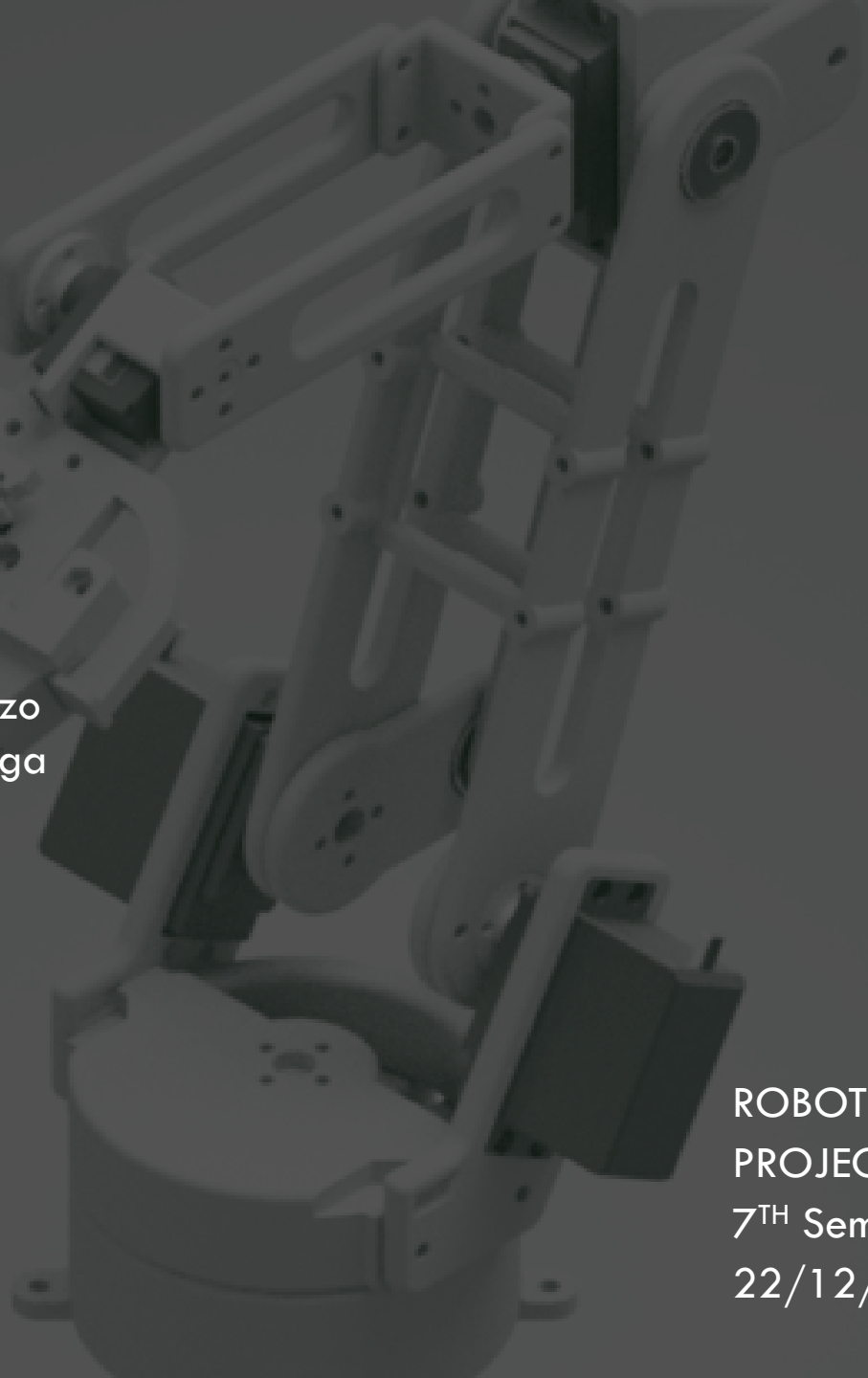
# DESIGN AND IMPLEMENTATION OF A PURELY ROTARY ROBOTIC MANIPULATOR WITH 5 DOF TO PICK UP AND PLACE OBJECTS FROM ONE PLACE TO ANOTHER THROUGH SMARTPHONE CONTROL

Ricardo Yépez
Melissa Arias
Jean Carlo Collaguazo
Juan Esteban Chiriboga



ROBOTICS I
PROJECTS VI
7TH Semester
22/12/2021

# OBJECTIVES

## MAIN OBJECTIVE

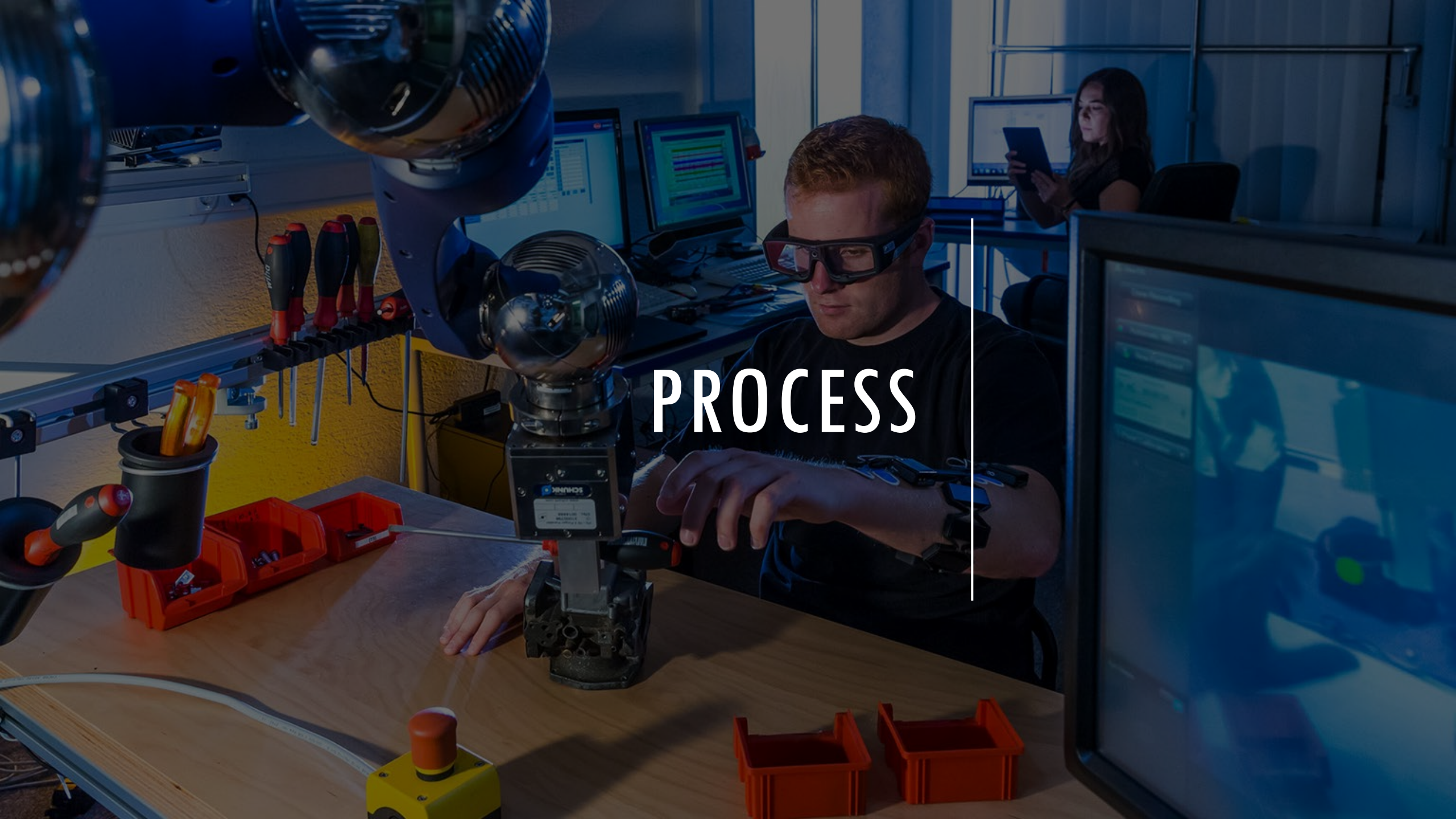
- Design, simulate and implement a purely rotatory robot manipulator with 5 DoF which will be controlled wirelessly through a smartphone application.

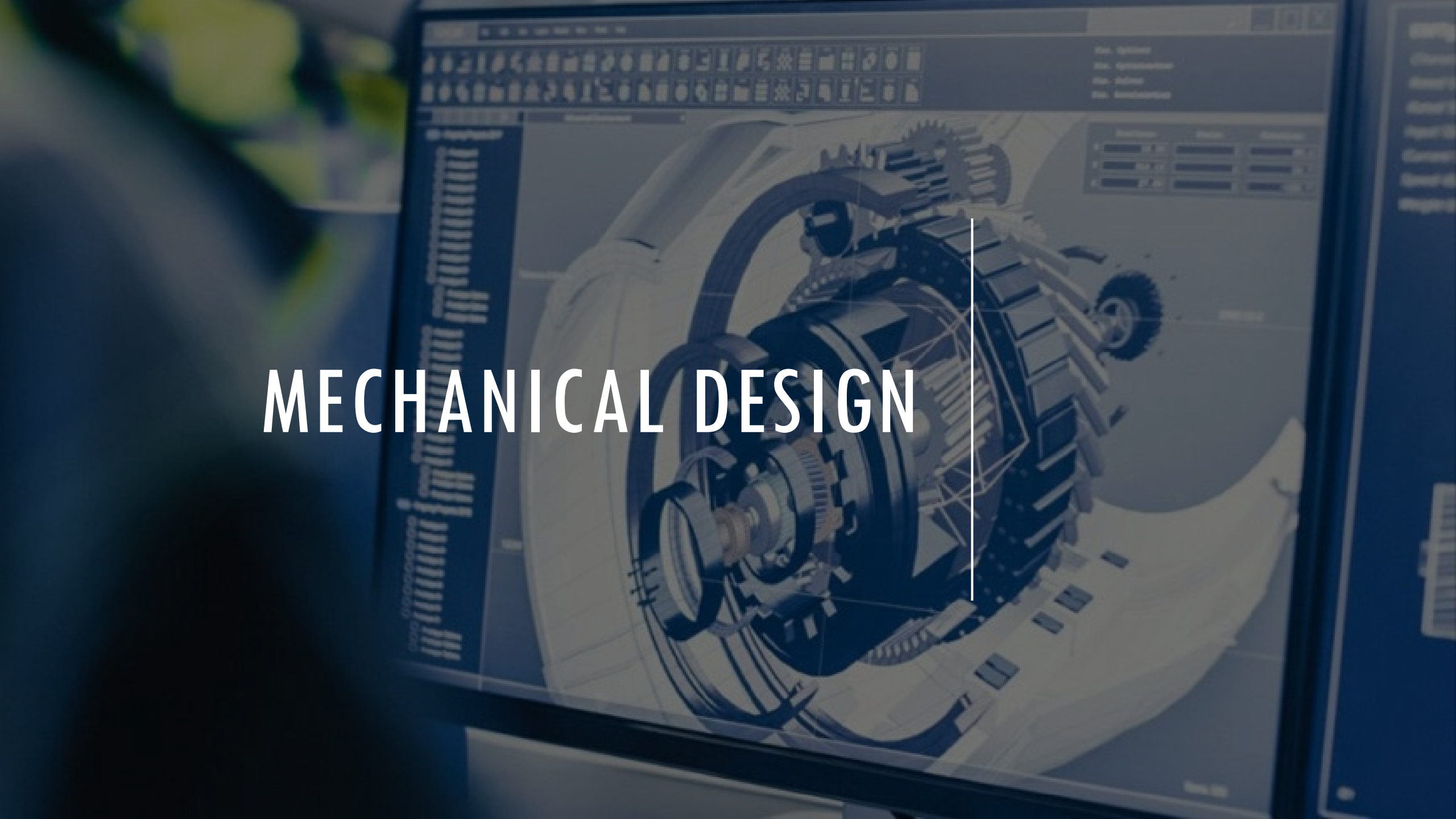
## SPECIFIC OBJECTIVES

- Develop a wireless control system that activates and moves the robot manipulator by means an application for smartphones made in MIT App Inventor
- Design the mechanism from scratch of a purely rotatory robot manipulator that has 5 degrees of freedom using Solidworks.
- Implement the robot manipulator designed that allows it to pick up an object from one place and leave it in another without causing any damage.

