



Institute for  
advanced  
architecture  
of Catalonia

**MRAC**

Master in Robotics and  
Advanced Construction

*Hardware II - SENSORS & DATA  
ANALYSIS*

IaaC, 25.02.2022

Faculty/ Oscar Gonzalez  
Assistants/ Daniill Kosheleyuk

**FREBUJAR**

*Alfred Bowles  
Shamanth Thenkan  
Vincent Verster*

# | State of the art

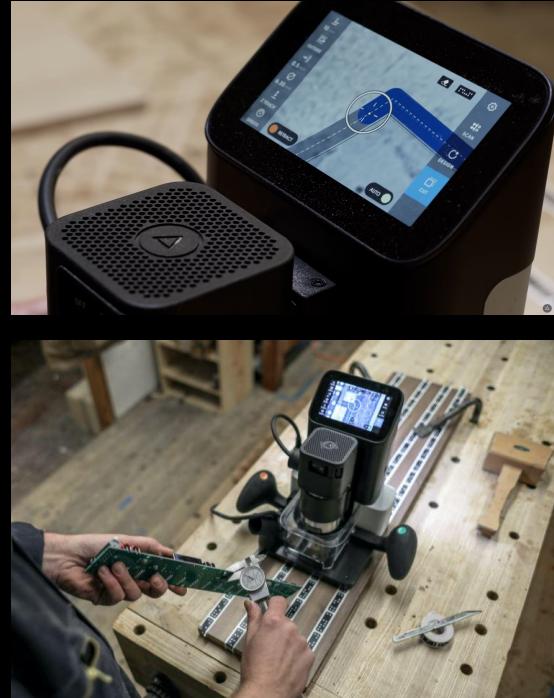
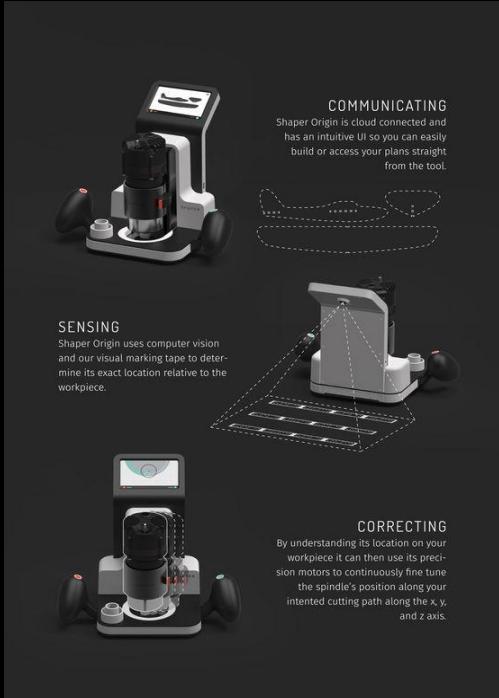
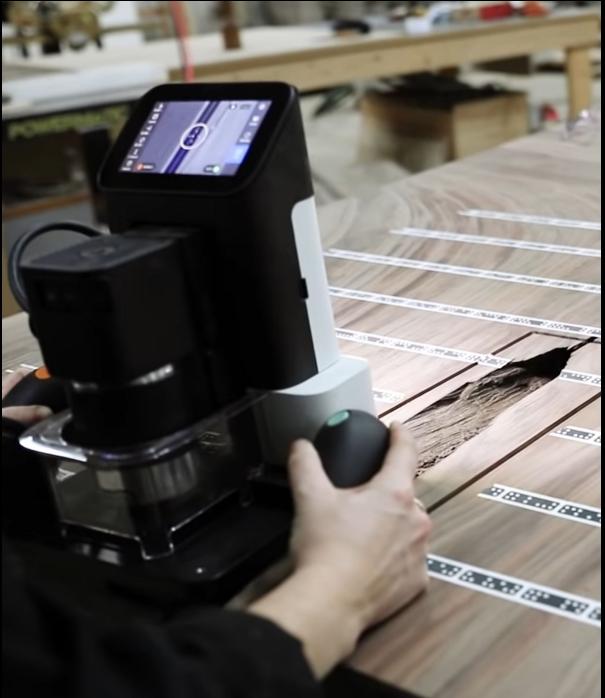


| CNC Machine



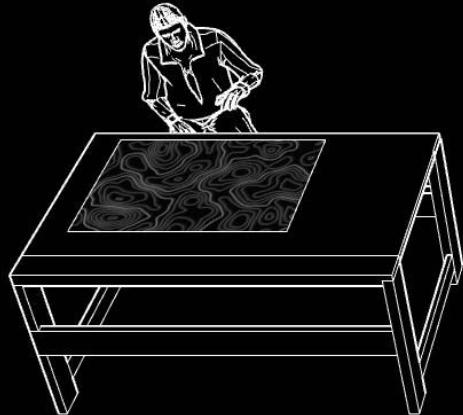
| Hand Router

# State of the art

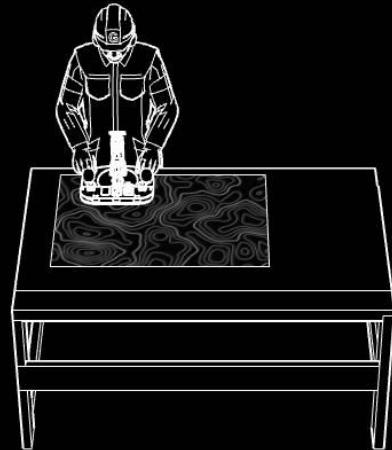


Shaper Origin

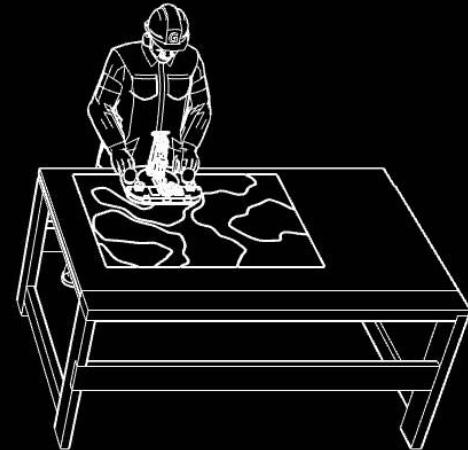
# FREBUJAR



| Draw / Print



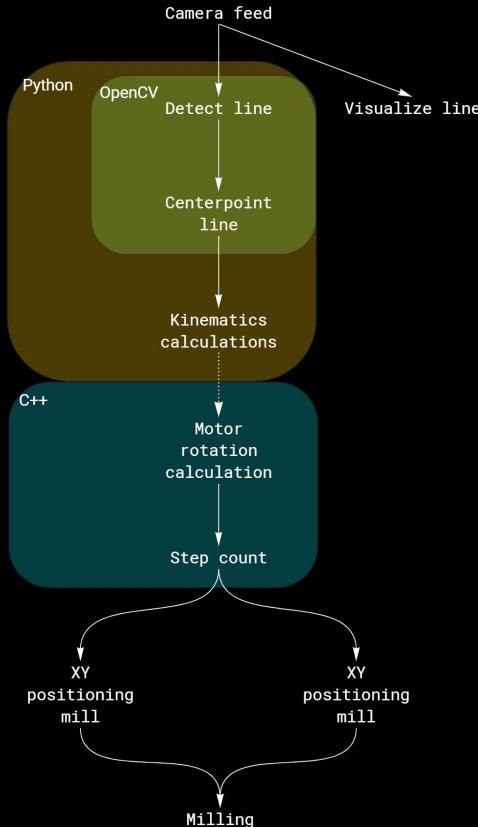
| Trace & Mill



| Milled Curves

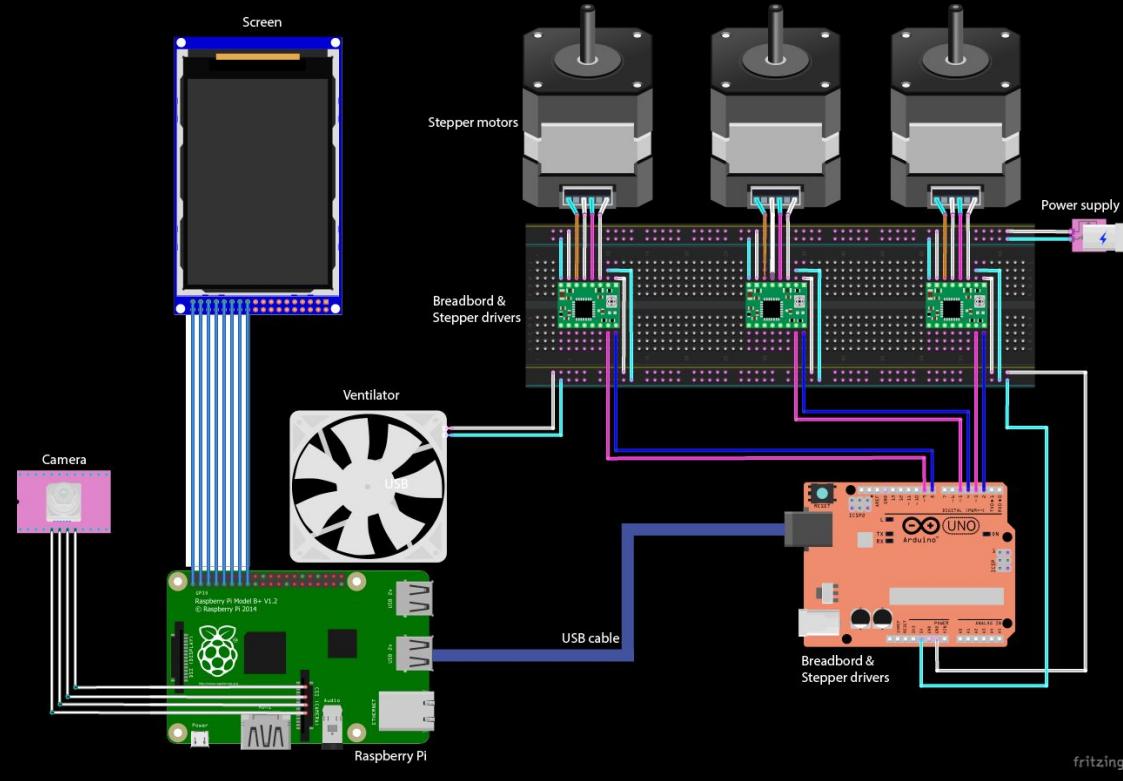
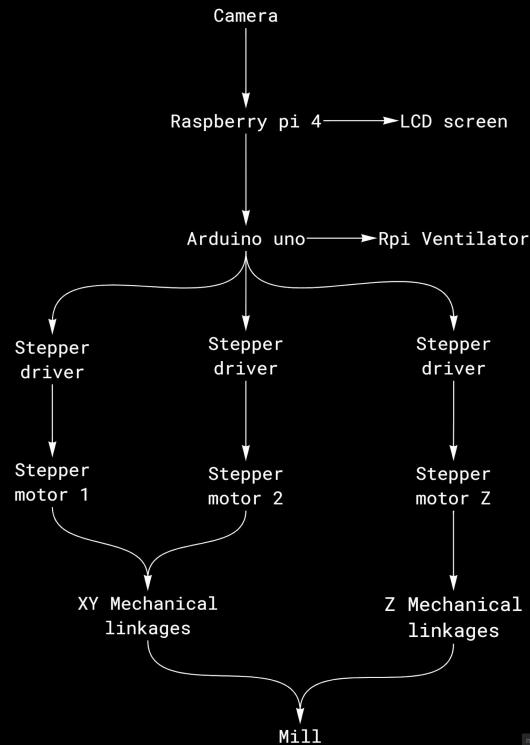
# Project Pseudo code

