Newtype Painting System: Preventing Repetitive Strain Injury In Gunpla Painting Hobbyists

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Abstract

Repetitive Strain Injury (RSI) is a damage or pain caused by repetitive movement or overuse. It can be easily seen in people's daily activities causing different level of severity and symptoms. However, most of the people just try to take longer rest to get rid of the pain and the effect is always temporary. Through the interview with the model painter who have painting experience for more than ten years, we learnt some of the repetitive hand gestures can be substituted by assistive device. Therefore, we proposed the device which is a mechatronic stand that fulfills the role of the part-holding hand. The device is manipulated in two dimensions using motor control, and can help alleviate the pain from wrist, it is able handle different types of part and can be used everyday without a daily interval.

I. Introduction

Repetitive Strain Injury (RSI) is a damage or pain caused by repetitive movement or overuse [1]. Artists are at risk of contracting RSI or other forms of musculoskeletal discomfort pertaining to the wrist [2]. In this project, we targeted the population of artists using air brushes as their hobby to paint model parts. When painting model parts, users will use one hand to hold the airbrush and the other hand to hold the clip that clamps the model parts on top. Through the process, it requires users to rotate their wrist constantly to paint every side of the part while holding the part which could lead to RSI. Our project plans on addressing this problem by designing a new button controlling system that replaces the holding hand with the same function of rotating the parts.

A. Background

Fig. 1: Gunpla model painted using painting techniques focused on in this study.

Gunpla: Our focus is on the people that use airbrushes to paint their model parts, and more specifically Gunpla model parts. Gunpla is a combination of the words Gundam and Plamo. Gundam is a famous Japanese robot anime and Plamo is an abbreviation of plastic model kits [3].

Painting Setup: The airbrush will be connected to an air pump that provides air pressure to the airbrush which allows the user to paint colors **??**. On the other hand, the user will hold the parts. Normally, users do not use their hands to hold the parts because the colors could be toxic and are hard to wash off. In addition to that, users tend to paint every side of the parts from an aesthetic perspective, so users tend to hold the part on a rotatable item.

Hand and wrist motion: In order to paint model parts, both hands need to cooperate with each other. Since the airbrush holding hand performs complex motion [4], we focused more on the part-holding hand. In the part-holding hand, the wrist performed a combination of flexion, extension, radial deviation, and ulnar deviation to paint different sides of the model parts. And it could cause De Quervain Tenosynovitis, also known as radial styloid tenosynovitis, a condition which involves tendon entrapment affecting the first dorsal compartment of the wrist [5]. With the De Quervain Tenosynovitis, the user will feel pain when grasping the object, turn wrist, or even holding a fist [5].

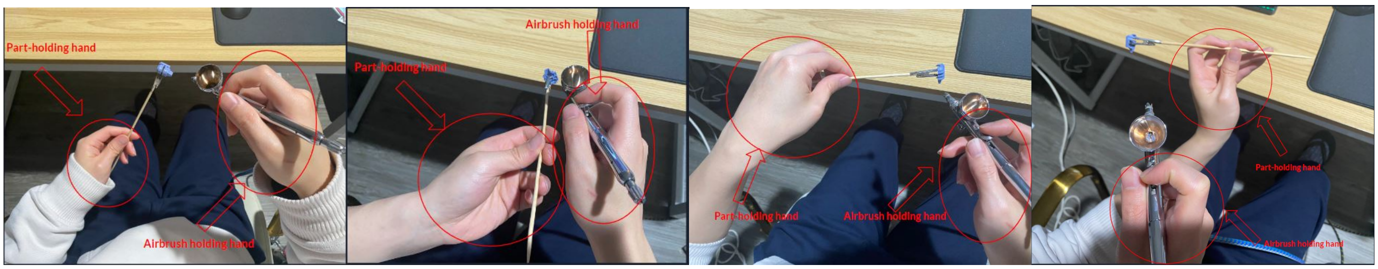

Fig. 2: Different part-holding positions

Based on our research, in the current market there are no products that fulfill the requirements of using less wrist, in the meantime of painting all sides of the model parts. From the functionality perspective, a rotatable platform or a stationary holding platform is available in the current market, however, it could only allow the user to paint model parts in limited sides (not including the bottom and back side); On the other hand, a wrist brace is available in the market, but limit the motion of the wrist that lead to low quality of the painting work. Our goal in this project is to design a system that can fulfill both requirements and can be used multiple times in a day.

