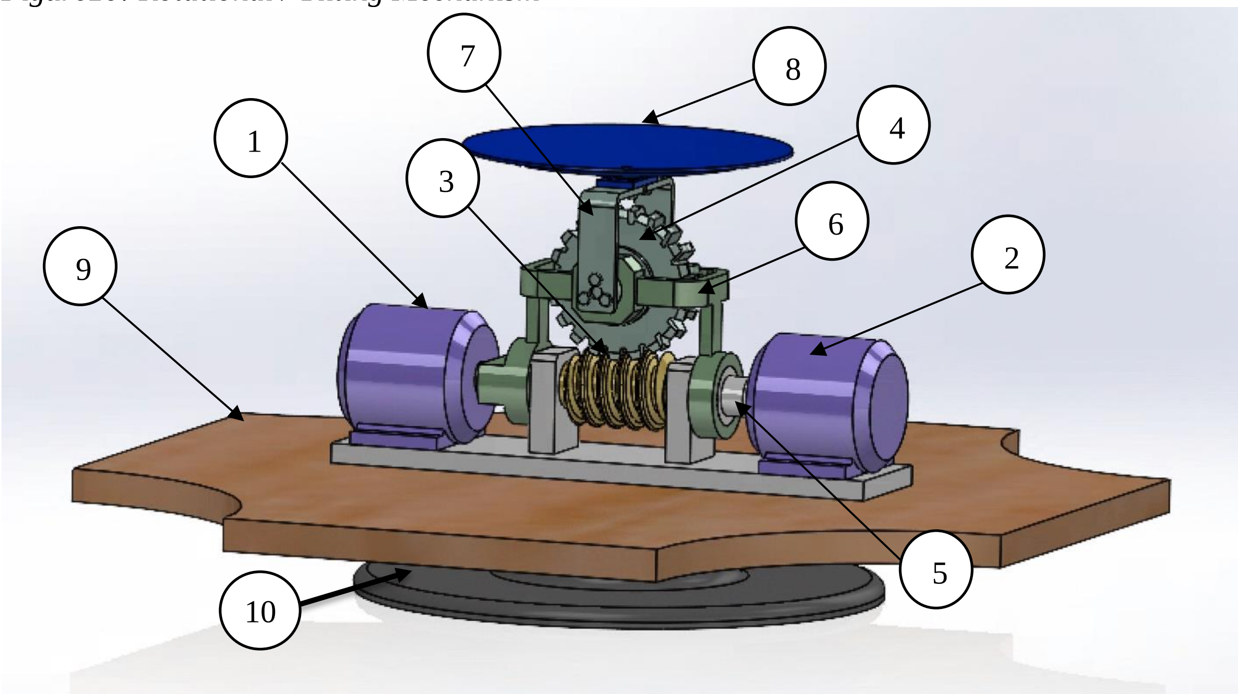


Rotational/ Tilting Mechanism

For canvas tilting, a rotation mechanism is used, which consists of two motors, two gears, and three shafts. This combination enables the canvas to rotate along the x and z-axes. At the same time, a spinner underneath provides a 360-degree rotation along the y-axis. It is shown in the following figures. When Motor 1 is rotating, the solo shaft (number 6) will rotate along the x-axis without interfering with the worm gear by using a ball bearing. When motor 2 is rotating, the worm shaft will rotate and lead to the rotation of spur gear at the top, which makes the canvas tilt along the z-axis. These motors will be controlled by a microcontroller and the provided joystick that makes it easy to use for the client. Furthermore, for the global concept, a rectangular base was used, which, after getting design feedback, has changed to the shape seen in the picture so that it would be more comfortable for the client to rotate the canvas along the y-axis by the spinner.

The Paint Collection (number 8) tray is a shallow, concave structure securely attached to the spur shaft (number 7) and will also be connected to the adjustable brackets. This tray is positioned directly beneath the canvas to collect any paint runoff. It is made from a durable, easy-to-clean material such as acrylic or plastic. At one end of the collection tray, there will be a small drainage hole with a valve or plug mechanism. This allows collected paint to be drained into a separate container or reused. The tray is generously sized to accommodate even the largest canvas sizes, ensuring it remains effective.

