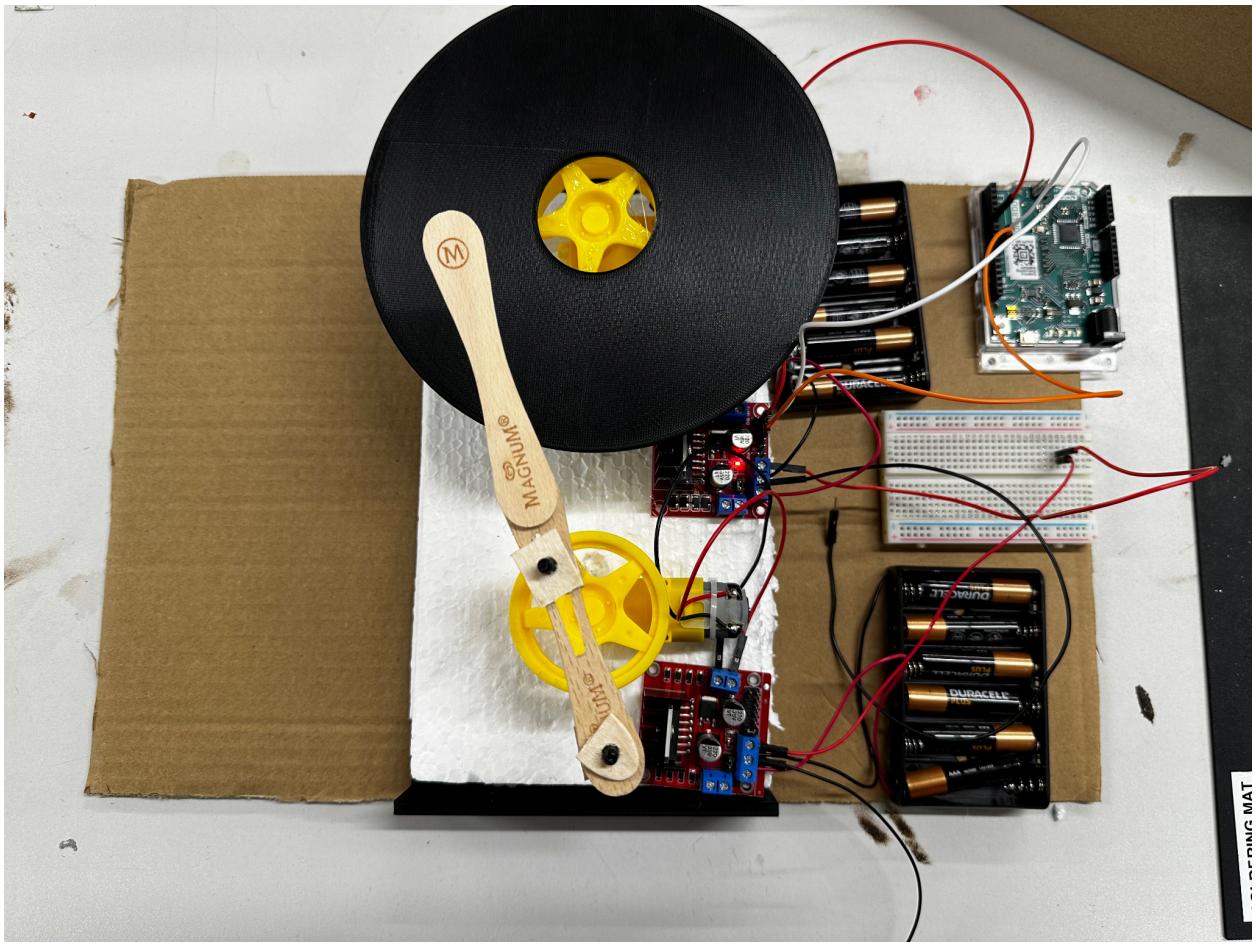
# Circular Motion Drawing Machine made with Arduino

*Made by Andrii Artemenko, BSc CCI student ( 1st year )*




# Video at Youtube:

https://www.youtube.com/watch?v=agd0HM6mXiM
Link

# Part 1: Inspiration & Research

Originally, I wanted to create a pen-plotter CNC machine with Arduino as making an automated art-making machine has been an exciting topic for me. I have seen videos on Instagram of machines that make analog art using pen or pencil, or machines that can ‘hand-write’ paragraphs of text.