Functional diagram



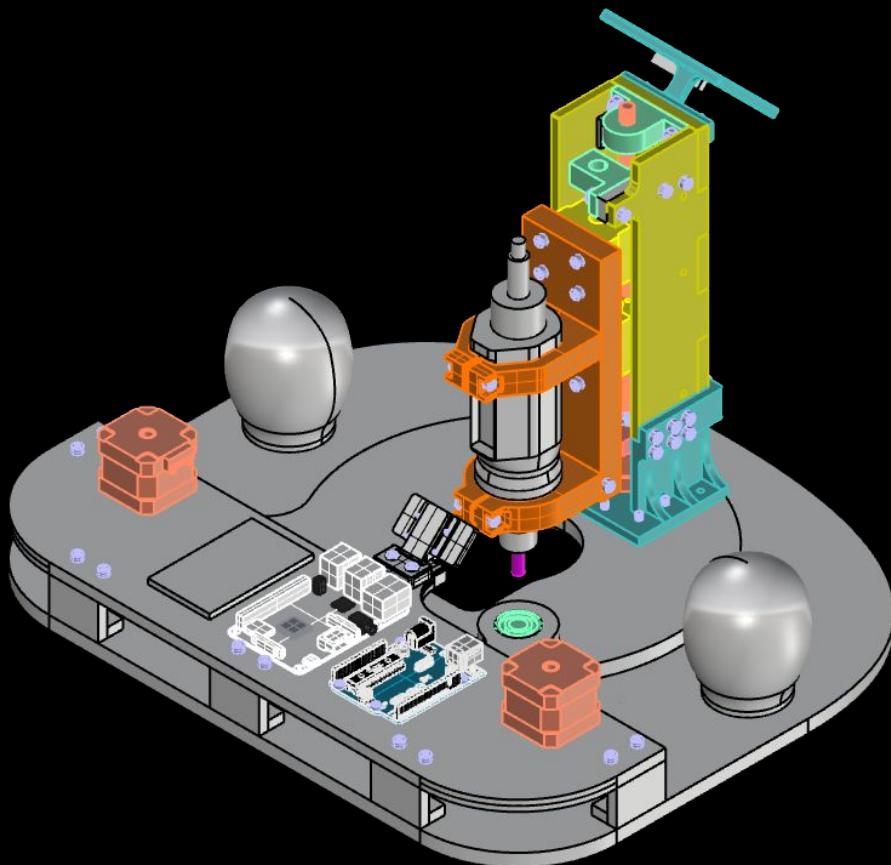
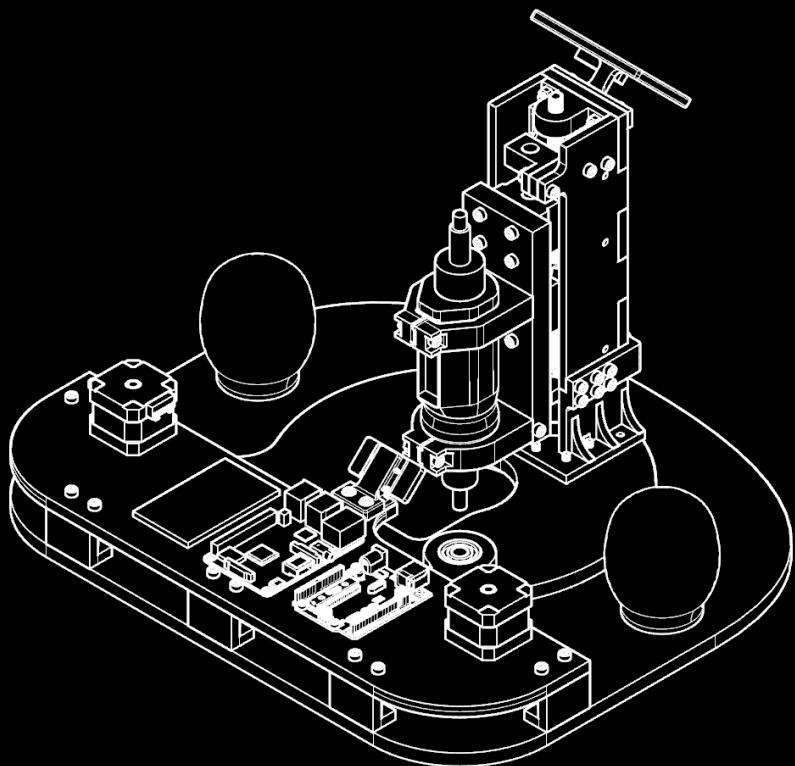
# Project Pseudo code

## Hardware diagram

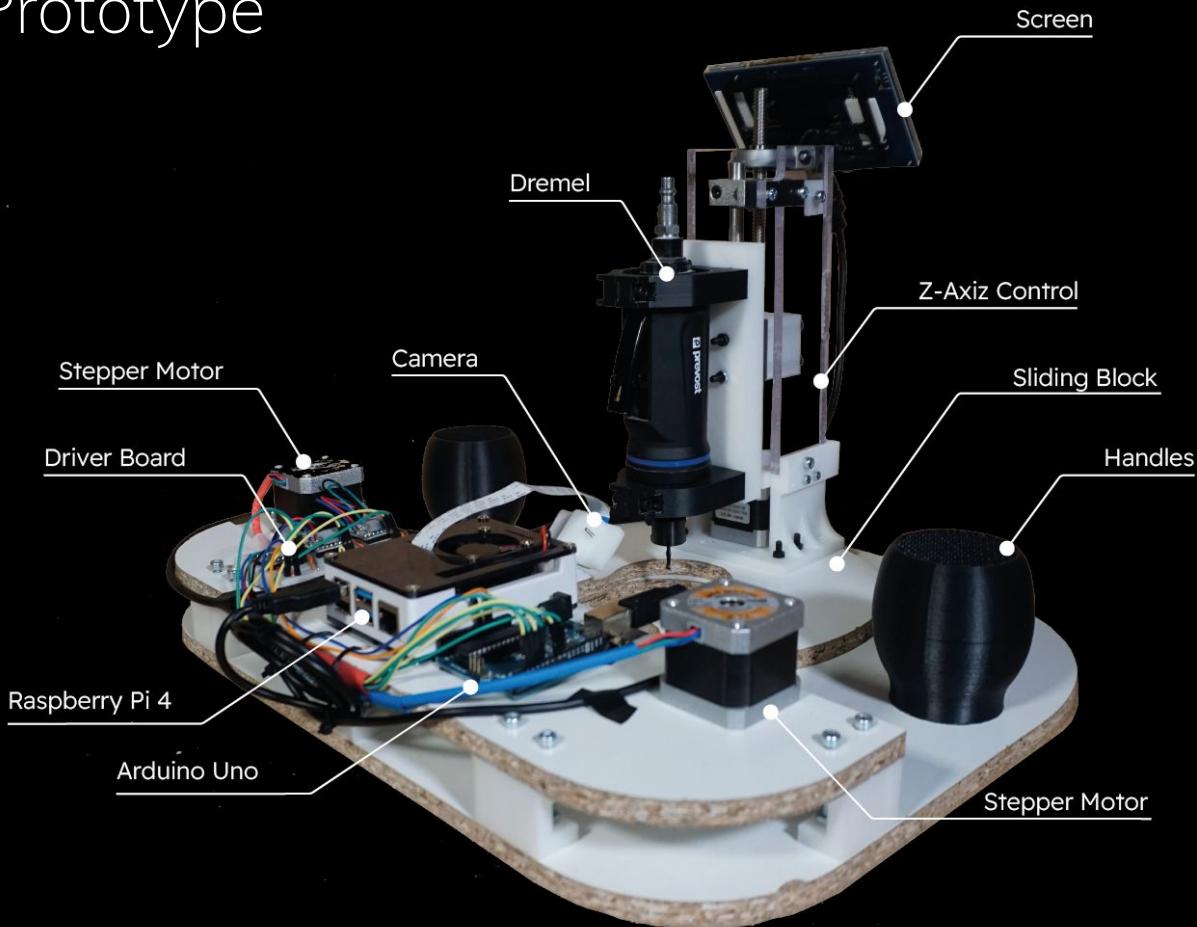


fritzing

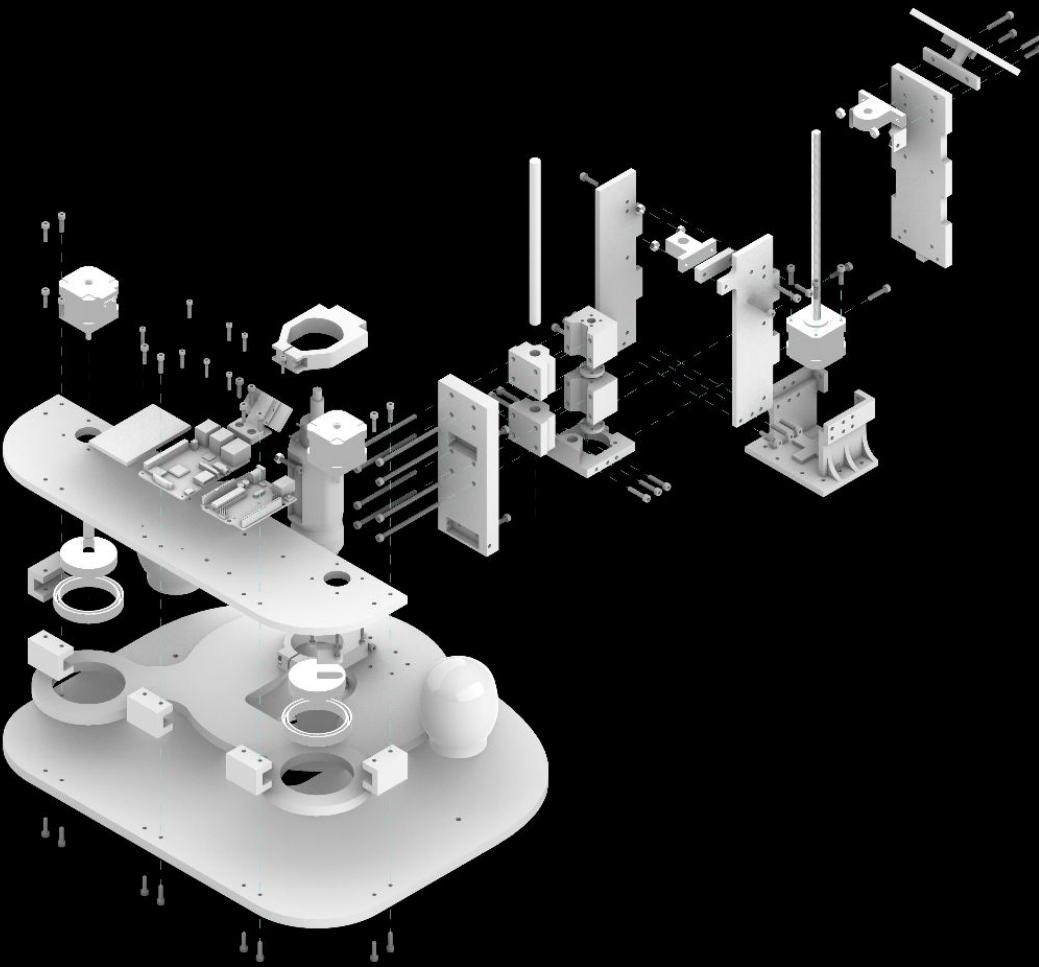
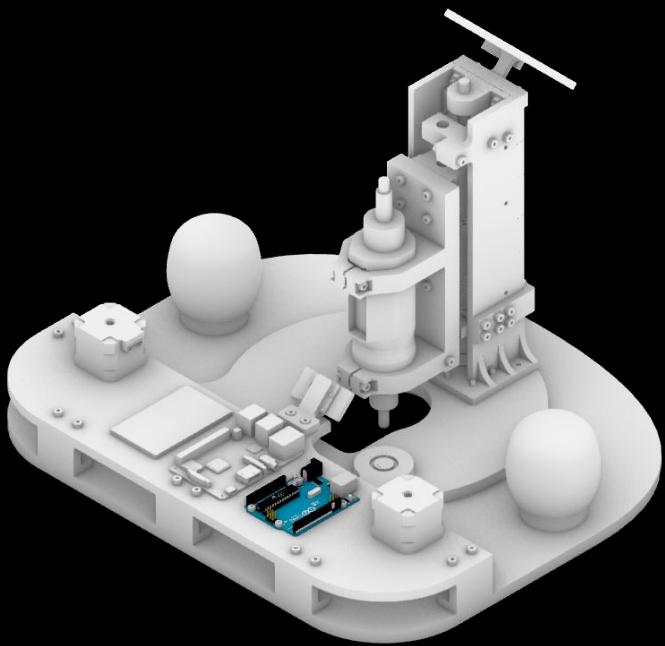
# FREBUJAR