Figure10: Rotational / Tilting Mechanism



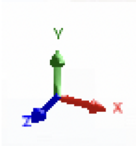
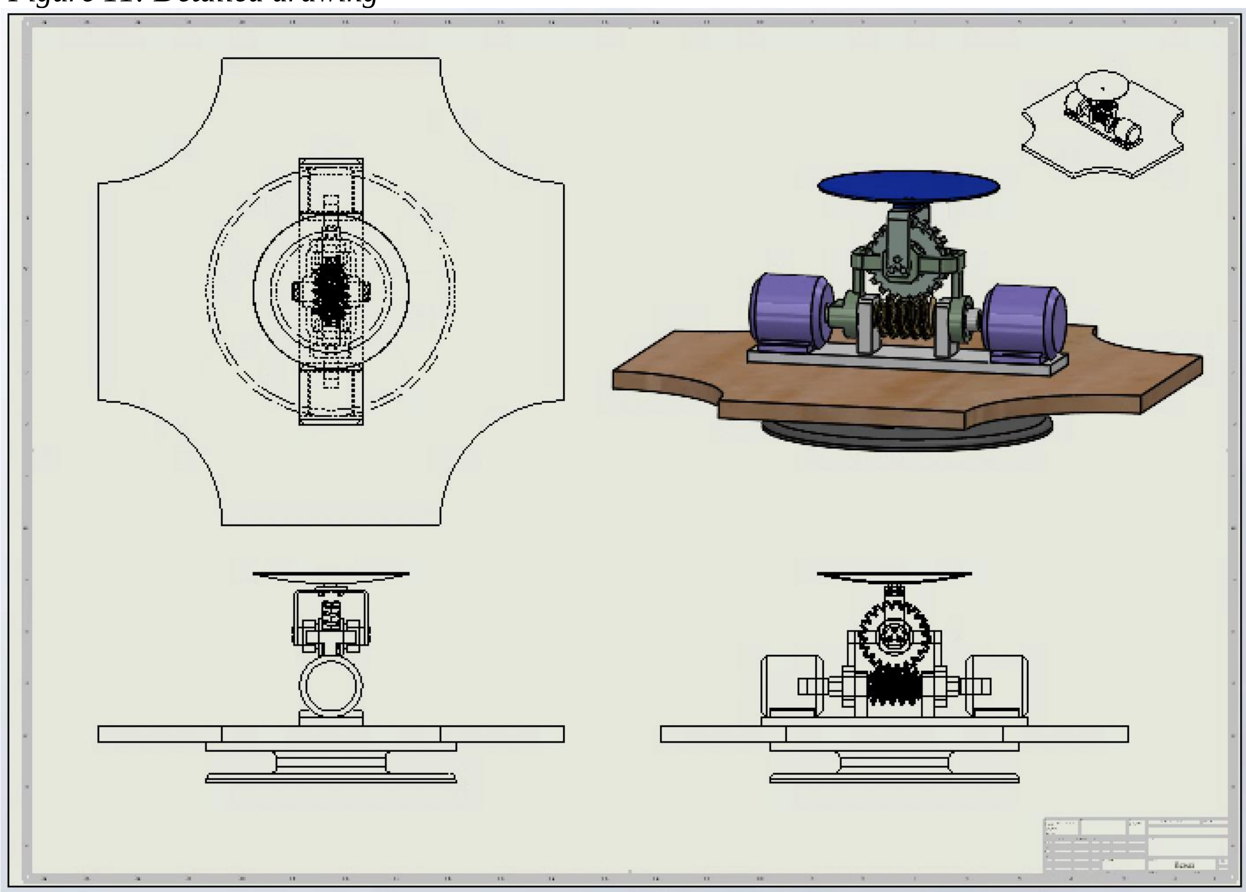


