3-Axis Machine for Wound Imaging and Plasma Medicine

ME 195B Final Presentation

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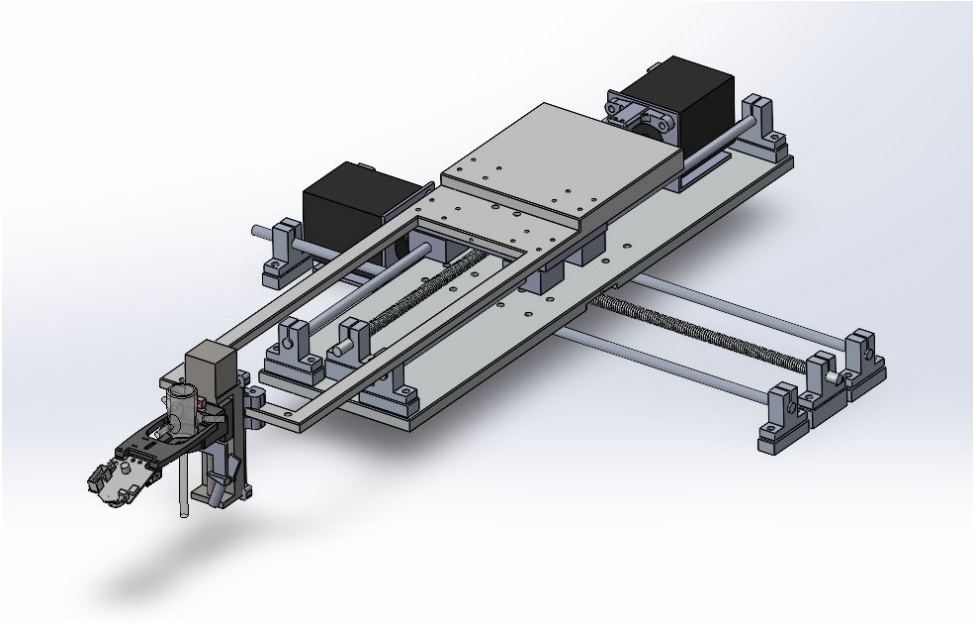


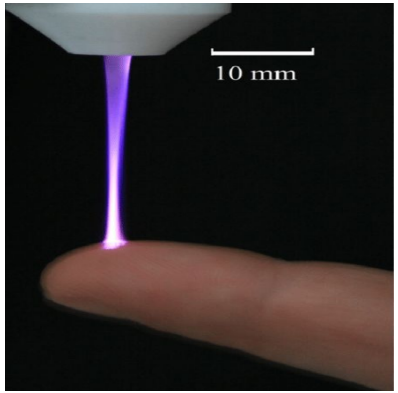
Background

- Insufficient/improper patient wound sanitization.
- Increase in wound infection rates.
- Prolonged recovery times with patient wound healing.
- Inconsistencies with patient wound sanitizations due to human error.
- Shortage in antiseptic products post covid.

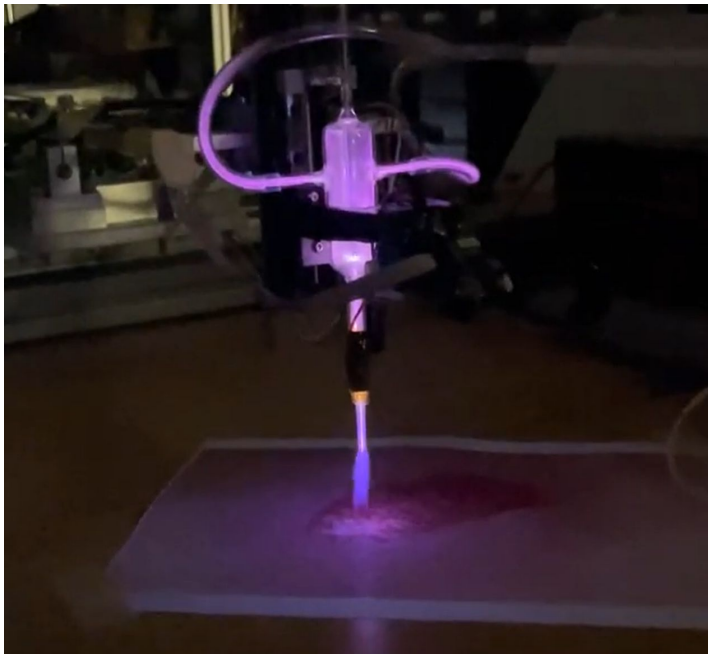
How Do You Treat a Wound That Won't Heal . 10 Oct. 2022. *Result Integrative Medical Centers*.

Motivations and Social Impacts

- Provide patients with proper, high quality wound sanitization.
- Ensure accurate, precise, and consistent wound coverage.
- Provide patient a relatively painless experience.
- Reduce wound recovery time for patient



Topala , Lonut. *The experimental arrangement scheme of the plasma jet source and the photography of a human finger under direct atmospheric pressure plasma jet.* Mar. 2011. *ResearchGate.*



Literature Review: Wound Sanitization

Michaels, Coleen. *Isopropyl alcohol and hydrogen peroxide in a medical cabinet with cotton balls.* Mar. 2020. *Dreamstime*.

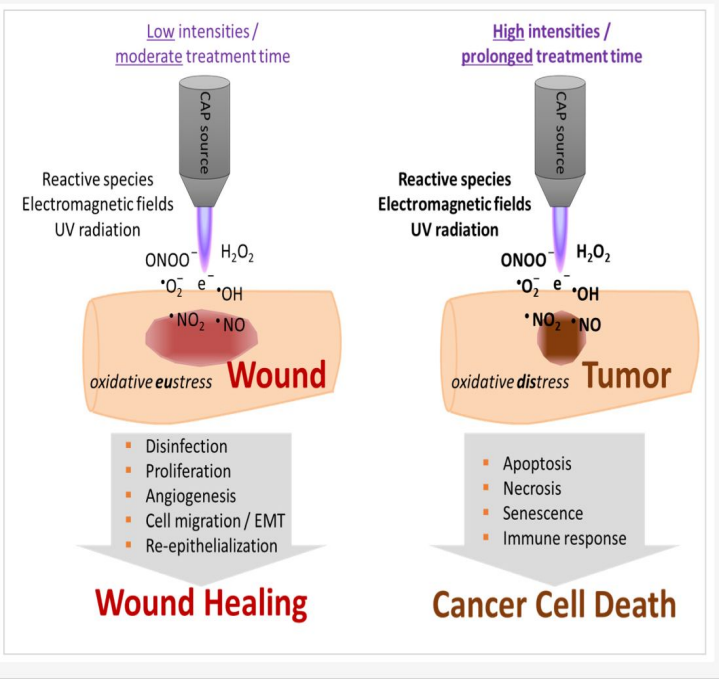
Advantages

- Quick and easy sterilization
- Over the counter products
- Does not requires personnel training

Disadvantages

- Kills bacteria and skin cells
- Typically an unpleasant experience to the patient
- Inconsistent product application to the wound
- Excess product causes further damage

Literature Review: Cold Atmospheric Plasma



Applied Sciences | Free Full-Text | Cold Atmospheric Pressure Plasma in Wound Healing and Cancer Treatment (mdpi.com)

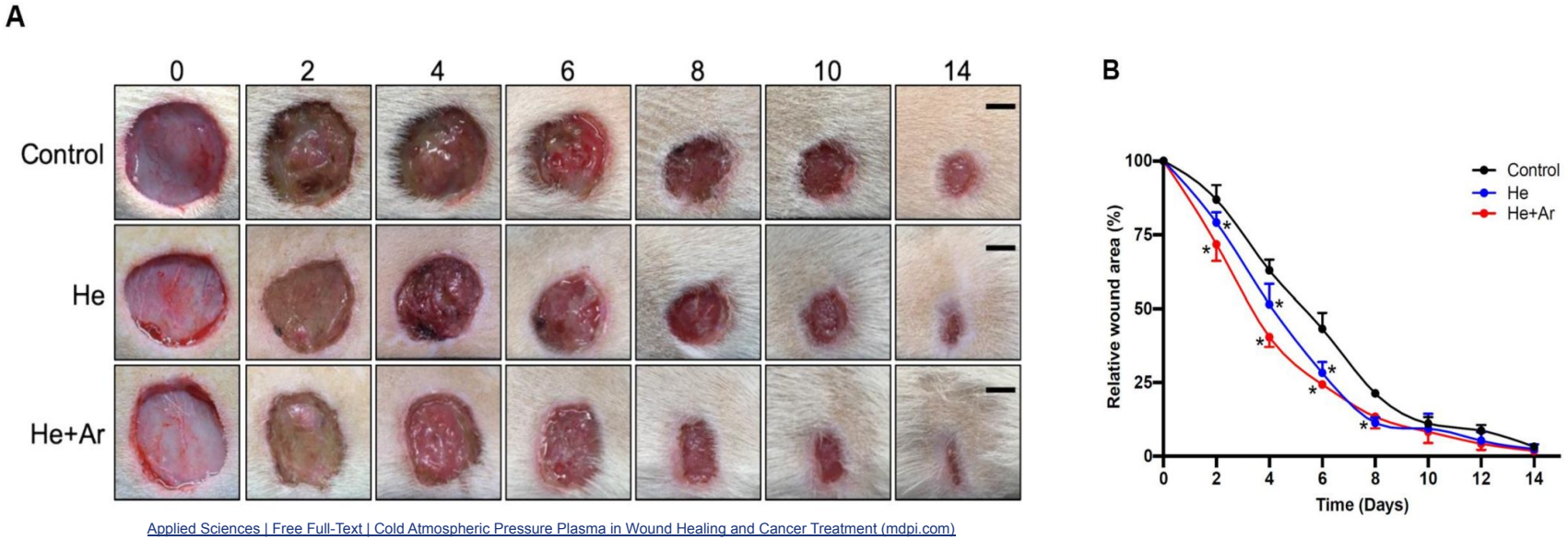
Advantages:

- Kills and reduces microorganisms/bacteria
- Promotes tissue regeneration
- Promote tumor regression

Disadvantages:

- Gas mixtures affect plasma performance
- High concentration and duration of plasma may cause damage
- Plasma exceeding 40°C damages wounds

CAP Treatment vs. Control wound recovery comparison



Applied Sciences | Free Full-Text | Cold Atmospheric Pressure Plasma in Wound Healing and Cancer Treatment (mdpi.com)

Literature Review: Mechanism

The repetitive application of cold atmospheric plasma (CAP) improves microcirculation parameters in chronic wounds - ScienceDirect

Hand held Devices

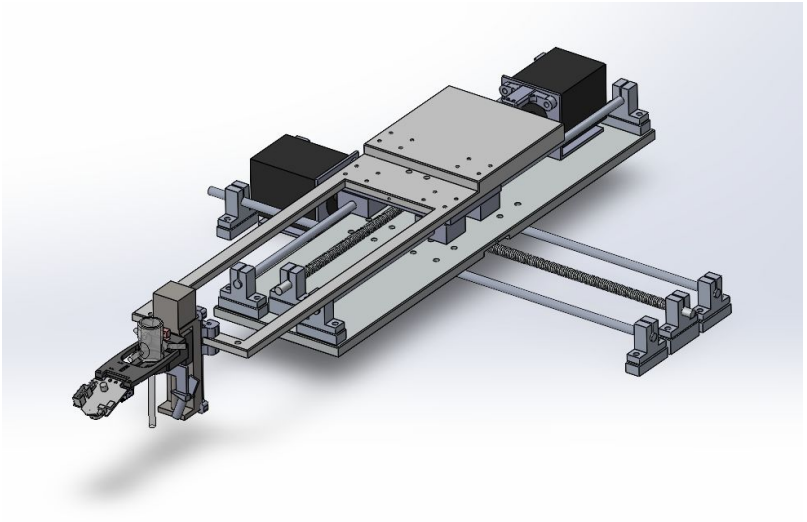
- Advantages
  - Portable
  - Minimal operation training required
- Disadvantage
  - Inconsistent coverage

Gantry Robot

- Advantages
  - Automated
  - Easy to operate
- Disadvantages
  - Bulky
  - Limited workspace

Objectives

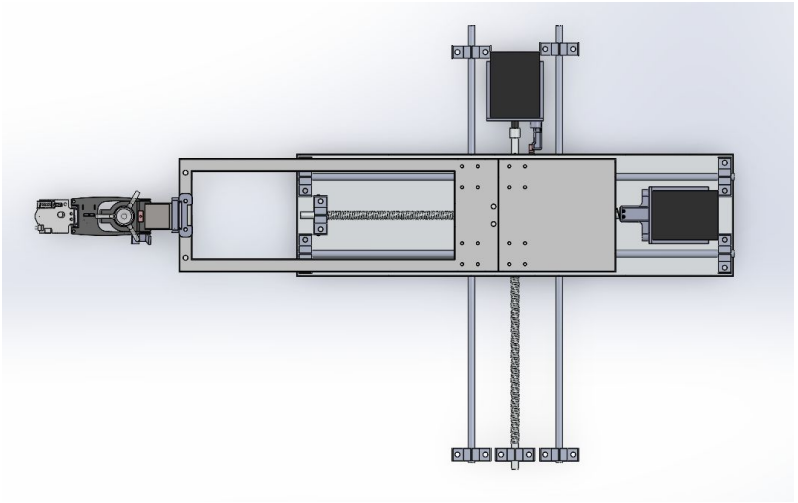
- Overhaul both the software and hardware components of the mechanism.
- Incorporate a live camera to automatically detect a wound and communicate with stepper motors to perform the required movement.
- Implement an additional mechanism that operates a plasma torch vertically.
- Optimize previous design for lighter weight and more accurate movement.