# Frebujar / Prototype



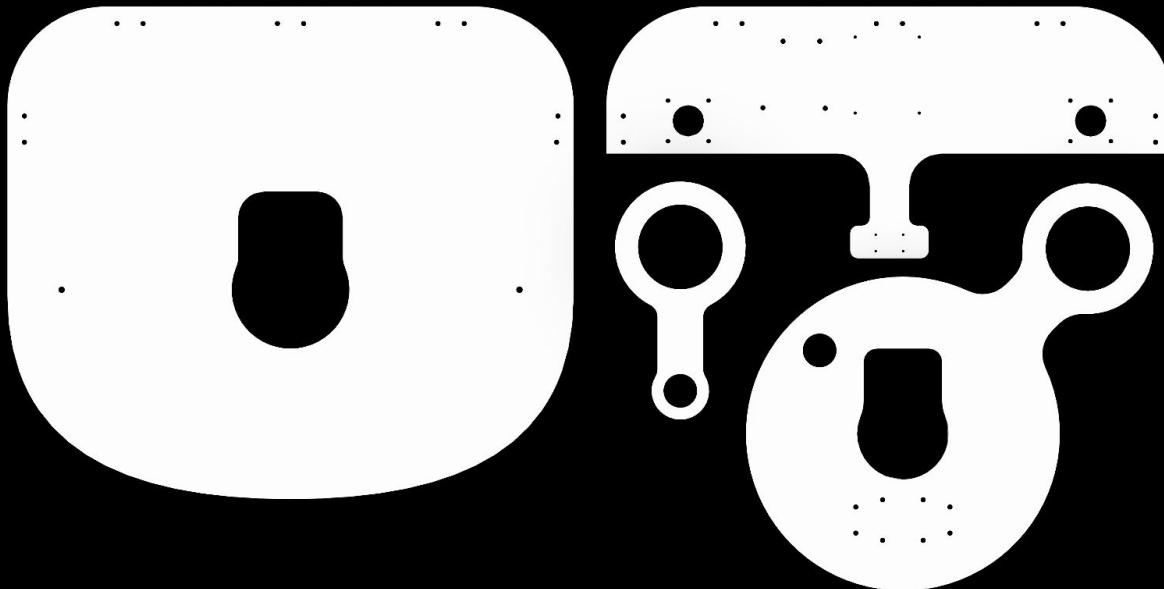
# Frebujar Exploded



# Frebujar Fabrication

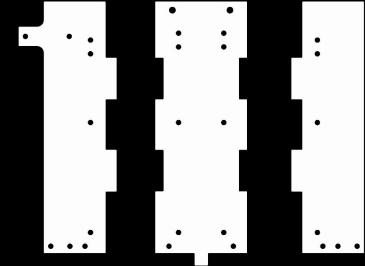
## 3 Axis Milling

Laminated MDF



## 3 Axis Milling

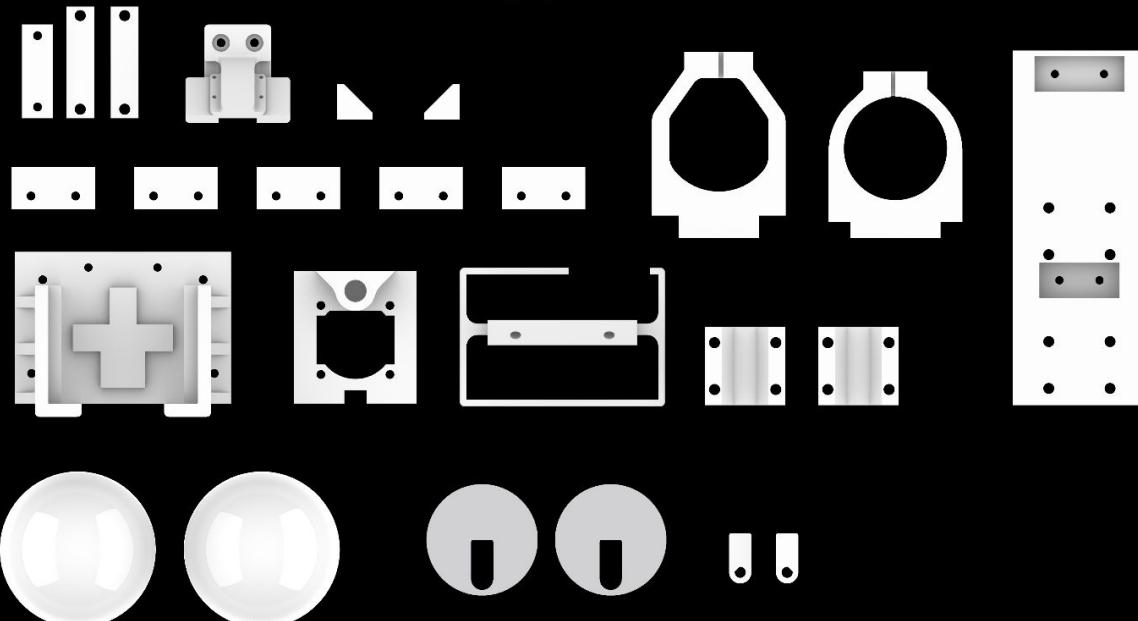
Clear Polycarbonate



Frebujar Fabrication

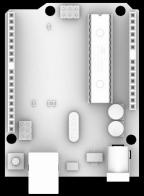
# 3D Printing

ABS

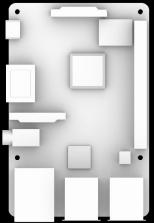


## Hardware

Arduino Uno



Raspberry Pi 4



3x a9488  
Stepper Drivers



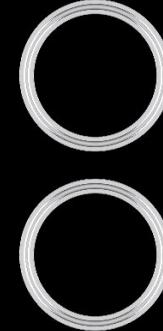
Raspberry Pi  
Camera V2.1



Linear Bearings



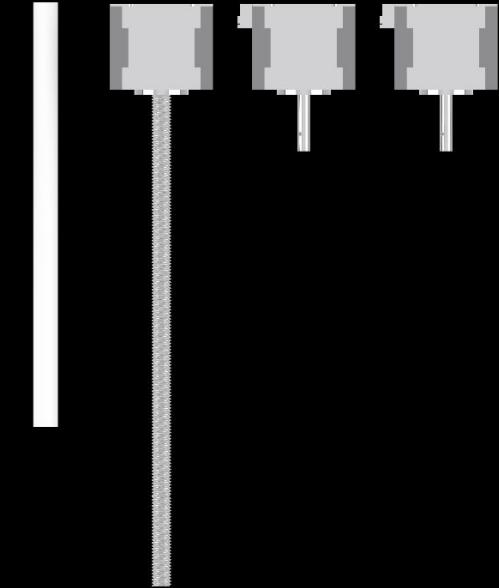
Radial Bearings  
ID=50mm



Radial Bearings  
ID=10mm



3x Nema 17 Stepper Motors



## Mechanical

Shaft Support



Threaded Shaft  
Bearing