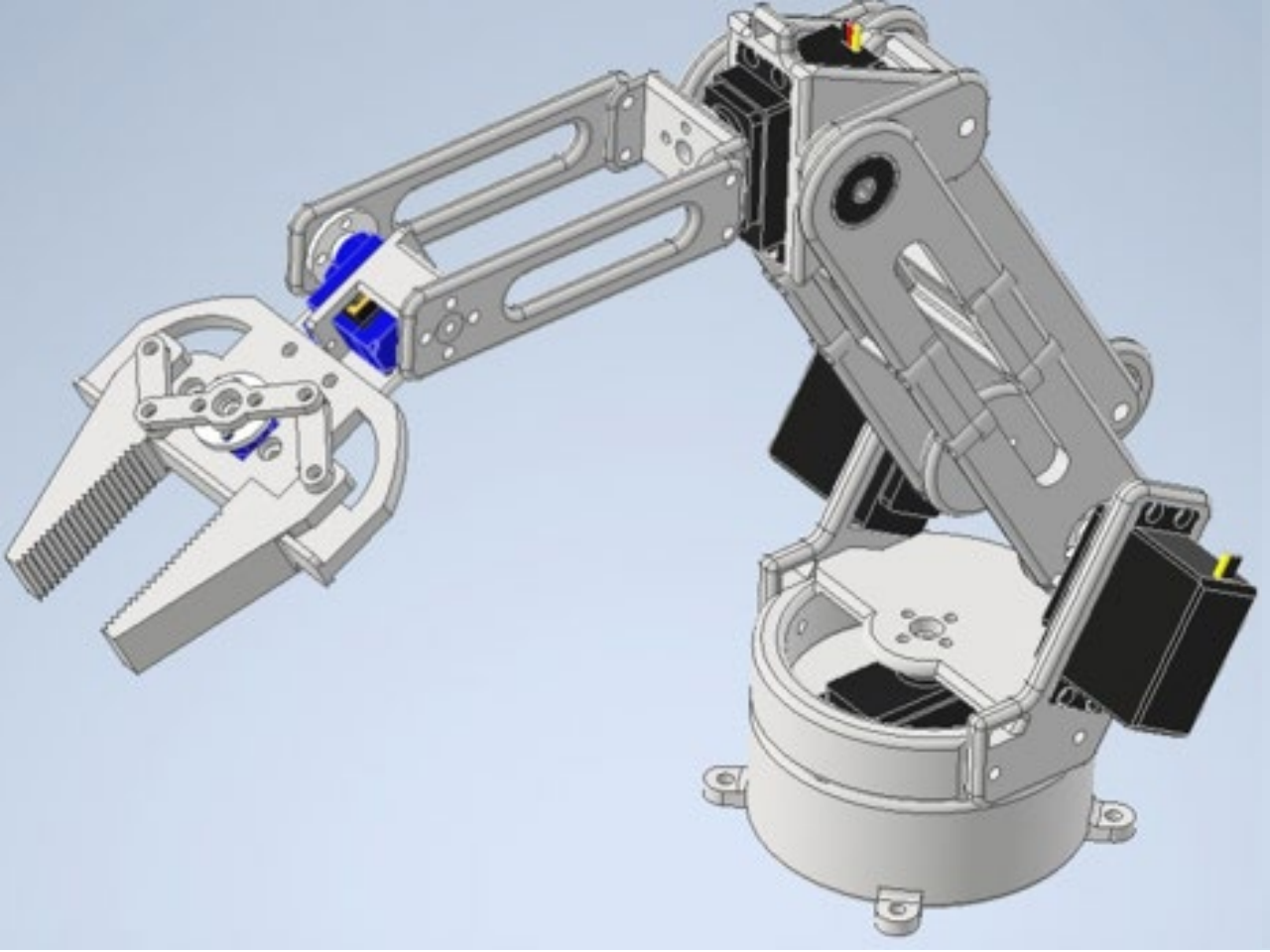
# MOTIVATION

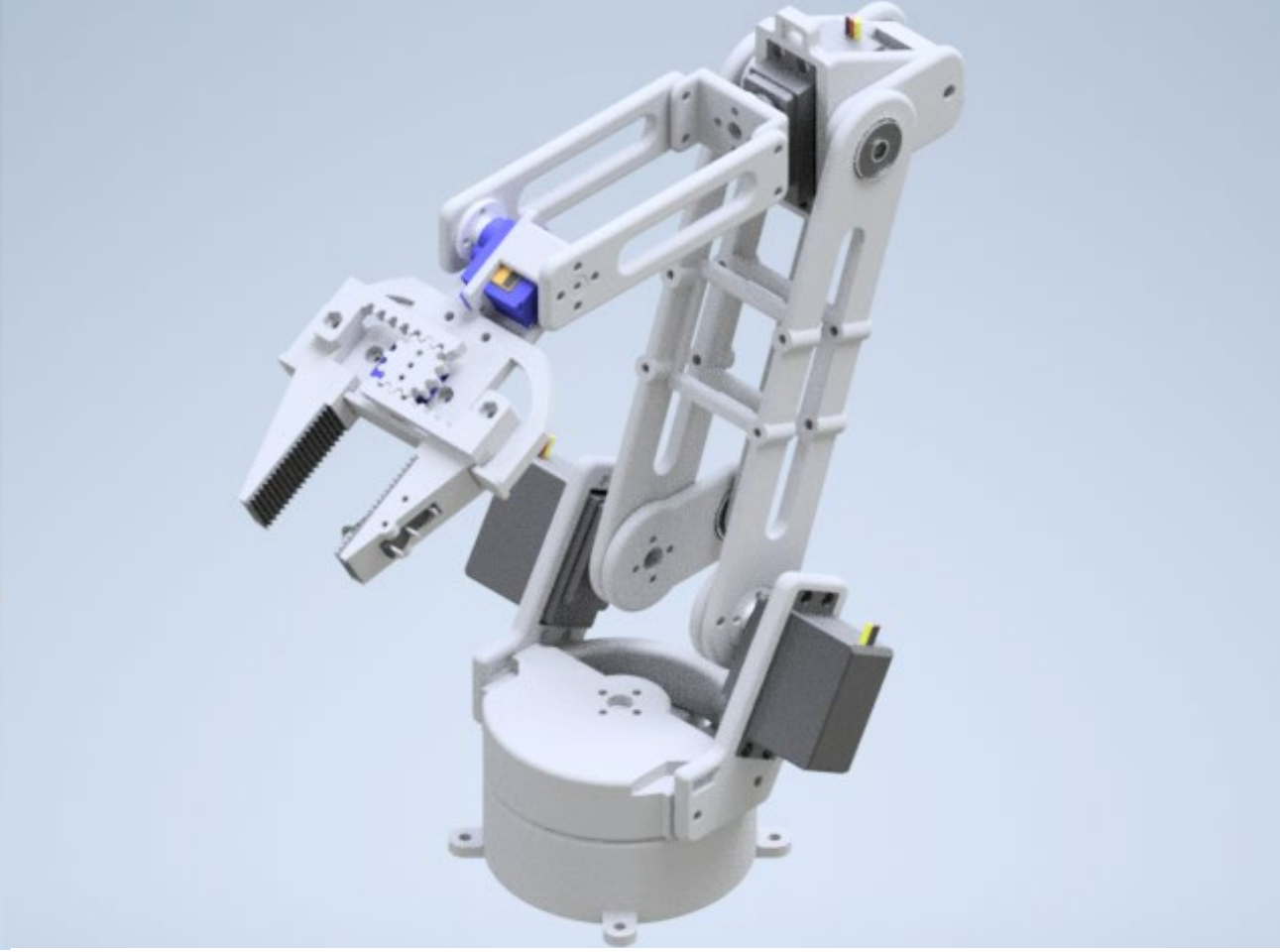
Mainly knowing how the robotic manipulators work, analyzing the complexity in making mechanisms for their correct operation and at the same time that each movement of the robot is useful, in addition to the correct electronic and control design so that the robot works optimally.