3D Traversing Plasma Wound Treatment with Image Processing Development Timeline
Sep-23
Oct-23
Nov-23
Dec-23
Jan-24
Feb-24
Mar-24
Apr-24
May-24
Project Selection
Planning/Brainstorming
CAD Design Process
Electrical Design Process
Acquire Project Materials
3D Print Components
Assemble Mechanism
Software Development
Testing/Troubleshooting Period
Final Revisions

Technical Specifications

- Material: Aluminum 6061 T6
- Z-axis range of motion: 85 mm
- Workspace: 218mm x 167mm x 85mm
- Fasteners tightened to 15 N/m
- X and Y Traversing Velocity: 24mm/s



Motor Sizing and Specifications

1. **Steps to move 25.4mm**

$$25.4\,mm \cdot \frac{1\,Rev}{2\,mm} \cdot \frac{1600\,Pulses}{1\,Rev} = 20,320\,Pulses$$

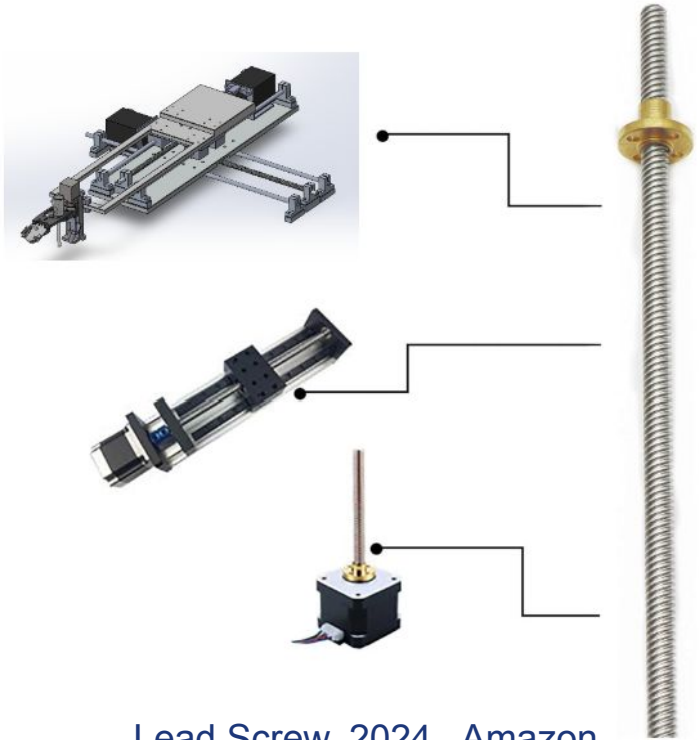
2. **Position Accuracy**

$$\frac{2\,mm}{Rev} \cdot \frac{1\,Rev}{1600\,Pulses} = \frac{1.25\,\mu m}{Pulse}$$

3. **Motor Speed**

$$480\,RPM$$

4. **Weight to move = 4.053 Kg**
   a. **Top Mount = 1.22 Kg**
   b. **Bottom Mount = 1.79 Kg**
   c. **Z-Axis = 1.043 Kg**
5. **Torque Required** $0.722\,\frac{N}{m}$



Lead Screw. 2024 . Amazon

Torque Required

Coefficient of Friction for Leadscrew Thread

Screw Material	Nut material
	Steel
Steel, dry	0.15 - 0.25
Steel, machine oil	0.11 - 0.17
Bronze	0.08 - 0.12

Input

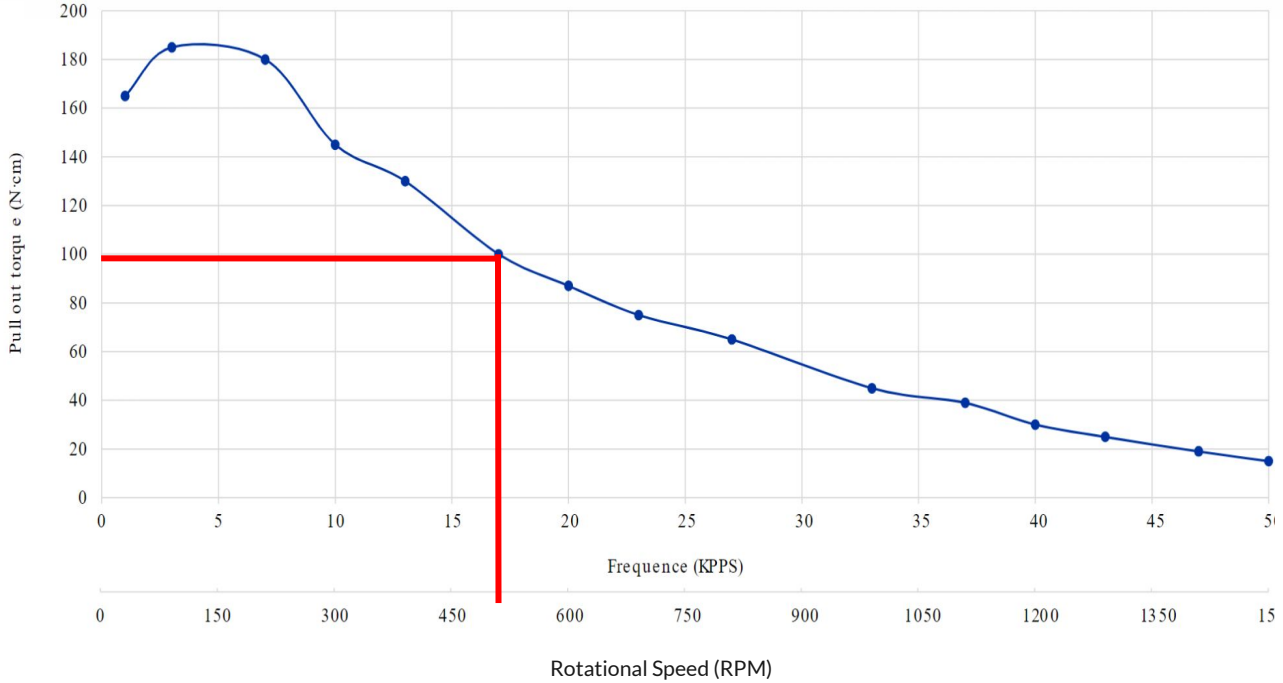
Force	4053 ○lb ○oz ◉g ○N
Pitch Diameter	8 ○in ◉mm
Thread density	.2 Threads per ○in ◉cm
Coefficient of Friction	0.25 (See table below)
Result Units	◉N*m ○N*cm ○lb*in ○oz*in
	Compute

Result

Torque (Raise)	0.722 (Selected Units)
Torque (Lower)	0.561 (Selected Units)

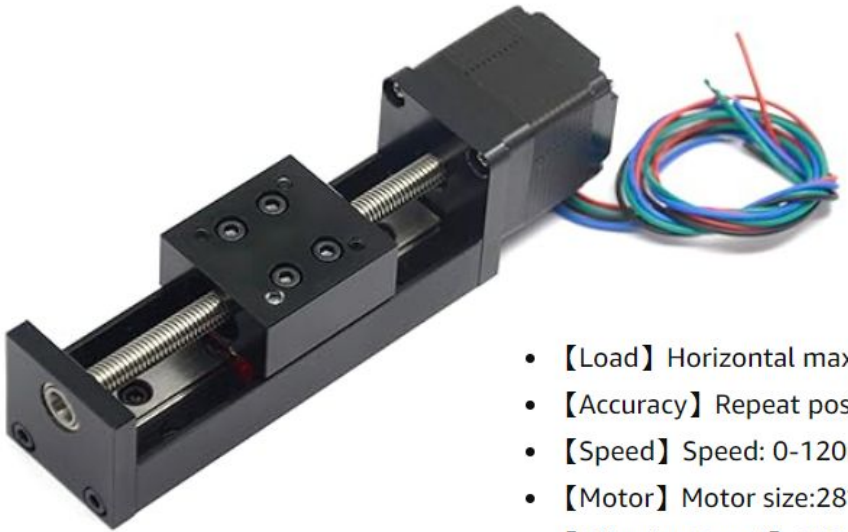
Lead Screw Torque and Force Calculator . 2024. Daycounter.

Nema 23 Stepper Motor Performance & Sizing



[Nema 23 Stepper motor and Torque Graph. 2024. OMC-Stepperonline]

Z axis Nema 11 Lead Screw Assembly Specifications



- 【Load】Horizontal maximum load capacity: 2.5kg; Vertical maximum load capacity: 1kg
- 【Accuracy】Repeat positioning accuracy of ± 0.05mm
- 【Speed】Speed: 0-120mm/min
- 【Motor】Motor size:28*28*30mm,Motor voltage:DC 24V,Current: 0.5A,Step angle:1.8 degrees
- 【Effective Travel】100mm Effective Travel,T6x1:diameter 6mm and lead 1mm pitch 1mm (The lead screw moves 1mm in one turn)

Nema 11 Lead Screw Assembly. 2024. Amazon

Z axis camera tilt micro servo

Controlled with a rotary encoder, the motor arm starts at an initial position of 180 degrees to hold the camera lens perpendicular to the workspace. The maximum position of 80 degrees allows users to keep the wound in view after a toolpath has begun.

Specifications

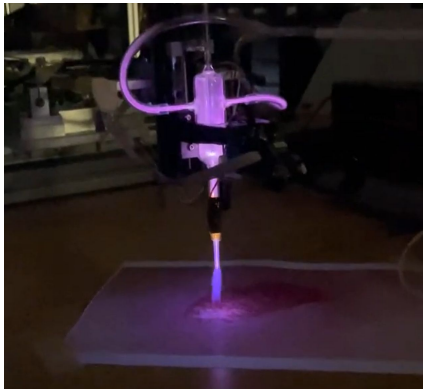
- Weight: 9 g
- Dimension: 22.2 x 11.8 x 31 mm approx.
- Stall torque: 1.8 kgf·cm
- Operating speed: 0.1 s/60 degree
- Operating voltage: 4.8 V (~5V)
- Dead band width: 10 µs
- Temperature range: 0 ºC – 55 ºC

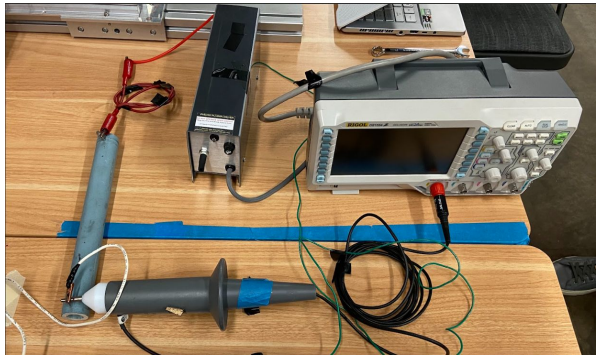
Position "0" (1.5 ms pulse) is middle, "90" (~2ms pulse) is all the way to the left. ms pulse) is all the way to the right, ""-90" (~1ms pulse) is all the way to the left.