# How does it all work?

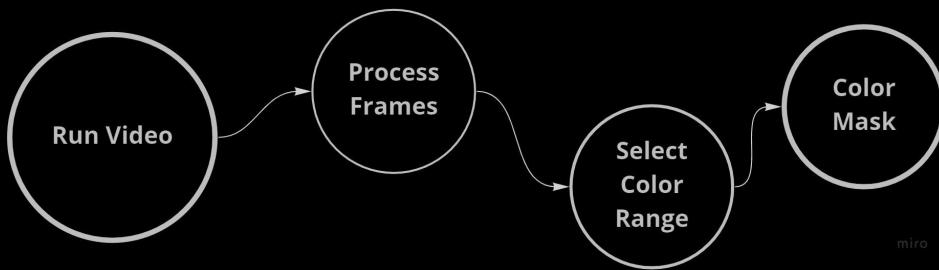
# Computer Vision

Track pixels by Colour Range

Extract centroid

Export Vectors of Centre point

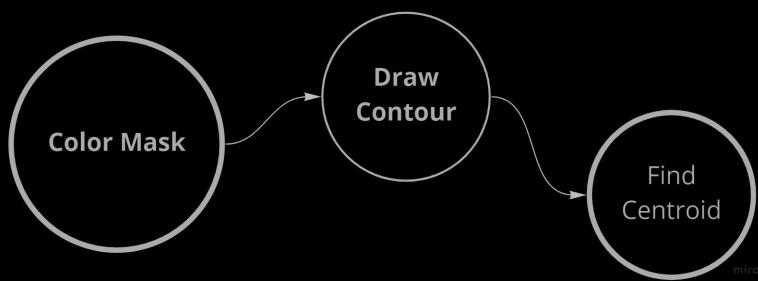
# Computer Vision



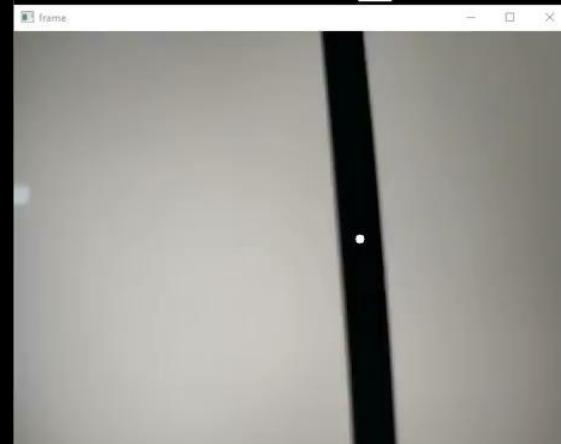
Color Mask

# Computer Vision

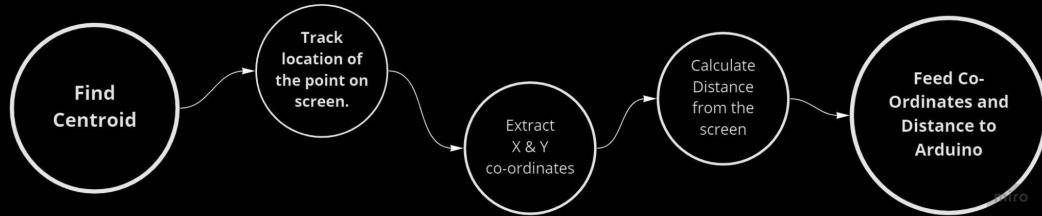
www.BANDICAM.com



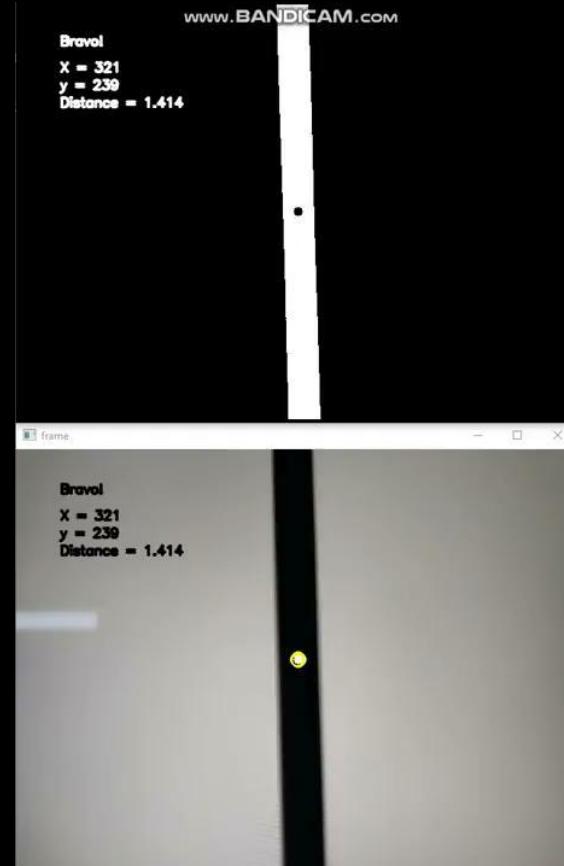
Centroid Detection

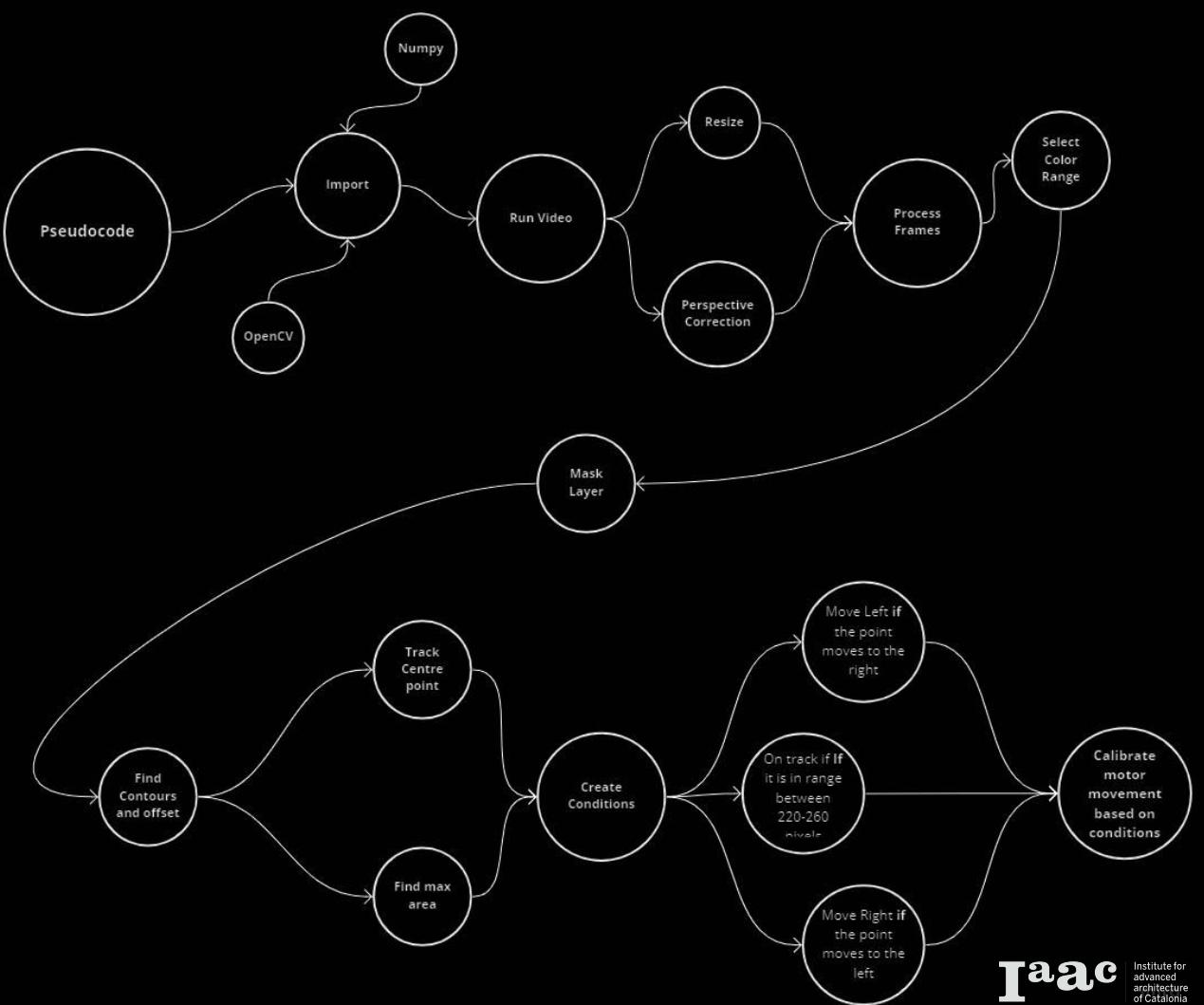


# Computer Vision



| Vector export

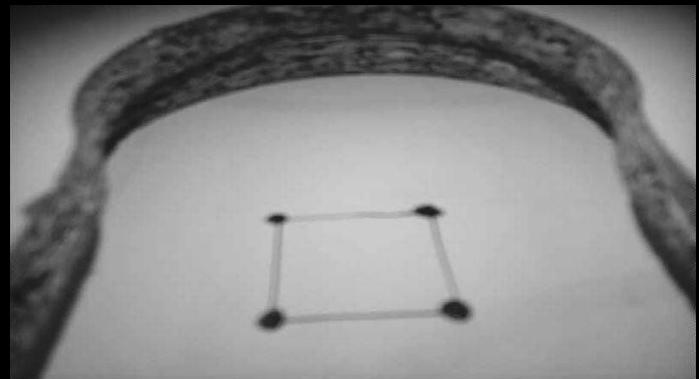
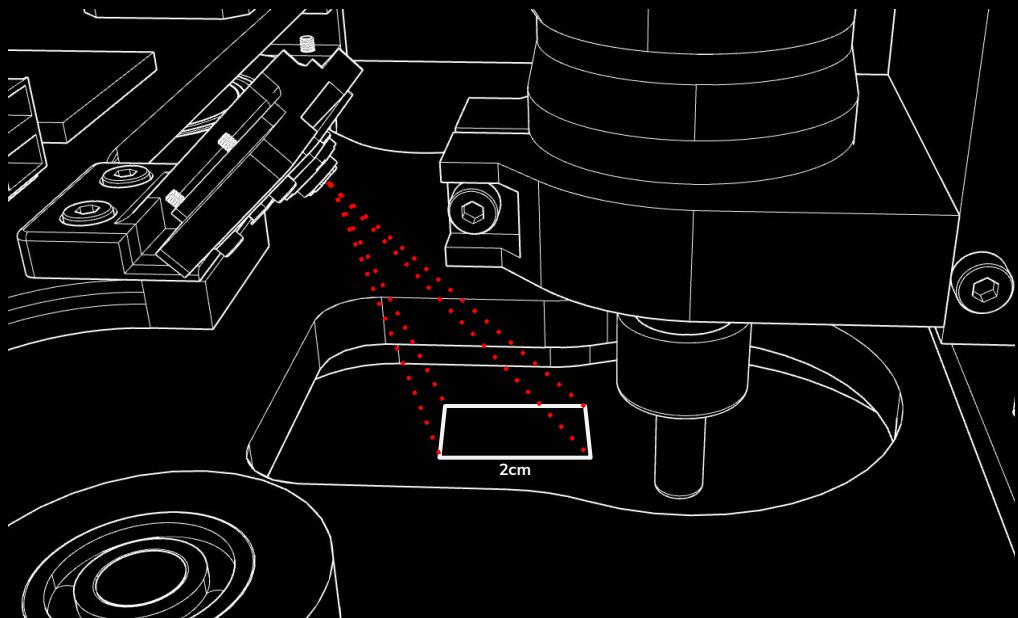




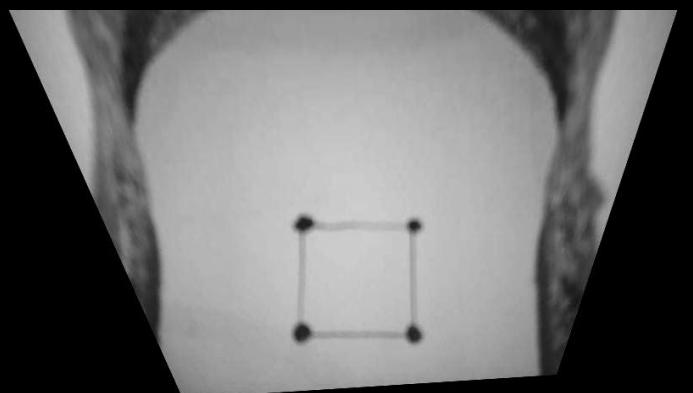
# Under the hood

# Computer Vision

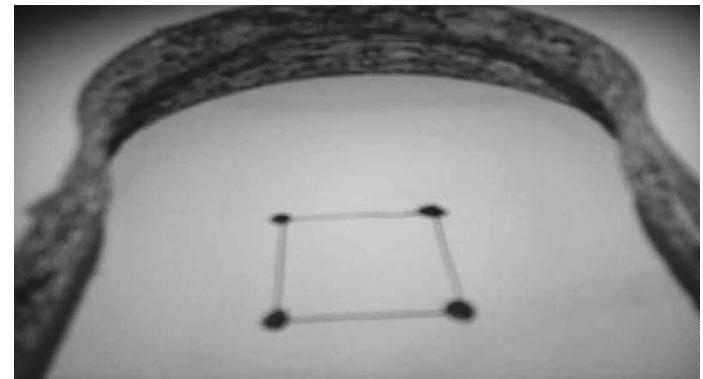
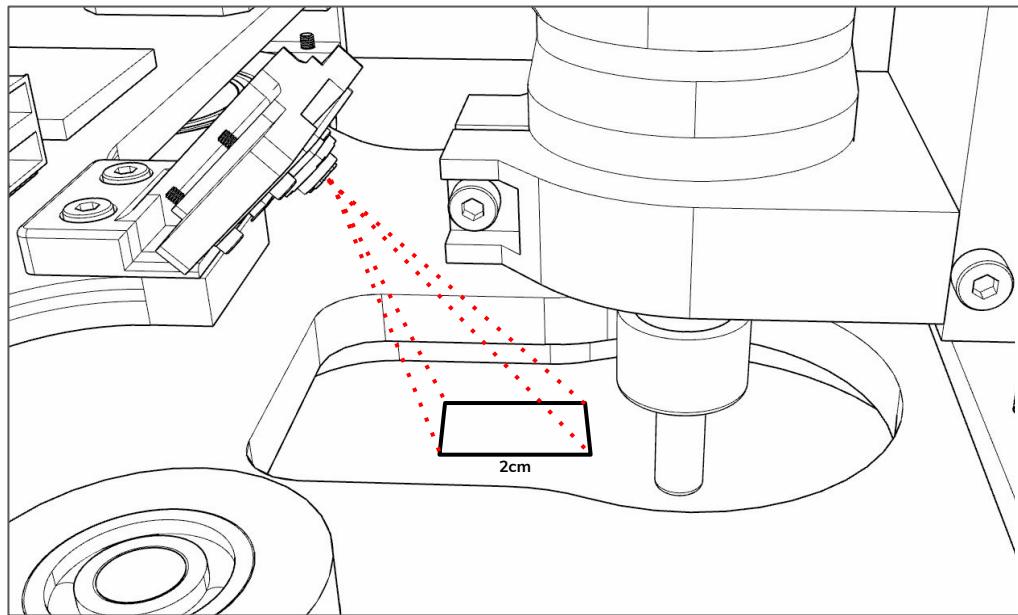
Homography