B. Overview

We hypothesize that a system with 2 degrees of freedom, imitating the flexion and rotation motions of the wrist, will allow users to paint all sides of the parts without largely moving the airbrush hand. In section II, we summarize the Interview data and generate important information for our design purpose and direction. In section III, we talked about our design and testing methods. In section **??**, we talk about intellectual merit of our project and followed by section V which gives a broad impact of our project.

II. Interview case study

Before designing the prototype, our team interviewed a need-knower who has over ten years of model painting experience. The need-knower paints on a weekly basis and often participates in the Gunpla Builder World Cup (GBWC). A 50 minutes face-to-face interview was conducted to understand more about the painting process and the possible difficulties within it.

During the whole interview, interviewers tried to get the insights of how the painting process is like as outsiders, and adjusted the questions set up prior according to the interviewee's description and reactions. Throughout the interview, the team extracted requirements for the device that help with Gundam painting and relieving the possible pain or soreness. From the interview, the highest ranking criterion for the proposed device, the Newtype Painting System (NPS), was as follows:

- NPS can rotate the parts for painting
- NPS can help alleviate the pain from wrist
- NPS can handle different types of part

- NPS can be used everyday without a daily interval
- NPS will not limit the movement of elbow

Direct interview quotes may be found in Appendix B-1.

Through the interview the team successfully understood the painting process more, what position is being used, and where the movements mainly are. The interviewee also brought the airbrush to the interview, and let the team use it directly, to get the first-hand experience. Through the hands on experience, the team learned that airbrush did not weigh as heavy as they expected, and the airbrush trigger jam is something that can be handled with small finger adjustments, and does not need to be addressed by the device. The team also generated more questions through using the airbrush in person.

After asking the series of questions prepared beforehand and generated during the interview, the team learnt that interviewee does not think the paint brush need to be changed at all. The back pain does exist in the process, but the forearm pain is the one that really needs to be handled. Therefore, a device that assists holding the part would be ideal. The final expectation for the device is that it can **rotate the parts for painting,** help **alleviate the pain from wrist,** it is able to **handle different types of parts** and can be **used everyday without a daily interval.** At the same time it **should not limit the movement of the elbow.**

III. Proposed Device & Test Methods

A. *Proposed Device*

Our device is a mechatronic stand that fulfills the role of the part-holding hand. The device is manipulated in two dimensions using two buttons, with one button correlating to spinning the fixed DC motor, and the other button to the mounted DC motor. The purpose of this is to imitate two functions of the user's wrist when manipulating a model part: flexion and rotation [6]. The device will also be able to sustain the weight of an average model part, as well as be able to have a clip fixed to the mounted motor shaft.

The device required design of three custom parts, as seen in Figure 3. The design motivation was to create supports that are lightweight enough for the motor to handle, while also sturdy enough to support the weight of the motors and model parts.

Our current wiring configuration, Appendix B2, uses two axes of movement. These axes are covered by two different DC motors. An important design decision made by our team was to restrict motor rotation to one direction; although the DC motors are both capable of multidirectionality, we wanted to maintain a level of that tactile input of touching the painted part, which was emphasized as important by our need-knower. In addition, repetitive button-pressing is a cause of RSI, and we wanted to have a balance between manual and button-driven control for the user. As a result, the user must backdrive the y-axis motor manually.

B. *Test Methods*

Our group plans to submit our testing protocol to the Internal Review Board for the Protection of Human Subjects. Additionally, each member of our group has completed the CITI Training for Group 1 Biomedical Research Investigators.