PROCESS

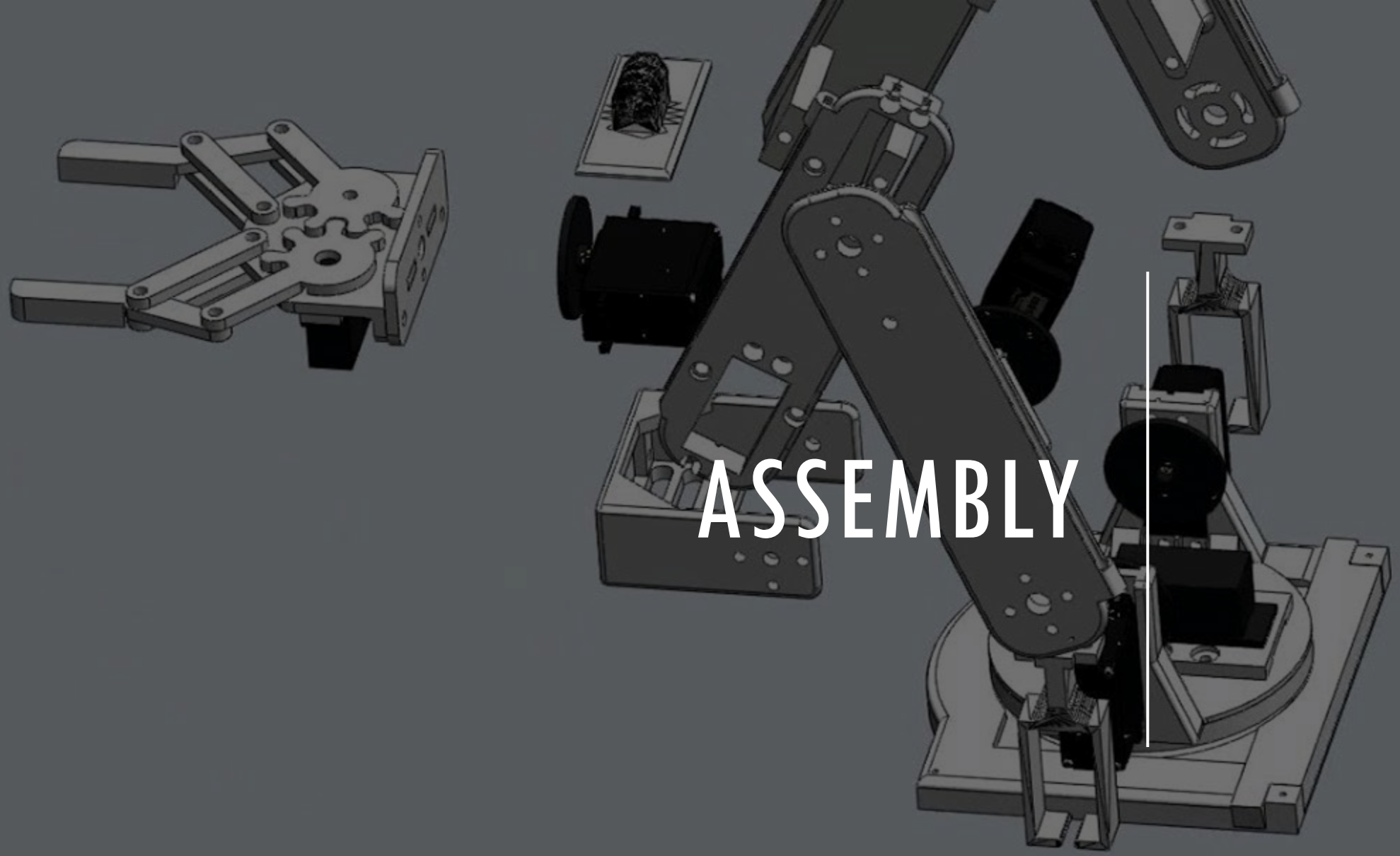


# MECHANICAL DESIGN





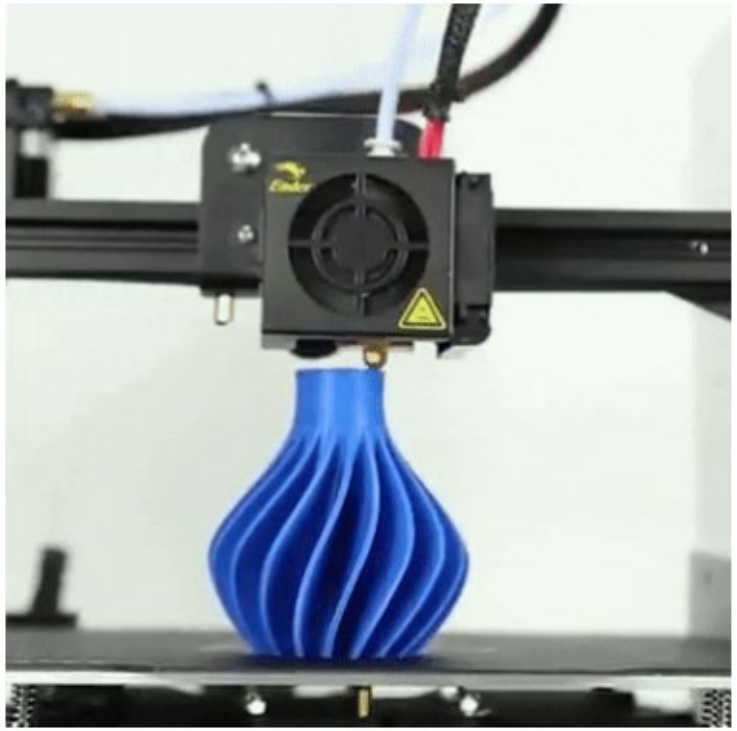
# COMPLETED ALTERNATIVES: VERSION #1 AND VERSION #2



# ASSEMBLY

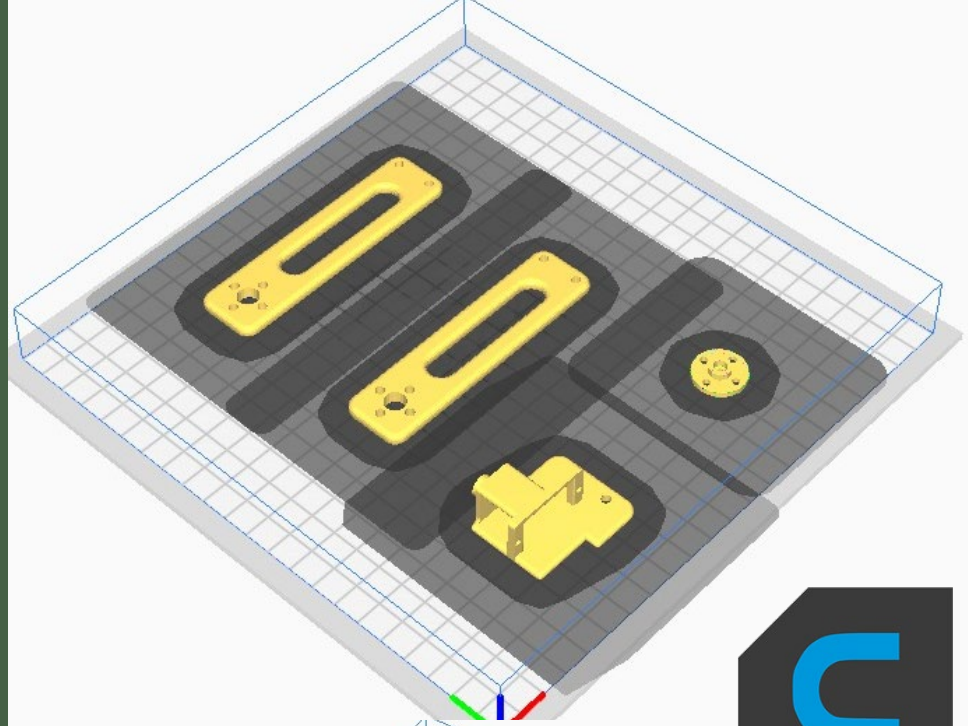
# MANUFACTURING

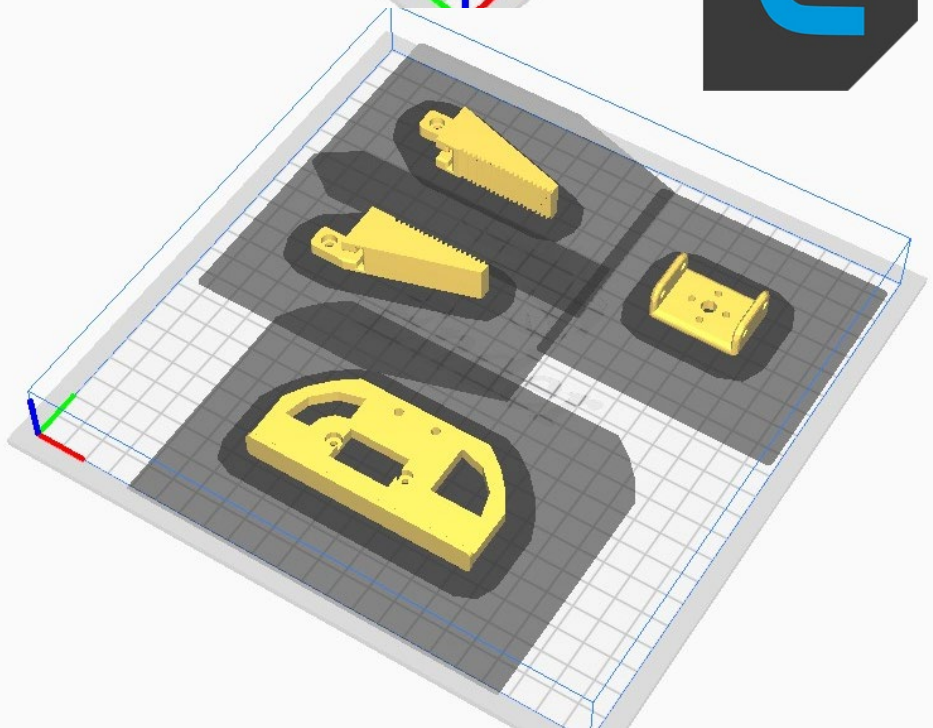
- Process: 3D Printing
  - Ender 3V2
  - Ender 3
  - Prusa MK2
- Material: PLA
  - Colors: white and gold
  - Brand: Creality
  - Series: CR
  - Print Temperature: 195-220°C
  - Bed Temperature: 60°C



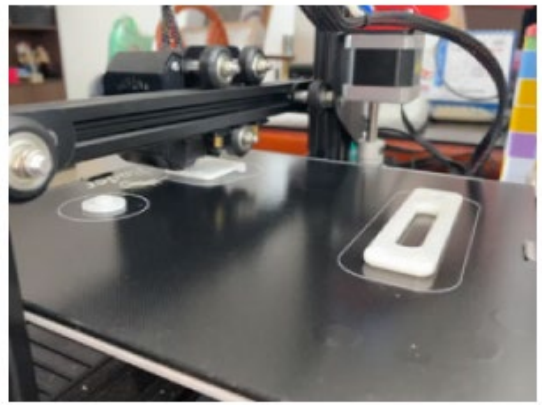
# PREPARING THE PARTS TO PRINT

- Transformation to .STL format
- Slicing Software: ULTIMAKER CURA
- Slicing Parameters:
  - Infill: 20%
  - Layer hight: 0.2
  - Horizontal expansion: -0.1
  - Walls: 3
  - Printing Temperature: 205°C
  - Build Plate Temperature: 60°C



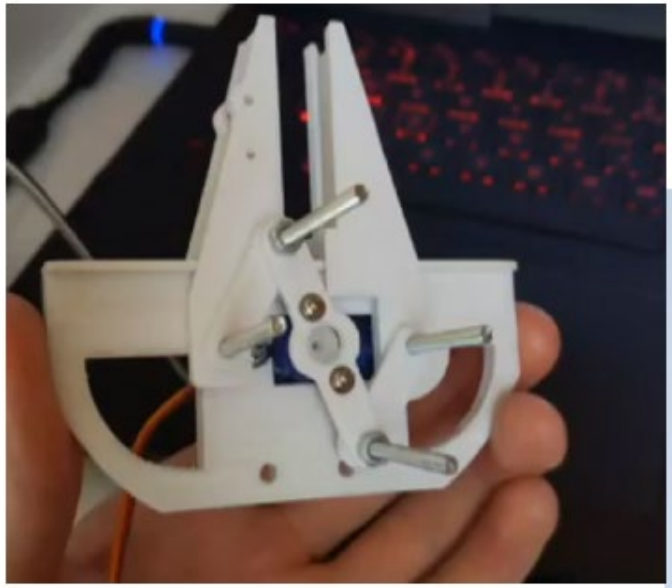


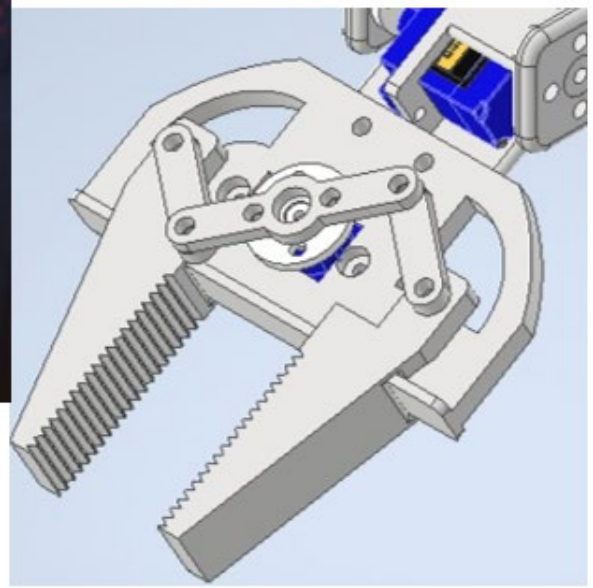
# PRINTING THE PARTS

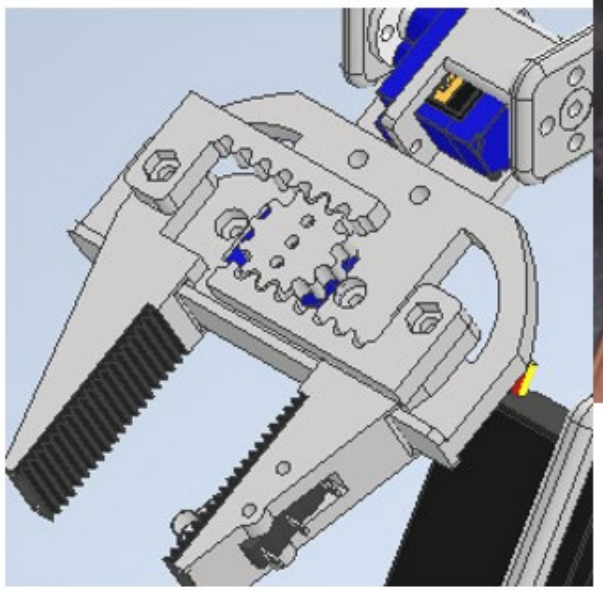
# REDESIGN OF THE GRIPPER

## GRIPPER VERSION #1

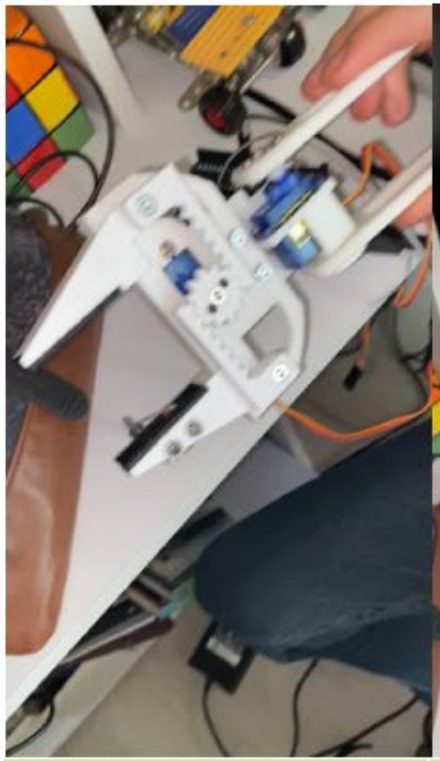




## GRIPPER VERSION #2



# FUNCTIONALITY TESTS



GRIPPER

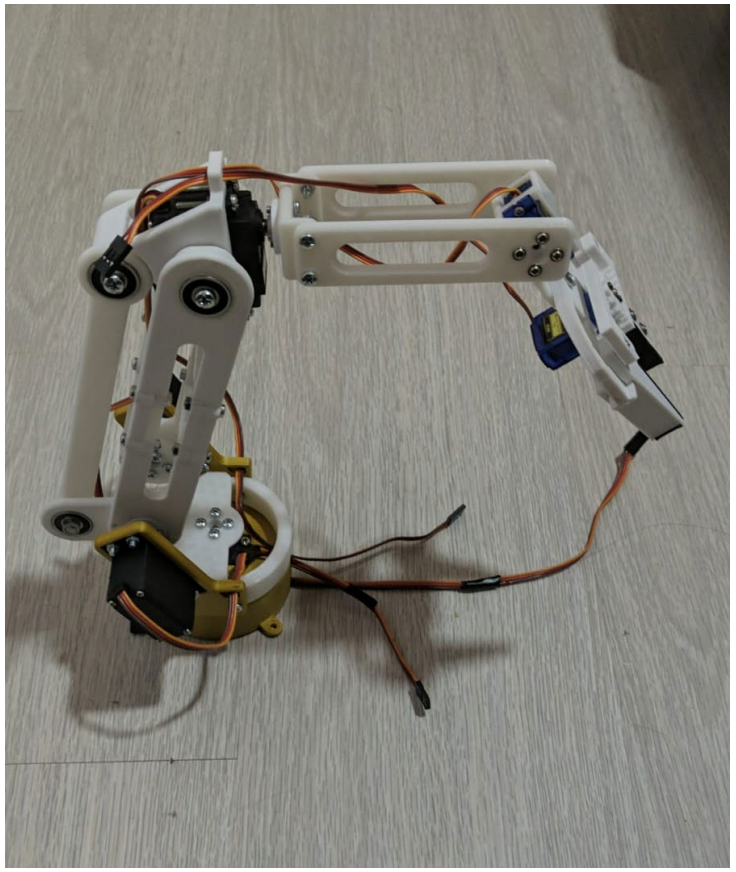
WRIST

FOREARM

ELBOW

ARM

BASE



# ASSEMBLYING THE PRINTED PARTS WITH THE MECHANICAL COMPONENTS

MECHANICAL COMPONENTS:

- Bults
- Nuts
- Bearings (d=20mm)

ELECTRICAL COMPONENTS:

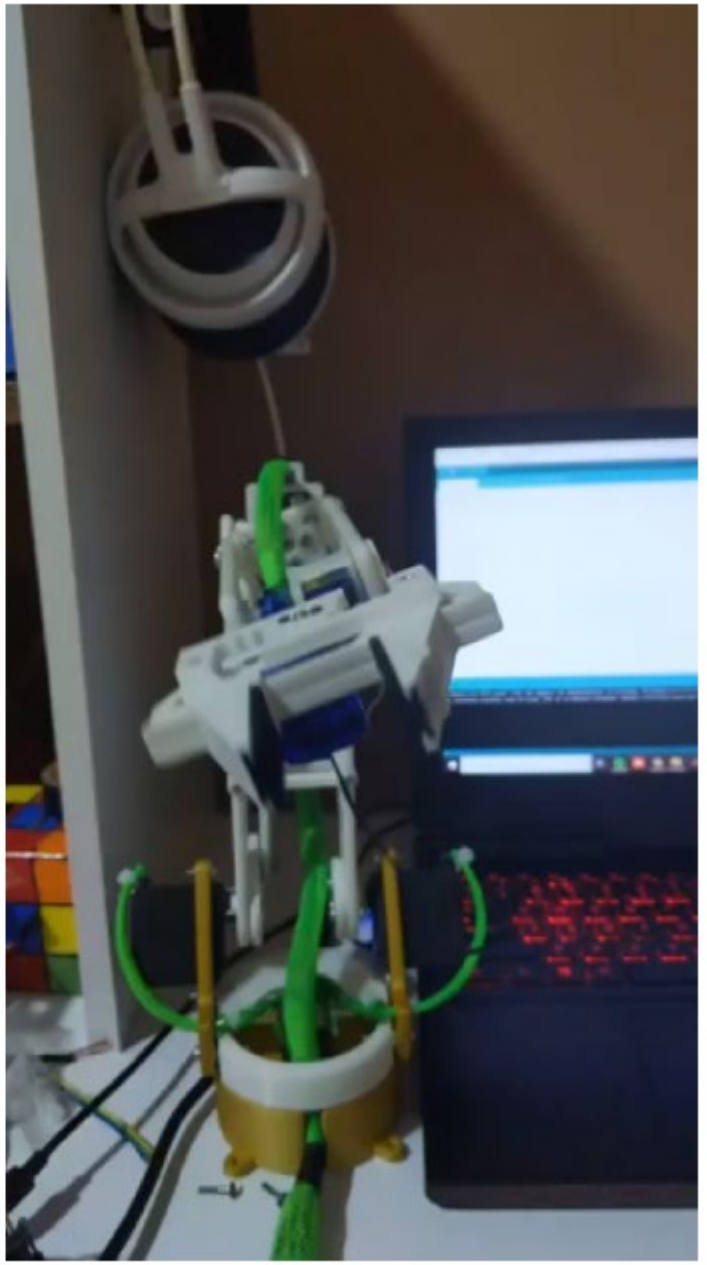
- Servomotors (MG996R and SG90)
- Limit switch

EXTRAS:

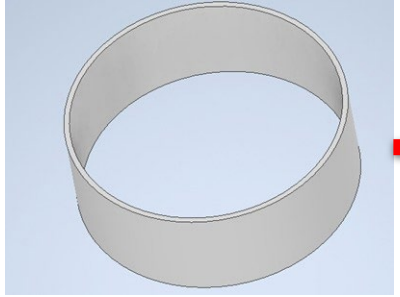
To move freely without causing tangles or disconnections