Table 12: List of Components

Item Num.	**Part Name**	**Description**
1	Motor for rotation along x-axis	Motor 1 results in the rotation of the spur shaft and titling along x-axis
2	Motor for rotation along z-axis	Motor 2 results in the rotation of the worm shaft and titling along the z-axis
3	Worm Gear	Driving Gear - Rotate with motor 2 results in rotation of spur gear and tilting along z-axis
4	Spur Gear	Driven Gear - Rotate with motor 2 results in rotation of spur shaft and tilting along the z-axis
5	Worm Shaft	Rotating with motor 2 results in rotation of worm gear

6	Solo Shaft	Rotating with motor 1 results in tilting along x-axis
7	Spur Shaft	Rotating by spur gear results in tilting along z-axis
8	Paint Collection	Light wight acrylic for collecting additional paint
9	Wooden Base	Main base is attached to the spinner and rotational mechanism
10	Manual Spinner	Rotate 360 deg along y-axis and controlled by hand

Figure 11: Detailed drawing



Software and Electrical Subsystem

Microcontroller: ESP32

The ESP32 is a series of low-cost, low-power system-on-chip microcontrollers with integrated Wi-Fi and dual-mode Bluetooth. In simpler terms, it's the "brain" of your device, handling input and output signals, processing information, and executing the code. The role of this device is to receive input from the joystick, process it, and send signals to control the lights (green and red) based on joystick movement.

Analog Joystick

An analog joystick provides variable resistance depending on its position. In this context, it's a two-axis joystick, with each axis (x and z) providing a different voltage output depending on its tilt. Its role in this device is when a user moves the joystick, and it generates two different voltages based on its position on the x-axis and z-axis.

The x-axis controls the green light. The position of the joystick on the x-axis will correspondingly adjust the intensity or state of the green light. The z-axis controls the red light. Its position dictates the intensity or state of the red light.

Mini Power Supply Unit (PSU)

A power supply unit converts mains AC to low voltage regulated DC power for the internal components of a device. The role is to provide consistent, regulated power to the ESP32 microcontroller, the joystick, and the lights. Ensures that the components operate safely and effectively without the risk of over or under-powering.