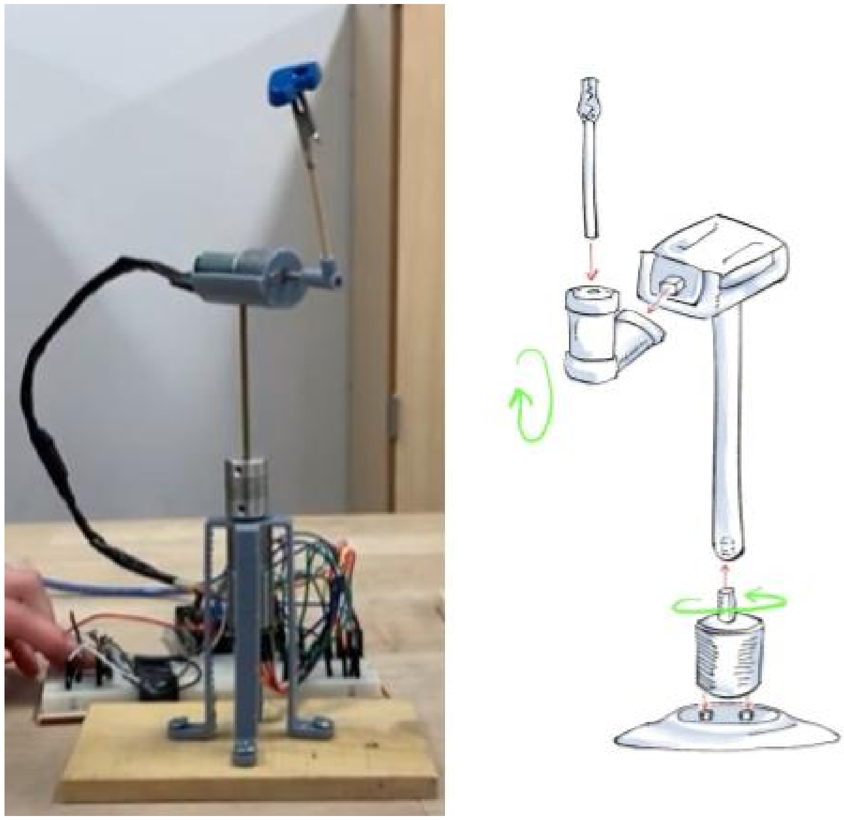

Fig. 3: Final device design and exploded diagram of the initial device design.

1) Phase 1: Interfacing with Client: Following the construction of our final device prototype, our team plans to reach out to our initial client for a round of in-person testing of the device. The goal of this test phase is to observe how well the device meets the desired functions initially outlined by our client during their interview. The testing phase would involve the test subject painting a part under the following conditions:

- Holding the part in their hand, utilizing all wrist motion (base case)
- Single axis rotation (x-axis) with part mounted on device
- Single axis rotation (y-axis) with part mounted on device
- Dual axis rotation with part mounted on device

2) Phase 2: Designing Protocol for Voluntary Research Trial: Because the device is meant to mimic functions of the human wrist, we looked to studies of wrist movement to use in a trial with volunteers. This trial would utilize motion capture technology to track wrist motion. Following the trial, the test subject will respond to a survey focused around the following factors pertaining to our device:

- Ease of use
- Ergonomic benefit
- Painting quality

3) Optional Phase: Open Survey Form: Depending on the outcome of the client and research trials, our team may pursue reaching out to a larger user base with an online survey. The purpose of the survey would be to quantify the importance of each of our design's attributes; the results may allow us to fine-tune aspects of our device based on the priorities of the larger populace. In order to maximize the survey's effectiveness, the survey would be shared to model building web communities.