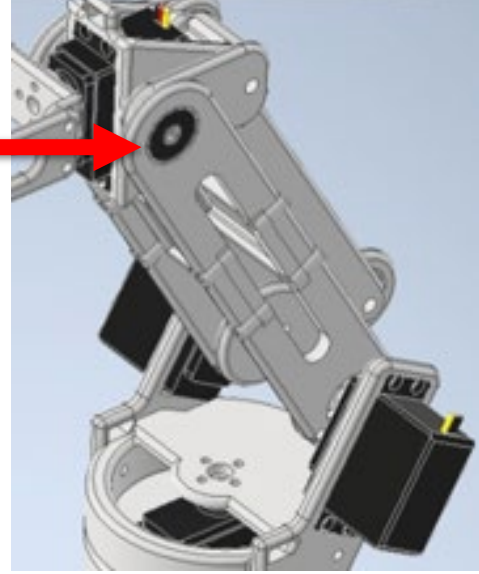
- Cable ties
- Tapes
- Mesh covers

# FINAL TEST AND SPEED REGULATION



# PROBLEMS



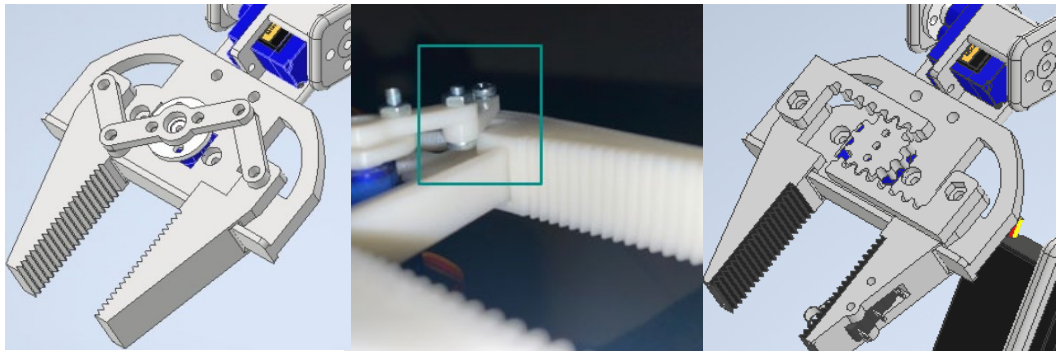


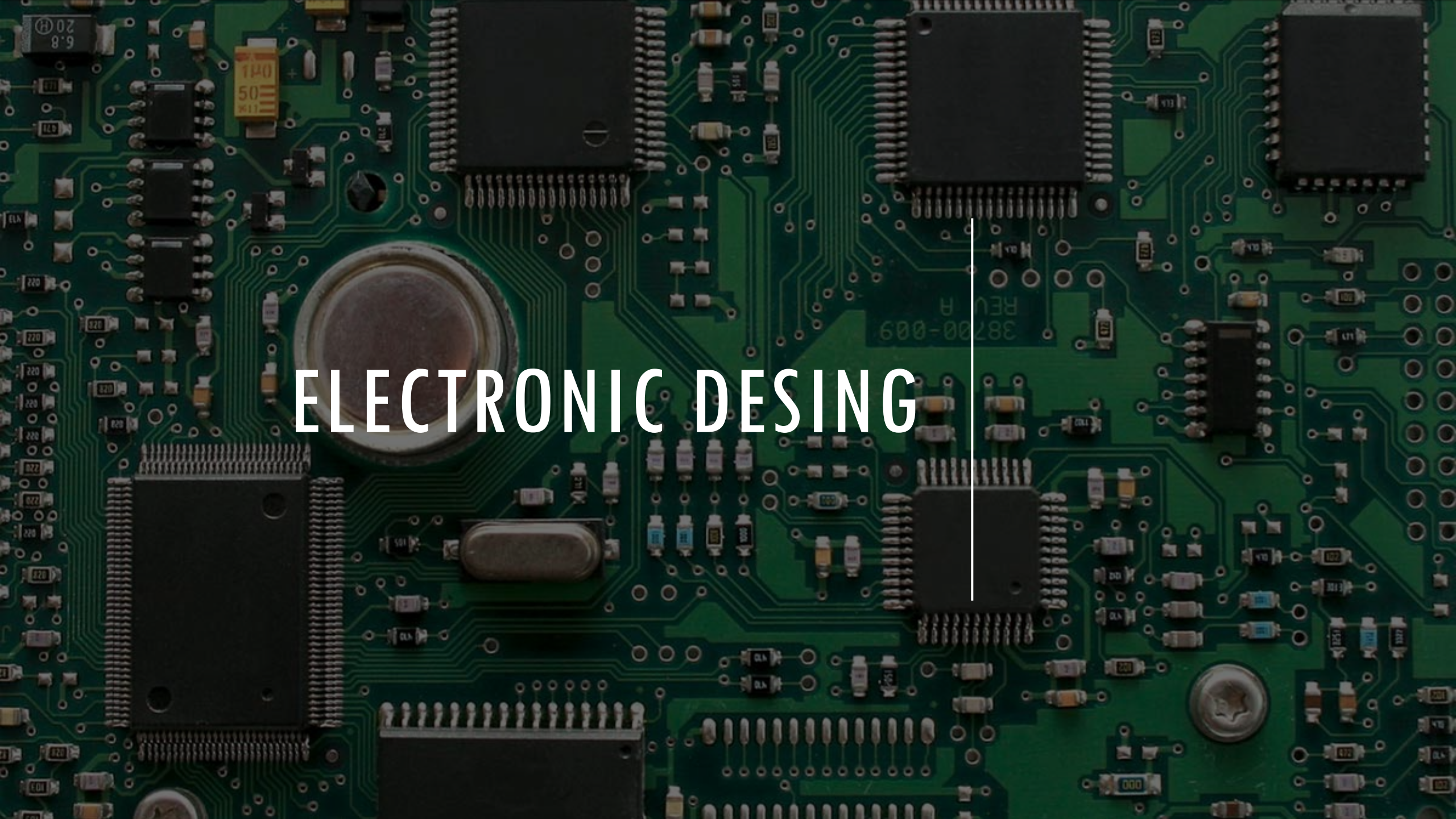
## COMPLICATIONS

- Unconsidered tolerances
- Gripper: Bults and nuts crashing with the parts
- Not fitting bearings

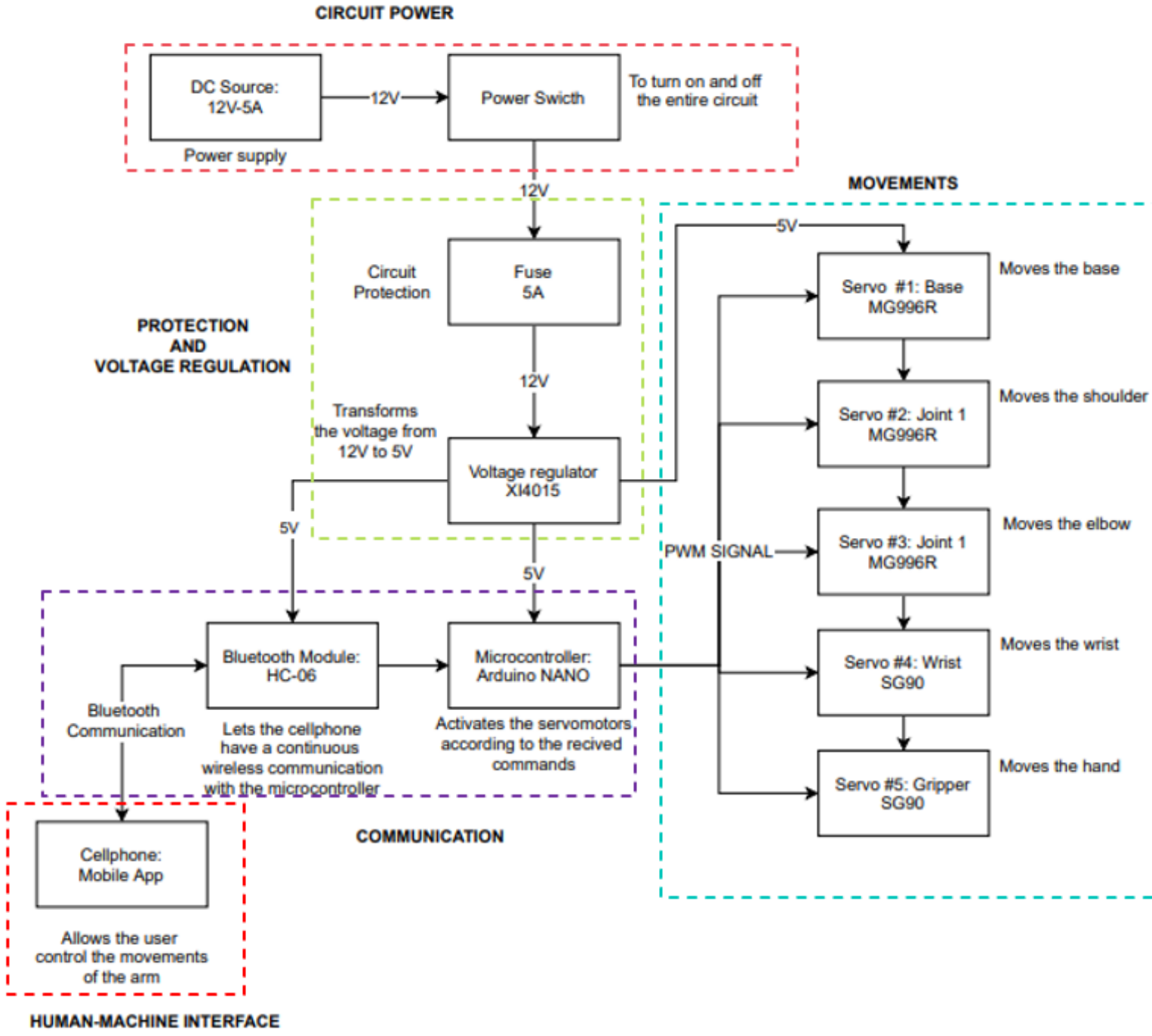
## SOLUTIONS

- CURA parameters: Horizontal Expansion =-0.1mm
- Changing the gripper mechanism.
- Printing a ring with the size of the necessary space to make the bearings fit.