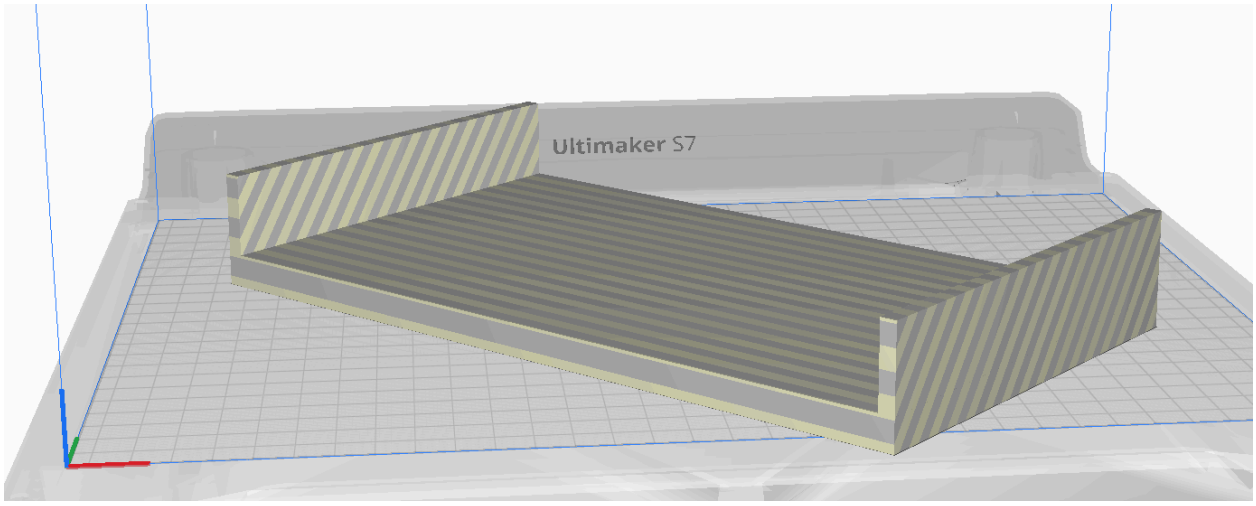
However, after doing some research online such as watching and reading tutorials, and consultations with my tutor and technical specialists at CCI I realized that this project may be too ambitious, complex and potentially very confusing, as I have been told that there are CNC pen-plotters in the lab, but even the technicians struggle with them and hardly anyone understands how to work with them; so I decided to take a different approach and made an additional research on the topic of the automated art and I came across a method of making automated patterns with the use of rotation and periodic motion. This tutorial combines the principles of spirograph and physical computing, using hardware particles such as gear motors, motor drivers and arduino.
Youtube video that I took an inspiration from:
https://www.youtube.com/watch?v=MKkzr9VueqI&t=86s&ab_channel=SriTuHobby
However, I have to point out that I only used it as an inspiration and a sort of foundation for my project, as I had to make my own 3d models, design my own base and element placement, use different set of tools, use somewhat different electronics and actuators, write my own code for it etc. I do not consider it a complete tutorial actually, as the code provided in it did not work as well.

# Part 2: Process Pt 1 - Material considerations and 3D-modeling // Digital Fabrication

The process of choosing materials for the project was somewhat non-linear for me, as I had to iterate my design and experiment, so I had to get rid of some materials for example, for my final prototype, or add new materials.
The basic and most fundamental particles of my project are:

1. Arduino board x1
2. Adafruit gear motor x2
3. Wheels for gear motors x2
4. Motor driver L298 x2
5. Foam sheets
6. Breadboard
7. Wires
8. 3D-printed holding sticks
9. 3D-printed base
10. 3D-printed disk
11. Cardboard
12. Popsicle sticks

To make the base of my machine more stable, transportable and organized I designed a plastic holder that has a bottom side and 2 closed sides. I specifically left out free space on the longer sides of my base so I can have easier access to the components and rearrange my prototype if needed, which would be hardly doable if it was a box-like base.




I made the design in Fusion 360, exported it to the .STL file and sliced it to Black PLA with Ultimaker Cura before actually printing it out.
I measured my foam sheets beforehand and made sure that the distance between the

top and the bottom side of the 3D-printed base will be enough to put 2 sheets of the foam inside it.

I also printed out a circular disk for myself, because I did not have a CD disks available so it was easier to make it myself.

I also printed out my holding sticks, as I did not have access to the welding workshop and did not have anything to use as an alternative to what was presented in the video I used as my inspiration, so I decided I may as well make my own sticks from thicker PVA material with a higher printing density. However, later it turned out that even thick plastic is not a good enough alternative to the iron sticks in terms of stability and holding power, but I did not know that at the time.

