GNG 2101

Design Project User and Product Manual

Painting Assist

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1 Introduction

1. Context for the Work: Our client faces physical limitations that hinder their ability to engage in acrylic flow painting independently. To address this, we have developed an assistive painting device, designed to tilt with precision, providing the necessary range of motion and velocity to facilitate accurate painting. The device is joystick-controlled, making it accessible for individuals with limited physical abilities, particularly those with the use of only one arm.

2. Assumptions: a. The user has a basic understanding of acrylic flow painting techniques. b. The user possesses the ability to operate a remote control with one arm. c. The environment in which the device is used is suitable for painting activities.

3. Document Structure:

a. **Introduction:**

- Brief overview of the assistive painting device.
- Purpose of the document.
- Acknowledgment of the user's physical limitations and the need for assistance.

b. **Device Overview:**

- Technical specifications of the assistive painting device.
- Demonstration of the device's range of motion and velocity capabilities.

c. **User Manual:**

- Step-by-step instructions for setting up the device.
- Guidance on operating the device using the remote control.
- Tips for achieving optimal painting results.

d. **Maintenance:**

- Instructions for routine maintenance to ensure the device's longevity.
- Troubleshooting guide for common issues

e. **Safety and Privacy Considerations:**

- Recommendations for a safe painting environment.
- Privacy considerations related to the use of the remote control.

4. Purpose of the Document: The document aims to provide comprehensive guidance on the setup, operation, and maintenance of the assistive painting device. It serves as a resource for users who require assistance in acrylic flow painting due to physical limitations.

5. Scope of Activities: The document covers the entire lifecycle of the assistive painting device, from initial setup to ongoing maintenance. It focuses on user-friendly instructions to empower individuals with limited physical abilities to engage in acrylic flow painting independently.

6. Intended Audience: The primary audience includes individuals with physical limitations seeking assistance with acrylic flow painting. Secondary audiences may include caregivers, family members, or support personnel involved in the setup and maintenance of the device.

7. Security/Safety and Privacy Considerations: a. **Security/Safety:**

- Users should ensure the painting environment is well-ventilated.
- The device should be placed on a stable surface to prevent accidents.
- Cautionary notes about potential hazards and how to mitigate them.

By following this user and product manual, users can enhance their painting experience and achieve greater independence in their artistic pursuits.

This User and Product Manual (UPM) provides the information necessary for users to effectively use the Acrylic Painting Assist (APA) and for prototype documentation.

2 Overview

The problem at hand is the client's physical inability to engage in acrylic flow painting without assistance. This limitation hinders their creative expression and denies them the therapeutic benefits associated with art. The importance lies in fostering independence and enabling individuals with physical challenges to actively participate in artistic activities. Acrylic flow painting, known for its therapeutic and expressive nature, can significantly enhance the quality of life for the user, making the development of a suitable assistive device crucial.

Fundamental Needs of the User:

a. **Independence:**

- The user needs a solution that allows them to paint independently, overcoming physical limitations.

b. **Precision and Control:**

- The device must provide precise control over the tilt, ensuring accurate and intentional painting flow.

c. **Ease of Use:**

- The user requires a device that is easy to set up, operate, and maintain, considering potential challenges in physical dexterity.

d. **User Interface**

- Given the user's one-arm functionality, the user interface should be easily manageable with a single hand.

e. **Safety:**

- The user needs a safe painting environment, free from potential hazards associated with the device.

Key Aspects Differentiating Our Product:

a. **Customizable Tilt Range:**

- Our device offers a wide range of motion, allowing users to customize the tilt according to their comfort and artistic requirements.

b. **User-Friendly Remote Control:**

- The remote control is designed with a focus on accessibility, allowing seamless operation with one arm.

c. **Low Maintenance Requirements:**

- Our device is engineered for durability and has minimal maintenance needs, ensuring a long lifespan and consistent performance.

e. **Comprehensive User Support:**

- The accompanying user manual provides detailed guidance on setup, operation, and maintenance, ensuring users have the necessary support throughout their experience.

In summary, our product addresses the specific needs of individuals with physical limitations, offering a unique combination of customization, accessibility, safety, and therapeutic design that sets it apart from other solutions on the market.

2.1 Conventions

2.2 Cautions & Warnings

The following cautionary procedures need to be followed prior to the use of the machine at any time:

- Make sure the machine is fully turned off prior to inserting a new canvas.
- Place the machine on a stable surface.
- When placing the canvas onto the machine, make sure the clamps are securely tightened onto the machine and the canvas is not loose.
- Make sure there is nothing that would cause the obstruction of the machine's movement.
- Make sure a box or storage device of some kind is placed for there to be a place for the excess paint to flow into without making a mess.