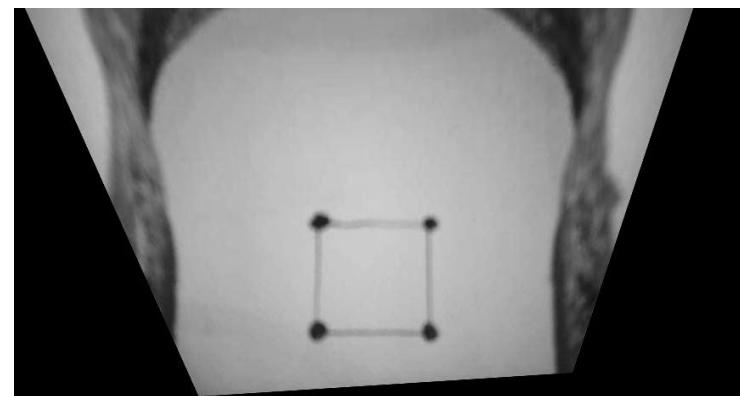
Perspective Image



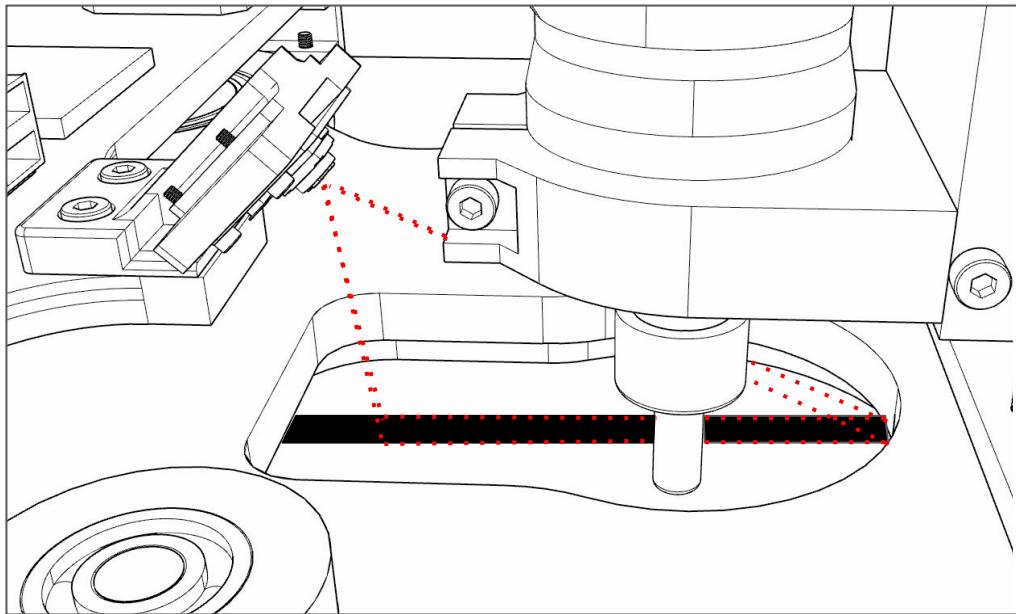
Corrected Image



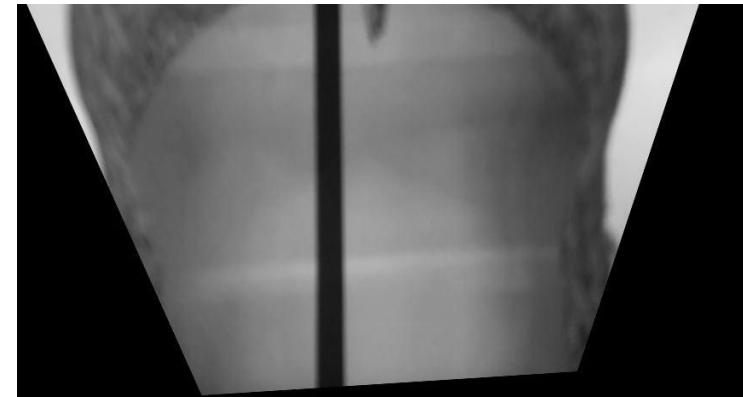
Perspective Image



Corrected Image



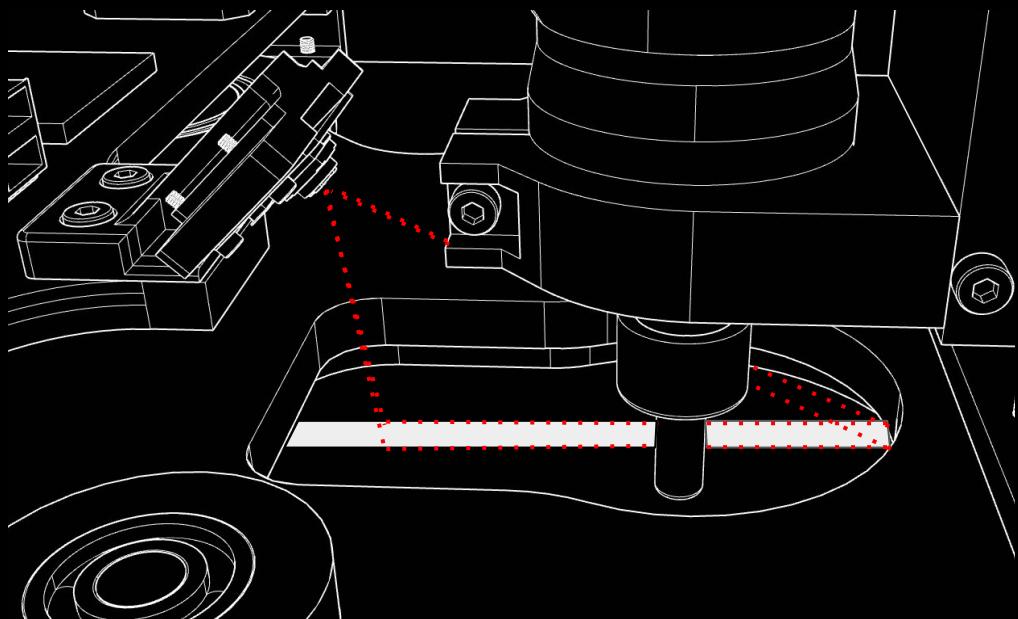
Perspective Image



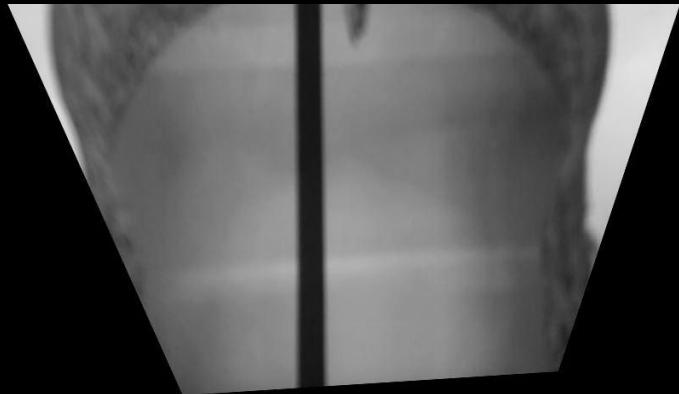
Corrected Image

# Computer Vision

Homography



Perspective Image

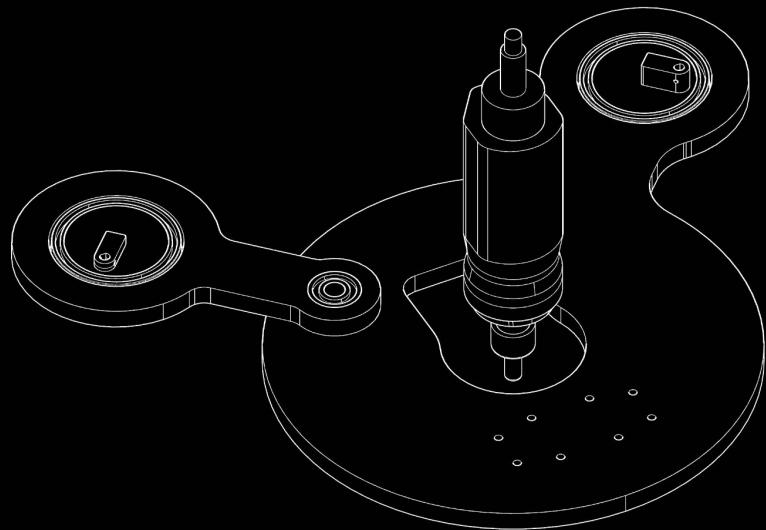


Corrected Image

# Kinematics

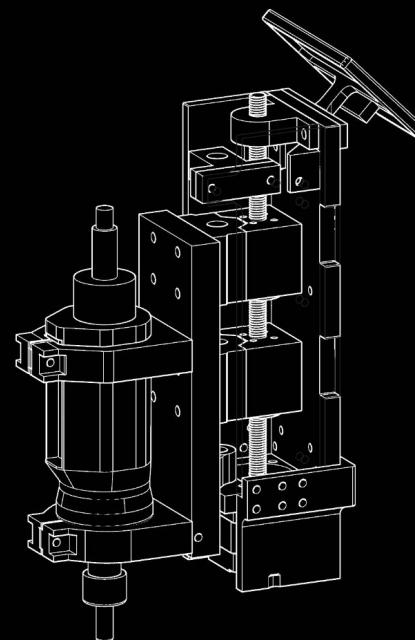
## XY Sliding CAM System

For xy calibration of the bit while user is manually tracing the tool

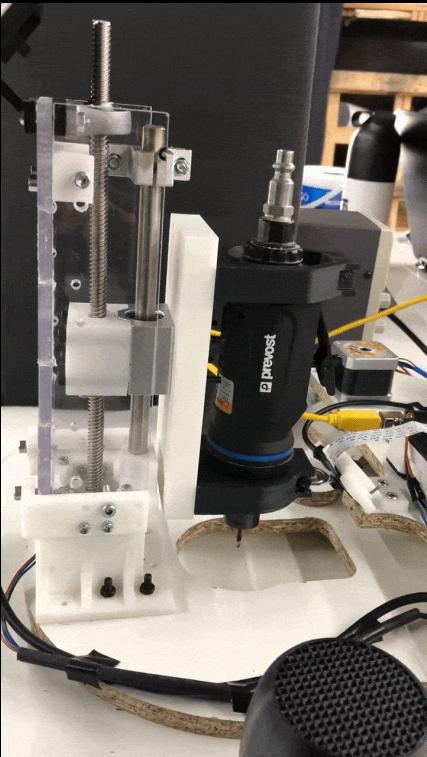


## Z-Axis Block

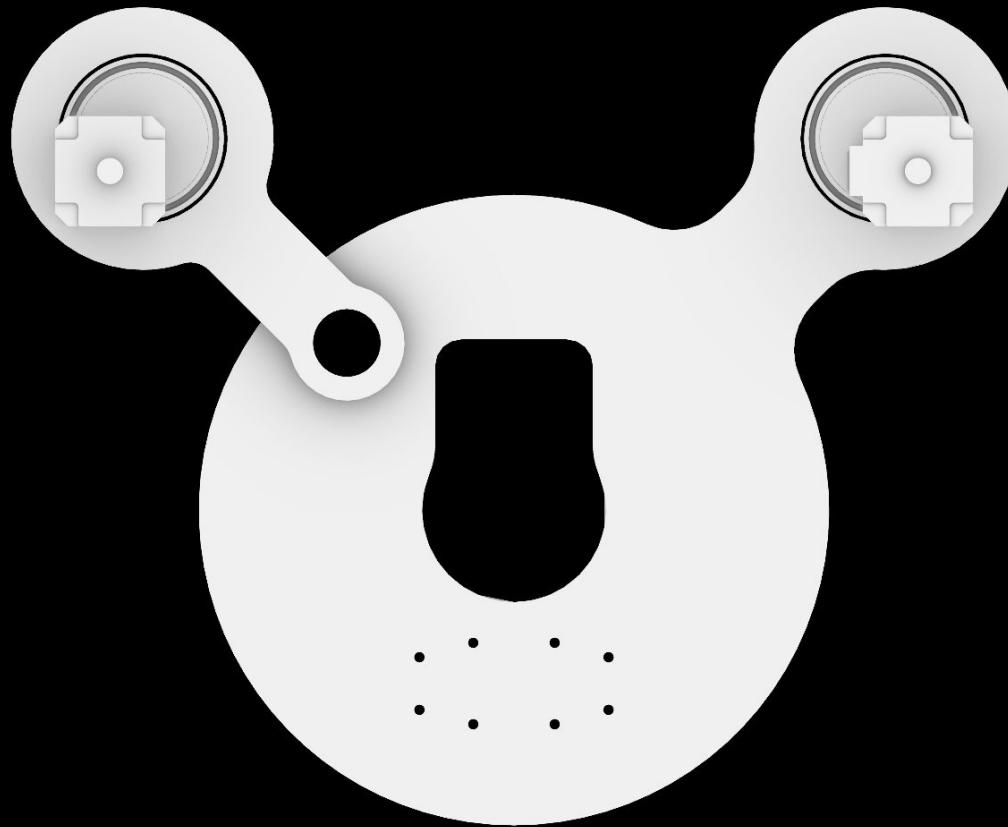
Threaded bar Z-Axis control for depth control and retraction



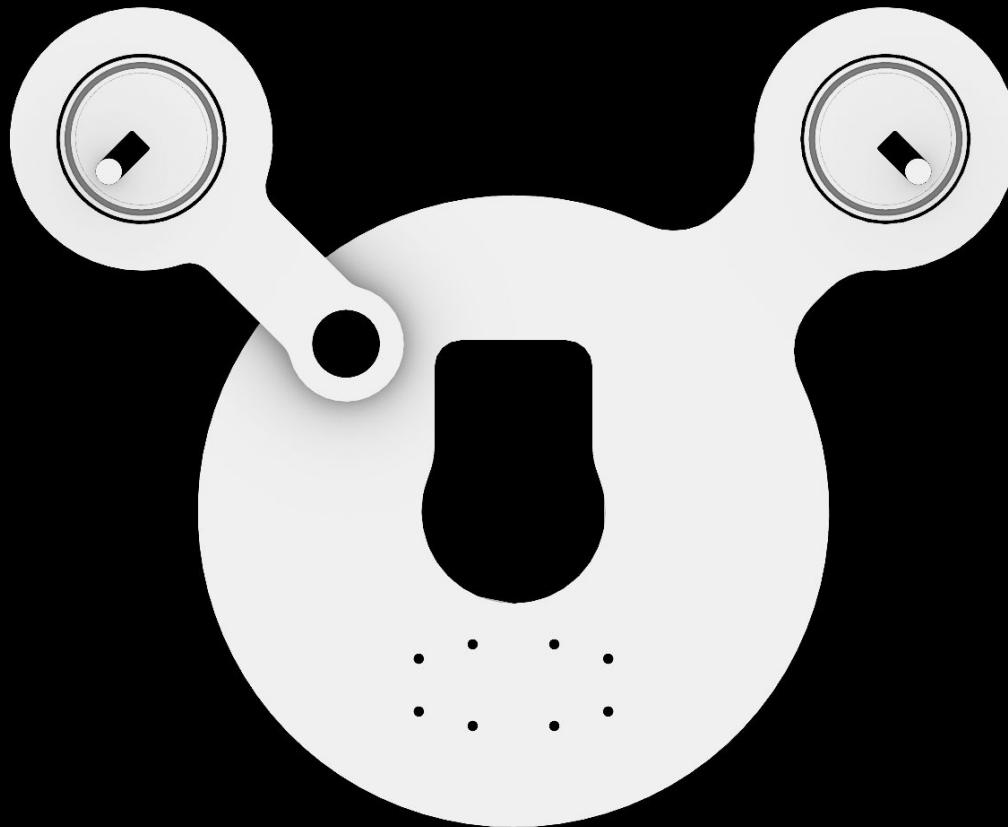
# Mechanics / Z-Axis Block

A screenshot of a terminal window on a Linux system. The terminal shows the execution of a Python script named 'testwrite.py'. The output indicates a UnicodeDecodeError due to 'utf-8' codec not being able to decode a byte sequence. The error message points to line 9 of the script. The terminal also shows a KeyboardInterrupt interrupt.