In terms of my 3D-designing I followed a simple pathway

1) make a 2d-sketch using simple shapes such as rectangles, ellipses, etc. Use tools like offset or combine if needed
2) check all the dimensions and measure them as needed. Do research. For example for my disk and holding sticks I had to google what is the diameter of CD-disk, and iron sticks respectively, as precision is important at 3D-modeling
3) extrude 2D sketch into a 3D model
4) make sure the model stands stable at the ‘ground’ and not floating in space. There should be no gaps, unstable elements etc. otherwise the print will be ruined
5) export to .STL file

Then I had to familiarize myself with Ultimaker Cura software, which helps to convert stl models into some form that a 3D-printer can actually print. I basically had to make sure that all the parameters for the model I slice match the printer I am using and the material available.

To actually use the printers I also did a 3D-printing and laser-cutting induction where the technician has helped me to learn how to use 3D-printers and laser-cutting machines at the Digital Fabrication Lab. Overall, I had previous experience from my last year when I was doing the Product Design course, so I had a foundation in Digital Fabrication. This made this part of the project slightly easier for me, as I had used Fusion 360 before and it may have taken me less time, in comparison to the other students.

# Part 3: Process Pt 2 - Physical Design

In this Part I will outline my process of physical design step by step

Step 1: When my 3D prints were finished, I took my printed plastic base and attached 2 foam sheets to it using a hot glue gun. I had to measure the parameters of the base as well, and cut foam pieces to the accurate size. I put two sheets for extra support as well.

I am using foam as a main surface to attach my L298 drivers and gear motors on top of it because it is easy to pin the surface of the foam and/or make holes in it if needed for the project, and glue parts to its surface. My original plan was to place all the components to the foam sheet but unfortunately later I discovered that they do not fit nicely, plus I had to use battery holders as well so I had to attach a piece of cardboard on the side as well, but I will get to that later.

Step 2: Then I marked the central line of the foam sheet and made holes for my gear motors ( so that the motor can spin freely ). I took the measurements from the inspiration video but I also adjusted it to my disk size a little. It was important to make sure that the distance between the two gears is big enough to ensure that the radius of the gear is slightly less then the distance between two gear motors.

Step 3: When I placed and glued the gear motors, I then placed spinning wheels on top of them and attached a disk to the first wheel using a glue gun.

Step 4: I then placed L298 drivers next to each spinning motor and connected the black wire from the motor to GND ( when I order on amazon gear motors came already with attached ground and power wires on them ),  and hot ( live ) wire to the +5V pin of L298 motor drivers

Step 5: I then took my 3D-printed holding sticks. One stick is 10 cm ( the one that should be connected to the foam directly ), and another one is 5 cm ( the one that goes on the second wheel ). I used a hot glue gun to attach them.

Step 6: I had to make a wooden stick that holds and controls the movement of the pen. To make one I had to use 3 ice-cream popsicle sticks, because I only had mini popsicle

available to me at the time. I had to make one hole at the beginning of the popsicle and a longer hole at the diameter of the second wheel to ensure that while it rotates, the shorter holding stick attached to the second wheel can move freely along its diameter of rotation. So I used a drill and a cutting knife to drill the holes. When I was done with that I also had to make 4 smaller wooden pieces that would hold the popsicle ‘hand’ from both bottom and the top, preventing it to slip out during the motion

Step 7: I also had to attach one popsicle to another to make it longer, as I had to also reach the center of the disk. At this point my main part of the physical work was done, but I also had to figure out how to