3 Getting started

3.1 Configuration Considerations

This device requires an open environment with a flat and stable surface for the device to sit on. The floor and/or a stable tabletop are recommended. While the device is designed to catch and contain runoff paint, painting is a messy endeavor, and the user may wish to use plastic/paper or similar layer to protect from paint spill/splatter.

3.2 User Access Considerations

This device is designed specifically to enable individuals with physical limitations to participate in acrylic flow art. Depending on the degree of limitation, these users may require assistance securing the canvas to the device, pouring paint onto the canvas, and cleaning the device after operation.

3.3 Accessing/setting up the System

3.4 Step 1: Device Placement

Place the device on a stable surface, this could be on the floor or tabletop, as preferred by the user.

Step 2: Plug in the device

Plug in the device to power it on.

Step 3: Canvas Attachment

3a – Fully unscrew clamp screws so the clamp is fully open.

3b – Fit the canvas edges into the opened clamps.

3c – Tighten the clamp screws so that the canvas is secured in place.

Step 4: Set the system neutral position

4a – Using the joystick control tilt rotate the canvas so that it is parallel with the ground.

4b - Press the joystick button to set the current position as neutral. This sets the tilt limit in either direction to be +/- 55 degrees.

3.5 System Organization & Navigation

The device has 5 subsystems which work together to allow the device to function. These are the base, frame, canvas attachment, paint collection and electrical subsystems.

3.5.1 Base

The base is responsible for keeping the device stable during operation and ensuring it doesn't move. The base is connected to the frame through the motor on one side and a shaft/bearing on the other side.

3.5.2 Frame

The frame is responsible for tilting the canvas about one of the two axes, this is done by the motor on the base. The frame attaches to the canvas interface through the second motor on one side, and a bearing and shaft on the other. Tilt about the second axis is performed by this motor.

3.5.3 Canvas Interface

The canvas attaches to the device through four clamps, these clamps have a simple screw mechanism to tighten/loosen. The clamps can slide in a slot to accommodate a canvas of any shape and up to 12" x 12" in size.

3.5.4 Paint Collection

To collect runoff paint, the system has two acrylic layers where the canvas attaches. The lower layer has a 1" rim around the edges, this ensures any runoff paint from the canvas is caught by the rim and contained within this layer.

3.5.5 Electrical

This device uses two stepper motors to control the tilt of the canvas, a joystick to receive user input and a Arduino Uno to control the motors based on the joystick input.

3.6 Exiting the System

The following procedures need to be followed to properly store the machine:

- Turn the machine off
- Unplug machine from electrical socket
- Unclamp canvas from machine and place canvas away from machine on a stable surface for drying
- Unscrew frame on which the canvas was previously lying on to access the excess paint storage device
- Remove the excess paint.
- Clean off any excess paint from the machine
- Screw the machine back together.
- The machine may now be placed in a storage place of choice until the next use of the machine

4 Using the System

4.1 Canvas Interface

Unscrew all clamp screws to the open position. Place the canvas rim into the clamps. Retighten the screws to secure the canvas.

4.2 Tilt System

Tilit is controlled via the joystick. Moving the joystick away/towards you causes the canvas to tilt away/towards you, and the same for moving the joystick left/right. If the joystick is not moved the canvas will be held in the current position. The canvas is limited to +/- 55 degrees in either direction.

5 Troubleshooting & Support

5.1 Error Messages or Behaviors

Listed below are some of the common issues that may arise throughout the lifespan of the device. Many of these problems can be circumvented through regularly following the maintenance procedures in section 5.2.

Issue: Canvas slipping or not securely held in place.

Troubleshooting: Check if the clamping mechanism is tightened properly. Adjust or replace clamps if necessary. Ensure the canvas is within the recommended size and weight limits.

Issue: Wear and tear on components.

Troubleshooting: Regularly inspect components for signs of wear. Tighten any loose screws, bolts or joints. Replace any damaged parts.

Issue: Motors not working or tilting mechanism is uneven.

Troubleshooting: Check to ensure motor connections are secure and the power supply is properly connected. Check that the motors are not obstructed and adjust the tilting mechanism in case of any jams or misalignments.

Issue: Joystick or control interface malfunctions.

Troubleshooting: Check wiring connections. Ensure the joystick or controls are not physically damaged. Replace or repair faulty components.

Issue: Electrical problems affecting motorized parts or controls.

Troubleshooting: Check power connections, replace any faulty wires, and inspect the power supply unit. Ensure all electrical components are functioning correctly.

