DRAW-E

3-Degree of Freedom Robotic Arm

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User Needs

Safety

Autonomous

Painting

“The Department of National Defence needs a portable, reliable, and safe robotic arm to paint surfaces on the Halifax Class Steel Warship which can be operated by boatswains to free up sailors so they can complete other tasks.”

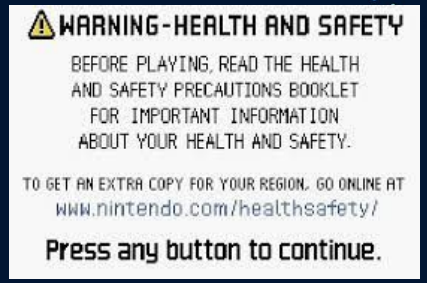
Safety

Emergency Stop Button

Machine

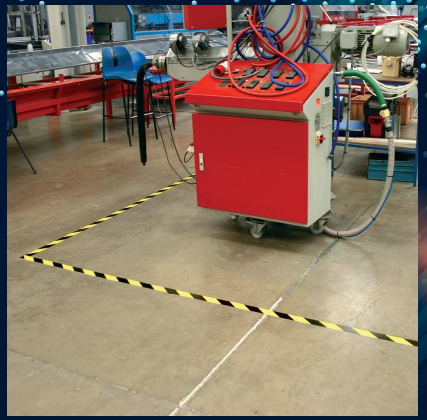
Machine Safety Signs

Machine



Health and Safety Warning