IV. Intellectual Merit

The device developed by our team is unlike totally automatic painter, we still keep the aesthetic joy that painting contains. Also provide a interactive experience that model painters could enjoy during the painting process. This interaction is the novel part of this design, keeping painting still be a fun task but in a less tiring way. If the hypothesis is true, the design can be extended to other kinds of similar hobby, reducing the repetitive strain injury. The gap in this design is the function of the device is very specific to model support, if more time is given improvements can be done on extending the design functions to be more variable and diverse.

Future work can be done to improve the interactive experience between the user and the device, or extend the use of the painting support to other activities. Example might be using a interactive wearable glove to substitute the Arduino controller we are using, giving the user a more immersive experience and quicker feedback.

V. Broader Impact

The device designed by our group give an example of how people who don't have many physical difficulties can use assistive device in the daily life. The design of the device can include other activities aside of the airbrush painting, giving people inspirations to use assistive device for substitution of repetitive strain injury. Giving people the opportunity to liberate their hand and ease the possible pain and soreness in their daily activities. The design is not only targeted at a small specific group of people but instead includes all the people seeking for a solution for the repetitive work that might exist in the daily activities. Furthermore, it shows the opportunity that technology or automation can be combined with our daily activities, and the innovation is not as expensive as people might imagine of. Overall our design is an illustration of how interactive assistive design can exist in people's daily life, and more exploration can be found in the future with the study of human hand gesture and movements to develop products that help to relief the pain and soreness in the repetitive daily activities.

References

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[2] C. M. S. Dana L. Keester, "Investigation of musculoskeletal discomfort, work postures, and muscle activation among practicing tattoo artists," *Applied Ergonomics*, vol. 58, pp. 137–143, 2017.

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[5] S. C. T. Ellen Satteson, "De quervain tenosynovitis," *National Library of Medicine*, 2023.

[6] D. M. R. G. AK Palmer, FW Werner, "Functional wrist motion: a biomechanical study," *Journal of Hand Surgery*, vol. 10, no. 1, pp. 39–46, 1985.

Appendix A
Discovery Decomposition

Topic of the interview: Repetitive strain injury

1) Repetitive strain injury: [1]

- Background/Hypothesis: The article focuses on repetitive strain injury (RSI), which is a common condition that affects individuals who perform repetitive activities. The authors aim to provide an overview of RSI, its causes, symptoms, and treatment options.
- Methods: The authors reviewed various studies and literature related to RSI and its management. They also discussed the various factors that contribute to the development of RSI, including biomechanical, psychosocial, and occupational factors.
- Results: The authors found that RSI is a common condition that affects a wide range of individuals, including office workers, musicians, and athletes. The most common symptoms of RSI include pain, numbness, and weakness in the affected area. The authors also found that early intervention and treatment are crucial for managing RSI effectively.
- Conclusion: RSI is a complex condition that requires a multidisciplinary approach for its management. They emphasized the importance of early intervention, proper diagnosis, and individualized treatment plans for individuals with RSI.
- Test Hypothesis: Early intervention and individualized treatment plans are effective in managing RSI.

2) Investigation of musculoskeletal discomfort, work postures, and muscle activation among practicing tattoo artists,: [2].

- Background/Hypothesis: Musculoskeletal discomfort experienced by tattoo artists during their work. The authors hypothesize that the work postures and muscle activation patterns of tattoo artists may contribute to their musculoskeletal discomfort.
- Methods: The authors conducted a study involving 14 practicing tattoo artists. The participants' work postures and muscle activation patterns were assessed using motion capture technology and electromyography. The participants also completed a survey on their musculoskeletal discomfort.
- Results: Tattoo artists frequently experienced musculoskeletal discomfort in the neck, shoulders, and upper back. They also found that the participants' work postures and muscle activation patterns were associated with their musculoskeletal discomfort. Specifically, prolonged periods of working with the arm elevated and the head tilted forward were associated with increased discomfort in the neck and shoulders.
- Conclusion: The work postures and muscle activation patterns of tattoo artists may contribute to their musculoskeletal discomfort. Author recommended that tattoo artists take breaks, stretch regularly, and use ergonomic equipment to minimize their discomfort.
- Test Hypothesis:The work postures and muscle activation patterns of tattoo artists are associated with their musculoskeletal discomfort.