5.2 Maintenance

Any paint splatter on moving parts should be cleaned while the paint is still wet. If the paint dries it will be harder to remove, and the device will face more resistance during operation.

It is also recommended to remove excess paint buildup and clean paint splatter regularly. Excess paint buildup increases overall weight and thus increases overall load the device must support, and the torque required by the motors.

6 Product Documentation

6.1.1 BOM (Bill of Materials)

acrylic 24"x18"x1/8"	$17.99	2	https://www.amazon.ca/Clear-Acrylic-Plexiglass-Sheet-Thick/dp/B01NAFYRPE?th=1
mdf 24"x18"x1/8"	$3.00	2	https://www.homedepot.ca/en/home/categories/building-materials/lumber-and-composites/plywood/mdf.html
mdf 24"x18"x1/4"	$6.00	1	
1/2" bearing	$9.99	2	https://canadianbearings.com/web/en/products-and-services/bearings-and-seals/
Arduino Uno	$15.25	1	
3D printed motor mount #1	$0.00	1	
3D printed motor mount #2	$0.00	1	
3D Printed shaft attachment #1	$0.00	1	
3D Printed shaft attachment #2	$0.00	1	
3D Printed bearing mount #1	$0.00	1	

3D Printed bearing mount #2	$0.00	1	
3D Printed standoff	$0.00	4	https://www.homedepot.ca/product/paulin-1-4-20-x-1-2-inch-hex-head-cap-screw-18-8-stainless-steel-unc/1000142251
1/4-20 x 1 bolt	$0.55	8	https://www.homedepot.ca/product/paulin-1-4-20-x-1-1-2-inch-hex-head-cap-screw-18-8-stainless-steel-unc/1000132209
1/4-20 x 1-1/2 bolt	$0.95	4	https://www.homedepot.ca/product/paulin-1-4-inch-bolt-size-flat-washers-hot-dipped-galvanized-1pc/1000141551
1/4 flat washer	$0.16	20	https://www.homedepot.ca/product/paulin-1-4-20-inch-nylon-insert-stop-nut-pozi-lok-zinc-plated-grade-5-unc/1000122477
1/4-20 nut	$0.24	12	https://www.homedepot.ca/product/paulin--10-3-16-inch-steel-spacer-washer/1000128951
Canvas clamps	$4.75	4	
Arduino Motor Shield	$9.89	1	https://www.amazon.ca/Shield-Expansion-Module-Arduino-button/dp/B01LZAEY5P
Arduino male-male wire	$0.00	5	
Arduino male-female wire	$0.00	8	

Arduino joystick Breakout Module	$3.00	1	https://www.amazon.ca/Gikfun-6x6x5mm-Switch-Arduino-EK1019C/dp/B06Y6DDG8K/ref=sr_1_2_sspa?crid=2BU2QSI88458M&keywords=arduino+button&qid=1698954000&sprefix=arduino+button%2Caps%2C83&sr=8-2-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&psc=1
Stepper Motors	$10.00	2	https://www.amazon.ca/NEMA17-Stepper-Torque-Bipolar-Printer/dp/B0B1Q4CF87/ref=sr_1_19?hvadid=604685782687&hvdev=c&hvlocphy=9000671&hvnetw=g&hvqmt=e&hvrand=11635384495772675185&hvtargid=kwd-312551382456&hydadcr=6722_13264631&keywords=nema+17+bipolar+stepper+motor&qid=1701283717&sr=8-19
Total	$120.37		

6.1.2 Equipment list

- 3D Printer (Ultimaker 2+ was used)

- Laser cutter (must be able to accommodate up to 18”x18”)

6.1.3 Software List

- Solidworks
- Inksacape
- Ultimaker Cura
- Arduino IDE

6.1.4 Instructions

Please refer to these images for reference in the steps below:

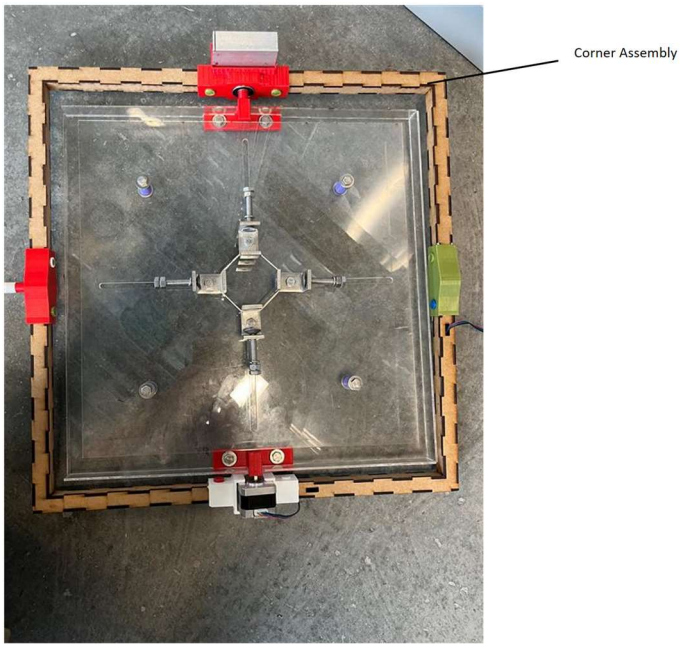

Figure 1 - Frame and canvas assembly

Figure 2 - Vertical base assembly

Step 1 – Laser canvas_2, canvas_3, 2 x canvas_5 and 4 x canvas_6 from 1/8” acrylic.

Step 2 – 3D print canvas_1, canvas_2 and 4 x canvas_5.

Step 3 – Attach the clamps onto the slots in canvas_2 using a ¼-20 1 bolt with washer and nut per clamp.

Step 4 – Attach canvas_2 to canvas_3 using the four standoffs, four ¼-20 1½ bolts, eight washers and four nuts.

Step 5 – Glue the canvas_6 and canvas_7 pieces into place.

Step 6 - Laser cut 4 x Frame_1, 4 x Frame_2, 4 x Frame_3, 4 x Frame_4, 1 x Frame_5 and 7 x Frame_6 from ¼" MDF.

Step 7 – Assemble the four frame corner assemblies using 1 Frame_1, 1 Frame_2, 1 Frame_3, 1 Frame_4 and 2 Frame_6. One of the assemblies will use a Frame_5 in place of a Frame_6, make sure to place insert 1 motor wire into this piece.

Step 8 – 3D print Frame_7, Frame_8, Frame_9, Frame_10, 8 x Frame_11 and 8 x Frame_12.

Step 9 – Attach Fram_7, 8, 9 and 10 to the corner assemblies using Frame_11 and 12 as pins.

Step 10 – Laser cut Base_1 from ¼" MDF.

Step 11 – Laser cut 4 x Base_2, 2 x Base_3, 2 x Base_4 and 2 x Base_5 from 1/8" MDF.

Step 12 – 3D print Base_6.

Step 13 – Attach 2 x Base_2, Base_3, Base_4 and Base_5 into the vertical assembly. Repeat this step twice.

Step 14 – Place one motor into one vertical assembly, and place Base_6 and 1 bearing into the other.

Step 15 – Laser cut all Housing_ files, cutting 2 x Housing_4.

Step 16 – Upload the Arduino sketch to the Arduino.

Step 17 – Assemble the circuit.

Step 18 – Assemble Housing_1-3 and glue to the vertical base assembly with the motor to contain the wires.

Step 19 – Assemble the Arduino and joystick assembly.

Step 20 – Connect the canvas assembly from steps 1-5 to the motor and bearing on the frame from steps 6-9.

Step 21 – Connect the frame to the two vertical base assemblies and then place everything into the slot on the base. Plug the device in and use.

6.2 Testing & Validation

6.2.1 Prototype 1

Prototype 1 was the electrical system with motors, Arduino and joystick. This prototype was used to test the legitimacy of our setup and ensure the desired tilt control was achievable with the input from the joystick.

6.2.2 Prototype 2

Figure 3 - Physical prototype 2, used to measure response to different amounts of motor torque

Prototype 2 was used to estimate the response to different amounts of motor torque. The torque on the shaft varies with the weight of the bucket. The piece of wood the shaft connects to is

built to represent the rotational inertial resistance of our system. In this way we can test if the motor toque will be sufficient to produce the response desired. Table 1 below shows the response time for input torque. The motors selected can output a maximum of 290 mNm. **Error! Reference source not found.**

Table 1 - Input torque and time to rotate 45^0

Input Torque (mNm)	Time from -45^0 to flat (ms)
290	875
261	921
232	1098
203	1170
174	1334
145	1532

7 Conclusions and Recommendations for Future Work

7.1 Major Issues

- Insufficient motor torque to tilt the device
- Frame bends more than desired

7.2 Maor Issue Fixes

- Offset the motor from the shaft and connect it with a gear reduction, could be done with a planetary gear system. This will increase the torque and decrease the speed, improving tilt precision.
- Build frame from metal to increase strength.

APPENDICES

8 APPENDIX I: Design Files

Please see makerrepo for all referenced files.