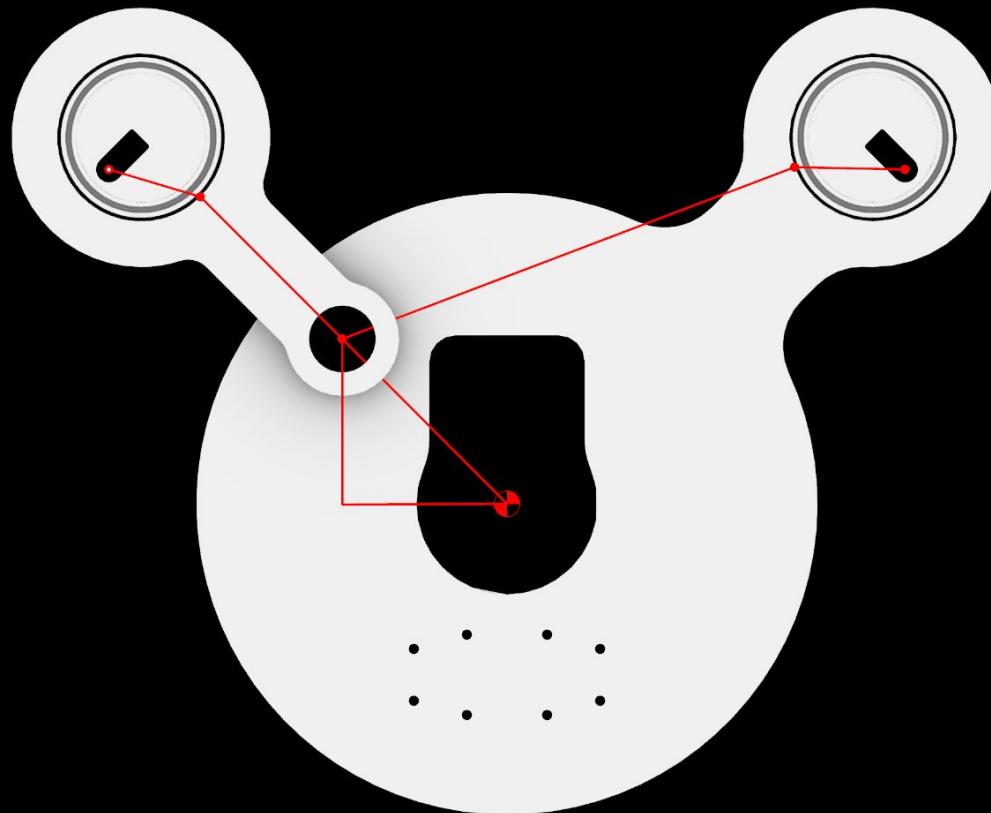
# Mechanics / Sliding Cam Mechanism



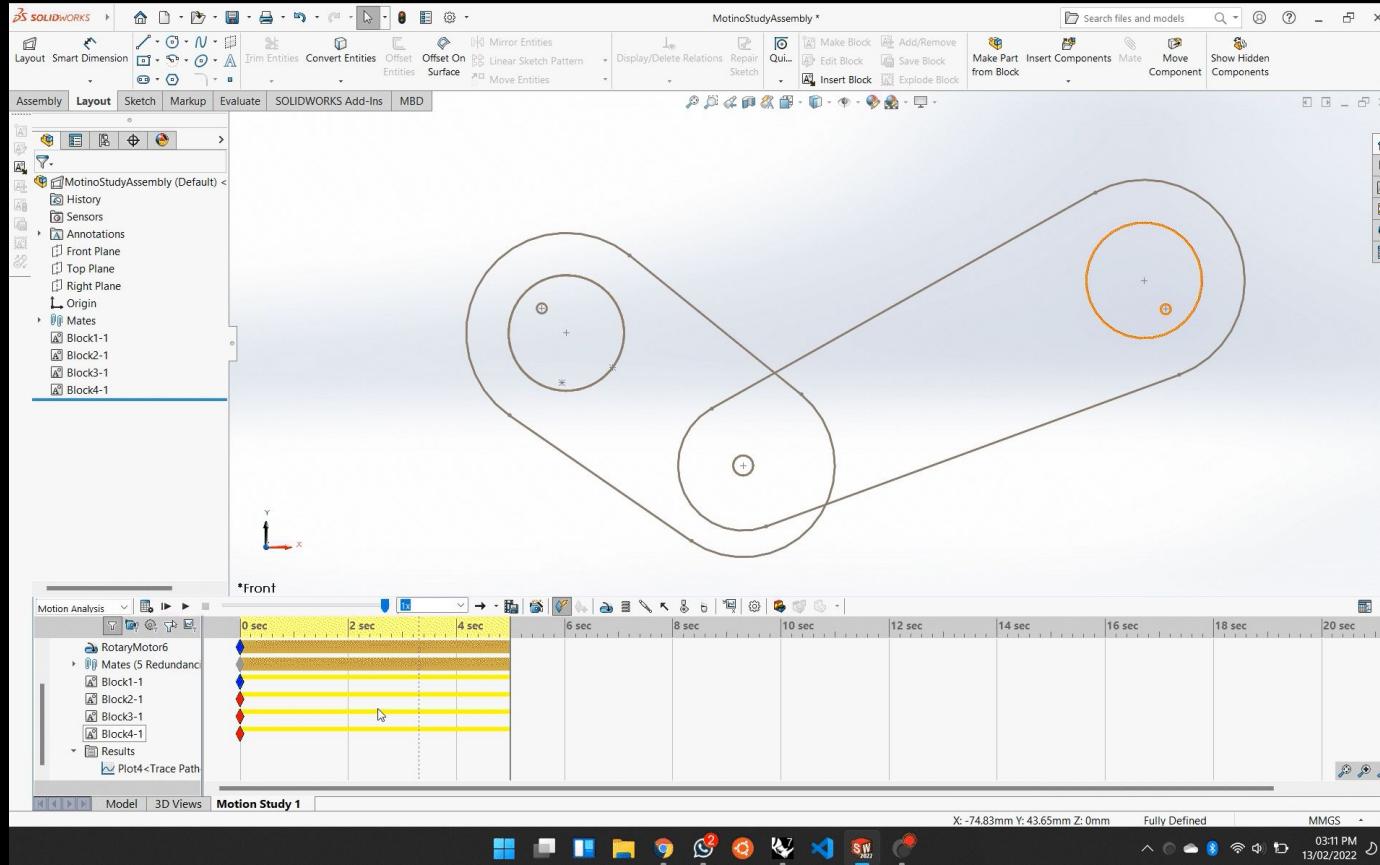
# Kinematics / Method 1



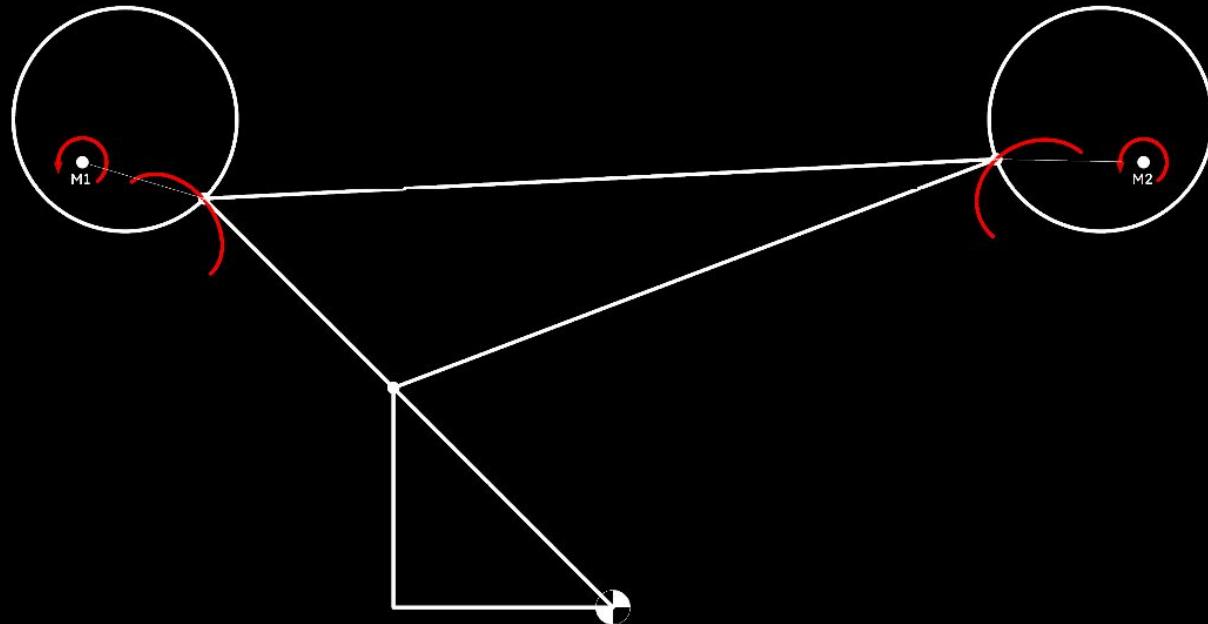
# Kinematics / Method 1



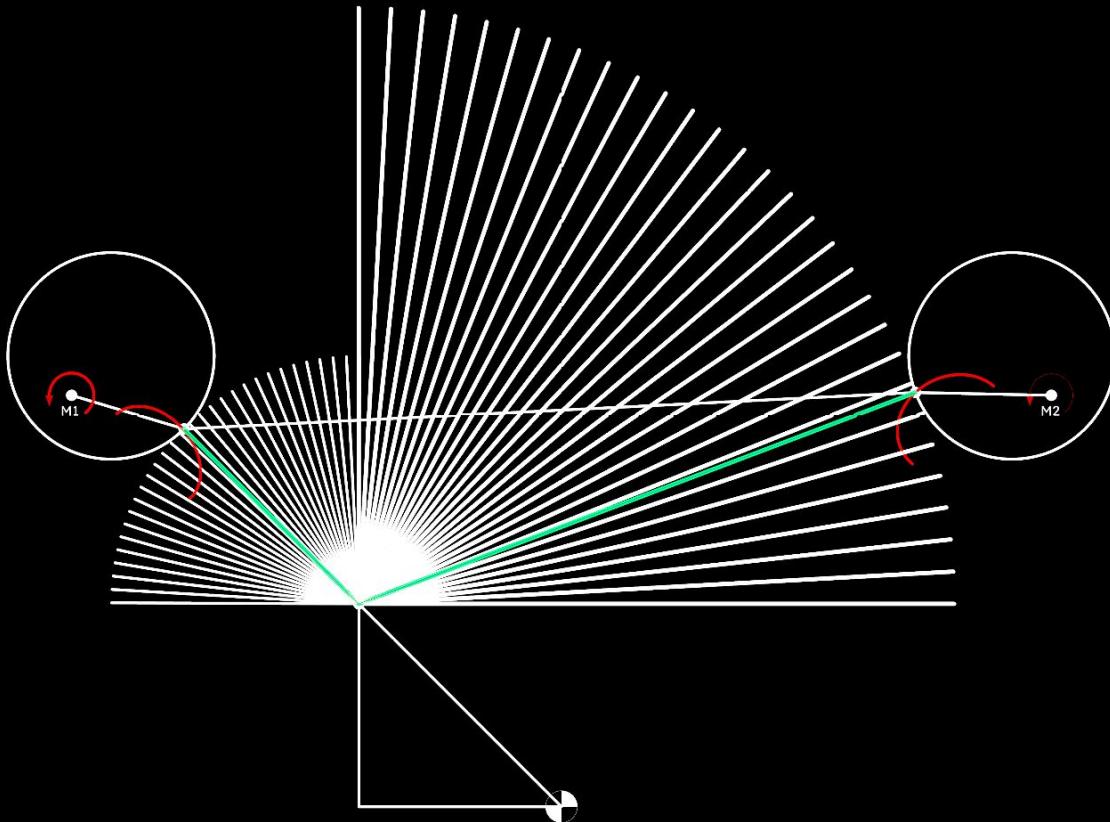
# Kinematics / Method 1



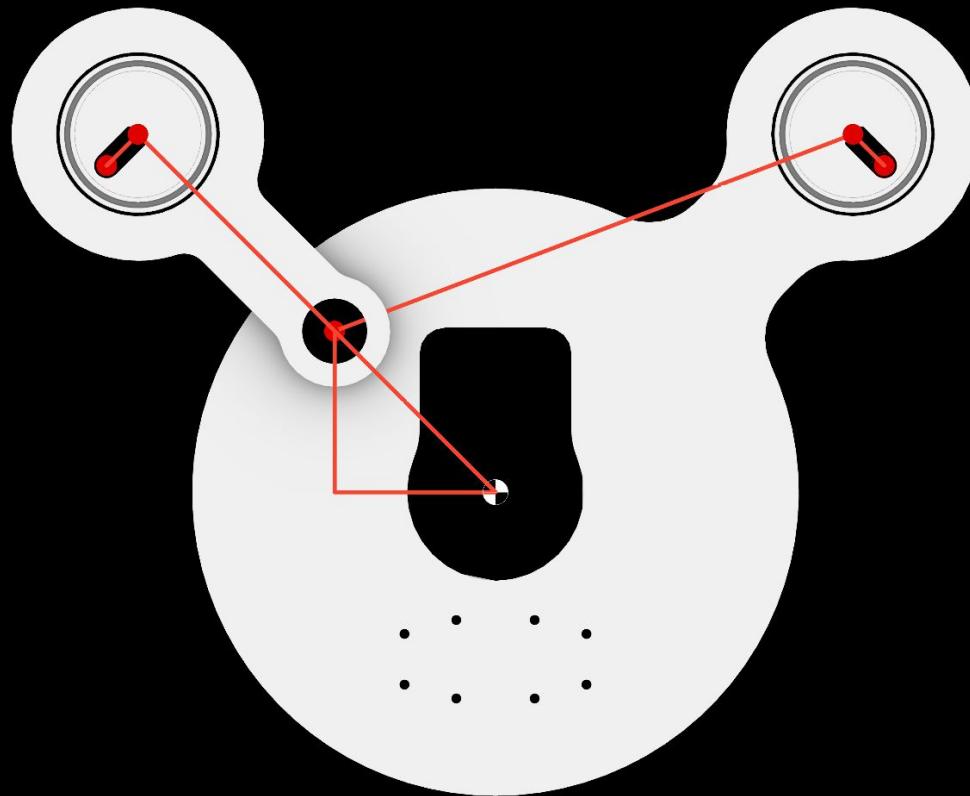
# Kinematics / Method 1



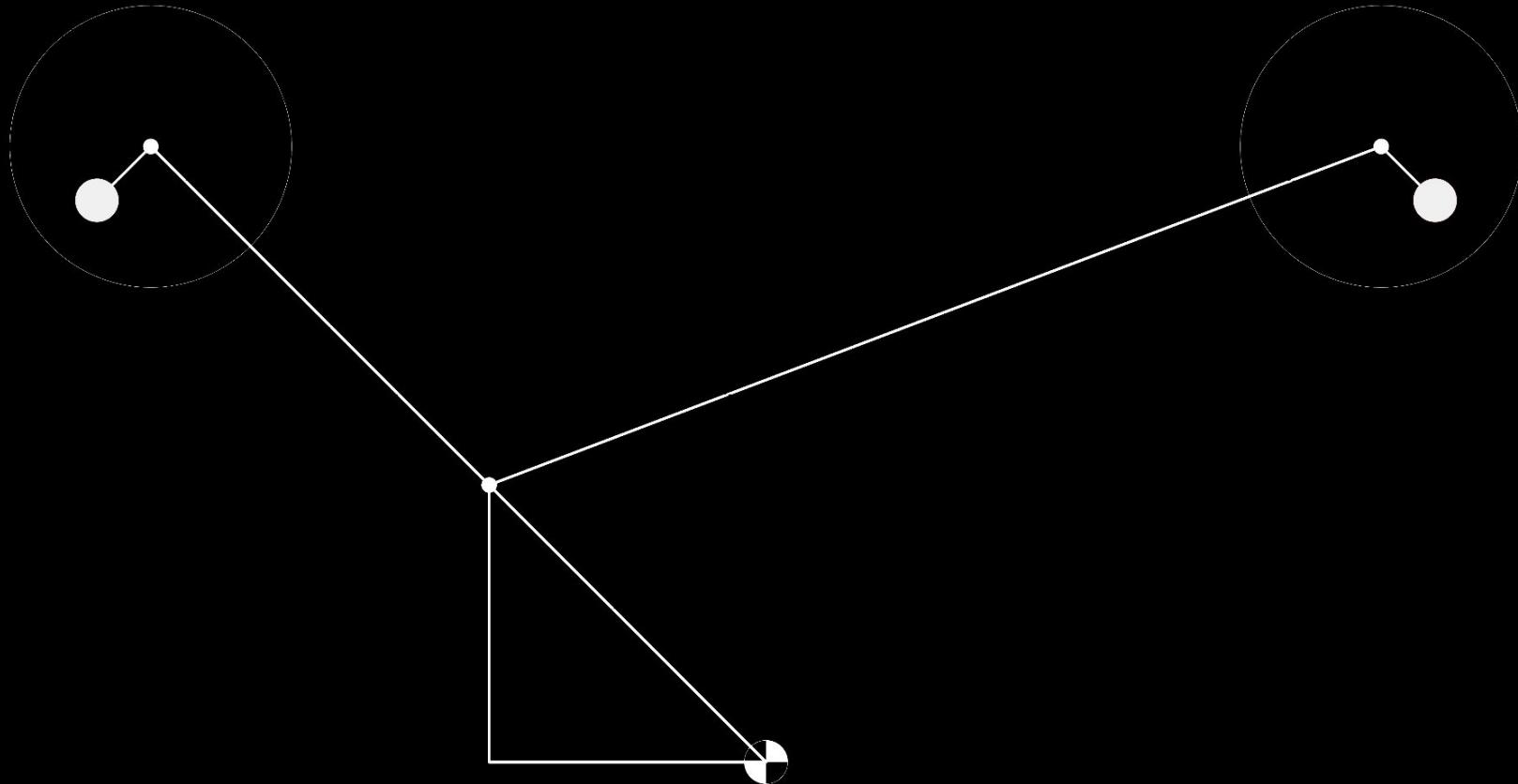
# Kinematics / Method 1



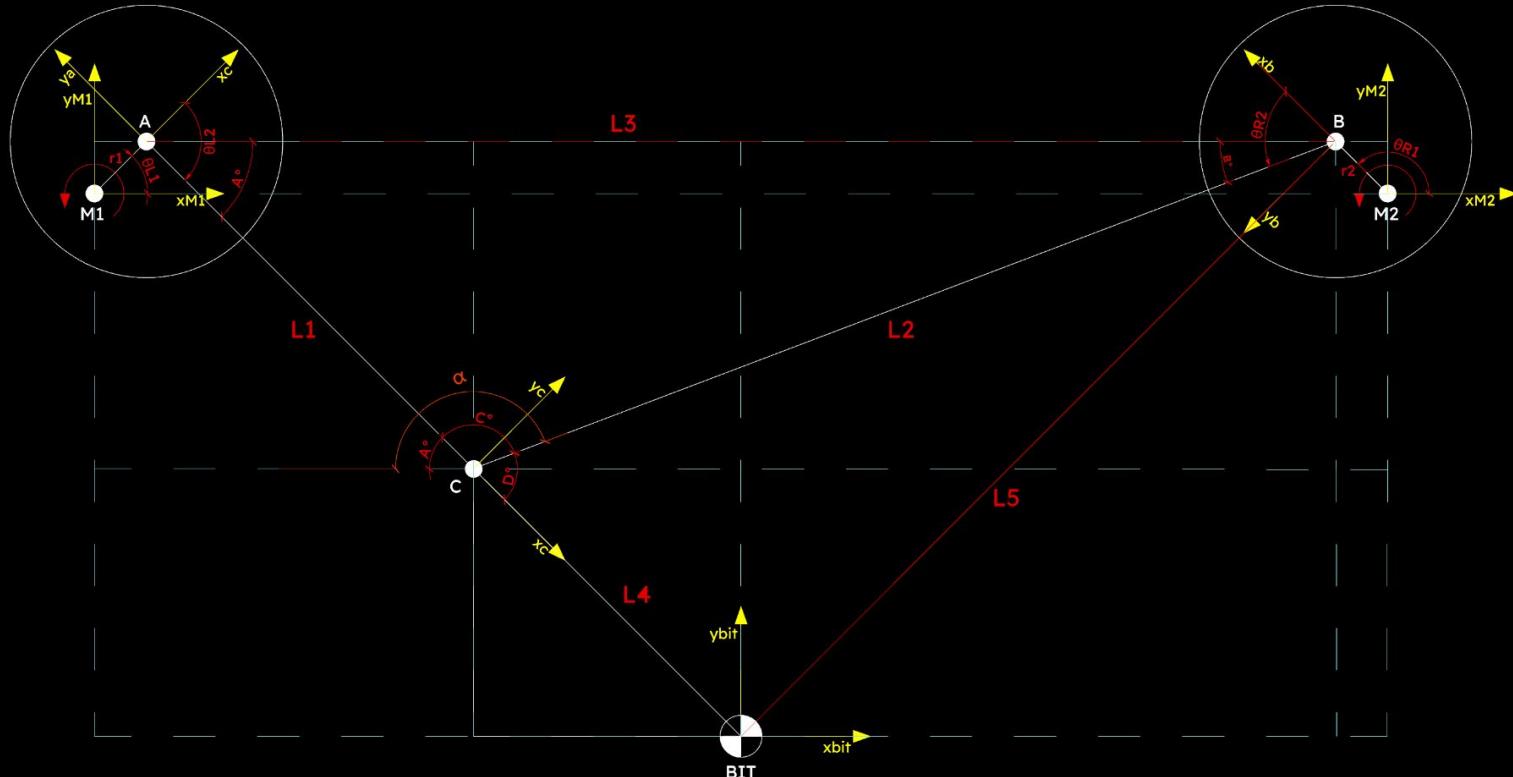
# Kinematics / Method 2



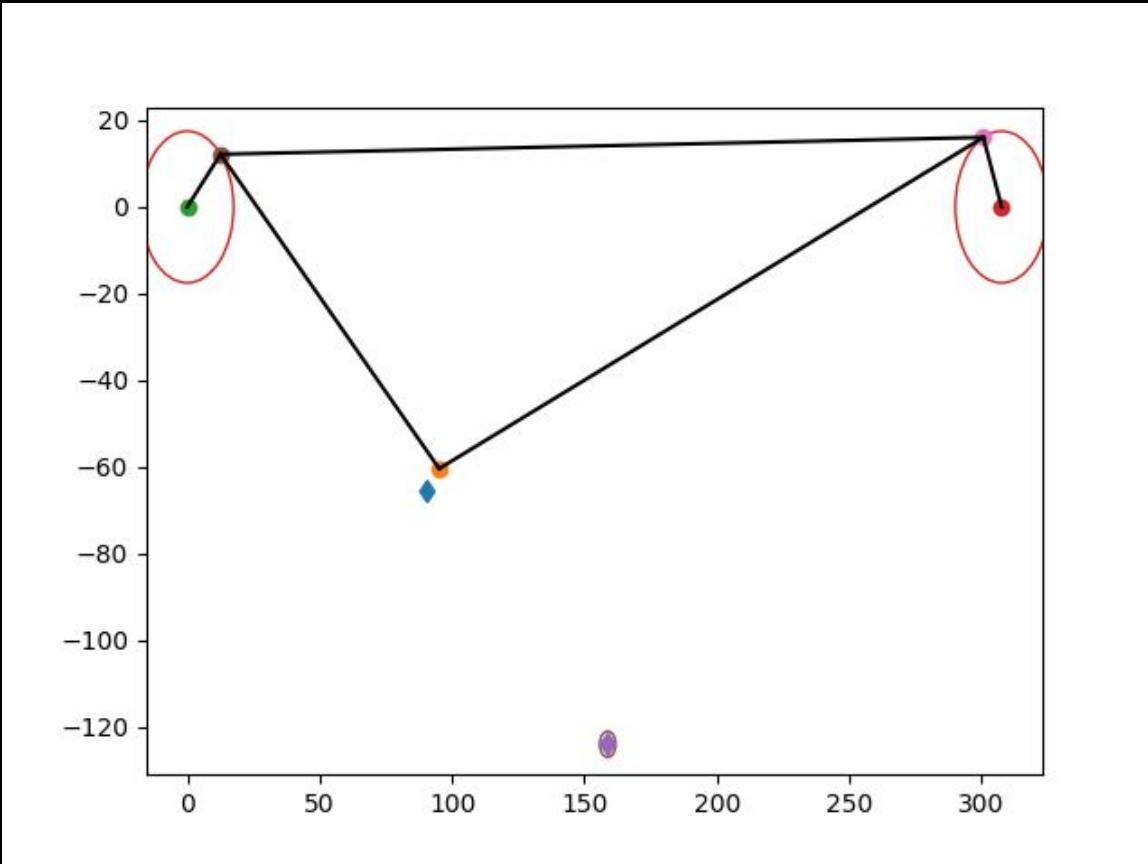
## Kinematics / Method 2



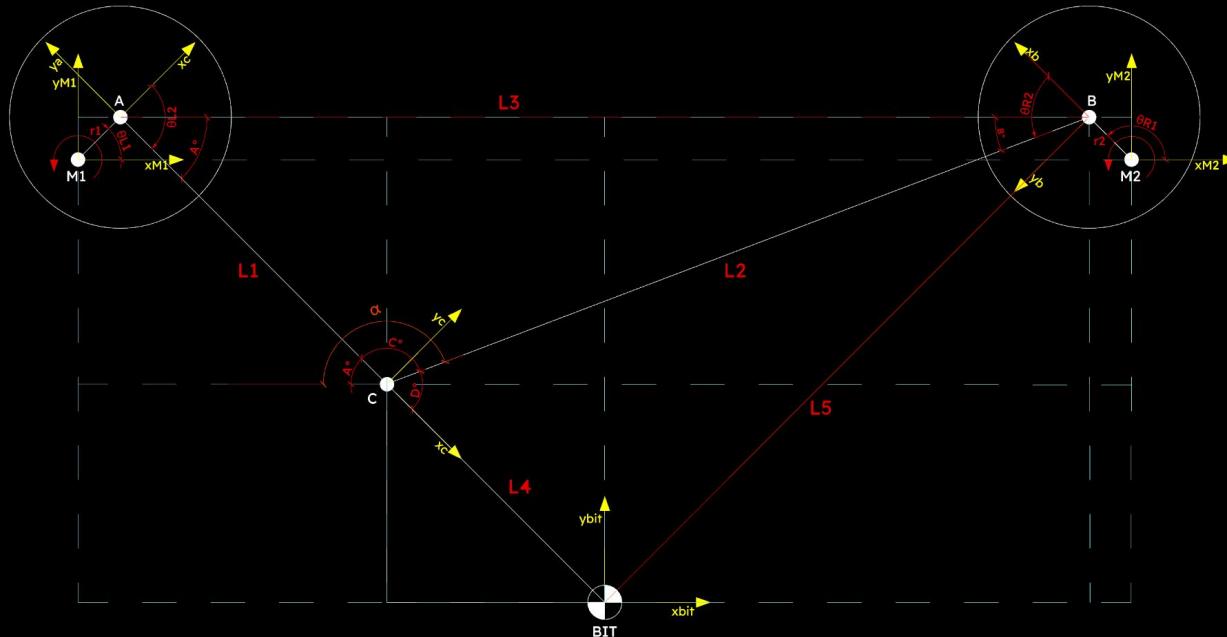
# Forward Kinematics / Method 2



# Kinematics / Method 2



# Forward Kinematics / Method 2



$$Cx = r_1 \cos(\theta_{L1}) + L_1 \cos(\theta_{r_1} + \theta_{L1})$$

$$Cy = r_1 \sin(\theta_{L1}) + L_1 \sin(\theta_{r_1} + \theta_{L1})$$

$$Cx = r_2 \cos(\theta_{R1}) + L_2 \cos(\theta_{r_2} + \theta_{R1})$$

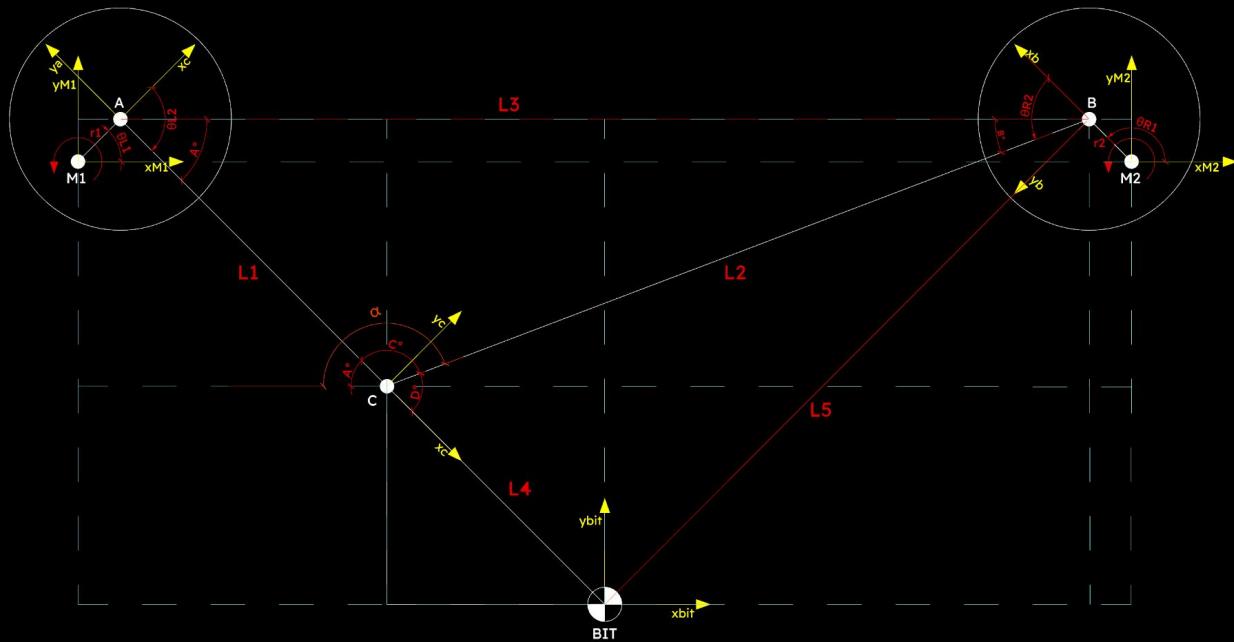
$$Cy = r_2 \sin(\theta_{R1}) + L_2 \sin(\theta_{r_2} + \theta_{R1})$$

$$\text{AngleA} = \cos^{-1}\left(\frac{L_1^2 + L_3^2 - L_2^2}{2(L_2)(L_3)}\right)$$

$$\text{AngleC} = \cos^{-1}\left(\frac{L_1^2 + L_2^2 - L_3^2}{2(L_1)(L_2)}\right)$$

$$(bitx, bity) = (Cx + 63.64, Cy - 63.64)$$

# Inverse Kinematics



$$\theta L_2 = \cos^{-1}\left(\frac{Cx^2 + Cy^2 - r1^2 - L_1^2}{2r1L_1}\right)$$