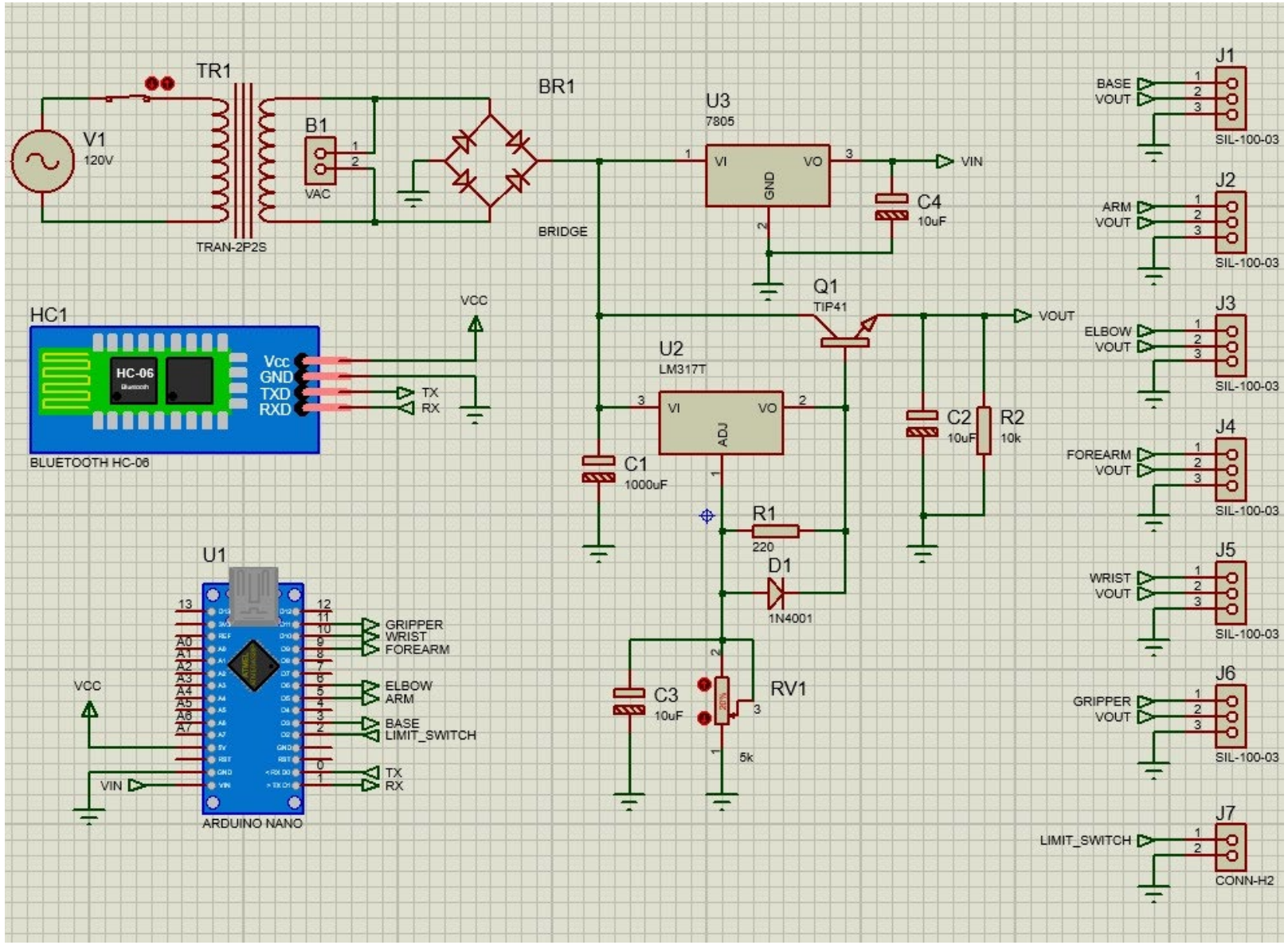


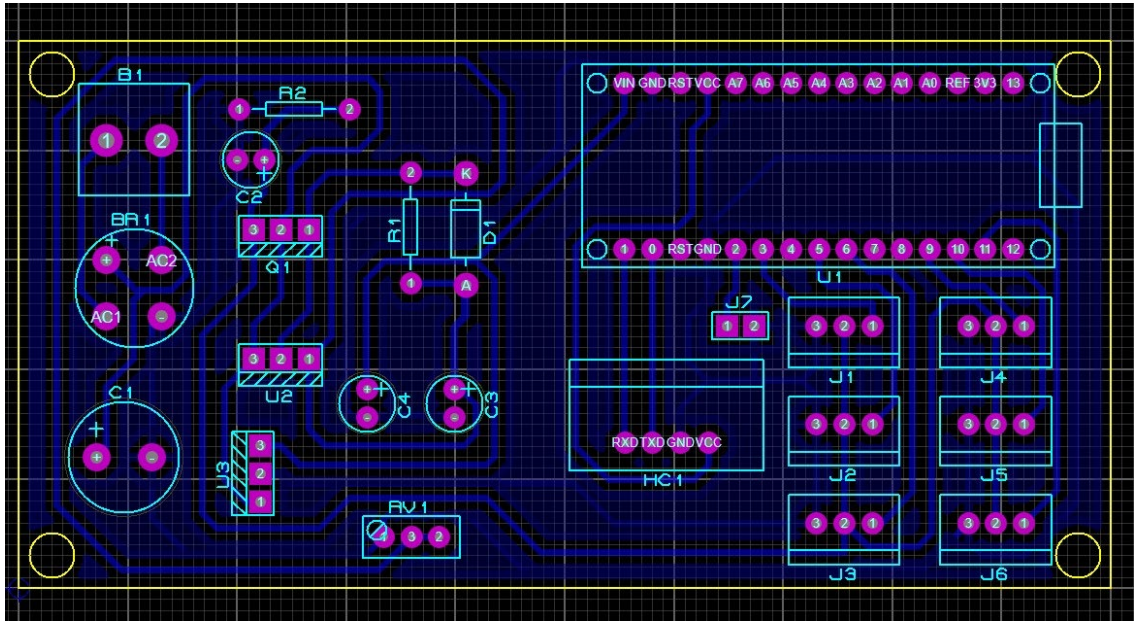

ELECTRONIC DESING

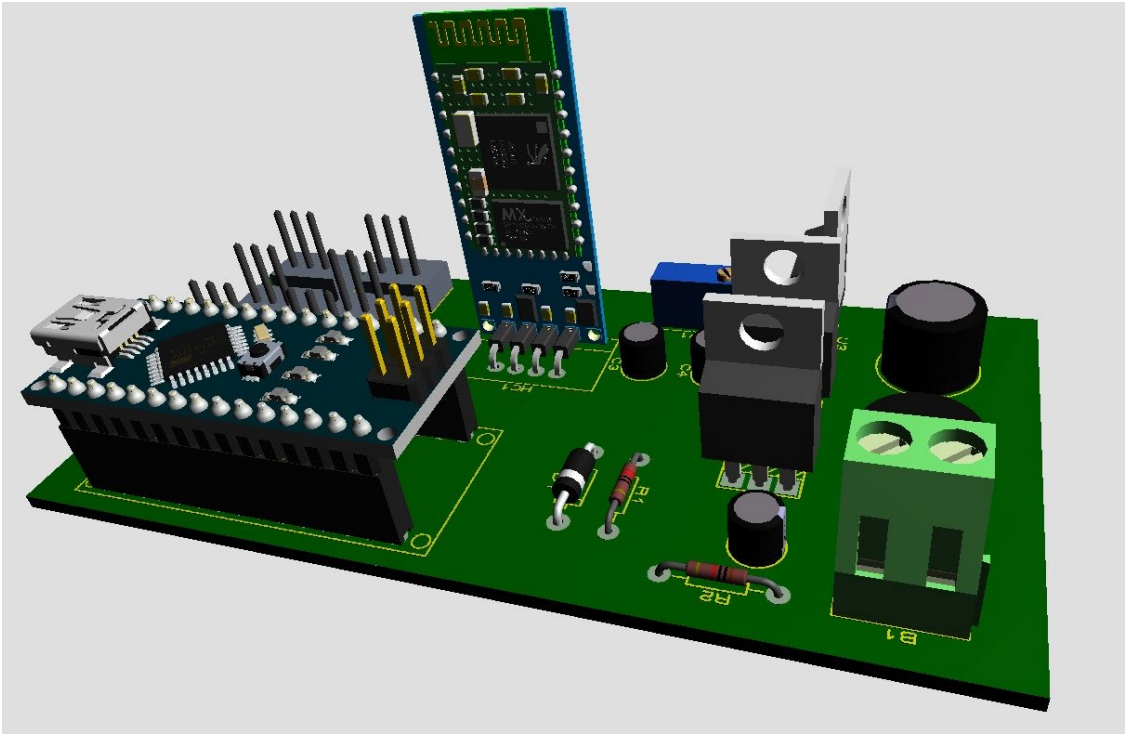
# INICIAL SCHEME



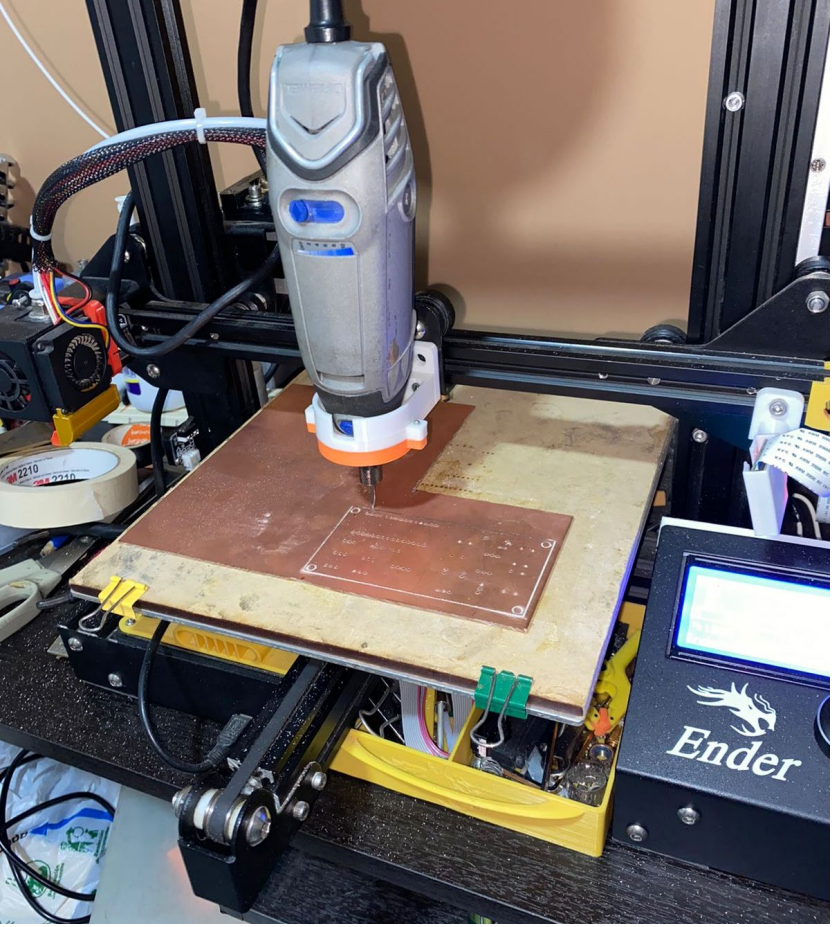
# ACTUAL PROTEUS IMPLEMENTATION

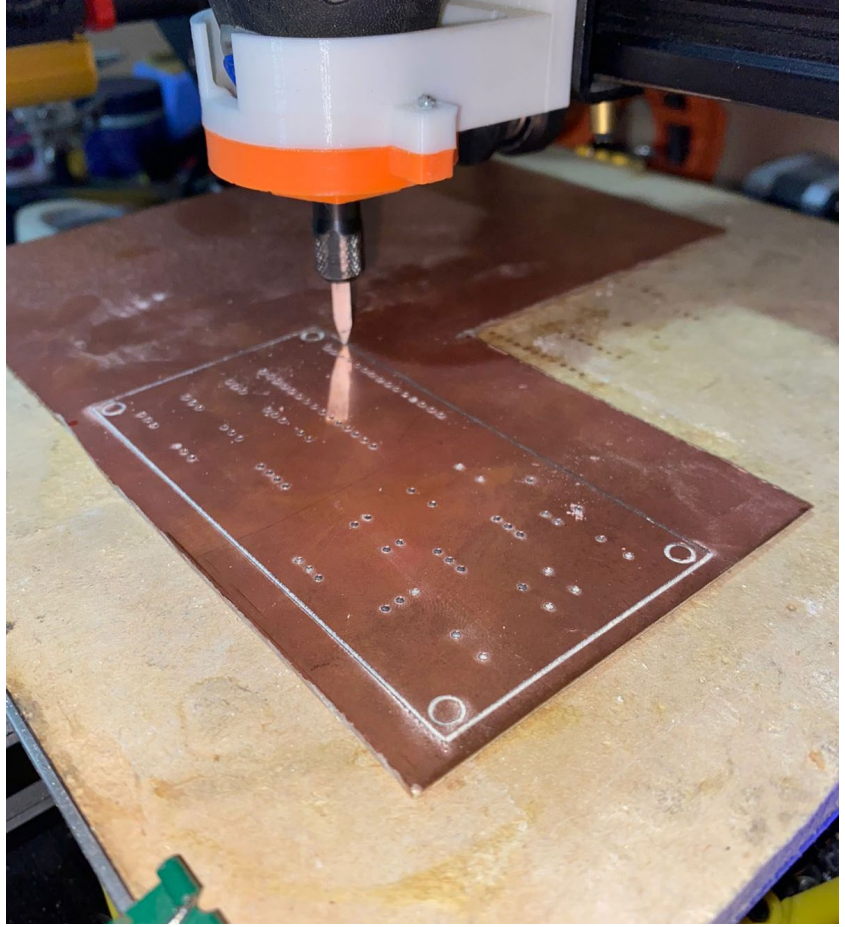


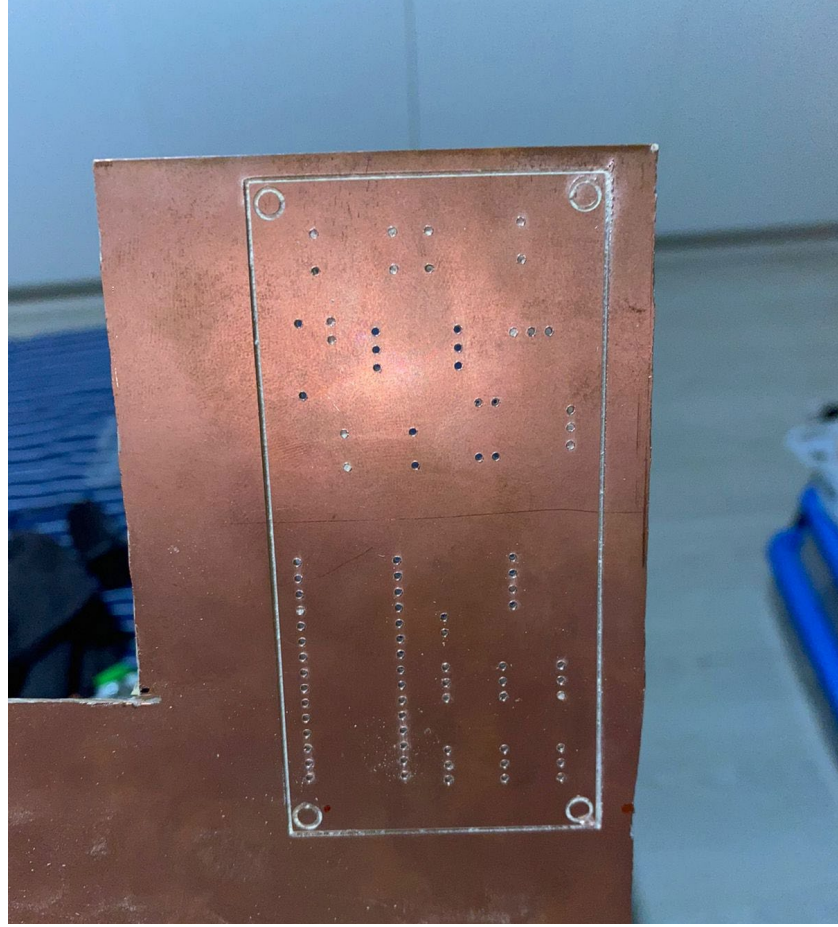

B1
R2
C2
BR1
AC2
AC1
Q1
R1
D1
U2
C1
C4
C3
U3
RV1
VIN GND RST VCC A7 A6 A5 A4 A3 A2 A1 A0 REF 3V3 13
1 0 RST GND 2 3 4 5 6 7 8 9 10 11 12
U1
J7
J1
J4
J2
J5
J3
J6
RXD TXD GND VCC
HC1