3) What is gunpla: [3].

- Background/Hypothesis: The article provides an overview of Gunpla, which is a popular hobby among anime and mecha enthusiasts. The author aims to explain what Gunpla is and why it is so popular.
- Methods: Provides information on Gunpla through a blog post
- Results: The author explains that Gunpla is a type of plastic model kit that allows individuals to build their own miniature versions of mecha robots from various anime and manga series. The kits come with various pieces that can be assembled together to create a detailed model. The author also notes that Gunpla is popular because it allows individuals to express their creativity and engage in a hands-on hobby.

- Conclusion: Gunpla is a unique and engaging hobby that allows individuals to express their creativity and passion for mecha and anime. The author also notes that Gunpla has a strong community of enthusiasts who share their work and techniques online.
- Test Hypothesis: Gunpla is a popular hobby among anime and mecha enthusiasts because it allows individuals to express their creativity and engage in a hands-on hobby.

4) Wrist Motion: [6].

- Background/Hypothesis: The article focuses on the biomechanics of wrist motion and aims to provide a better understanding of the functional range of motion of the wrist joint.
- Methods: The authors conducted a biomechanical study of the wrist joint using cadaveric specimens. The specimens were positioned in a testing apparatus, and various wrist motions were simulated while measuring the range of motion and the forces involved.
- Results: Wrist joint has six degrees of freedom, allowing for complex motions in multiple directions. They also found that the range of motion varied depending on the direction of the motion. For example, flexion and extension had a greater range of motion than radial and ulnar deviation.
- Conclusion: Wrist joint is a complex and versatile joint that allows for a wide range of motions. They also noted that understanding the biomechanics of the wrist joint is important for the diagnosis and treatment of wrist injuries.
- Test Hypothesis:The wrist joint has six degrees of freedom, allowing for complex motions in multiple directions, and understanding the biomechanics of the wrist joint is important for the diagnosis and treatment of wrist injuries.

5) AirBrush Introduction: [4].

- Background/Hypothesis: The article talks about technique using Airbrush.It describes the components of an airbrush, including the air compressor, airbrush gun, and the paint reservoir. The article also covers the different types of airbrushes available, including single-action and dual-action models. It concludes with some tips for beginners on how to get started with airbrushing, such as practicing with water first and maintaining a consistent distance from the surface being painted.
- Methods: The author shows the detail of the airbrush by providing details of the airbrush and also pictures of airbrush components.
- Results: Though Airbrush looks small and simple to use, it actually have varies types of airbrushes, and have different techniques to perform different effects. And it is hard to master airbrushes with different techniques.

6) De Quervain Tenosynovitis: [5].

- Background/Hypothesis: De Quervain tenosynovitis, a condition characterized by inflammation of the tendons and the synovial sheath that covers them in the wrist. The authors describe the anatomy of the wrist and thumb tendons involved in the condition, and the typical signs and symptoms, which include pain, swelling, and difficulty with grasping or pinching objects. The article also discusses the risk factors for developing De Quervain tenosynovitis, such as repetitive or forceful use of the thumb, pregnancy, and certain medical conditions.
- Methods: The author uses a descriptive method to explain De Quervain tenosynovitis, which involves providing detailed information about the condition, including its symptoms, risk factors, diagnosis, and treatment options. The author also emphasizes the importance of prevention and provides recommendations for avoiding and managing the condition.
- Results: The authors highlight the importance of an accurate diagnosis, which can usually be made based on the clinical presentation, and may be supported by imaging studies. Treatment options for De Quervain tenosynovitis include nonsteroidal anti-inflammatory drugs (NSAIDs), splinting or immobilization of the wrist and thumb, corticosteroid injections, and in some cases, surgery.