Figure 13: Subsystem Testing

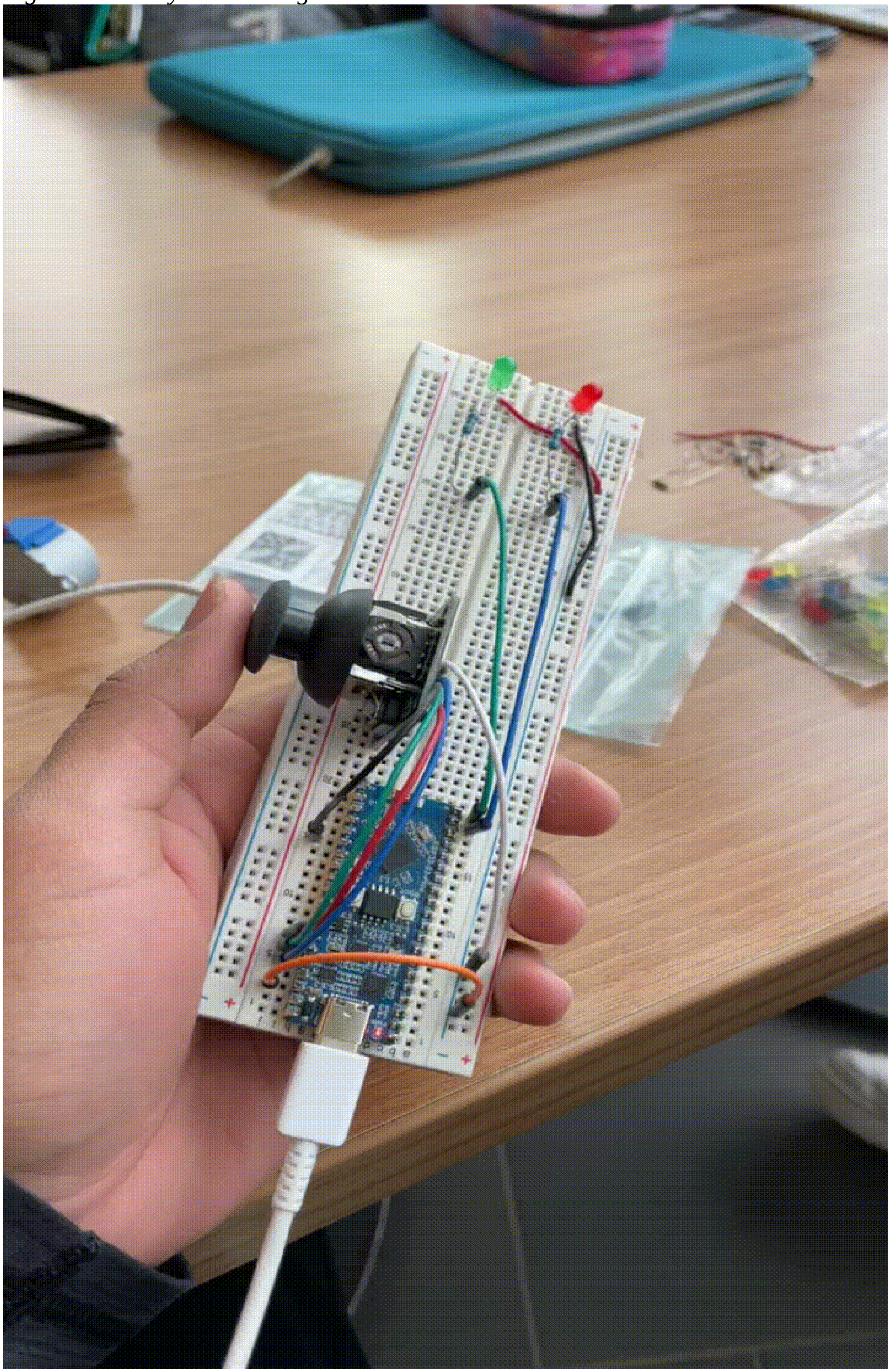
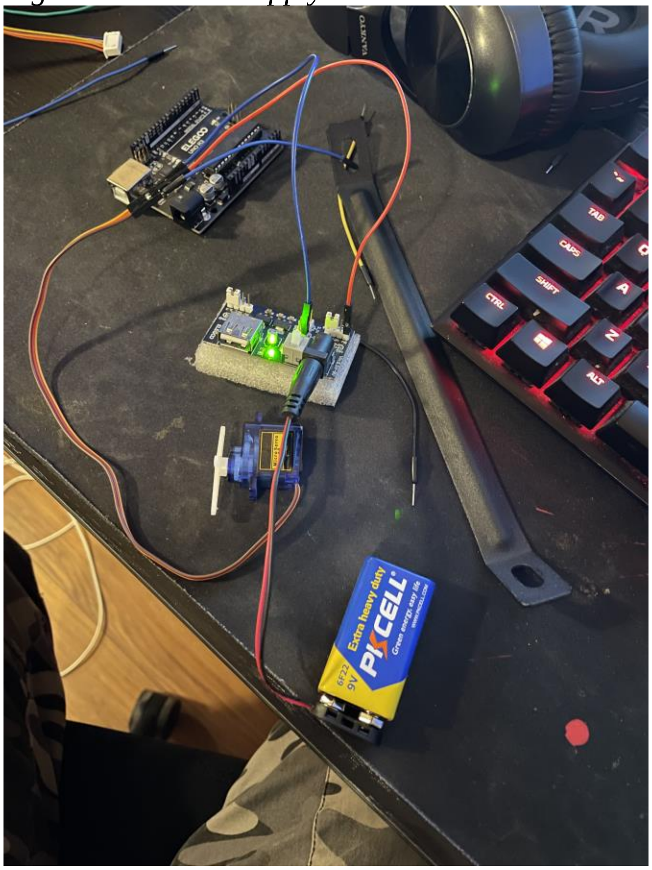


Figure 12: Power supply



Workflow:

1- Powering On: When the device is powered on, the mini-PSU provides the necessary power to the ESP32 and other components.