SG90 datasheet (datasheetspdf.com)

Cold Atmospheric Plasma Specifications

- Helium gas
- sinusoidal wave generator: 40kHz, ballast resistor, ceramic resistor, power supply: 7 kV
- ~ 40 degrees Celsius





Bill of Materials

Item/Component	Weblink	Vendor	Price	Amount	Total Price
Nema 23 Stepper motor	Befenybay 50mm Linear Stage Actuator	Amazon	$55.00	2x	$110.00
Heat Shrinks	Heat Shrink Tubing Kit	Amazon	$11.99	1x	$11.99
Wires	24 Gauge Solid Core Wire Kit	Amazon	$17.99	1x	$17.99
Arduino Mega 2560 Rev 3 Board	Arduino Mega 2560 REV3	Amazon	$48.99	2x	$97.98
USB Data Sync Cable	USB Data Sync Cable	Amazon	$8.58	2x	$17.16
Allen Key set	Hex Key Allen Wrench 26 Set	Amazon	$14.53	1x	$14.53
Micro Limit Switches	25 Pcs Limit Micro Switch	Amazon	$6.99	1x	$6.99
Temperature Sensor	Teyleten Robot IR Temperature Sensor Module	Amazon	$11.99	1x	$11.99
Threaded Inserts	Kadrick 420Pcs Threaded Inserts Assortment Kit	Amazon	$19.97	1x	$19.97
Shaft Couplers	Yeebyee 8mm to 8mm AL Shaft Coupler	Amazon	$12.99	1x	$12.99
Solderless Butt Connectors	Cionyce 100 Pcs Solderless Sleeve Heat Shrink Connectors	Amazon	$8.99	1x	$8.99
TB660 Stepper Motor Driver	EASON Stepper Motor Driver TB6600	Amazon	$12.89	1x	$12.89
DM556 Stepper Motor Driver	DM556 Stepper Motor Driver	Amazon	$16.68	2x	$33.36
Tiny Hex Socket Head Cap Screws	410 Pcs Tiny Hex Socket Head Cap Screws Bolts	Amazon	$8.99	1x	$8.99
Digital Camera Component	Charmed Labs Pixy2 Smart Vision Sensor	Amazon	$69.90	1x	$69.90
Digital Camera Component	Arducam 5MP SPI Camera	Arducam	$34.99	1x	$34.99
1 KG PLA	Polymaker PLA PRO Filament Dark Grey	Amazon	$24.99	1x	$24.99
PCB	PCB/Manufacture/Components	DigiKey	$15.44	1x	$15.44
Arduino Mega 2560 Header Pins	Treedix Header Pins	Amazon	$8.99	1x	$8.99
				Total	$540.13

Engineering Codes and Standards

- ISO 13850:2015: Safety standards of equipment field of machinery
- ISO 14971:2019: Risk management requirements for medical devices
- ASME Y14.5: GD&T Dimensioning and Tolerancing Standards

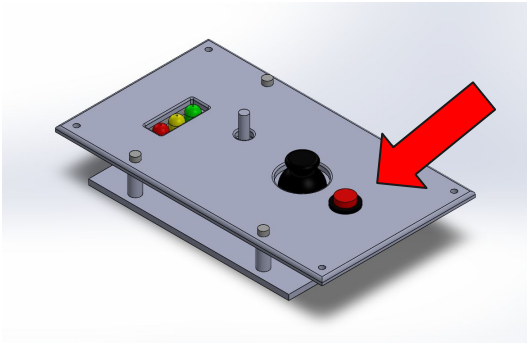
ISO Logo. 2024. ISO

ASME Logo, 2021, American Society of Mechanical Engineers

Design Compliance with ISO 13850:2015

- ISO 13850:2015 concerns the safety standards of equipment field machinery
- Section 3.1 refers to emergency stop function: avert arising or reduce existing hazards to persons, damage to machinery or to work in progress, and be initiated by a single human action
- Incorporate an emergency stop button into the design of the gantry robot to cease operation in the event of an accident or machine crash condition

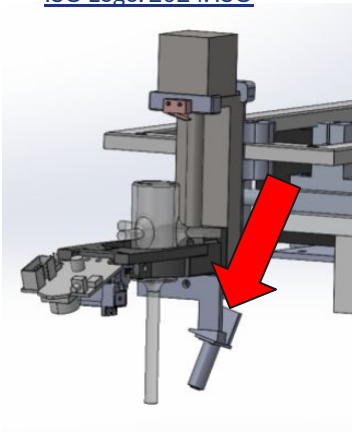
ISO Logo. 2024. ISO



Design Compliance with ISO 14971:2019

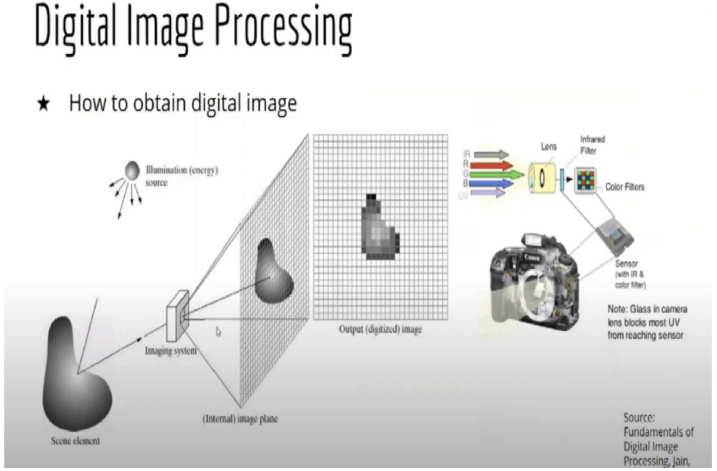
- ISO 14971:2019 - Risk management requirements for medical devices
- High temp plasma has potential to cause injury to patient
- Manual z axis will control plasma intensity to acting surface at the discretion of the operator
- Infrared Temperature sensor will stop operation if measured temperature value of 40 degrees celsius is exceeded
- Mitigate risk of damage to tissue

ISO Logo. 2024. ISO



Theoretical Background: Image Processing

- Use image processing to automate wound initialization
- Image of wound captured by camera, interpreted by a microcontroller to obtain useful information
- In this case, image processing is used to measure and locate a wound which a toolpath will be generated for in order to completely cover the wound without containing excess tissue
- To meet objective, image must be sized properly in the program relative to the physical domain



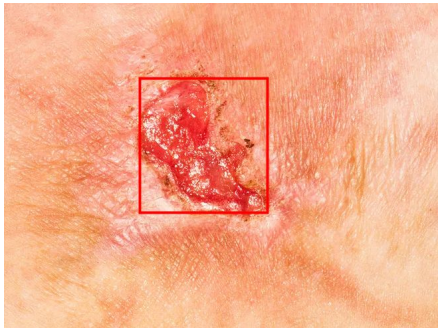
Akyol, Gokcenaz. *What is image Processing* . 13 Jan. 2023. *Medium.*

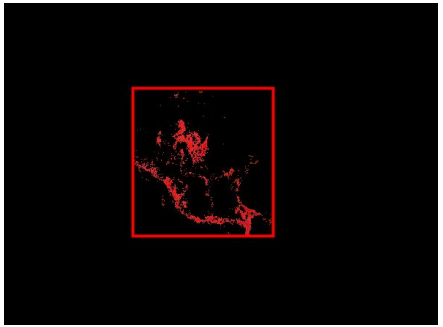
Initial and Final Designs for Image Processing and Machine Control

Initial Image Processing on ArduCam using Matlab

- ArduCam Mega 5MP
- ArduCam Mega Application
- Matlab Script
- Image Processing by RGB values

Arducam Mega 5MP . 2024. Arducam

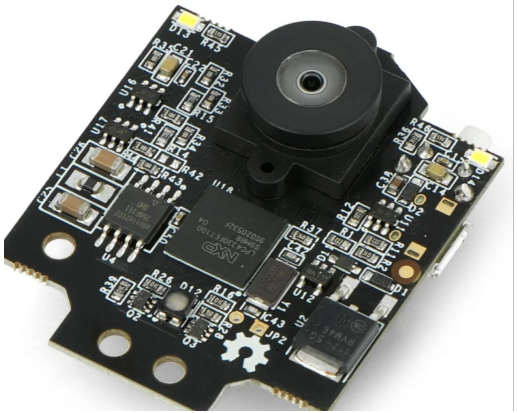




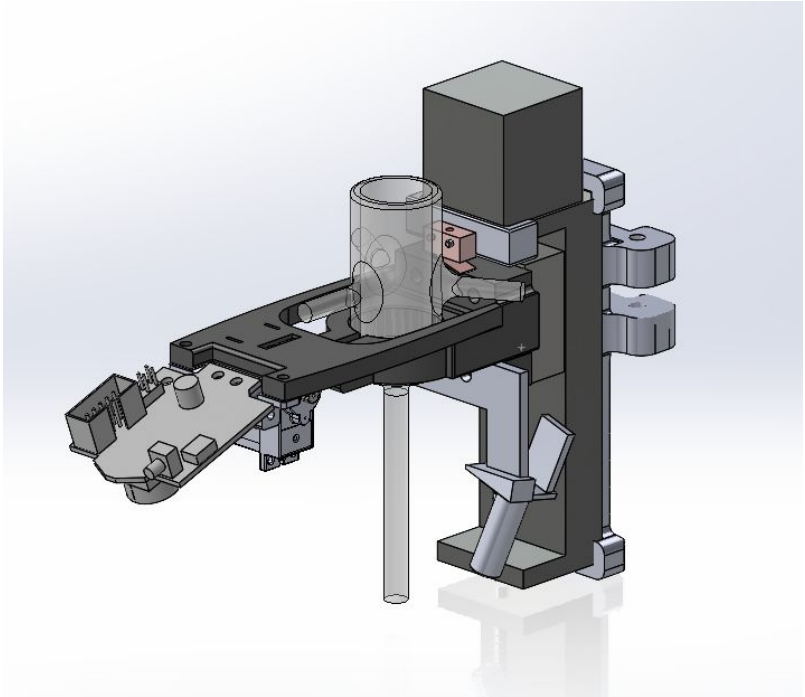
Con: Poor Interference Between Components

Image Processing on Pixy2

- Color Connected Components (CCC) algorithm
- 1.9 x 1.5 x 1 inches, 60 FPS
- Live Image processing



Pixy 2 Camera. 2024. Amazon



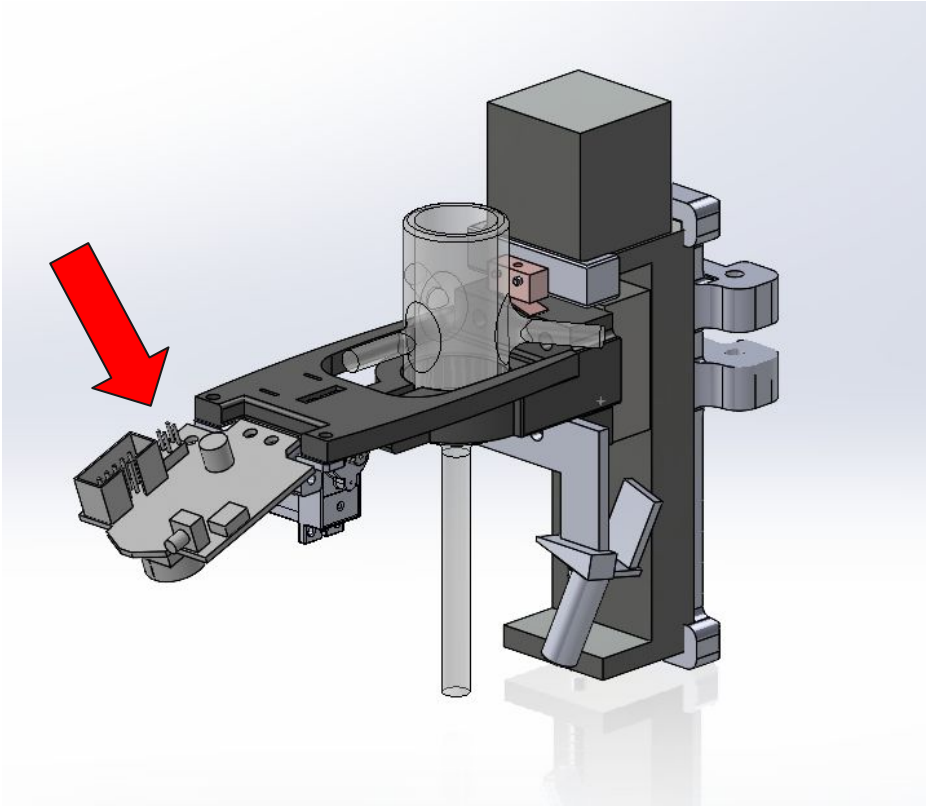
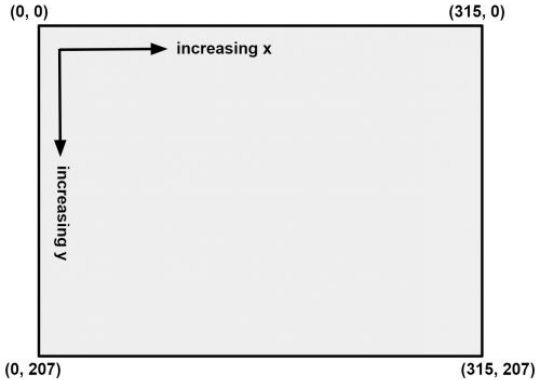
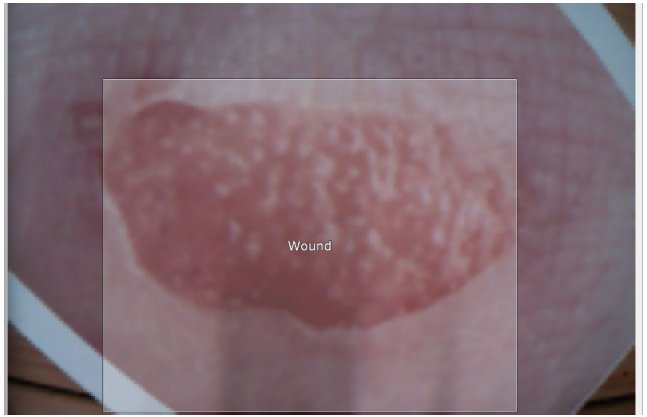


Image Processing on Pixy2

- PixyMon V2 Application
- Training the algorithm
- Properties of the bounding box