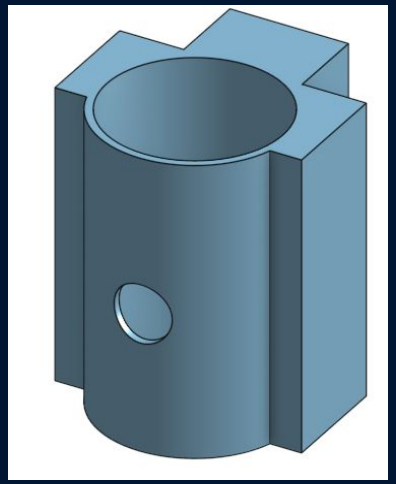
Application



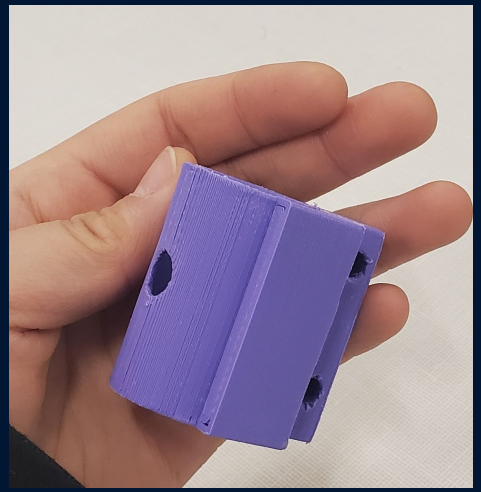
Floor Marking Tape

Machine Surrounding

End Effector

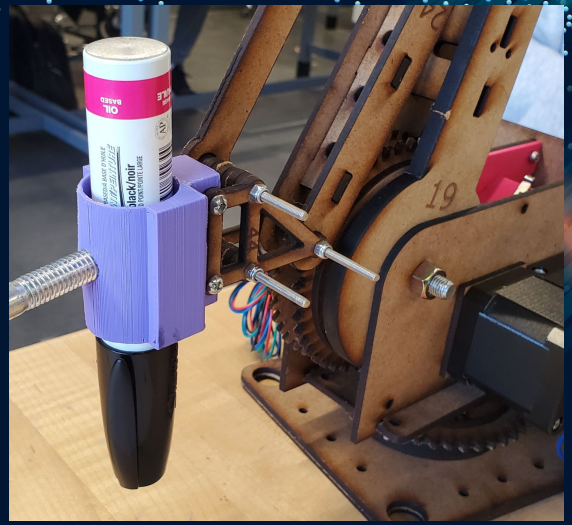


CAD Model



Manufactured Model

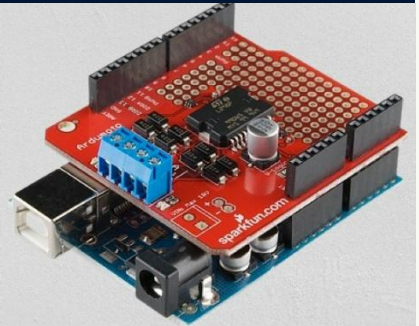
Marker Attached

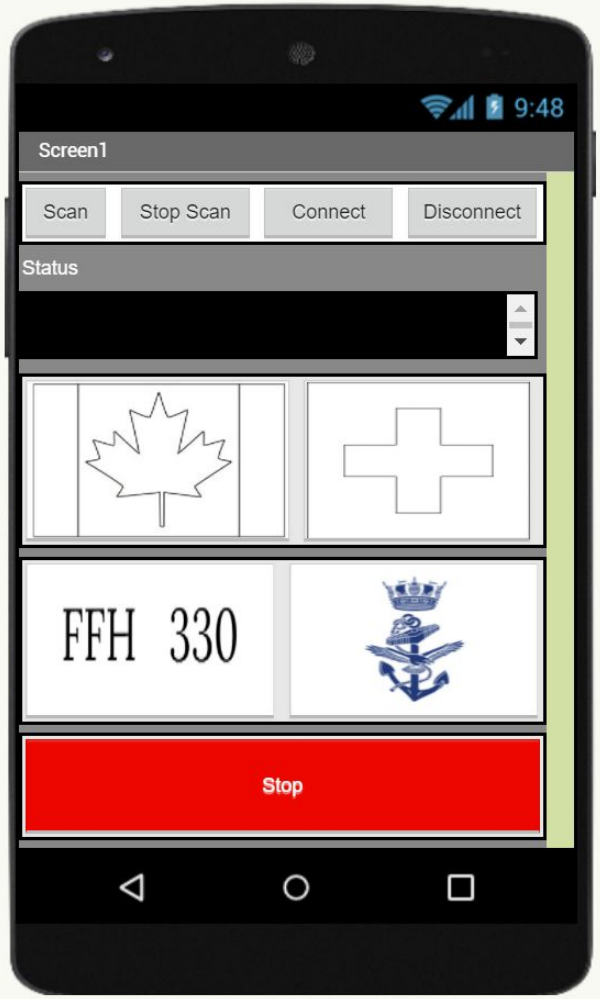


End Effector and Marker Attached to Arm

Procedure

1. User selects logo from selection screen
2. App sends image to be drawn to the Arduino
3. Arduino controls the robot and the logo is drawn





Our solution is:

Easy

Ready to run, Easy to fix and maintain

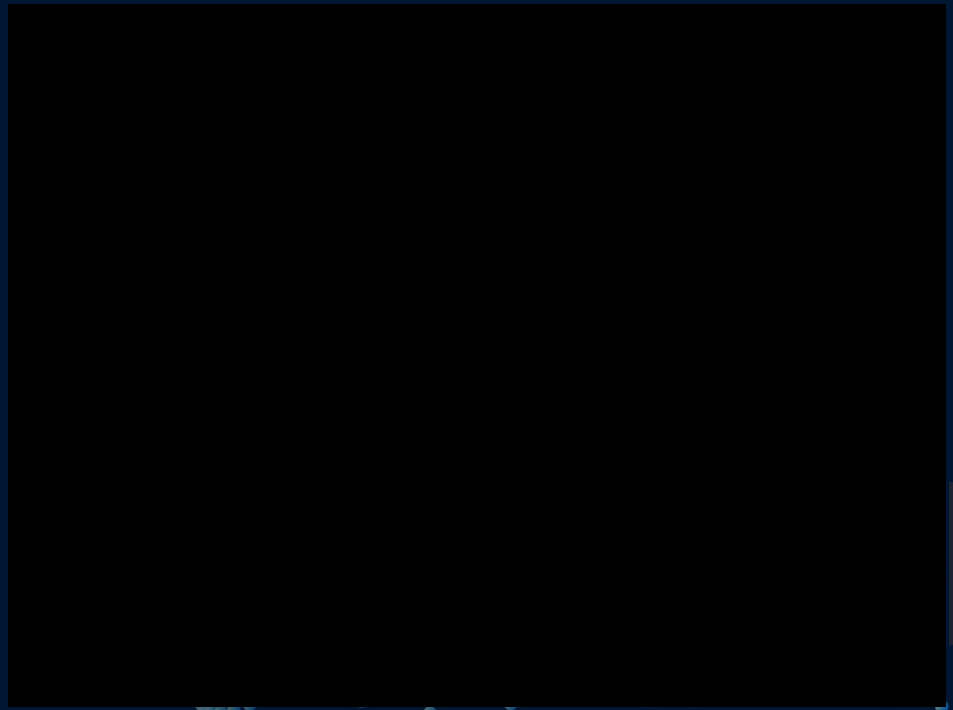
Simple

No technical skills required

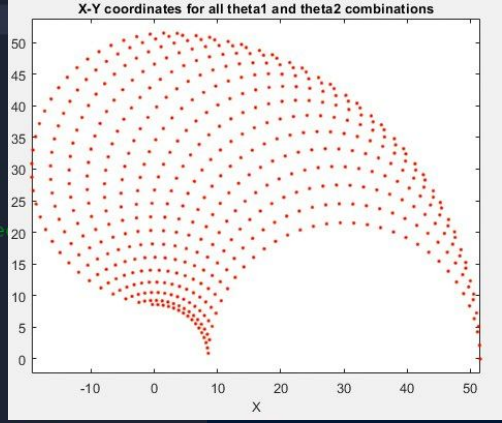
Adjustable

Use any drawing tool desired

Demonstration



```python
from numpy import *

# Length of links in cm
a1= 24.713
a2 = 25.073
a3 = 6.087  #'incl pen length

# Desired Position of End effe
px = -14
py = 3

phi = 90
phi = deg2rad(phi)

# Equations for Inverse kinematics
wx = px - a3*cos(phi)
wy = py - a3*sin(phi)

delta = wx**2 + wy**2
c2 = ( delta -a1**2 -a2**2)/(2*a1*a2)
s2 = sqrt(1-c2**2)  # elbow down
theta_2 = arctan2(s2, c2)

s1 = ((a1+a2*c2)*wy - a2*s2*wx)/delta
c1 = ((a1+a2*c2)*wx + a2*s2*wy)/delta
theta_1 = arctan2(s1,c1)
theta_3 = phi-theta_1-theta_2

print('theta_1: ', rad2deg(theta_1))
print('theta_2: ', rad2deg(theta_2))
print('theta_3: ', rad2deg(theta_3))
```

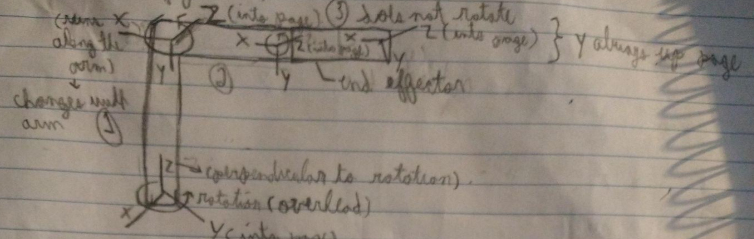



```
const int StepX = 2;
const int DirX = 5;
const int StepY = 3;
const int DirY = 6;
const int StepZ = 4;
const int DirZ = 7;
const int EnX = 8;

void setup() {
  //pinMode(EnX, OUTPUT);
  pinMode(StepX,OUTPUT);
  pinMode(DirX,OUTPUT);
  pinMode(StepY,OUTPUT);
  pinMode(DirY,OUTPUT);
  pinMode(StepZ,OUTPUT);
  pinMode(DirZ,OUTPUT);

}
 //200 is whole 360 deg
void loop() {
 digitalWrite(EnX, HIGH);
 digitalWrite(DirX, LOW);
 digitalWrite(DirY, HIGH);
 digitalWrite(DirZ, LOW);
```

Thank you for listening!