2- User Input: The user moves the joystick in various directions.

3- Signal Processing: The ESP32 reads the voltage from the joystick's x and z axes. The microcontroller then interprets this voltage to determine the joystick's position.

4- Output Activation:

- If the joystick moves along the x-axis, the ESP32 activates or adjusts the green light accordingly.
- If the joystick moves along the z-axis, the ESP32 activates or adjusts the red light.

5- Feedback: The user observes the change in light intensity or state as they manipulate the joystick, providing a direct interaction experience.

5.3 Project plan update

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=Ql1jny73HMQ5F49Ti9rcITbyqycqAgFu%7CIE2DSNZVHA2DELSTGIYA

6. Design Constraints and Prototype 2

1. Weight Capacity

> Justification: The client has emphasized the need for the device to support a range of canvas and bracket sizes. This points to weight capacity and body structures as significant non-functional design constraints that are crucial to ensuring the device can safely and effectively support the intended load.

Changes in Design:

- Performing a weight capacity analysis to ensure that the brackets can support the full range of canvas sizes, especially the larger ones. This might involve reinforcing the bracket structure or selecting more robust materials.
- The structural design should be tested using simulation software to validate the functioning under the expected loads. The design may need thicker beams or additional bracing to ensure stability.
- Revising the base to support the tilting mechanism and the added weight, which could include a broader footprint or a heavier counterweight to maintain balance.

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2. Adaptability and Size variety

Justification: There's a clear need for the device to handle various canvas shapes and sizes, including circles and ovals, which necessitates an adaptable design. The inclusion of an internal frame that fits inside different canvases and an enhanced paint collection system also underlines the importance of this constraint.

Changes in Design:

- Redesigning the clamping mechanism to be more adaptable, allowing it to secure various canvas shapes firmly. This may involve adjustable clamps that can be repositioned to accommodate different sizes and shapes.
- Integrating an internal frame that can be adjusted from the interior, perhaps through a telescopic design that can expand or contract to fit different canvas dimensions securely.

To satisfy these constraints, the design would need to be prototyped and tested continually, ensuring that they meet the client's specifications for weight support and adaptability while maintaining user-friendliness and cost-effectiveness.

To demonstrate the effectiveness of the proposed changes in satisfying the client's constraints, we can go through each of the requirements and provide justifications, calculations, and methods for meeting them:

Weight Capacity and Extra Brackets:

- Calculate the expected weight capacity: Assuming the maximum canvas size is 48' x 48' and the maximum bracket size is 35' x 35', you need to consider the weight of the canvas and brackets. The canvas material and brackets would have specific weights (e.g., in pounds per square foot). Calculate the total weight by multiplying the area of the canvas by the canvas weight and the area of the brackets by the bracket weight. Ensure that the device's structural components can support this weight.
- Conduct structural analysis and simulations: Use software like SolidWorks or finite element analysis (FEA) to simulate and analyze the device's structural integrity. Ensure that the chosen materials and design can support the calculated weight.

Paint Consumption Calculation:

- Calculate the required paint quantity: Measure the surface area of the canvas (e.g., square inches), and determine the paint consumption rate (e.g., 20-25 oz per square inch). Multiply the canvas area by the paint consumption rate to get the total paint required.
- Implement a reliable paint delivery system: Ensure that the device has a paint delivery system (e.g., pumps and nozzles) that can dispense the required amount of paint evenly across the canvas.

Platform Shape and Spin:

- Design the platform for various canvas shapes: Implement adjustable clamps or fixtures on the platform that can securely hold different canvas shapes, such as circles, ovals, etc.
- Add a spinning mechanism: Install a motorized spinning mechanism with speed control to achieve the spinning motion. Ensure it can start and stop as required.