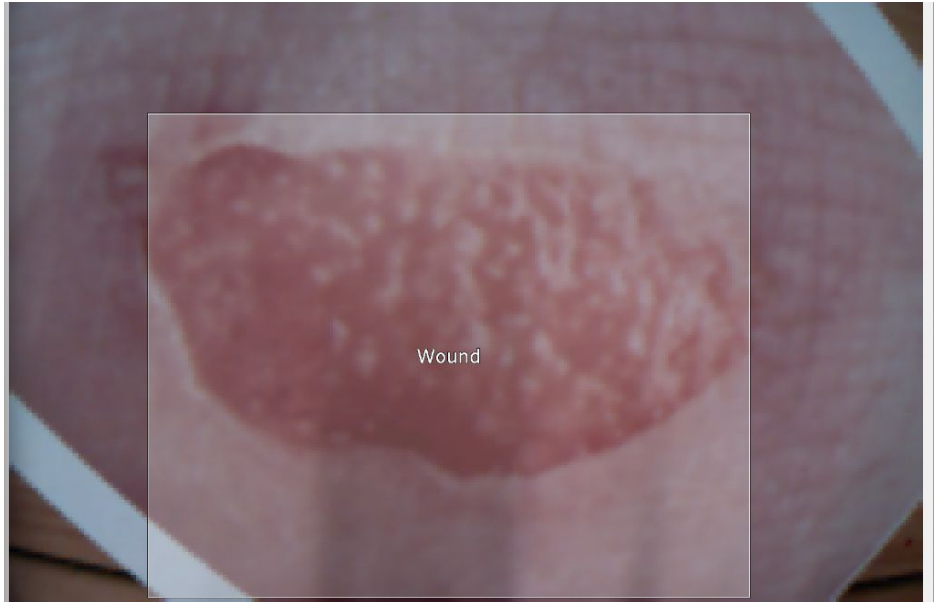
Video Image Coordinates from Pixy2's perspective



pixymon

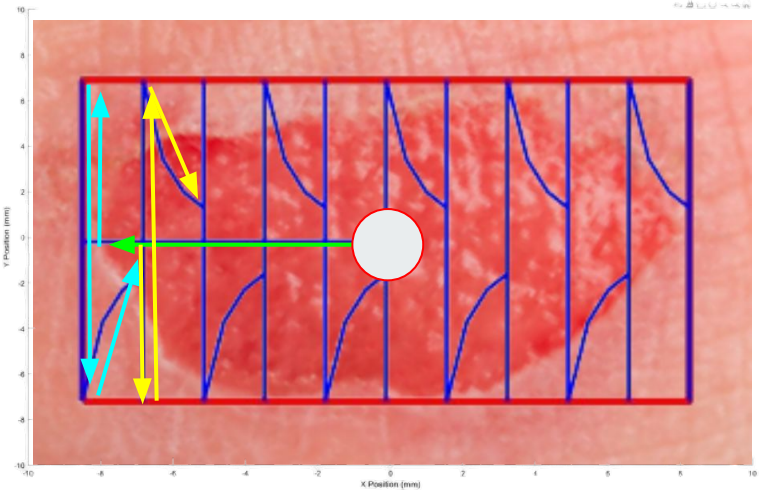
Wound Boundary Coordinates and Dimensions

```
// Grab the latest blocks from Pixy2. Color Connected Components
pixy.ccc.getBlocks();
if (pixy.ccc.numBlocks) {
  for (int i = 0; i < pixy.ccc.numBlocks; i++) {
    // Convert Pixy2 coordinates to machine coordinates
    if (pixy.ccc.blocks[i].m_signature == signatureNumber) {
      float cameraX = (pixy.ccc.blocks[i].m_x - 157.5) / 157.5 * 150;
      float cameraY = (pixy.ccc.blocks[i].m_y - 103.5) / 103.5 * 85 + 50;
      float boundaryWidthMM = pixy.ccc.blocks[i].m_width * widthScaleFactor;
      float boundaryHeightMM = pixy.ccc.blocks[i].m_height * heightScaleFactor;

      Serial.print("Wound Detected - X: ");
      Serial.print(cameraX);
      Serial.print(" mm, Y: ");
      Serial.print(cameraY);
      Serial.print(" mm, Boundary Dimensions - w: ");
      Serial.print(boundaryWidthMM);
      Serial.print(" mm, h: ");
      Serial.print(boundaryHeightMM);
      Serial.println(" mm");

    }
  }
```

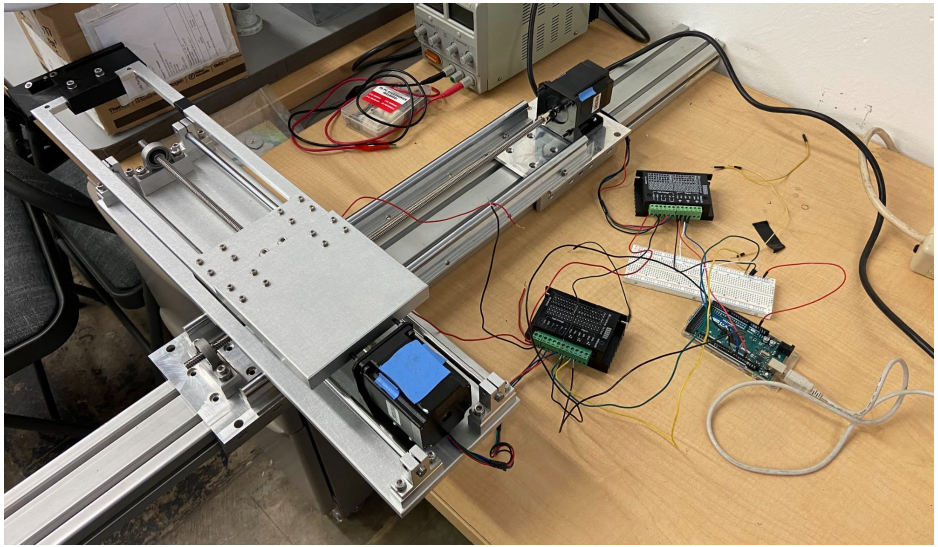


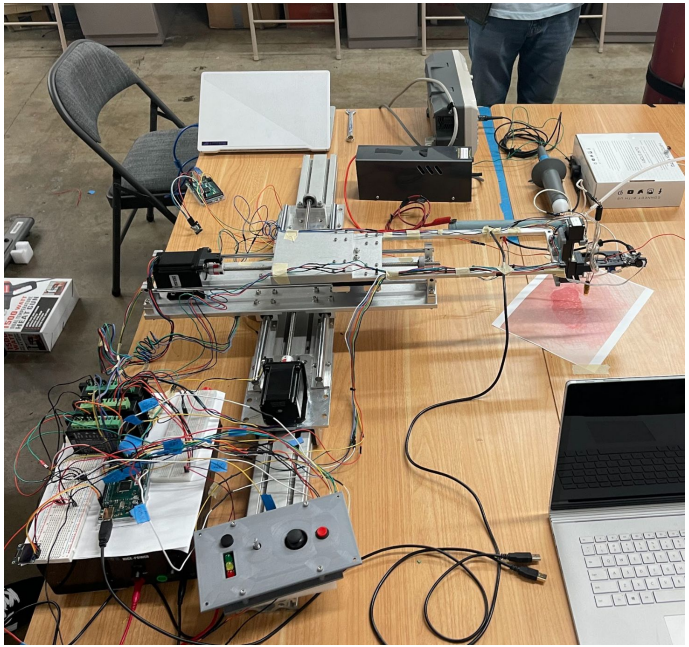
Toolpath

- Maximize wound coverage in the x and y directions.
- Starts in center of wound and then moves the torch to top left corner to begin the sequence shown
- Height and width equal to dimensions of the boundary box created by the pixycam
- Visual representation created in MATLAB for illustration purposes
- Green first, then blue, next yellow, repeat.

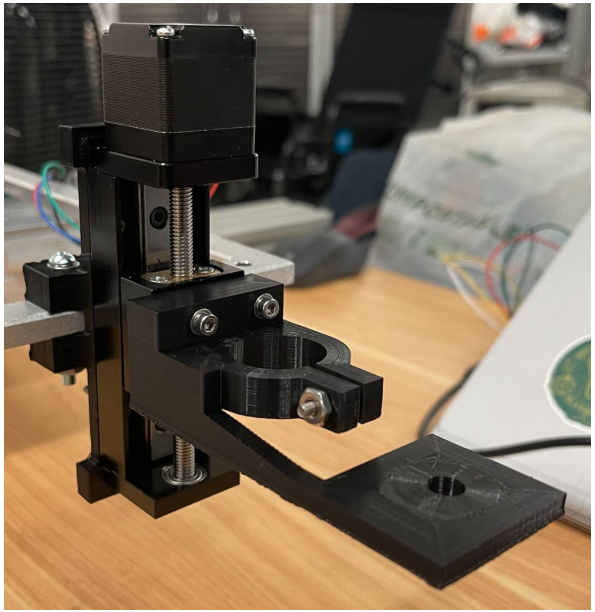


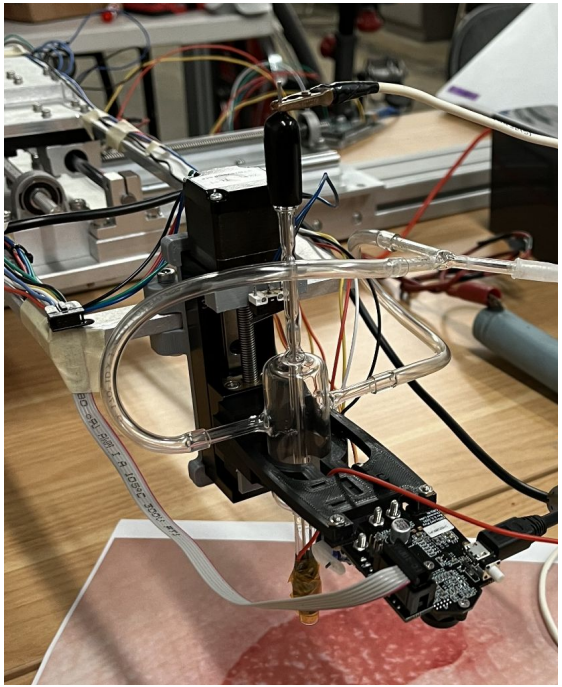
Progress from September to May





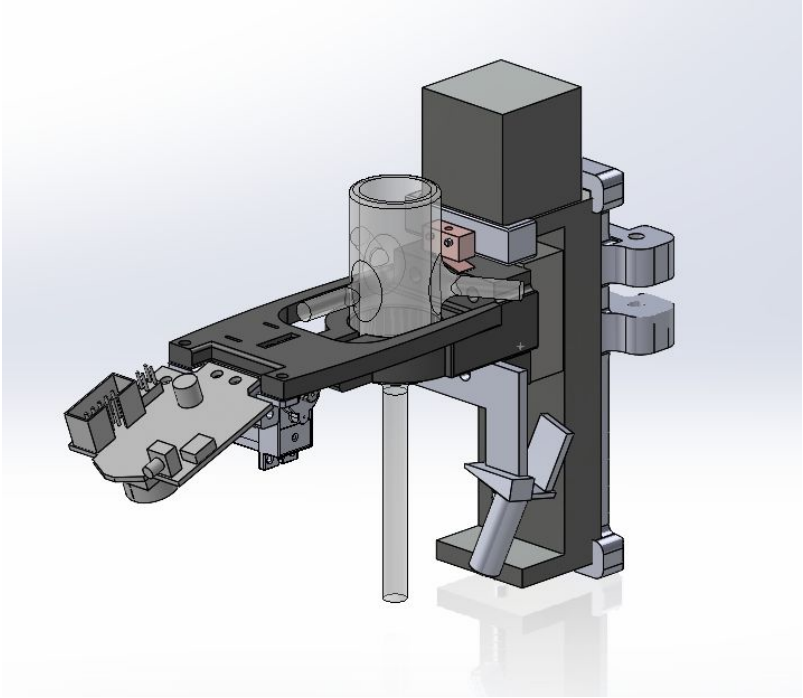
Z axis Leadscrew assembly





Z- Axis Subassemblies

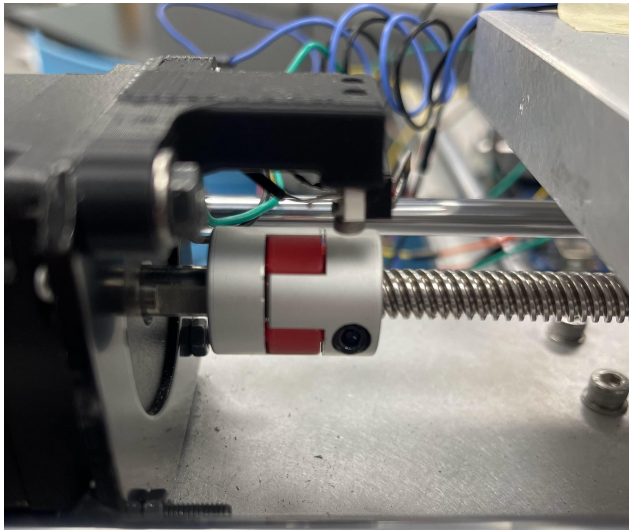
- Linear Actuator Sub-Assembly
- Infrared Heat Sensor Mount
- Micro Servo Tilting Sub-Assembly



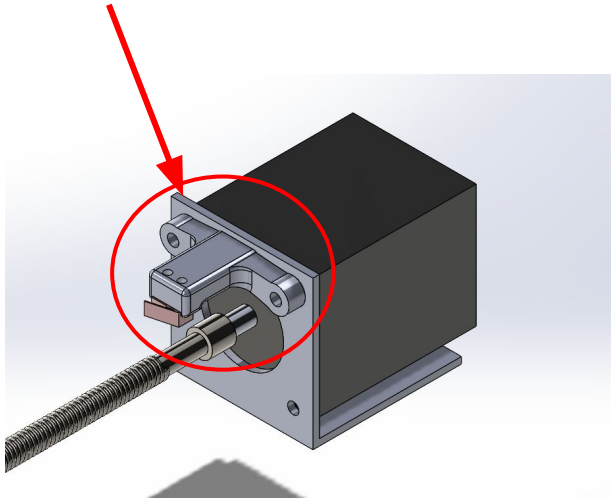
Lead Screw Coupler

The solid steel couplers at the junction between the Nema 23 motor shaft and T8 lead screw were not perfectly concentric with each other.