# PCB DESIGN



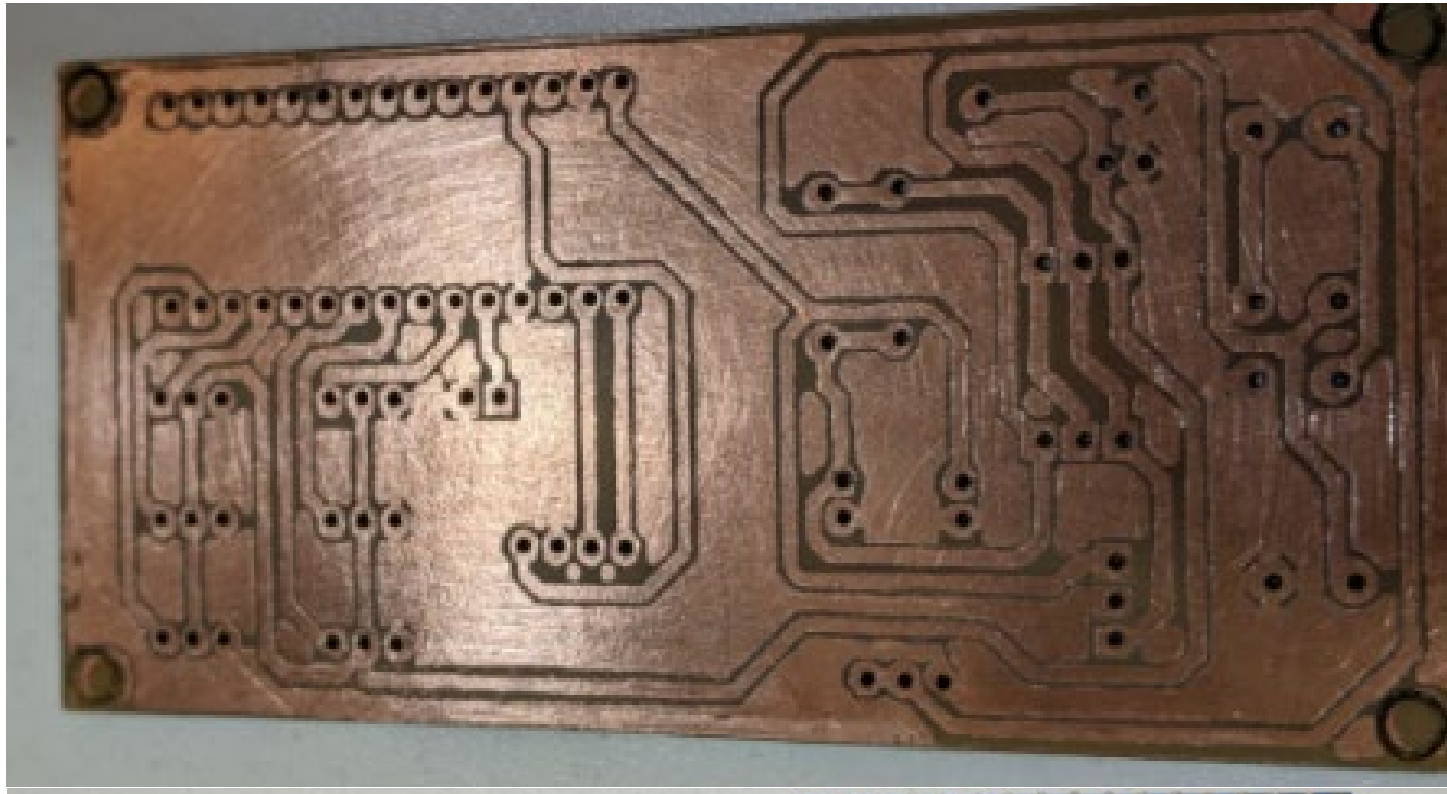


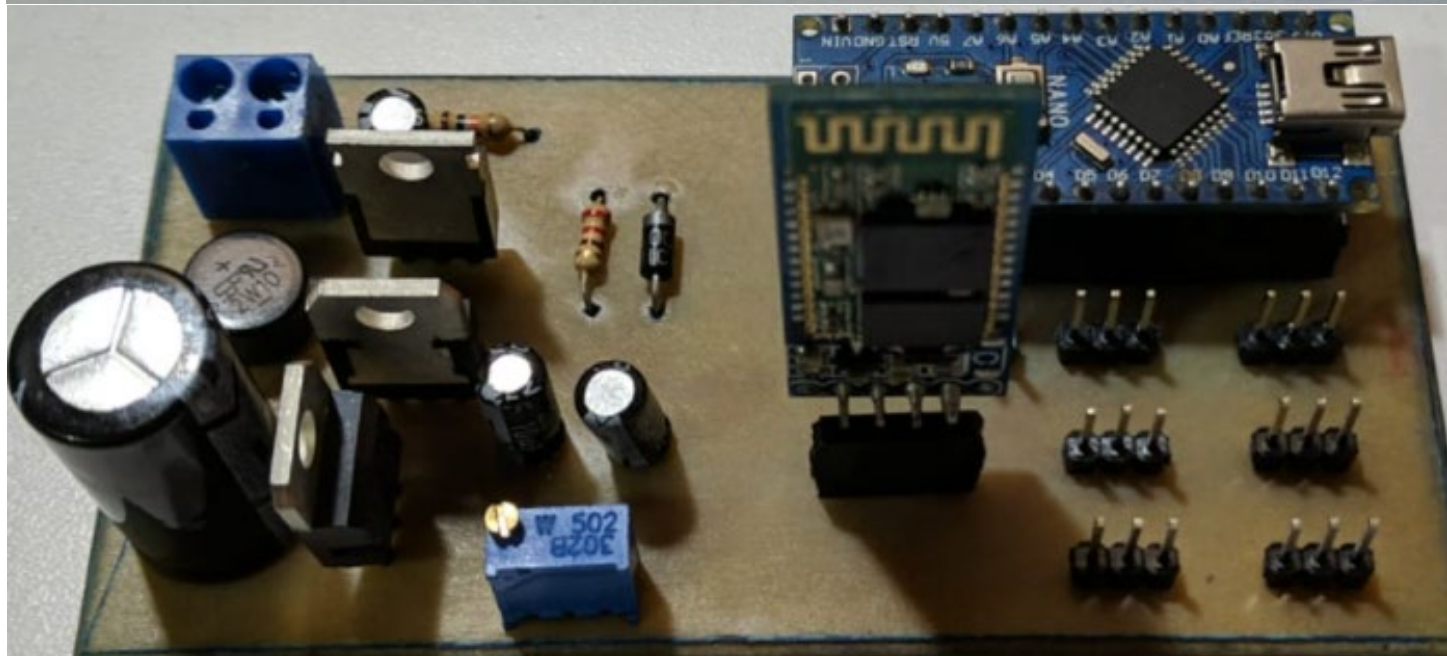
# PCB MANUFACTURING | CNC

# PCB MANUFACTURING

Ironing Method

Soldering



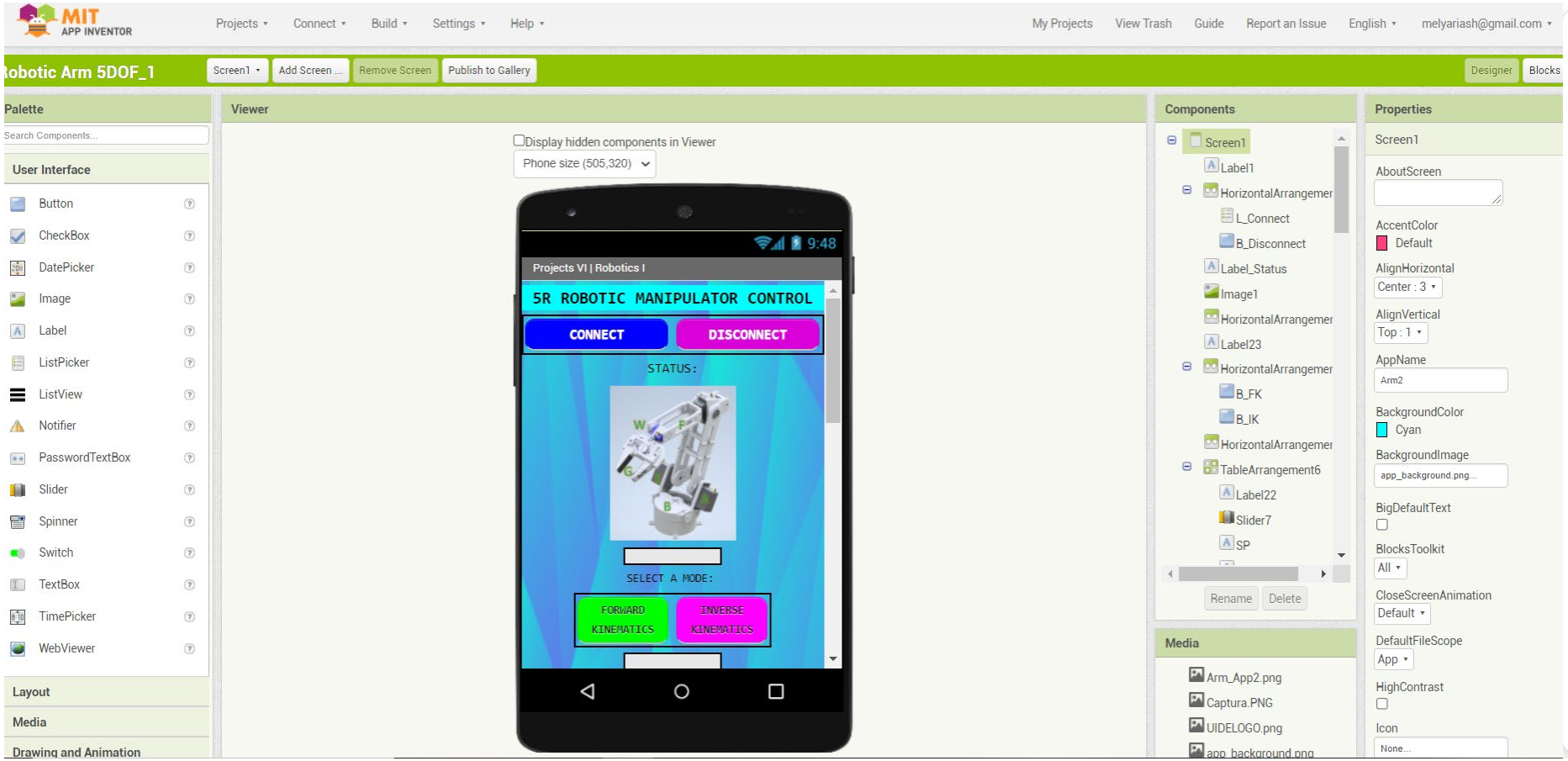


# SOFTWARE DESIGN


**SOFTWARE:**
MIT APP INVENTOR

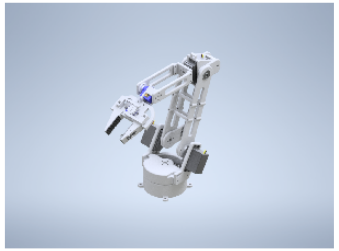
# MIT APP INVENTOR DESIGN

ACCES LINK:
https://gallery.appinventor.mit.edu/?galleryid=0a2205fc-54dc-416d-8233-d65bdfcbcf2e




## Robotic Arm 5DOF

*Dec. 22, 2021, 9:12 a.m.* Likes: 0



Control of the forward and inverse kinematics of a 5DOF robotic manipulator.

Credit:

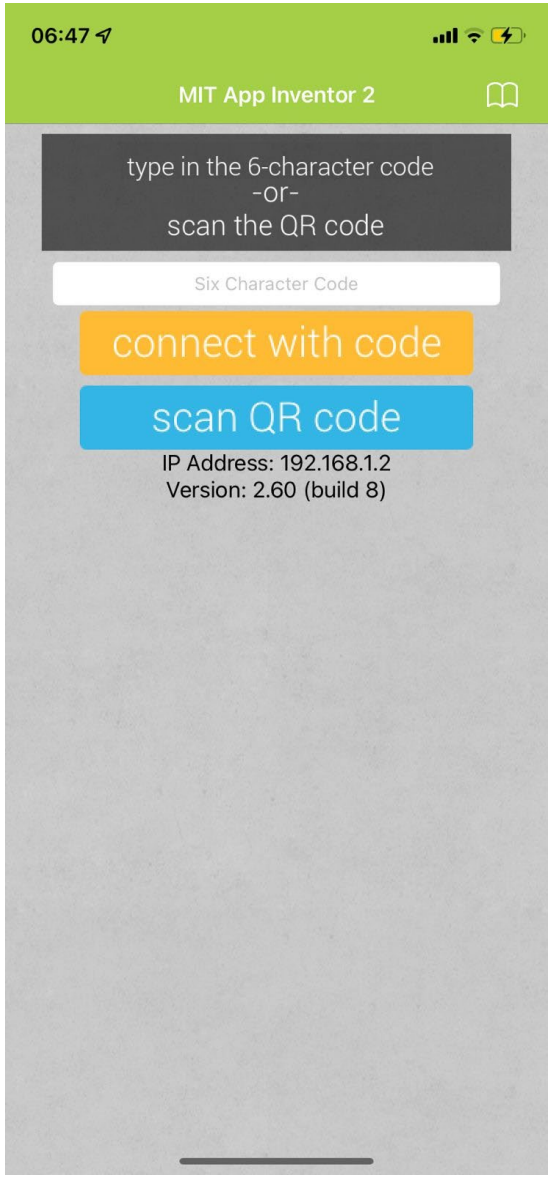
Juan Esteban Chiriboga

Melissa Arias

Jean Collaguazo

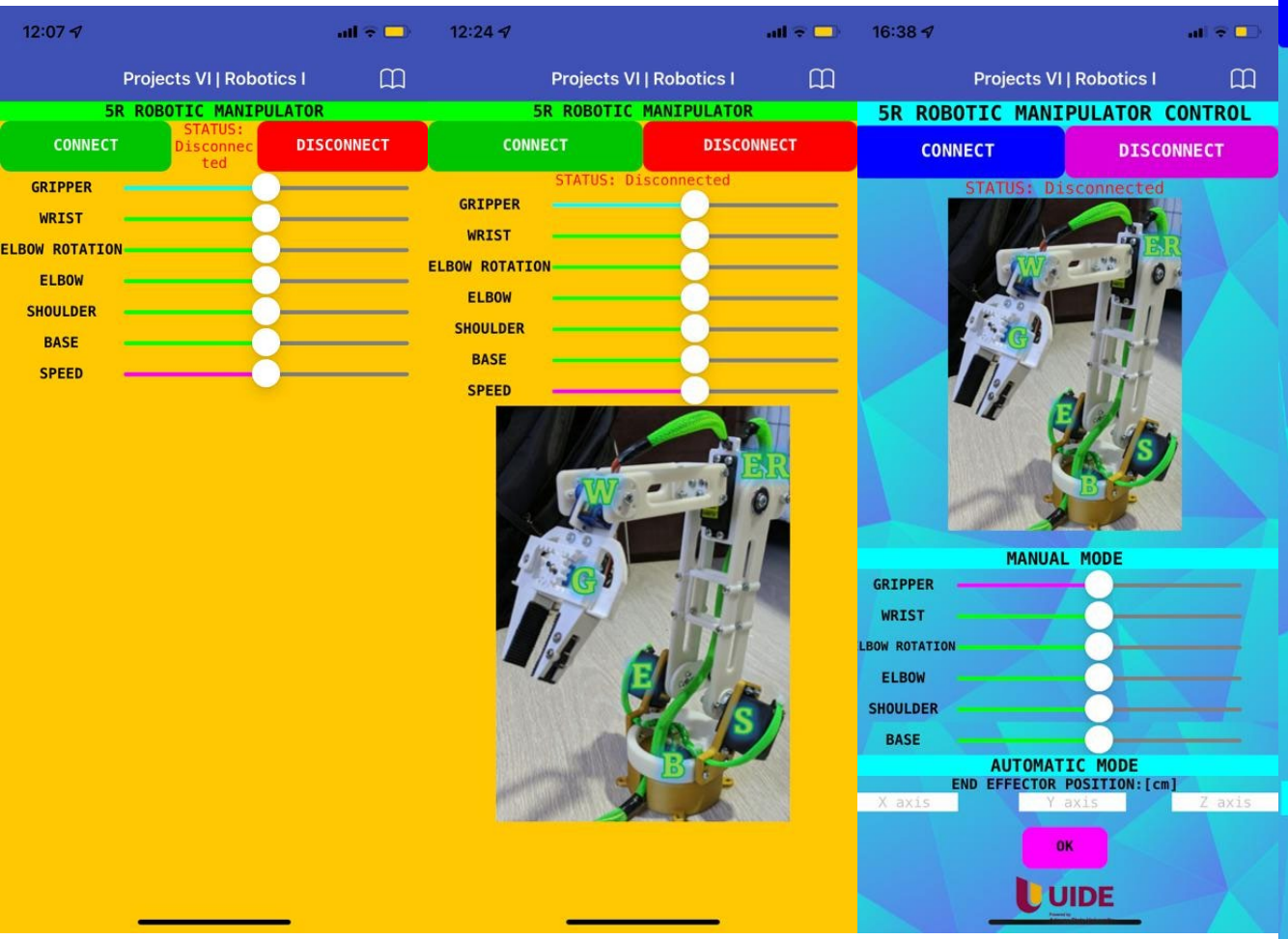
Ricardo Yépez

Load App Into MIT App Inventor
Other projects by same author
Report Project
Permanent link: https://gallery.appinventor.mit.edu/?galleryid=0a2205fc-54dc-416d-8233-d65bdfcbcf2e




# PHONE CONNECTION

# APPLICATION EVOLUTION

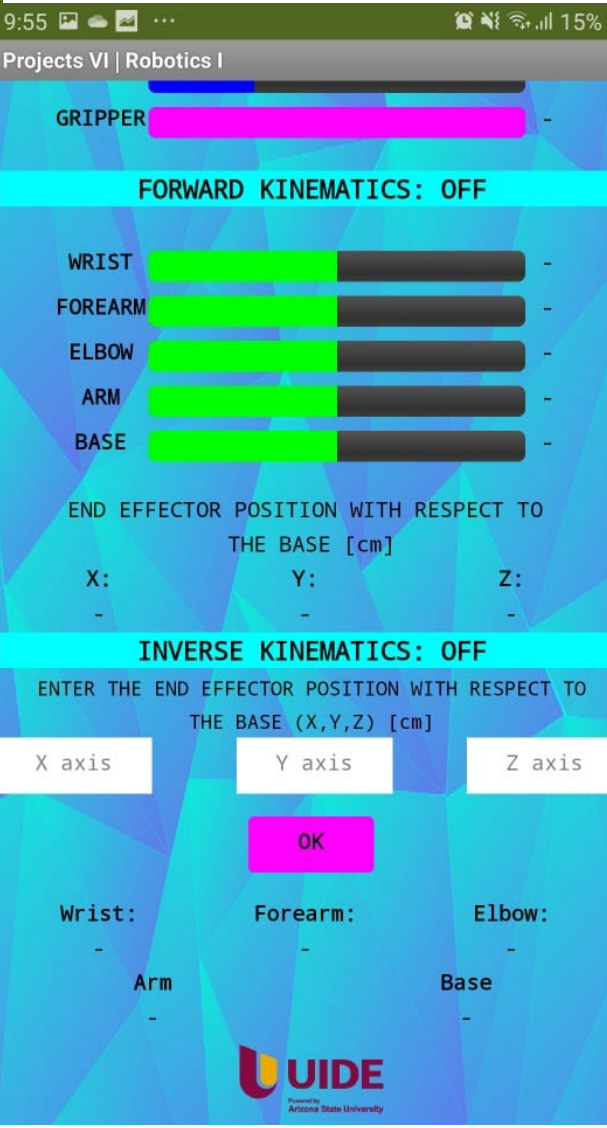




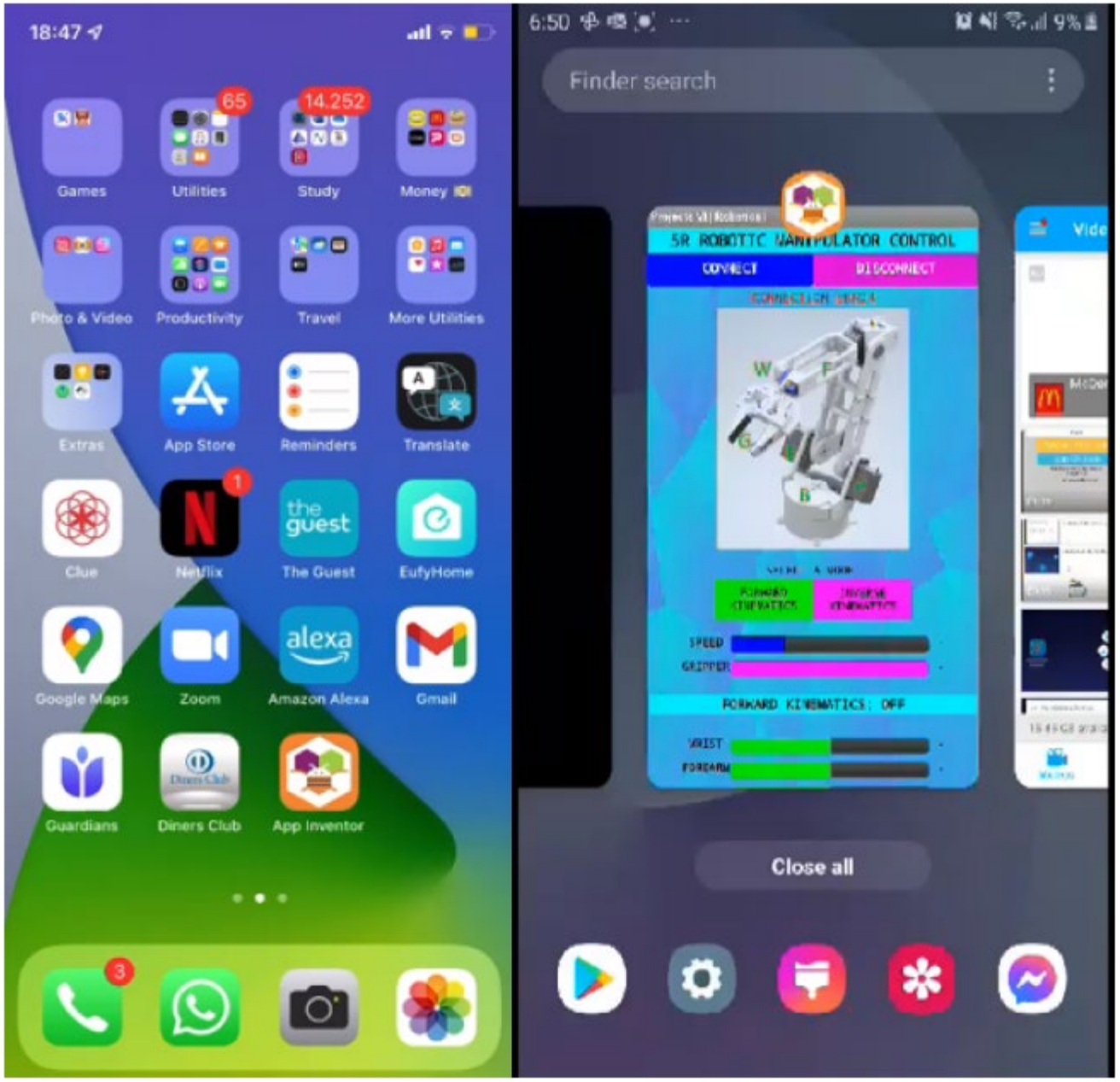




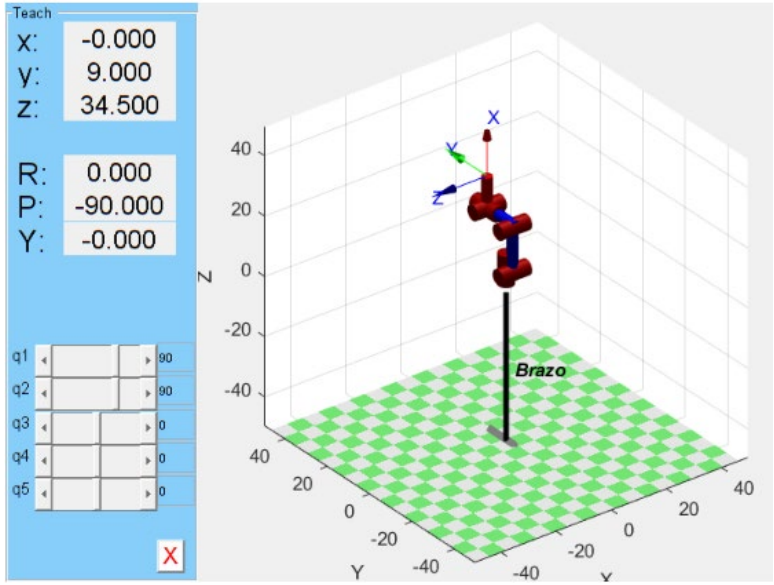




# APP FUNCTIONALITY



# DENAVIT-HARTENBERG PARAMETERS




```
L(1)=Link([0 8 0 0],'modified');
L(2)=Link([0 0 -3 pi/2],'modified');
L(3)=Link([0 0 15 0],'modified');
L(4)=Link([0 12 1 pi/2],'modified');
L(5)=Link([0 0 0 pi/2],'modified');
robot=SerialLink(L,'name','Brazo')
```

```
robot =

Brazo:: 5 axis, RRRRR, modDH, slowRNE
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|        q1|          8|          0|          0|          0|
|  2|        q2|          0|         -3|     1.5708|          0|
|  3|        q3|          0|         15|          0|          0|
|  4|        q4|         12|          1|     1.5708|          0|
|  5|        q5|          0|          0|     1.5708|          0|
+---+-----------+-----------+-----------+-----------+-----------+
```

## Denavit-Hartemberg table

$\alpha_{i-1}$ $a_{i-1}$ $d_i$ $\phi_i$

```
disp(dh)
```

$$\begin{pmatrix} 0 & 0 & L_0 & q_1 \\ \frac{\pi}{2} & -L_1 & 0 & q_2 \\ 0 & L_2 & 0 & q_3 - \frac{\pi}{2} \\ \frac{\pi}{2} & L_3 & L_4 & q_4 - \frac{\pi}{2} \\ \frac{\pi}{2} & 0 & 0 & q_5 \end{pmatrix}$$

**Jacobian**

```
q={q1 q2 q3 q4 q5};
p=fkinematics(1:3,end);
for i=1:3
    for j=1:5
        Jtool(i,j)=simplify(diff(p(i),q{j}));
    end
end
disp(Jtool)
```

$$\begin{pmatrix} 3\sin(q_1) - 15\cos(q_2)\sin(q_1) - 12\sin(q_1)\sin(q_2)\sin(q_3) - 9\cos(q_1)\cos(q_4)\cos(q_5) + 12\cos(q_2)\cos(q_3)\sin(q_1) - \cos(q_2)\sin(q_1)\sin(q_3) - \cos(q_3)\sin(q_1)\sin(q_2) + 9\cos(q_2)\cos(q_3)\sin(q_1)\sin(q_5) - \\ 15\cos(q_1)\cos(q_2) - 3\cos(q_1) - 12\cos(q_1)\cos(q_2)\cos(q_3) + \cos(q_1)\cos(q_2)\sin(q_3) + \cos(q_1)\cos(q_3)\sin(q_2) - 9\cos(q_4)\cos(q_5)\sin(q_1) + 12\cos(q_1)\sin(q_2)\sin(q_3) - 9\cos(q_1)\cos(q_2)\cos(q_3)\sin(q_5) + \\ 0 \end{pmatrix}$$