Frame Integration:

- Design a frame that fits inside the canvas: Create a frame structure that can be adjusted to fit various canvas sizes and shapes. The frame should securely attach to the canvas, providing stability during painting.

Tilt Range and Height:

- Design the tilting mechanism for a 45–90-degree range: Ensure that the tilting mechanism can tilt the platform within the specified range.
- Allow an inch over 45 inches for the base height: Design the base height adjustment mechanism to accommodate this requirement.
- **Redefine the Paint Collection System:**
- Implement an improved paint collection system: Redesign the paint collection system to prevent any falling paint. This may involve adding shields, trays, or collection channels to capture excess paint and direct it to a collection container. Test the system to ensure it effectively collects paint without affecting the device's operation.

Communication with The Client:

- Maintain communication with The Client: Ensure ongoing communication with the client to address any questions or concerns, and to provide updates on the design and development progress.

4. Updated design accordingly

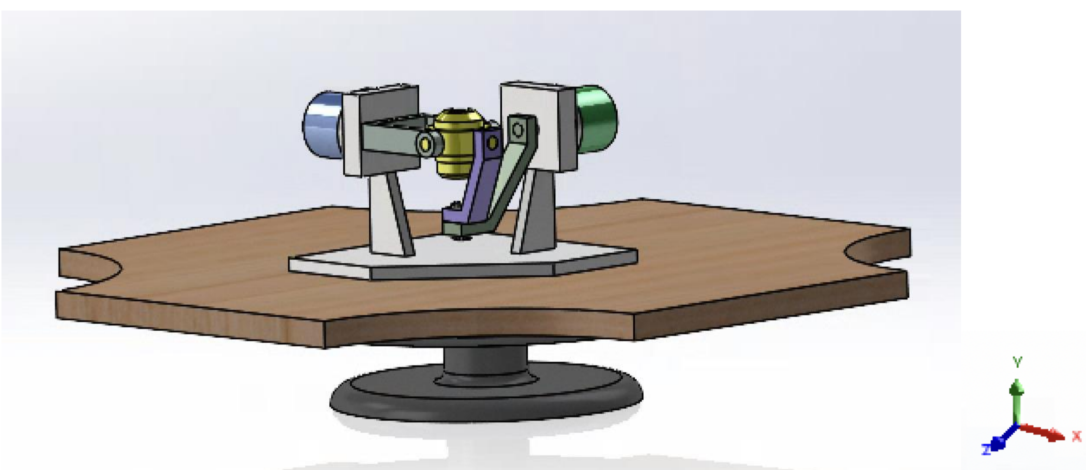
The new design showcased in the image (Figure 14) appears to implement a tilting mechanism similar to that found in security cameras, which is a robust solution for handling tilting along the x and z axes. This change would certainly affect the device's versatility in several ways:

Increased Weight Capacity: The security camera style mechanism likely offers improved weight handling capabilities due to its sturdy design, which is beneficial for supporting canvases of various sizes and weights.

Secure Tilting: This mechanism would provide more precise control over the tilt angle of the canvas, enhancing the device's adaptability to the artist's needs.

Simplified Operation: This mechanism is designed to be easily adjustable, often with motorized control, which could simplify the user experience.

Reliability: This mechanism is built to withstand continuous movement and adjustment, which could contribute to the longevity and reliability of the tilting function of the device.
Implementing this mechanism speaks to a thoughtful consideration of the client's feedback regarding the need for a secure, and versatile tilting mechanism. This would likely satisfy the requirements for a range of motion that can accommodate different painting positions, as well as provide the structural integrity needed to support larger canvases.
Figure 14: Updated Tilting mechanism



Prototype 2

New Client feedback

Weight Capacity and Brackets:

- Ensure that the device's weight capacity is well-matched with the addition of extra brackets, with bracket sizes ranging from 12x12 to 35x35 inches, while not exceeding a maximum canvas size of 48 feet.
- Perform rigorous weight capacity testing to confirm the device's structural integrity.