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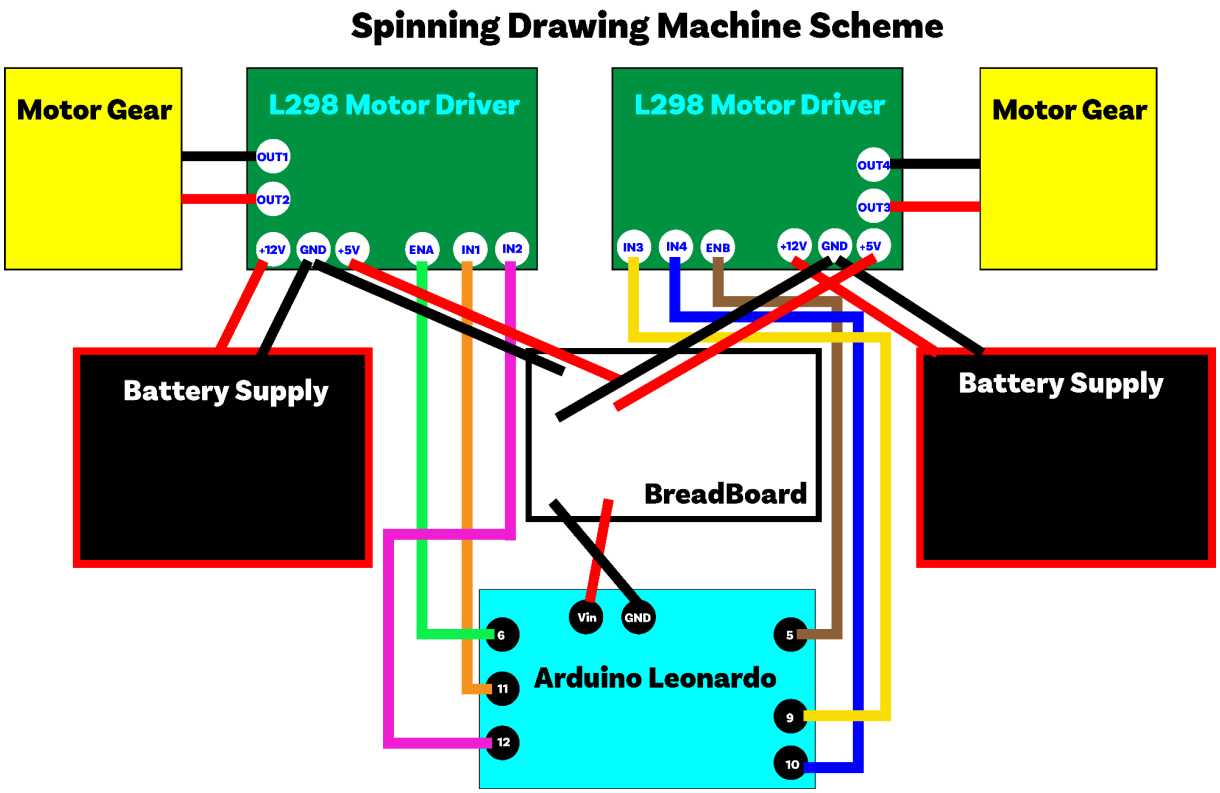
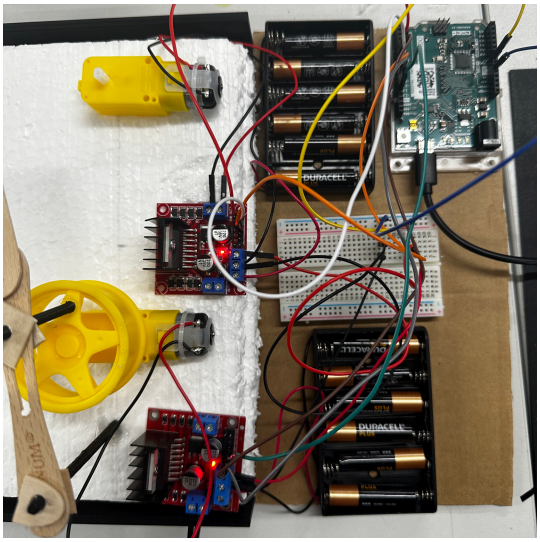
# Part 4: System Design and Technical specification




Here is a diagram of my circuit ( that I made in Adobe Illustrator ) which shows how the parts of the circuit are connected to each other



This project has taught me a lot about motors, and L298 in particular. I watched some videos on youtube to familiarize myself with its structure and how it works, such as this one for example:
https://www.youtube.com/watch?v=_TEZ2-3H0GY
I figured that gear motors should be connected to the Output pins as they ( output pins ) supply them with power and control signals based on the input
The input pins however ( There are 6 : ENA, IN1, IN2, IN3, IN4, ENB ) should be connected to the Arduino board as they are needed to receive signals from the code.
+12V pin is exclusively for power supply, and moreover, if power supply is not provided then the gears will not work.
GND goes to ground but in case with L298 you have to parallel-connect it - which means that both ground for power supply and arduino board should be connected to this pin.
Lastly, +5V is used to supply logic to the motor driver and in my case both drivers connect to Vin pin on the arduino board. I also had to use a breadboard to connect both L298 drivers to the Vin pin on my board.

One of the biggest challenges for me was to figure out how to power it properly and I was stuck at my progress for a while trying to find what the problem was, because everything seemed to be fine with the code, connections, etc. So eventually I figured that my power supply was not sufficient.