$$\theta L_1 = \tan^{-1}\left(\frac{y}{x}\right) - \tan^{-1}\left(\frac{L_1 \sin(\theta L_2)}{r_1 + L_1 * \cos(\theta L_2)}\right)$$

$$\theta R_2 = \cos^{-1}\left(\frac{Cx^2 + Cy^2 - r2^2 - L_1^2}{2r2L_2}\right)$$

$$\theta R_1 = \tan^{-1}\left(\frac{y}{x}\right) - \tan^{-1}\left(\frac{L_2 \sin(\theta R_2)}{r_2 + L_2 * \cos(\theta R_2)}\right)$$

$$Motor1 = \theta L_1[0] + \theta L_1$$

$$Motor2 = \theta R_1[0] + \theta R_1$$

# Pseudocode Arduino

Define:

- Pins
- Floats and integers
- Strings

Void setup:

- Serial begin (9600)
- Pinmodes: Output

Void loop:

Serial read:

- First and second bracket: index
- End number: length
- Convert to angles in floats

Motor 1

if: Current angle - angle > tolerance:  
- Motor clockwise  
- Make step

if: Current angle - angle < tolerance:  
- Motor counterclockwise  
- Make step

if: Current angle - angle > tolerance:  
- Motor clockwise  
- Make step

Motor 2

if: Current angle - angle > tolerance:  
- Motor clockwise  
- Make step

if: Current angle - angle < tolerance:  
- Motor counterclockwise  
- Make step

if: Current angle - angle > tolerance:  
- Motor clockwise  
- Make step

Motor 3

if: Current angle - angle > tolerance:  
- Motor clockwise  
- Make step

if: Current angle - angle < tolerance:  