Paint Consumption Calculation:

- Calculate the paint requirement in terms of square inches, targeting a consumption rate of 20-25 oz of paint per square inch.
- Accommodate The Client's preference for a snowflake-like shape for the base.
- Include a mechanism for both starting and stopping the paint application.

Versatility with Different Canvas Shapes:

- Ensure that the device can support a variety of canvas shapes, including circles, ovals, and others, by incorporating adaptable canvas clamps or fixtures.

Internal Frame Integration:

- Seek to find a solution for a frame that fits inside the canvas from the interior, allowing for adjustability to match varying canvas sizes and shapes. This internal frame should guarantee stable and secure canvas attachment during use.

Tilt Range and Base Height:

- Develop a tilting mechanism that offers a range of motion between 45 to 90 degrees.
- Allow for an additional inch in base height over the specified 45 inches.

Enhanced Paint Collection System:

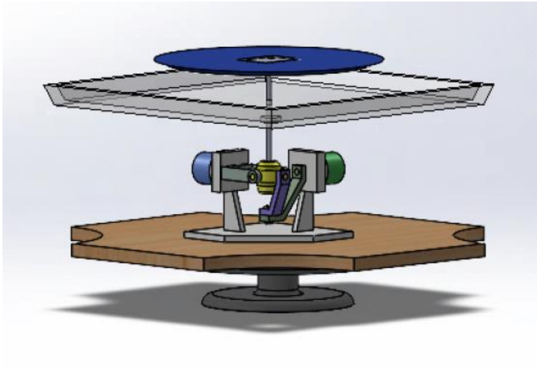
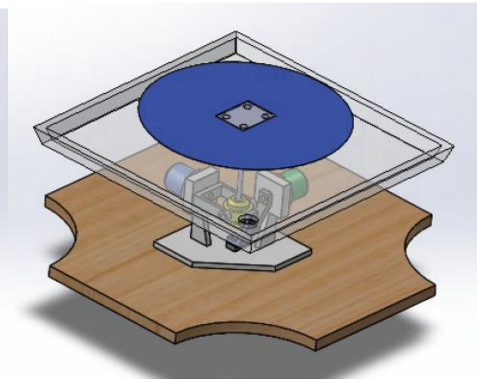
- Revise the design of the paint collection system to effectively prevent paint spillage and ensure that collected paint can be easily managed and disposed of without hindering device functionality.

Clear Communication:

- Maintain a direct line of communication with The Client through phone calls to promptly address any further questions or concerns as they arise during the project's development

Updated Prototype

Figure 15: Prototype 2 - Assembly



Prototype Testing

Table 13: Prototyping Tests

Test ID	***Test Objective***	***Description of Prototype used and of Basic Test Method***	***Expected Results***	***Actual Results***

1	The purpose of this test is to print out a proof of concept for the rotating mechanism, and determine if the DC motors will fit inside of the motor housing.	The 3D printers at the MakerSpace will be used to print out the rotating mechanism from the concept design. Once the printing is complete, the rotating mechanism will then be inspected for any defects, and the piece will be re-printed if needed. Sandpaper can also be used to smooth out imperfections on the piece. After this, the DC motors will be fitted into the printed shell.	Once the detailed design of the rotating mechanism is altered to the fit the dimensions of the Nema 17 stepper motor, the DC motor should fit into the compartment with little to no alterations made on the printed rotating mechanism.	The Nema 17 stepper motor has not arrived yet, so the fitting can not be tested yet.
2	The purpose of this test is to determine if the motors and brackets on the prototype will be able to withstand the weight of the estimated maximum paint capacity of the largest canvas.	Our client, The Client, has specified that the estimated weight of the canvas can be calculated per square inch, using the ratios for her average paint usage on a 20 x 20 canvas (20-25 oz/ 20 x 20 canvas). The paint per square inch measurement is approximately 0.05oz/square inch. This number can then be used to calculate the estimated maximum weight of the paint for the largest canvas size, which is 48x48.	1 - It is expected that the small DC motors used in the previous iteration will not provide enough torque to rotate the canvas. However, the Nema 17 stepper motors should be able to rotate the platform/canvas. 2 – It is expected that the connection points between the base of the canvas platform and the rotating mechanism will be able to withstand the 8lbs of paint, and the weight of the acrylic base. However, if this system does fail, it will	1 – The DC motors were unable to withstand the 8lbs of paint. Though, the Nema 17 stepper motors have not been tested. 2 – The connections of the base will be tested, once the Nema 17 stepper motors arrive.