APPENDIX B
INVESTIGATIONAL DEVICE DETAILS

1) Bill of Materials:

- Arduino Uno (1)
- Dual MAX14870 Motor Driver Shield (1)
- Solderless Breadboard (1)
- Button (2)
- Arduino (1)
- 156:1 Metal Gearmotor 20Dx44L mm 12V CB with Extended Motor Shaft (2)
- Magnetic Encoder Pair Kit for 20D mm Metal Gearmotors, 20 CPR, 2.7-18V (2)
- 12V Power Supply (1)
- 1K Ohm Resistor (2)
- Jumper Wires

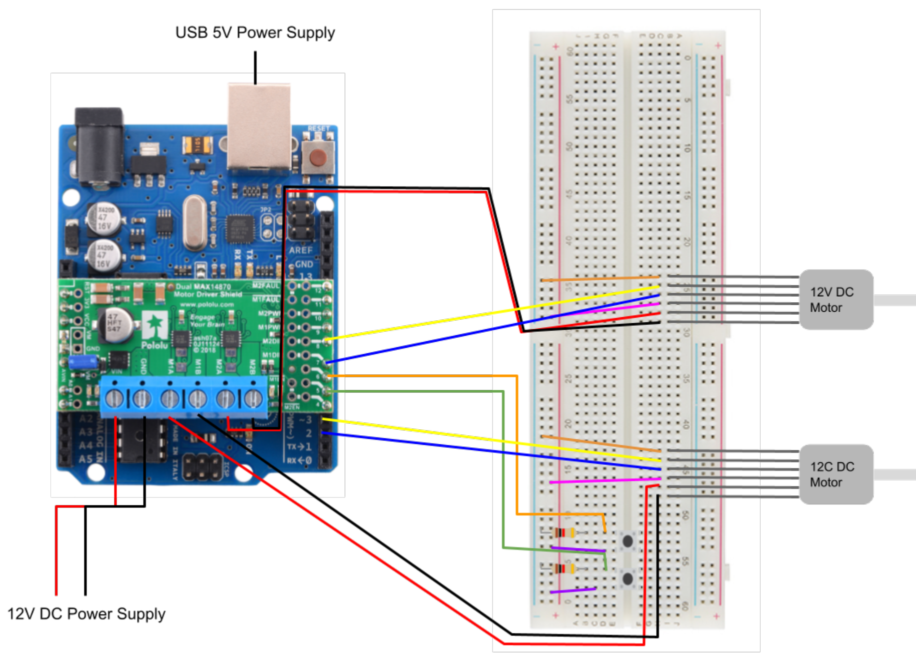

Fig. 4: Wiring diagram for dual-motor tactile button control

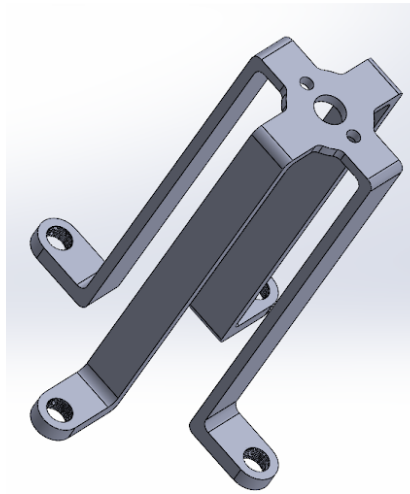

Fig. 5: Bottom holding part CAD

Fig. 6: 3D printed Bottom holding part

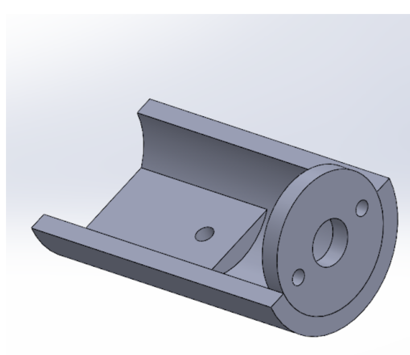

Fig. 7: Motor holder CAD

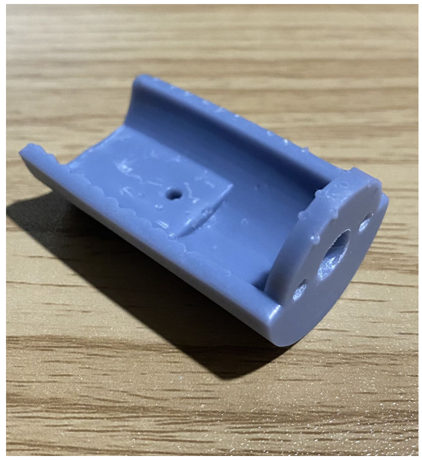

Fig. 8: 3D printed motor holder

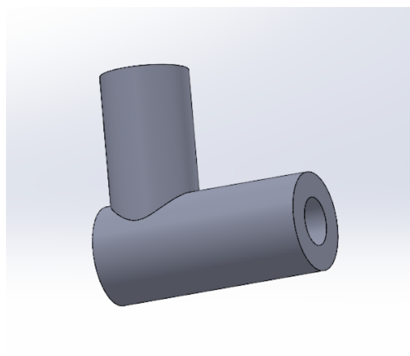

Fig. 9: Connector CAD

Fig. 10: 3D Printed Connector

Prompt/Theme	Interview statement	Interpreted need
Experienced fatigue	‘After a few hours I can feel the weight of the airbrush.’	The airbrush should be lighter to reduce fatigue.
	‘I stop painting when my arm gets tired.’	The user needs to stop pain that prevents from continuing the painting process.
	‘I take 20-30 minute breaks and stretch when my arm hurts’	Pain can be alleviated from breaks and stretches.
	‘A device that helps stop the pain in my forearm would be helpful.’	The user needs to stop pain that prevents from continuing the painting process.
	‘My arm gets sore, but its my lower back that needs to be stretched the most after painting.’	The arm and lower back need to be alleviated from pain.