- Motor counterclockwise  
- Make step

Input example:

20.153;90.4;65.7886

# BOM

Object	Details	Quantity	Unit Price	Subtotal	Supplier		
<b>Electronics</b>							
Raspberry Pi 3B+		1	€48.00	€48.00	Mike		
Arduino Uno		1	€0.00	€0.00	Pre-owned		
Camera		1	€28.00	€28.00	Amazon		
Stepper Motor - Nema 17		2	€12.78	€25.56	<a href="#">Thingibox.com</a>		
Stepper Motor - Nema 17 with Thread		1	€34.85	€34.85	<a href="#">Thingibox.com</a>		
Stepper Drivers		3	€4.00	€12.00	Amazon		
LCD Screen		1	€35.00	€35.00	Amazon		
<b>Mechanical</b>							
Bolts & Nuts	M2x15	4	-				
Bearings	ID = 10 , OD = 26, T = 10	2	€10.00	€20.00	Alaball Suministros Industriales S.L		
	ID = 50, OD = 65, T = 10	2	€15.00	€30.00	<a href="#">123rodamiento.es</a>		
Linear Bearings		2	€5.00	€10.00	Amazon		
Rod Holders		4	€1.72	€6.89	Amazon		
Thread Bearings and Internal Thread		1	€12.49	€12.49	Amazon		
<b>Raw Material</b>							
MDF - Laminated 10mm (800x600mm)		1	€10.00	€10.00	Servei Estacio		
Steel Rod D=10mm (1m)		1	€10.00	€12.41	<a href="#">Thingibox.com</a>		
<b>3D Printing</b>							



# Pseudocode Arduino

- Optimizing OpenCV
- Improve Motion Analysis & Inverse Kinematics
- Stress Analysis
- Automatic Zero-ing using Computer Vision
- Adding user controls

WE ARE OPEN FOR ORDERS!!!

# Computer Vision