		The maximum estimated weight for the largest canvas comes out to 7.2 or 8lbs of paint. To simulate the paint, 8 ounces of water or a different viscous liquid will be poured onto the paint catching. After this, the DC motors will be turned on to see if there is enough torque to move the platform. The brackets will be observed to see if there are any weak spots at the connection points.	most likely fail near the bottom of the system.	
3	The purpose of this test is to determine if the altered thumb joystick will be able to withstand regular use by our client.	The thumb joystick that was previously used in the last prototype will be taken apart, and an additional hand joystick will be 3D printed, and attached to the circuit of the thumb joystick. Ideally, this altered joystick will be able to make tilt on both the X and Y axis, to allow for easy handling by our client.	During the first joystick iterations, it is possible that the printed joystick addition may disconnect from the circuit when tilted at a certain angle. Once the best joystick configuration is determined, the joystick should accurately control the tilting of the stepper motors.	This is a future prototype.

An additional assumption made is that the stepper motor will fit seamlessly into the cord that will be used for the system, as this product will have a plug-in power system.

Client Meeting 4 Outline

Our team plans to present our clamping mechanism, as well as our new rotating mechanism. Ideally, the team will receive feedback on the functionality of the clamping mechanism, as it currently covers the edges of the canvas, preventing the paint for touching all sides of the canvas. The client should also confirm the feasibility of the rotating mechanism or provide any concerns for the existing system.

In the next client meeting, all 3 prototypes from *Table 13: Prototyping Tests* should be completed. The results from those tests should give us critical information, such as whether or not a 48 x 48 inch canvas capacity is feasible, or if the bracket system is strong enough to withstand the weight of the platform. Once this information is collected, the detailed design can be adjusted accordingly, and this model will be shown to The Client, our client. Additionally, the joystick subsystem will be shown to The Client to ensure that it would be comfortable for everyday use (i.e. not too big or too small).

Item	Description	Unit	Quantity	Cost	Link
Arduino UNO R3 (Clone)	Microcontroller board	item	x1	$15.25	MakerSpace
Acrylic sheet	Acrylic sheet for the canvas holder bass	24in x18in	x1	$20.0	MAKERSPACE
MDF	MDF for building the base box	12in x 24in	x3	$2.50 x 3 = $7.50	MAKERSPACE
MMOBIEL Nema 17 Stepper Motor	Stepper motors for the rotation	item	x2	$17 x 2 = $34.0	AMAZON
Power Supply Board Module	To fill the power requirements of the motors	item	x1	$10.0	AMAZON
Thumb Joystick	Used to control the device	item	x1	$7.0	MAKERSPACE

Wrike Update:

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=1Xuzjms8LvIXXINda5AE9U2lA48fL2uL%7CIE2DSNZVHA2DELSTGIYA

- ## Conclusions

In reflecting on the project, we acknowledge the successes achieved in meeting the initial objectives. The design process has taught us valuable lessons in the importance of iterative prototyping and user collaboration. The key aspect of user-centric design is crucial for any. designer, emphasizing empathy and a deep understanding of user needs. Moving forward, our new objectives and key results focus on further enhancing the device's performance, expanding its capabilities, and simplifying user interactions. Regular testing, user feedback, and continuous improvement will remain integral to our design philosophy. The journey so far has strengthened our commitment to delivering innovative solutions that truly address the client's requirements and challenges.