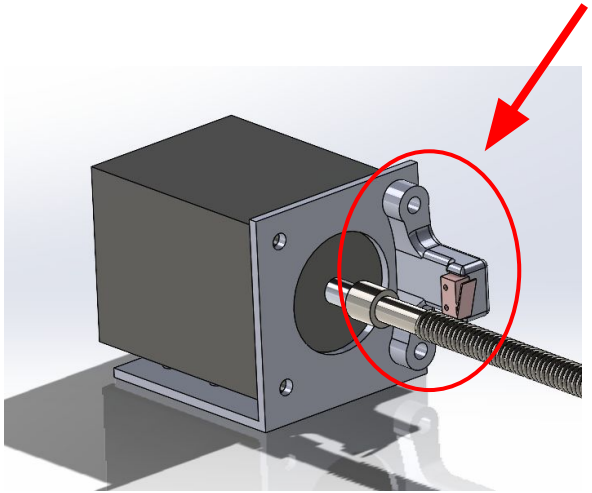
New couplers resulted in reduction of lead screw deflection during operation and vibrations when a stage changed directions.



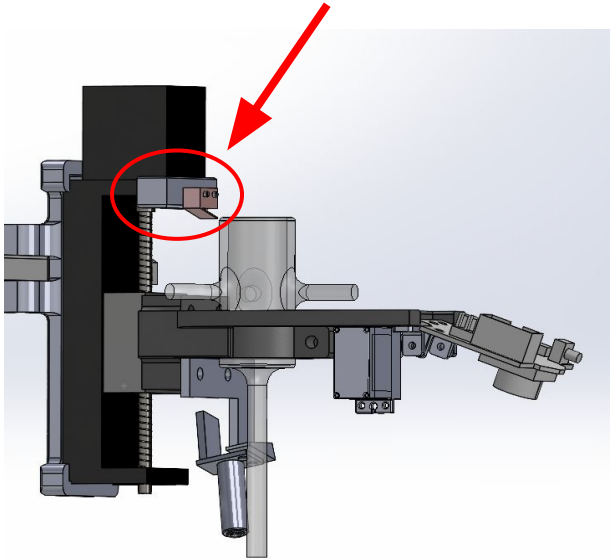
X, Y, Z limit switch mounts



Y-Axis Limit Switch Mount



X-Axis Limit Switch Mount



Z-Axis Limit Switch Mount

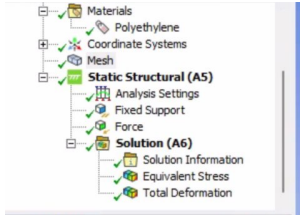
Limit Switch FEA using ANSYS

Outline of Schematic A2: Engineering Data

	A	B	C	D	E
1	Contents of Engineering Data			Source	Description
2	Material				
3	Polyethylene				
*	Click here to add a new material				

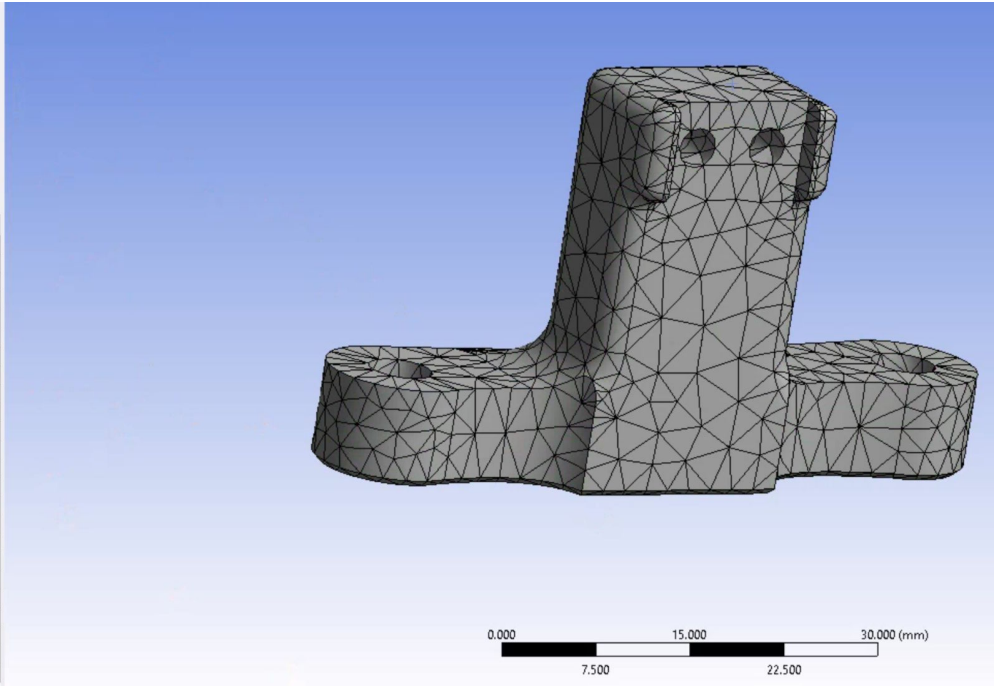
Properties of Outline Row 3: Polyethylene

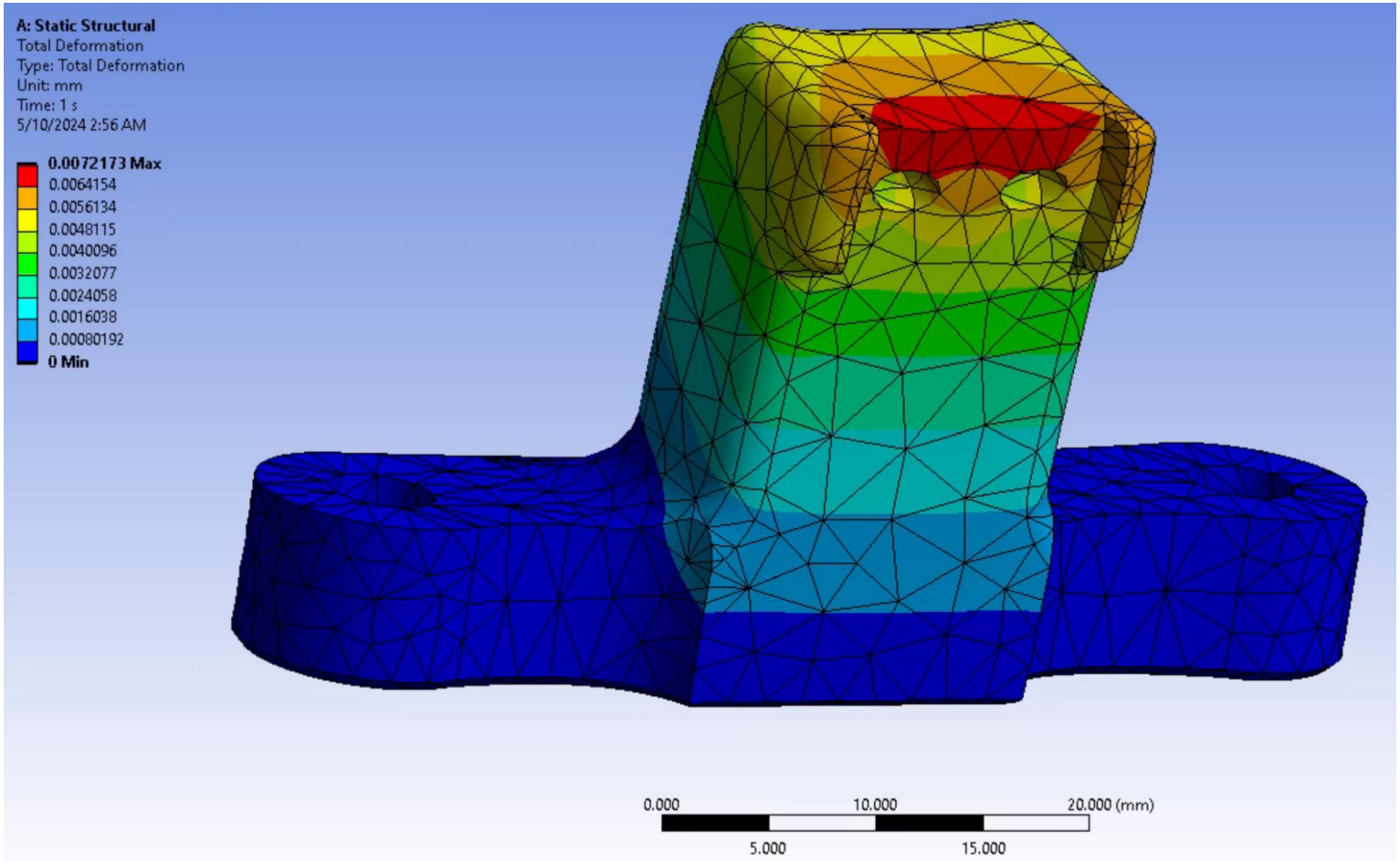
	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	1260	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Youn...			
8	Young's Modulus	1.1E+09	Pa		
9	Poisson's Ratio	0.42			
10	Bulk Modulus	2.2917E+09	Pa		
11	Shear Modulus	3.8732E+08	Pa		
12	Tensile Yield Strength	2.5E+07	Pa		
13	Compressive Yield Strength	0	Pa		
14	Tensile Ultimate Strength	3.3E+07	Pa		
15	Compressive Ultimate Strength	0	Pa		
16	Isotropic Thermal Conductivity	0.28	W m^...		
17	Specific Heat Constant Pressure, C_p	2300	J kg^...		

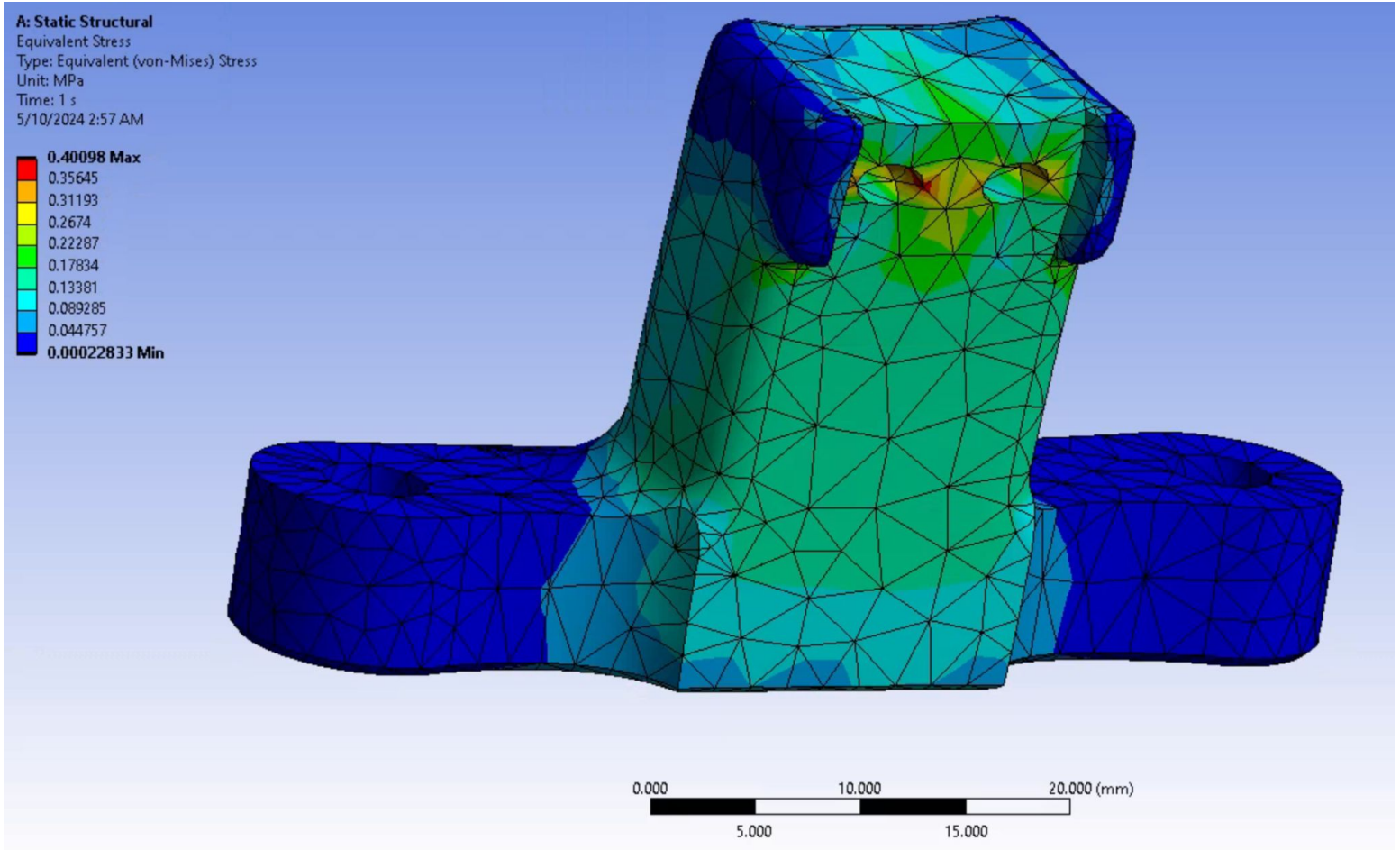


Details of "Mesh"