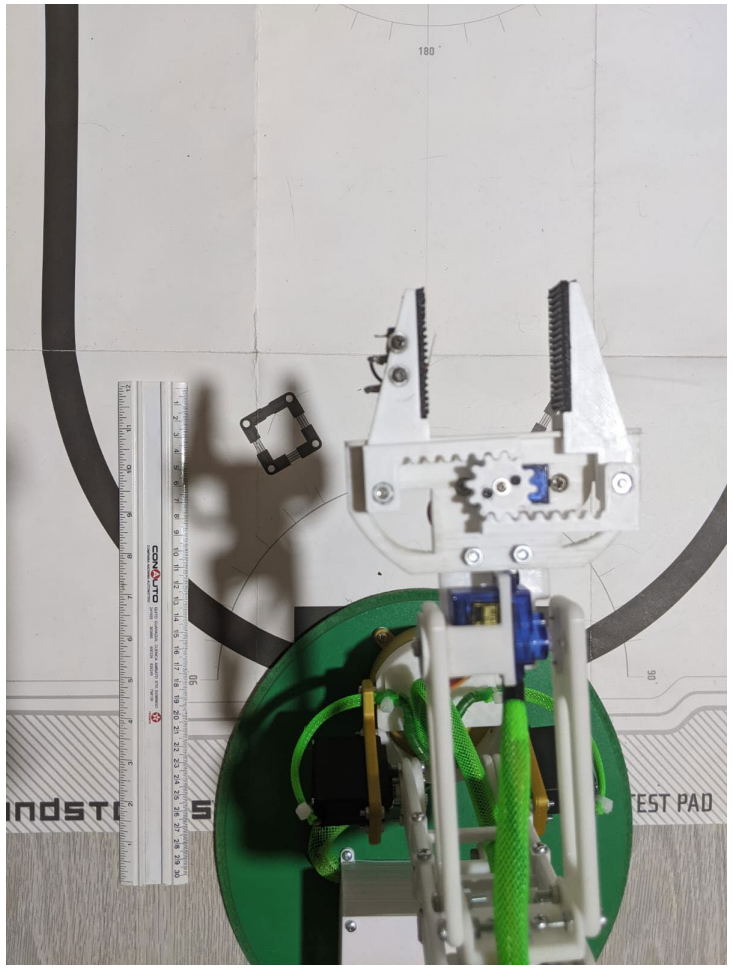
```
RrelT=tr2rt(fkinematics)';
J=simplify(RrelT*Jtool);
disp(simplify(J))
```

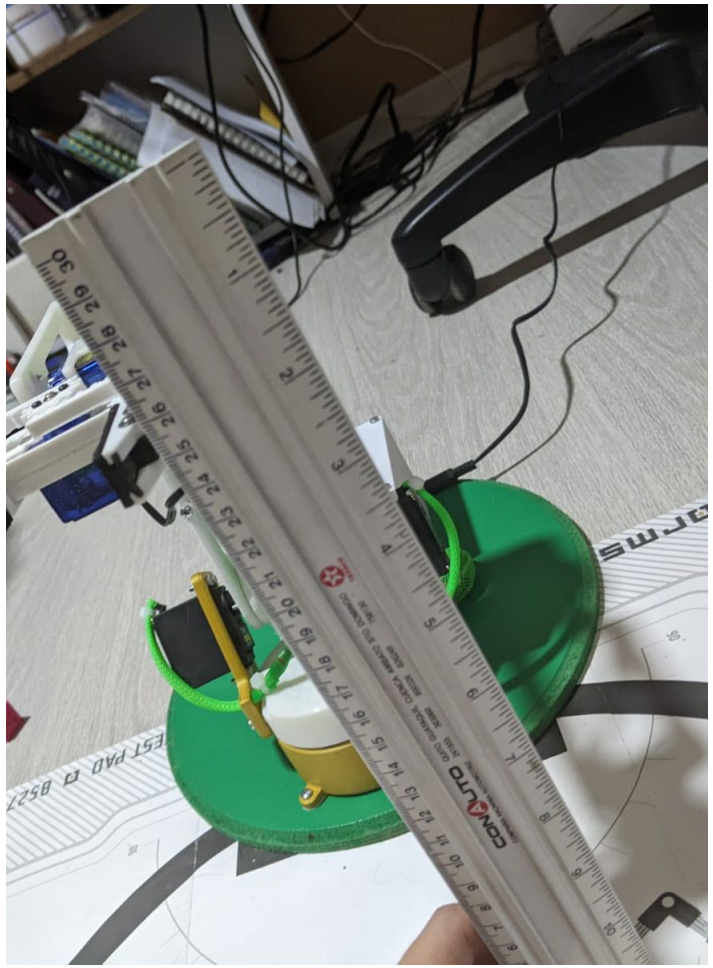
$$\begin{pmatrix} -\cos(q_4)\cos(q_5)\left(12.0416\cos(q_2+q_3+0.0831) - 15\cos(q_2) + 3\right) \\ -\cos(q_4)\left(15\cos(q_2)\sin(q_5) - 9\cos(q_2)\cos(q_3) - 3\sin(q_5) + 9\sin(q_2)\sin(q_3) + 12\sin(q_2)\sin(q_3)\sin(q_5) - 12\cos(q_2)\cos(q_3)\sin(q_5) + \cos(q_2)\sin(q_3)\sin(q_5) + \cos( \\ 15\cos(q_2)\sin(q_4) - 3\sin(q_4) + 12\sin(q_2)\sin(q_3)\sin(q_4) - 12\cos(q_2)\cos(q_3)\sin(q_4) + 9\cos(q_2)\cos(q_5)\sin(q_3) + 9\cos(q_3)\cos(q_5)\sin(q_2) + \cos(q_2)\sin(q_3)\sin(q_4) + \cos(q_3)\sin(q_2)\sin(q_4) - 9\cos(q_2) \end{pmatrix}$$

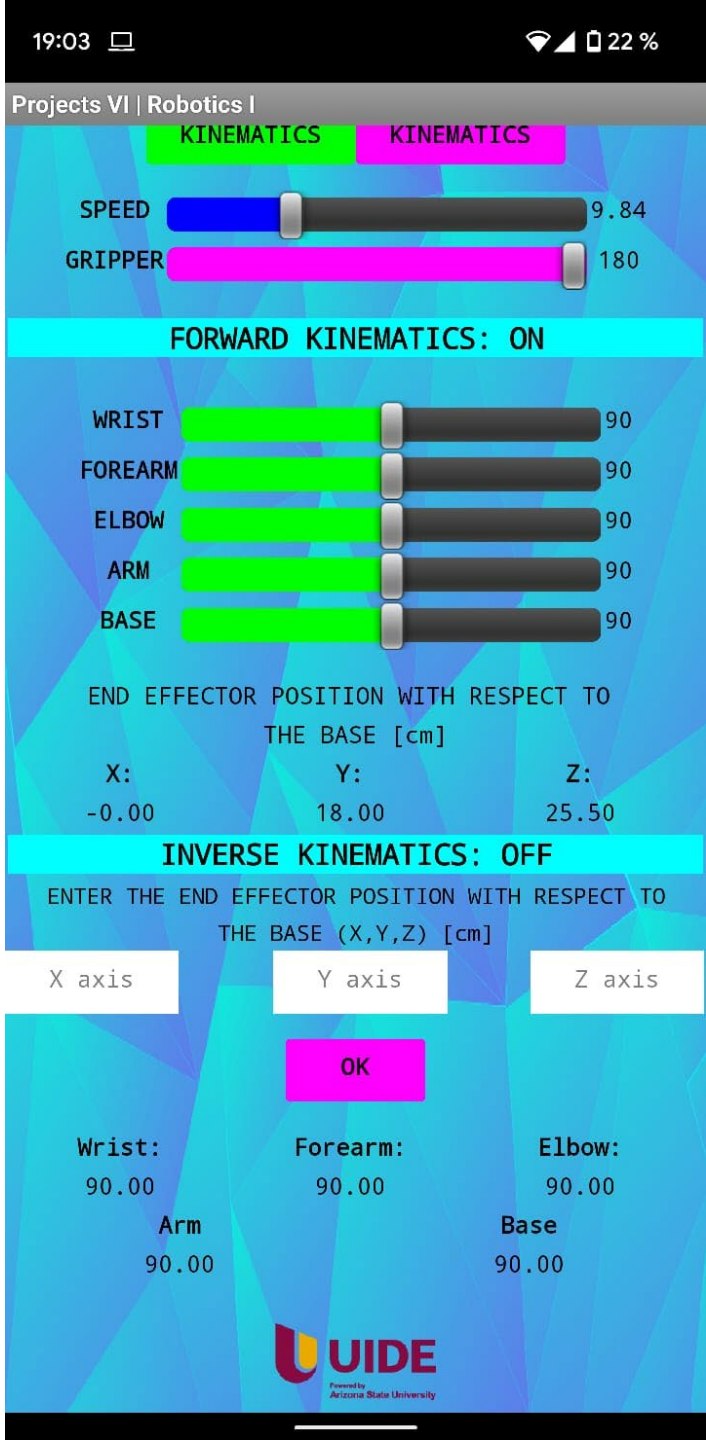
# JACOBIAN

# TESTS AND RESULTS

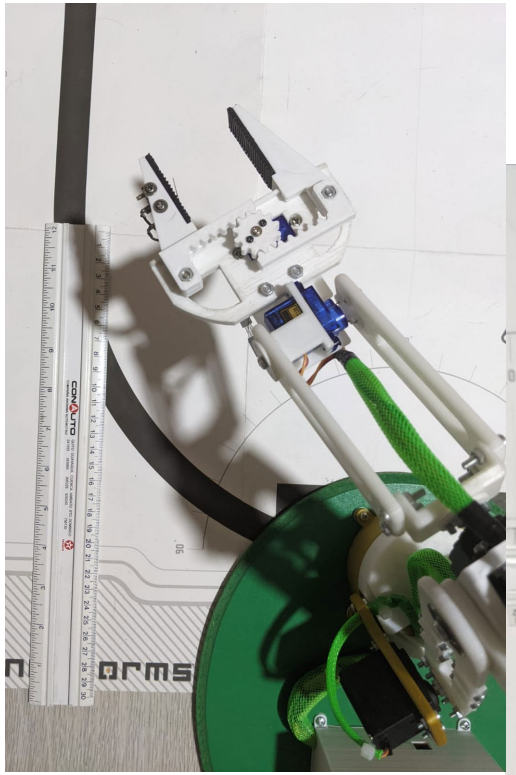
# TEST #1

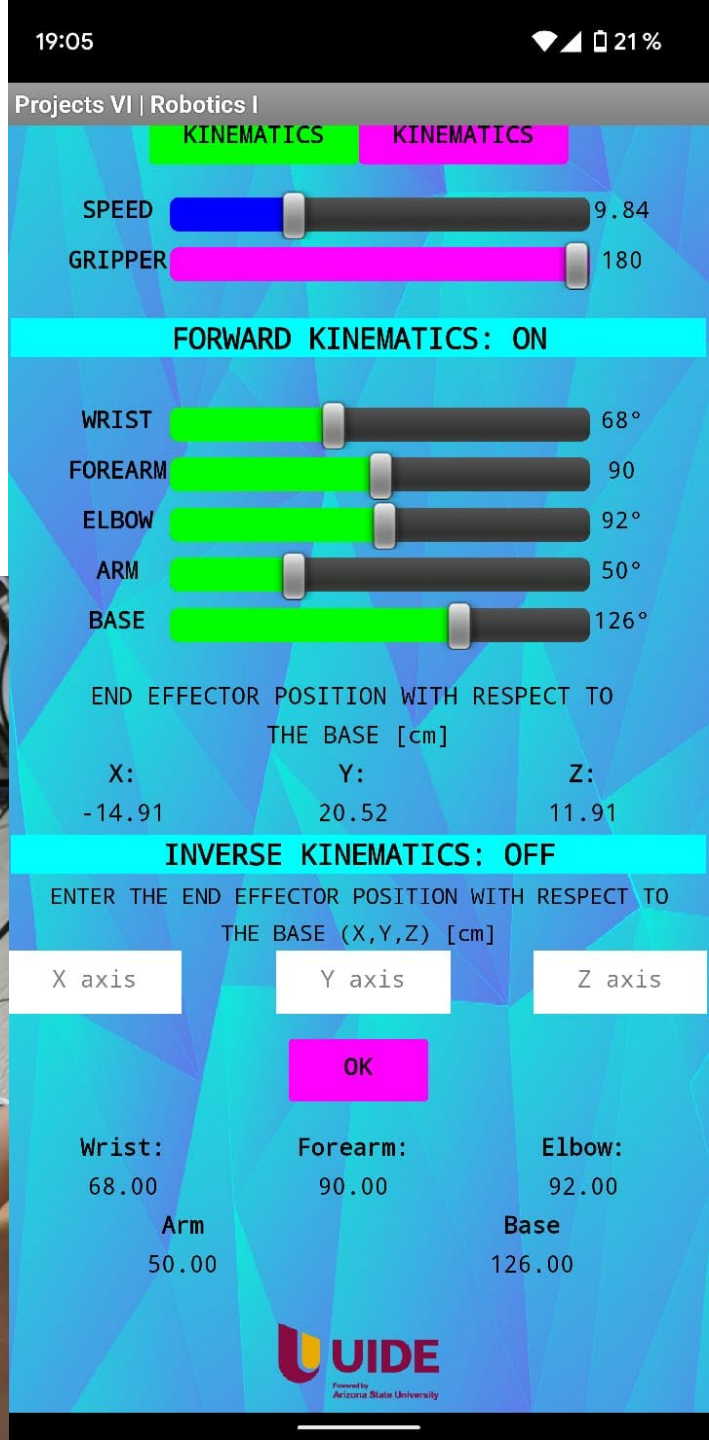





19:03
22 %
Projects VI | Robotics I
KINEMATICS
KINEMATICS
SPEED
9.84
GRIPPER
180
FORWARD KINEMATICS: ON
WRIST
90
FOREARM
90
ELBOW
90
ARM
90
BASE
90
END EFFECTOR POSITION WITH RESPECT TO THE BASE [cm]
X:
-0.00
Y:
18.00
Z:
25.50
INVERSE KINEMATICS: OFF
ENTER THE END EFFECTOR POSITION WITH RESPECT TO THE BASE (X,Y,Z) [cm]
X axis
Y axis
Z axis
OK
Wrist:
90.00
Forearm:
90.00
Elbow:
90.00
Arm
90.00
Base
90.00
UIDE

# TEST #2




19:05
21 %
Projects VI | Robotics I
KINEMATICS
KINEMATICS
SPEED
9.84
GRIPPER
180
FORWARD KINEMATICS: ON
WRIST
68°
FOREARM
90
ELBOW
92°
ARM
50°
BASE
126°
END EFFECTOR POSITION WITH RESPECT TO THE BASE [cm]
X:
-14.91
Y:
20.52
Z:
11.91
INVERSE KINEMATICS: OFF
ENTER THE END EFFECTOR POSITION WITH RESPECT TO THE BASE (X,Y,Z) [cm]
X axis
Y axis
Z axis
OK
Wrist:
68.00
Forearm:
90.00
Elbow:
92.00
Arm
50.00
Base
126.00
UIDE

# THANK YOU FOR YOUR ATTENTION