I was using a barrel jack and a socket power supply at first that gave me only 5 volts and I needed something close to 12 volts, so I decided to use battery holders and AAA batteries instead. As a bonus it was easier to place them and there was no need to place my prototype close to the socket, with the battery holders it could now work more autonomously.

I was also trying to use just one L298 motor driver to power both gear motors, but eventually I decided that using each motor driver for each gear motor might be a better solution, given that with 6 AAA batteries for each battery holder I only supply 9 volts total.

# Part 5: Coding, Debugging

For the first time I was trying to run my gear motors I was trying to use a code from the tutorial video :

```
// Define motor pins
#define ENA 9
#define IN1 2
#define IN2 3
#define IN3 4
#define IN4 5
#define ENB 10

void setup() {
// Set these pins as output pins
  pinMode(ENA, OUTPUT);
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);
  pinMode(ENB, OUTPUT);
}
void loop() {
  motor1();
  motor2();
}
// Rotate the first motor
void motor1() {
// Set the speed of the motor
  analogWrite(ENA, 80);
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
}
// Rotate the second motor
void motor2() {
// Set the speed of the motor
  analogWrite(ENB, 80);
  digitalWrite(IN3, HIGH);
  digitalWrite(IN4, LOW);
}
```

Link: https://srituhobby.com/how-to-make-a-diy-circle-drawing-machine-using-arduino/

which I used as an inspiration, but I quickly figured that the code doesn't work and I had to find a solution myself. At that point I just wanted to make at least one of the gears spin, so I was trying to brainstorm it. Hopefully, I was able to talk to the technicians and they helped me to set up a working code.

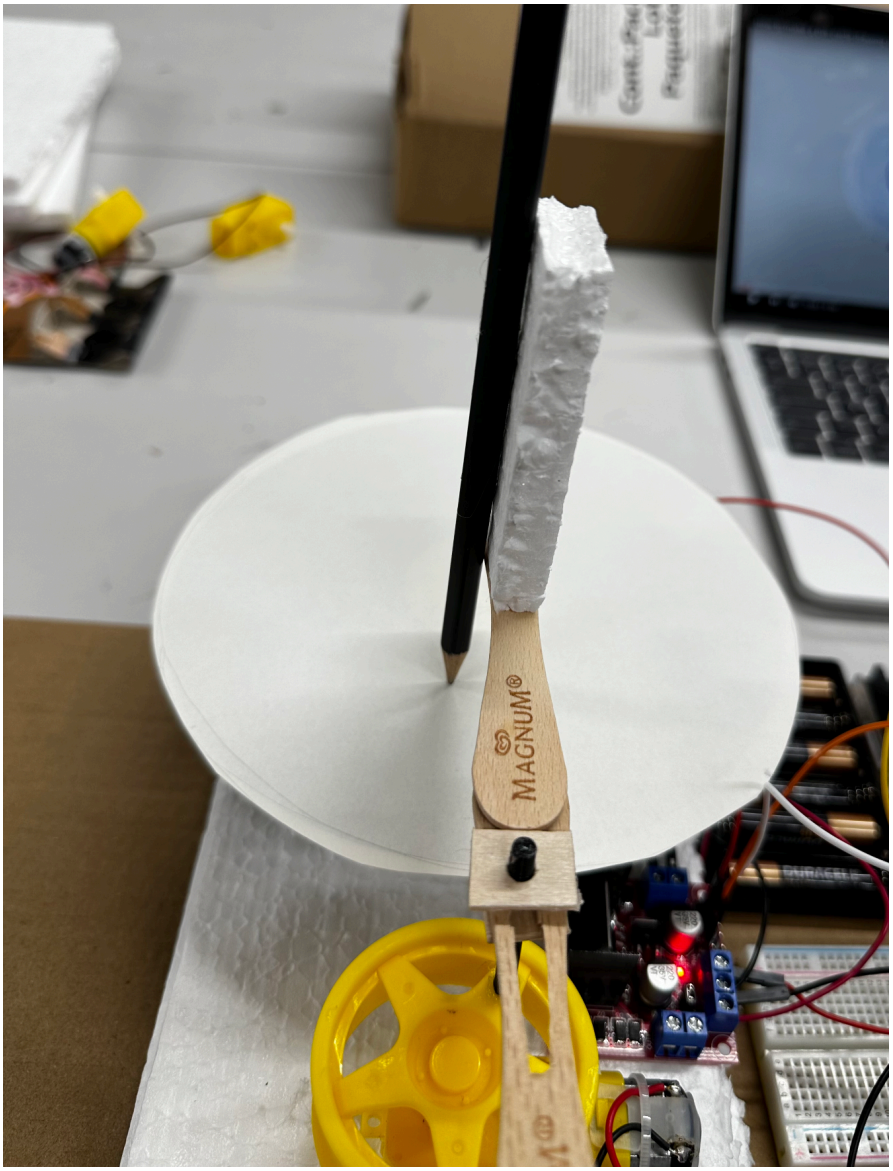
I can break it down into 3 parts:
1) defining the pins , where we assign each input pin to the digital input pin in arduino. This should be accurate according to how the pins are connected physically. I am using const int here because it helps me to debug more easily, instead of #define
2) Setup - where I define the input and output of my pins and set the initial rotation speed to zero in the //initial position part.
3) Loop - This is the part where I actually run the code and define which speed I want my gear motors to rotate with. As we have two sides of the gear motor, one of which is 'hot' wire and another one is 'ground' wire, it means that one side should be power positively ( HIGH ) and the other side should not be powered ( LOW ). As for the analogWrite - this is a PWM function that helps me to set and control the speed. Initially I set the motors to full speed at 255, but then after seeing that it spins uncontrollably, I decided to change it manually and set up the speed that is more controllable. With some trial and error I set it to 80 and 100 respectively.

```
// defining pins
const int motorIn3 = 9;
const int motorIn4 = 10;
const int motorENB = 5;
const int motorIn1 = 11;
const int motorIn2 = 12;
const int motorENA = 6;

void setup() {
 // assigning input - output
 pinMode(motorIn1, OUTPUT);
 pinMode(motorIn2, OUTPUT);
 pinMode(motorENA, OUTPUT);
 pinMode(motorIn3, OUTPUT);
 pinMode(motorIn4, OUTPUT);
 pinMode(motorENB, OUTPUT);

 // Initial Position
 digitalWrite(motorIn3, LOW);
 digitalWrite(motorIn4, LOW);
```

```
 analogWrite(motorENB, 0);
 digitalWrite(motorIn1, LOW);
 digitalWrite(motorIn2, LOW);
 digitalWrite(motorENA, 0);
}

void loop() {
 // spinning part
 digitalWrite(motorIn3, HIGH);
 digitalWrite(motorIn4, LOW);
 analogWrite(motorENB, 100);

 digitalWrite(motorIn1, HIGH);
 digitalWrite(motorIn2, LOW);
 analogWrite(motorENA, 80);

 }
```