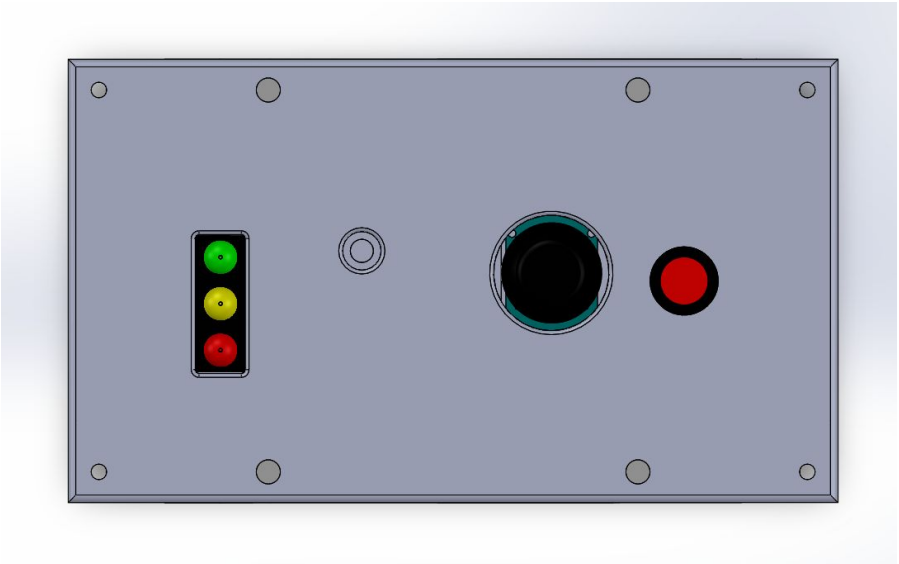
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	2.0 mm
Sizing	
Use Adaptive Sizing	Yes
Resolution	Default (2)
Mesh Defeaturing	Yes
Defeature Size	Default
Transition	Fast
Span Angle Center	Coarse
Initial Size Seed	Assembly
Bounding Box Diagonal	70.751 mm
Average Surface Area	66.385 mm²
Minimum Edge Length	0.11077 mm
Quality	
Inflation	
Advanced	
Statistics	
Nodes	6884
Elements	3693
Show Detailed Statistics	No

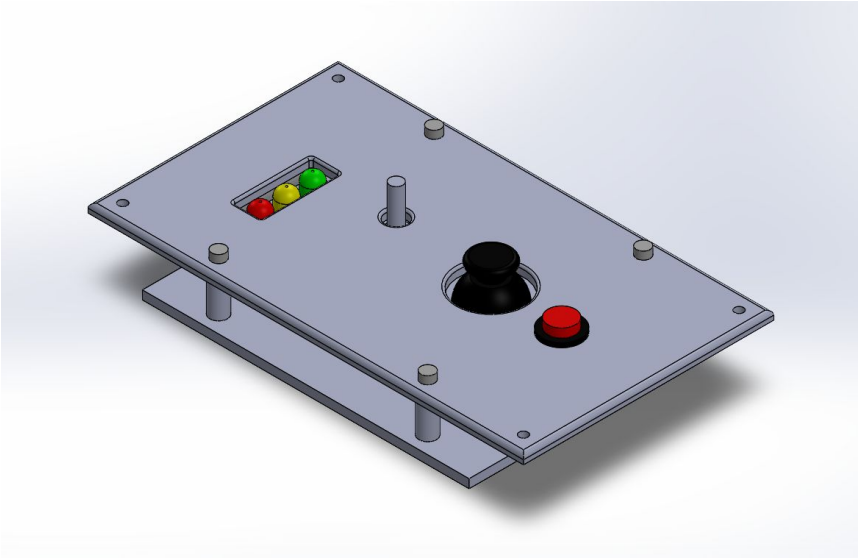



A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
5/10/2024 2:56 AM
0.0072173 Max
0.0064154
0.0056134
0.0048115
0.0040096
0.0032077
0.0024058
0.0016038
0.00080192
0 Min
0.000
10.000
20.000 (mm)
5.000
15.000


A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
5/10/2024 2:57 AM
0.40098 Max
0.35645
0.31193
0.2674
0.22287
0.17834
0.13381
0.089285
0.044757
0.00022833 Min
0.000
10.000
20.000 (mm)
5.000
15.000