Q&A Period

1) Robot configuration:



2) Table listing changes

angle needed to realign x-axes

	Z		X	
	θ	l_{z-1}	β	l_{x-1}
1	θ_1	$L_1 = 24.713$	90°	$\emptyset$
2	θ_2	$\emptyset$	$\emptyset$°	$L_2 = 25.073$
3	θ_3	$\emptyset$	$\emptyset$°	$L_3 = 6.087$

θ = angle between fixed / rotating joint and arm

3) Denavit-Hartenberg parameters (x3)

$$\begin{bmatrix} \cos\theta & -\sin\theta\cos\beta & \sin\theta\sin\beta & r_n\cos\theta \\ \sin\theta & \cos\theta\cos\beta & -\cos\theta\sin\beta & r_n\sin\theta \\ \emptyset & \sin\beta & \cos\beta & l_{z-1} \\ \emptyset & \emptyset & \emptyset & 1 \end{bmatrix}$$

$$\begin{bmatrix} \cos\theta_1 & -\sin\theta_1\cos 0^\circ & \sin\theta_1\sin 0^\circ & \emptyset\cos\theta_1 \\ \sin\theta_1 & \cos\theta_1\cos 0^\circ & -\cos\theta_1\sin 0^\circ & \emptyset\sin\theta_1 \\ \emptyset & \sin 0^\circ = 1 & \cos 0^\circ = 1 & 24.713 \\ \emptyset & \emptyset & \emptyset & 1 \end{bmatrix}$$

$$\begin{bmatrix} \cos\theta_2 & -\sin\theta_2\cos 0^\circ & \sin\theta_2\sin 0^\circ & 25.073\cos\theta_2 \\ \sin\theta_2 & \cos\theta_2\cos 0^\circ & -\cos\theta_2\sin 0^\circ & 25.073\sin\theta_2 \\ \emptyset & \sin 0^\circ = 1 & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & 1 \end{bmatrix}$$

$$\begin{bmatrix} \cos\theta_3 & -\sin\theta_3\cos 0^\circ & \sin\theta_3\sin 0^\circ & 6.087\cos\theta_3 \\ \sin\theta_3 & \cos\theta_3\cos 0^\circ & -\cos\theta_3\sin 0^\circ & 6.087\sin\theta_3 \\ \emptyset & \sin 0^\circ = 1 & \emptyset & \emptyset \\ \emptyset & \emptyset & \emptyset & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \cos\theta_1\cos\theta_2 - \sin\theta_1\cos 90^\circ\sin\theta_2 & -\cos\theta_1\sin\theta_2 & \emptyset & \cos\theta_1 25.073\cos\theta_2 \\ \sin\theta_1\cos\theta_2 + \sin\theta_2\cos\theta_1\cos 90^\circ & -\sin\theta_1\sin\theta_2 & \emptyset & \sin\theta_1 25.073\sin\theta_2 \\ \sin 90^\circ\sin\theta_2 & \cos\theta_2 & \emptyset & 25.073\sin\theta_2 + 24.713 \\ \emptyset & \emptyset & \emptyset & 1 \end{bmatrix}$$

C1 C2

$$= \begin{bmatrix} \cos\theta_1(\cos\theta_2\theta_3 - \sin\theta_2\theta_3) & -\cos\theta_1(\cos\theta_2\sin\theta_3 + \sin\theta_2\cos\theta_3) & \\ \sin\theta_1(\cos\theta_2\theta_3 - \sin\theta_2\theta_3) & -\sin\theta_1(\cos\theta_2\sin\theta_3 + \sin\theta_2\cos\theta_3) & \\ \sin\theta_2\cos\theta_3 + \cos\theta_2\sin\theta_3 & -\sin\theta_2\theta_3 + \cos\theta_2\theta_3 & \\ \emptyset & \emptyset & 1 \end{bmatrix}$$

C3 C4

$$\begin{bmatrix} \emptyset & -\cos\theta_1(6.087\cos\theta_2\theta_3 - 6.087\sin\theta_2\theta_3 + 25.073\cos\theta_2) \\ \emptyset & -\sin\theta_1(6.087\cos\theta_2\theta_3 - 6.087\sin\theta_2\theta_3 + 25.073\cos\theta_2) \\ \emptyset & 6.087\cos\theta_3\sin\theta_2 + 6.087\sin\theta_3\cos\theta_2 + 25.073\sin\theta_2 + 24.713 \\ \emptyset & 1 \end{bmatrix}$$