# Part 6: Results, Evaluation and Learning Outcomes

Finally, I want to evaluate the Final Prototype that I made and what worked out well, what needs improvements and what lessons and skills I have extracted from it .




First of all, I managed to make a functioning prototype at the end which I am happy about. I made well-designed 3D-printed details that work well and perform their functions nicely. I took a personal challenge with this project and went beyond what we have covered in the class; I learned some specifications of gear motors, L298 motor driver and the principle of continuous rotation in arduino. I have made a lot of physical making and physical designs, and designed my own machine in terms of placement and connections between different parts of the circuits. I tried to run different code sequences to familiarize myself with rotation principle in coding and now I understand how to build a similar project from scratch. I have solved the challenge with the power supply and learned how to connect the power properly and what other ways I can power

my projects except from the usual socket connection. Overall I have learned a lot throughout the process and I am happy with my achievements.

However, I also want to point out things that are not perfect and could be done better in the future

1) Stability. I think this is the biggest issue so far which is quite hard to fix because to make this model really stable I need to use iron sticks instead of plastic ones, as they cannot hold the weight of the pen properly and they are not as stable under pressure in general, as iron is more stable than plastic PVA
2) Cover up the wires in a nicer way. I think it may be hard to organize them when they reach a certain limit so it would be beneficial to learn some techniques of how to place them more neatly
3) Make sure that both wheels for motor gears are at a similar level. I think currently there might be an issue with that because the pen wobbles and I see that the disk does not rotate evenly enough. That might be because hot glue gun which I used to attach the first gear motor has burnt through the foam layer and as a result the disk is placed lower than the second gear motor, which creates unevenness in the pattern
4) Additional support. It would be nice to add additional support to the structure, especially the wooden ‘hand’ made from popsicle, because it doesn’t seem very durable at the moment
5) Use the appropriate voltage from the power supply ( might be fixed with 8-battery holders but we only had 6-max holders at CCI lab unfortunately ), and only use one L298 driver to reduce the space needed