Dashboard Assembly





6.Fabrication

Ender 3 Pro 3D Printer

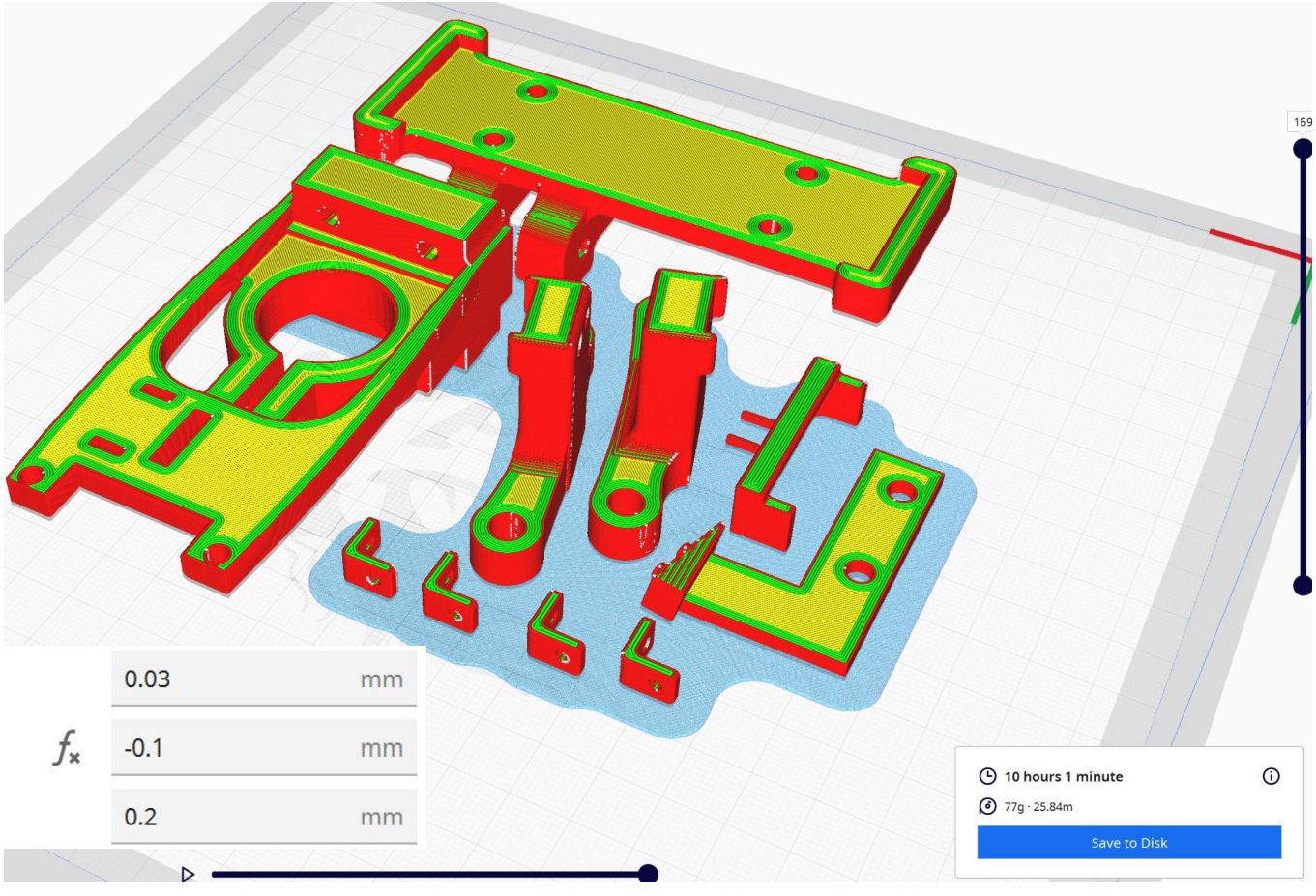
Ultimaker Cura Slicer

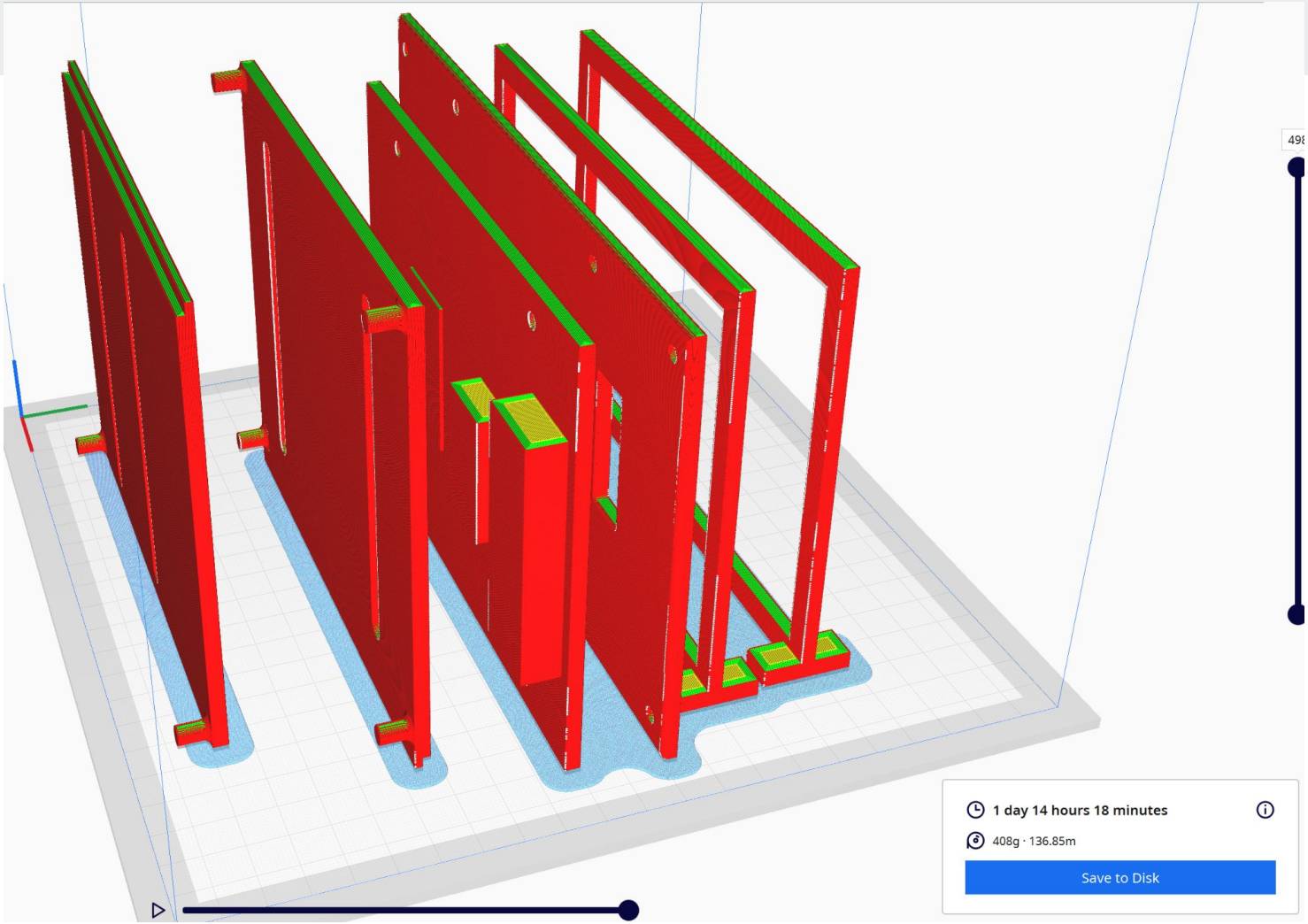
485 g of PLA at 195 C

0.20 mm layer height 30% Infill

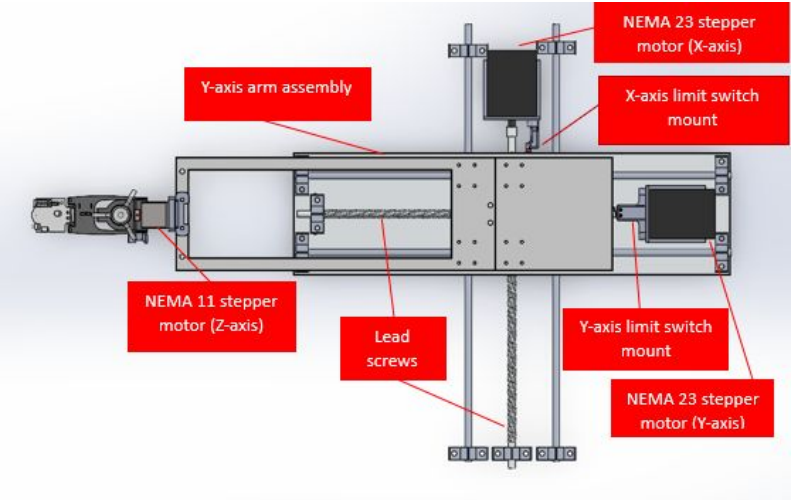
Raft and Tree supports

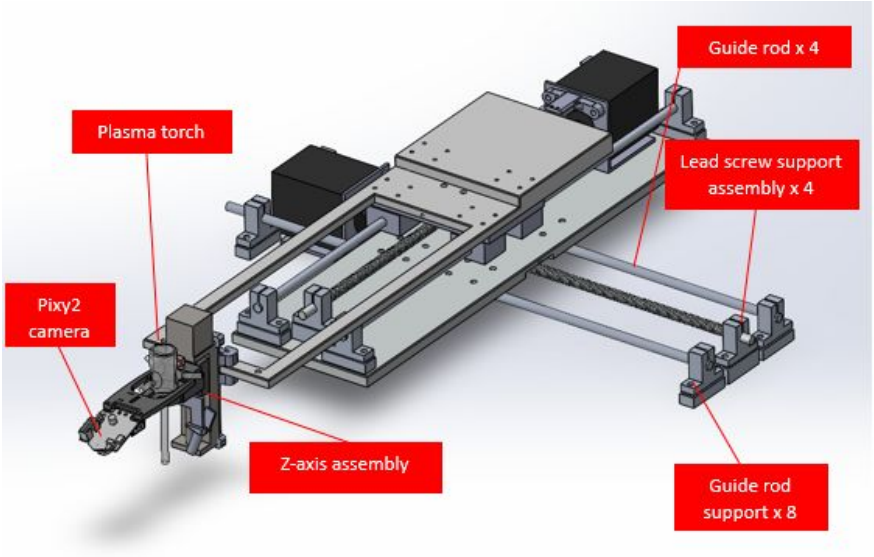
48 hours and 19 minutes



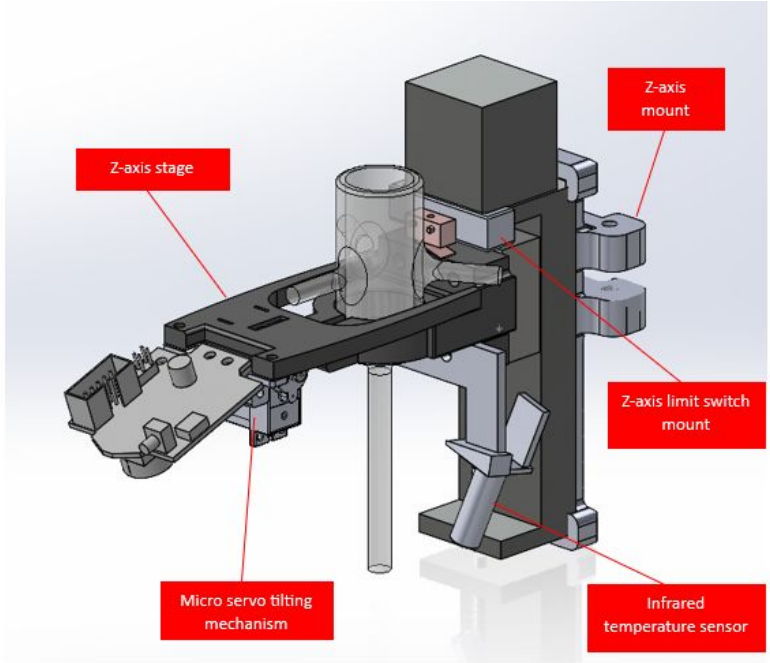

1 day 14 hours 18 minutes
408g · 136.85m
Save to Disk

Solidworks Images of Entire Assembly





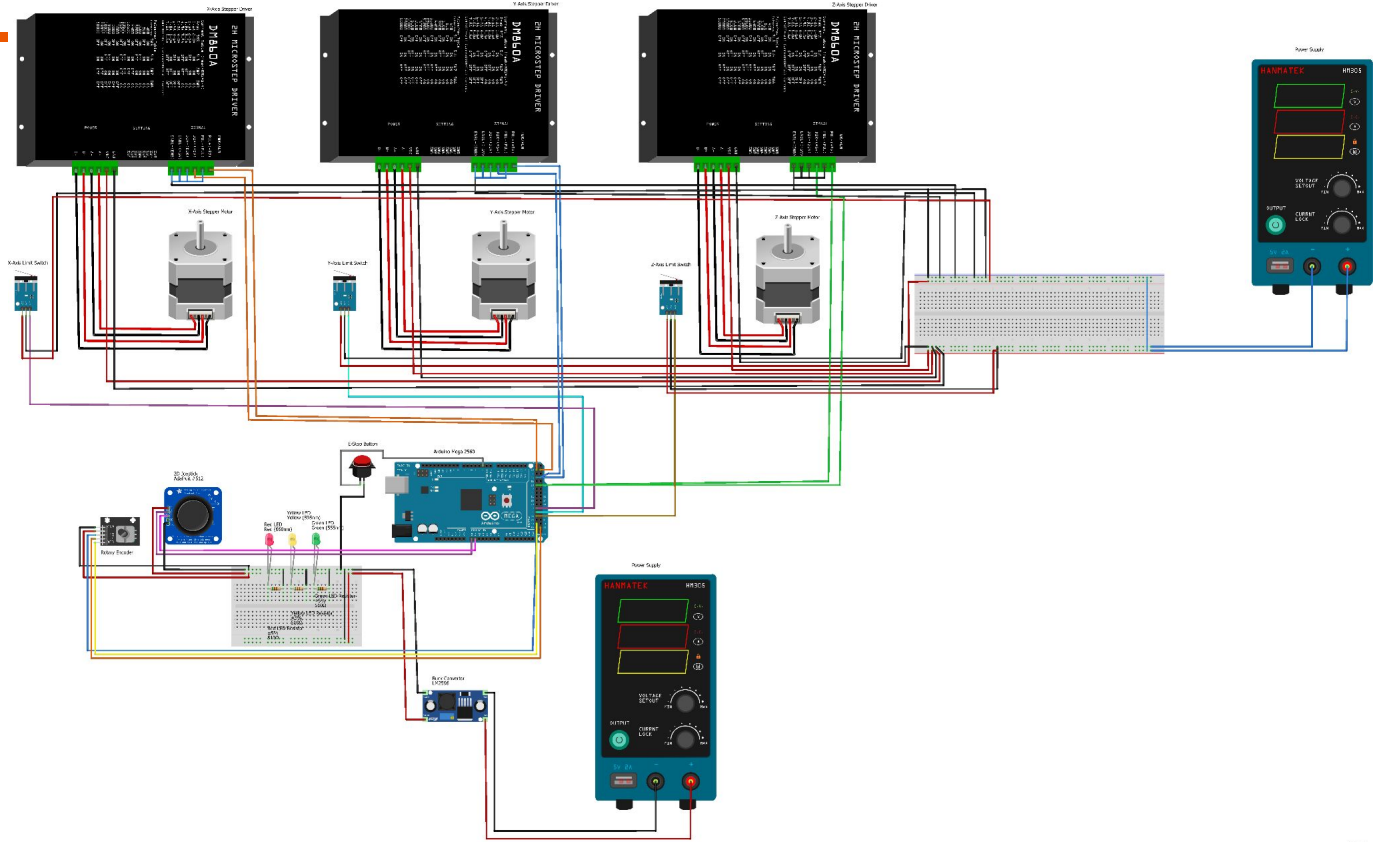
Solidworks Images of Entire Assembly (cont.)



Mechatronic Components

- Schematic Diagram
- Arduino Mega 2560
- Stepper motors
- DC power supply
- IR Temperature Sensor
- OLED display
- Three TB6600 Microstepping Driver

Schematic Diagram

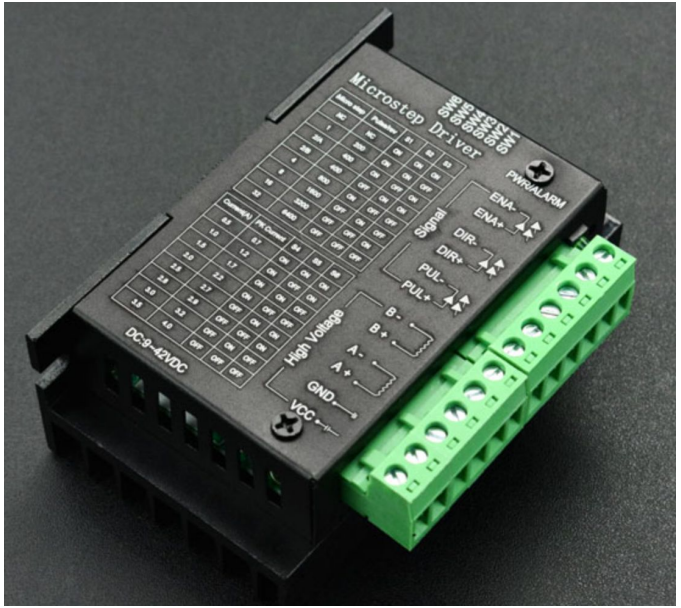


Arduino Mega 2560

- Microcontroller utilized our project
- Uses C/C++ as programing language

TB66OO microstepping driver

- Using the dip switches, we can set the micro step ratio/ pulses per revolution delivered to each stepper motor.
- Peak current (A) to X and Y motors set to 1.5A. Z motor set to 0.5 A



TB6600 Arduino Stepper Motor Driver - DFRobot

DC Power Supply

The microsteppers are connected to a 30V 1.5A rail. During position commands and toolpath execution, the maximum current drawn in 0.75A meaning the machine draws at most 22.5 W.

During idle, the motors draw 0.35A or 11W. A hiss can be heard, which can be solved through a more optimal power delivery system.

Joystick and Encoders

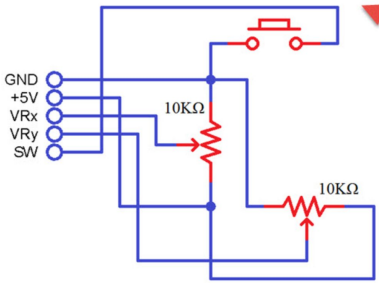
Two mechanically linked potentiometers in the joystick produce an analog signal with values ranging 0 to 1024 that can be plotted on a cartesian plane. We use the third quadrant to match the machine orientation

Detents on the rotor within the encoder send 30 digital signals per knob revolution that can command the z axis microstepper driver to send 400 pulses per encoder signal to the nema 11 motor.

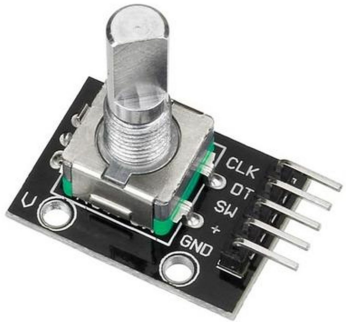
The same method is used for the micro servo tilting the camera. One encoder signal equals one degree of servo rotation.Switch button resets to 180 degree initial position.

Encoder debouncing and joystick deadzone solutions are implemented in our Machine Control script.