	‘Back hurt is long term, while the forearm feels sore’	Back hurt is like daily activity, what needs to be addressed is the forearm soreness.
	‘Elbows usually fixed (triangulation on table). Elbows can move if I hold the part up, etc.’	The elbows can’t be restricted during painting.
	’Finger hurt Little bit Push on the sticky trigger so you have to push/pull harder Fingernails for trigger Hurts on pad of finger where it makes contact with trigger	When the trigger is sticky, the index and thumb fingertips hurt.
Airbrush Usage	’If a device can help me to paint the parts that would be perfect’	Airbrush painting is still a tough process.
	’I am okay with the current holding method.’	The pencil grip is good.
	’I would say small piece [are the most difficult to paint], because it is easily over painted ’	Painting small pieces is more difficult.
	’Big parts that were not hold by the clippers [require me to change motions]. So I need to wait one side to dry and turn into another side’	Different parts will need to be handled differently and might require extra work.
	’Sometimes, when there is a speciality in the painting like parts are too large or waist hurt.’	Special parts require extra work and make users tired faster.
	’It does not have to be totally stable but somewhat stable is good enough, it take practice.’	Need to practice to keep stable.
	’I wouldn’t use the ‘gun’ hand grip.’	All needs are based on the pencil grip.
	’Holding the rod or the pencil, nothing to do with the fingers Rotating the part is all in the wrist.’	Moving the part almost exclusively uses wrist motion.