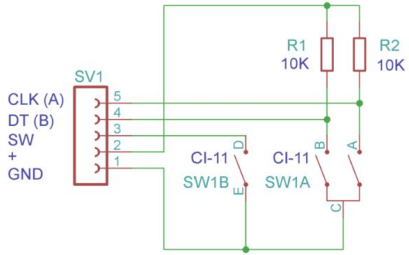
arduino DUAL AXIS XY JOYSTICK PS2 GAME MODULE CONTROLLER Game Electronic Hobby Kit Price in India - Buy arduino DUAL AXIS XY JOYSTICK PS2 GAME MODULE CONTROLLER Game Electronic Hobby Kit online at Flipkart.com



Arduino Joystick Interface - Control Servo using Arduino and Joystick - Control Servo using Arduino and Joystick (electronicshub.org)



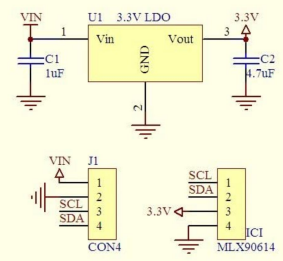
360 Degree Rotation Encoder Module - PiShop.us



Interfacing Incremental Rotary Encoder with Arduino - CIRCUITSTATE Electronics

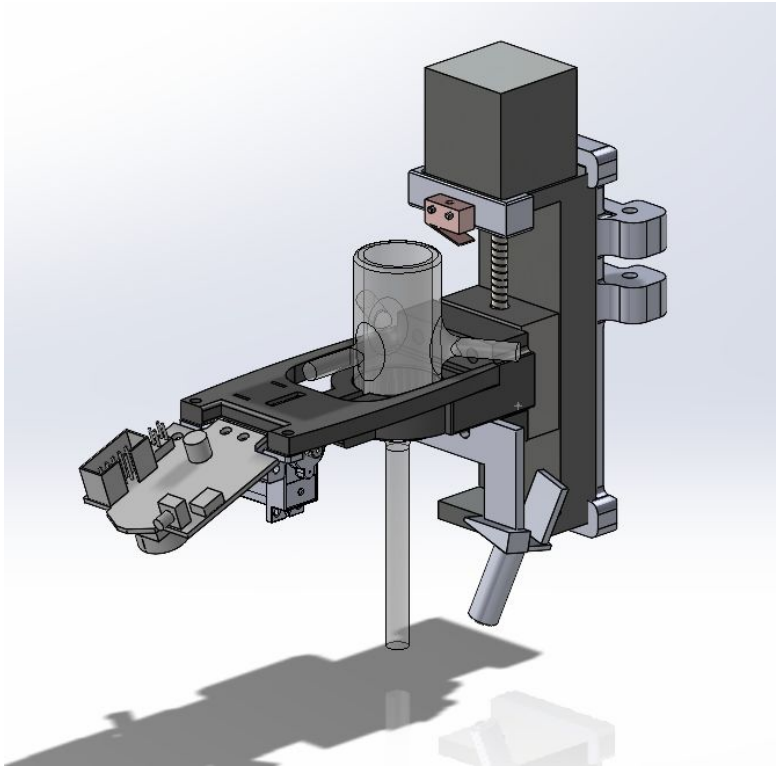
Non-Contact Infrared Temperature Sensor

- 50cm range
- 5° Field of View
- 0.5℃ Accuracy



Model: MLX90614 DCI Schematic. 2024. Amazon

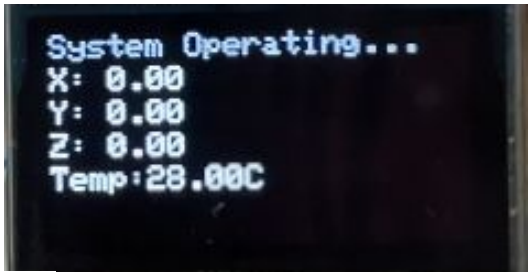
Model: MLX90614 DCI. 2024. Amazon



OLED Display

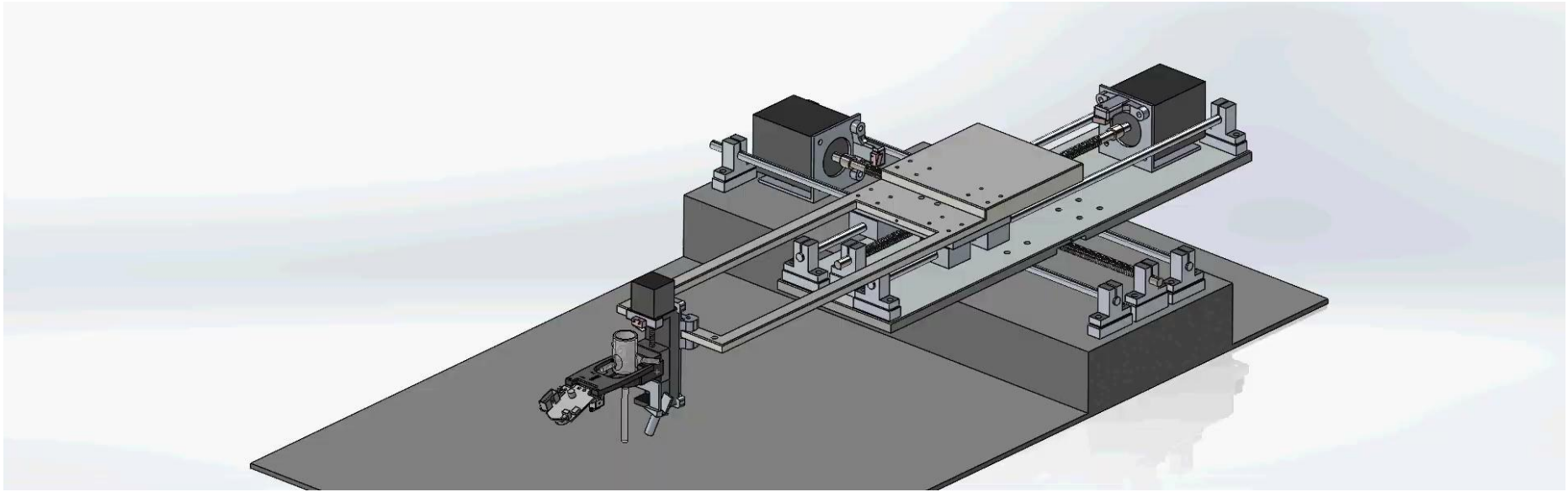
Displaying

- System Action
- X Y Z Coordinates
- Temperature

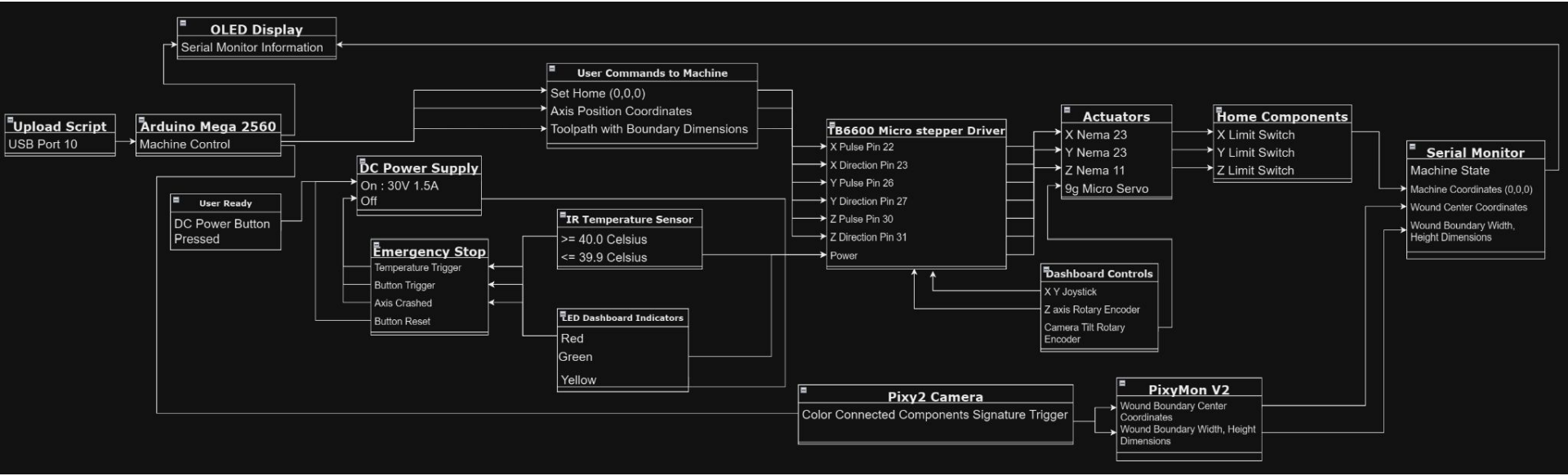


OLED Module 0.96 Inch

Solidworks simulation of toolpath



Machine Control Logic

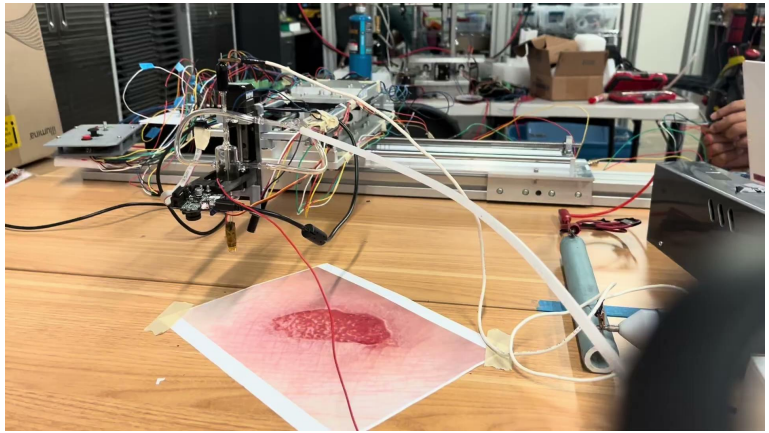


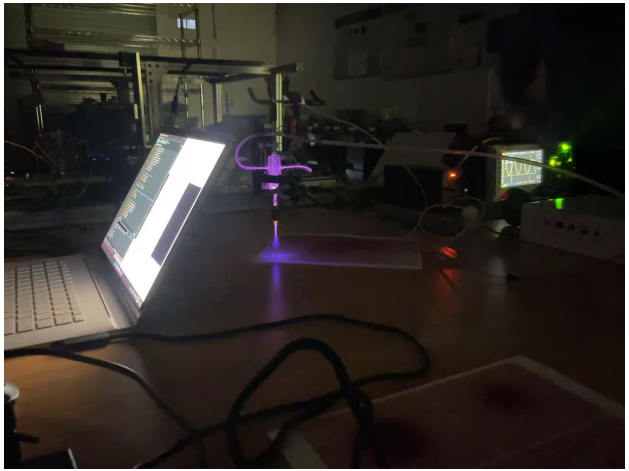
Machine Operation

Serial monitor input commands

- h: Returns each axis to home by triggering limit switches
- x -# y -# z-# : Moves each stage to the desired mm coordinate value in x, y, z order
- If the user types values that exceed x -300 y -140 z -85, triggers “Command Exceeds Machine Limits Type New Command”
- T w# h# : Initiates toolpath command at current machine position within the width and height dimensions

Video of operation





Conclusion

- Successfully met objectives
  - Overhauled and optimized mechanism design, live camera with image processing, manual z axis control
- Notable areas of success
  - Z axis range of motion: 85 mm
  - Consistent wound detection and toolpath execution as desired
- Areas to improve upon in future work
  - Workspace dimensions: 218mm x 167mm, larger workspace desired to treat larger variety of wounds
  - Streamline code and reduce need for operator intervention
  - Wiring and final assembly

Valuable experiences from this Project

Valuable Experience

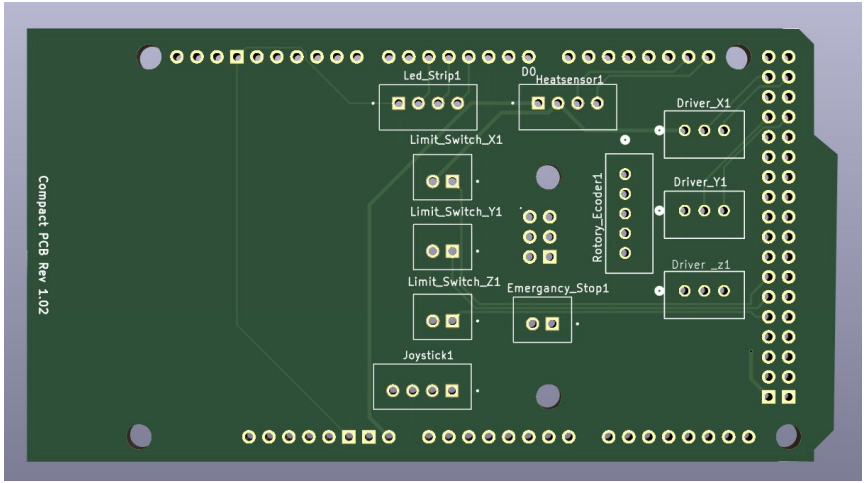
- Working on a large scale project
- Teamwork and delegating tasks
- Designing and prototyping a mechanism
- Application of engineering principles to solve a real world problem

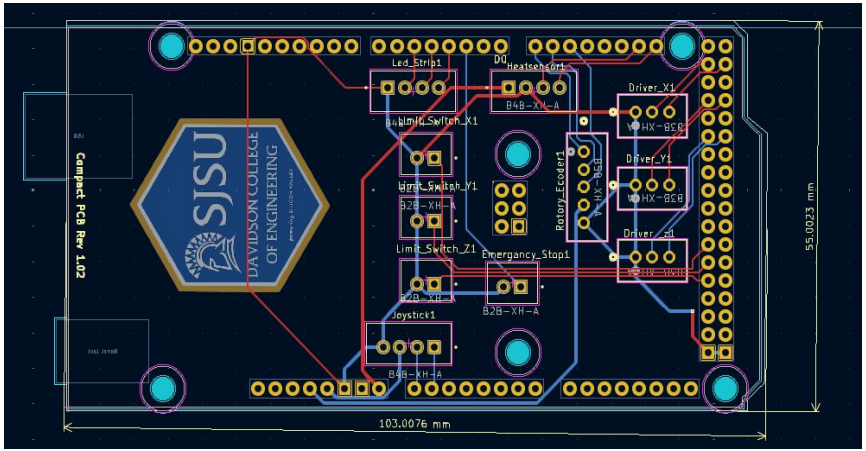
Challenges

- Coming to agreements for design decisions
- Time management
- Overcoming setbacks and obstacles
- Learning new skills (Arduino)

Future Work- PCB

- Reduces the amount of wiring
- Produces a more aesthetic project
- Allows for a compact and centralized housing for all components.





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Acknowledgements

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Thank You! Questions?