TABLE I: Customer Needs

Listing 1: Arduino Uno Code

```
/*
  This code is derived from original code developed by Arnaud Bard de Coutance and ...
      Hannah Stuart from the example provided in the DualMAX14870MotorShield library
*/

// Include Libraries ------------------------------------------------------------
#include <DualMAX14870MotorShield.h> //downloaded from link on the pololu website

// Define variables -------------------------------------------------------------
#define readA bitRead(PIND,3)//faster than digitalRead()
#define readB bitRead(PIND,2)//faster than digitalRead()
#define readC bitRead(PIND,9)//faster than digitalRead()
#define readD bitRead(PIND,8)//faster than digitalRead()
#define LED_PIN 13 // Pin 13 is associated with the "L" led near pin 13. You can turn it ...
    on and off in this script.

const byte encoderPinA = 3;//encoder output, channel A, digital pin2
const byte encoderPinB = 2;//encoder output, channel B, digital pin3
const byte encoderPinC = 9;//encoder output, channel A, digital pin2
const byte encoderPinD = 8;//encoder output, channel B, digital pin3
volatile int count = 0; //current number of total encoder counts from both A and B channels
int motorState = 0; // variable for turning motor on and off
int lastMotorState = 0; // variable to keep record of the last state
String report = ""; // string sent to computer terminal via seria communication

DualMAX14870MotorShield motors;

// Function Definition ----------------------------------------------------------
void stopIfFault() // this function is setup to provide a flashing led warning if a ...
    driver fault is triggered, such as over-temperature
{
  if (motors.getFault())
  {
    while (1)
    {
      digitalWrite(LED_PIN, HIGH);
      delay(100);
      digitalWrite(LED_PIN, LOW);
      delay(100);
    }
  }
}

void isrA() { //increment or decrement the encoder count if channel A changes
  if (readB != readA) { // if A and B are not equal
    count ++; //increment
  } else {
    count --; // or else decrement
  }
}

void isrB() { //increment or decrement the encoder count if channel B changes
  if (readA == readB) { //if A and B are equal (high or low)
    count ++; //increment
  } else {
    count --; //or else decrement
  }
}

void isrC() { //increment or decrement the encoder count if channel B changes
  if (readD != readC) { //if A and B are equal (high or low)
    count ++; //increment
  } else {
    count --; //or else decrement
```

```
  }
}

void isrD() { //increment or decrement the encoder count if channel B changes
  if (readC == readD) { //if A and B are equal (high or low)
    count ++; //increment
  } else {
    count --; //or else decrement
  }
}

// Setup -----------------------------------------------------------------------
void setup() {

  Serial.begin (115200); // set the baud rate, this must be matched in your terminal ...
      settings
  pinMode(LED_PIN, OUTPUT);   // initialize the LED pin as an output

  pinMode(encoderPinA, INPUT_PULLUP);
  pinMode(encoderPinB, INPUT_PULLUP);
  pinMode(encoderPinC, INPUT_PULLUP);
  pinMode(encoderPinD, INPUT_PULLUP);

  attachInterrupt(digitalPinToInterrupt(encoderPinA), isrA, CHANGE); //encoder channel A ...
      initialization
  attachInterrupt(digitalPinToInterrupt(encoderPinB), isrB, CHANGE); //encoder channel B ...
      initialization
  attachInterrupt(digitalPinToInterrupt(encoderPinC), isrC, CHANGE); //encoder channel A ...
      initialization
  attachInterrupt(digitalPinToInterrupt(encoderPinD), isrD, CHANGE); //encoder channel B ...
      initialization

  motors.enableDrivers(); //initialize motor driver, including timer frequencies -- note ...
      you want this to be above audible range
}

// Main loop -------------------------------------------------------------------
void loop() {
  //stopIfFault(); //if there is ever a motor fault, the pin 13 led will start flashing
  if (bitRead (PIND, 5) && bitRead (PIND, 6)) {
    digitalWrite(LED_PIN, HIGH);
    motors.setM1Speed(0);
    motors.setM2Speed(0);
  }

    else if bitRead(PIND, 5) {
      digitalWrite(LED_PIN, HIGH);
      motors.setM1Speed(150);
    }
    else if bitRead(PIND, 6) {
      digitalWrite(LED_PIN, HIGH);
      motors.setM2Speed(150);
    } else {
      digitalWrite(LED_PIN, LOW);
      motors.setM1Speed(0);
      motors.setM2Speed(0);
    }

  }
```