ME 224 Course Project

DrawBot - Precision Drawing with Polar Motion

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by

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Motivation and Application

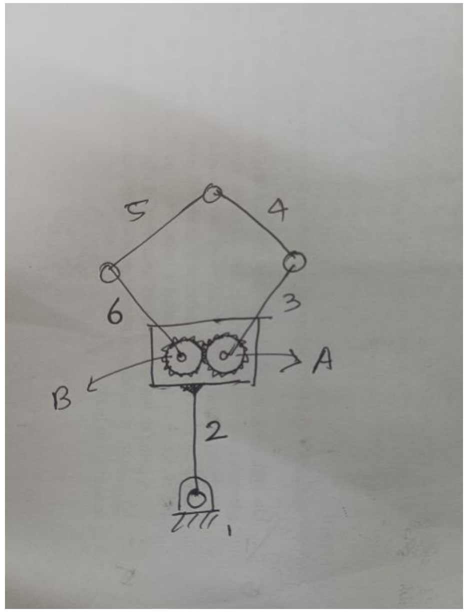
- Exploration and fascination towards the study of **inverse kinematics**
- Precise and repeatable tasks, such as drawing, writing, or pattern generation
- polar coordinate approach is much more **precisely controlled** by motor as they rotate
- Straight line mechanism components used in the making of this project

Application:-

- Assistive Writing Devices
- Educational Tool
- Automated PCB Tracing and Mask Drawing
- **Space-Constrained Robotics Applications**

Originality beyond class assignments or teaching notes

- Explored Various Robotic arms like SCARA bot, DELTA bot etc.
- Inter-relating topics - Tried to combine topics like straight line mechanism and adding angular coordinate control to it.
- We aimed for a **polar-coordinate control system**, which we haven't seen much in classroom assignment or teaching notes.
- Unique design with no online cad model/reference
- Own Kinematic Synthesis
- Complete project along with Mat-lab code and computer vision implementation



Kinematic Analysis

Type Synthesis: 4-bar linkage with rotational input and gear-coupled symmetry for smooth polar motion.

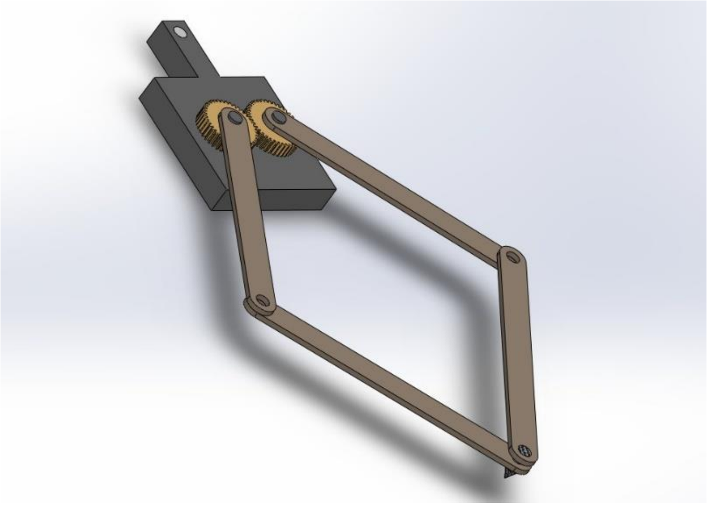
Mobility: -

$N = 6$; $P_1 = 6$; $P_2 = 1$ (Gear Pair)

*Gear and connected link are one body (Adjusted this in CAD model by doing Lock Mate)

$DOF = 3(N-1) - 2P_1 - P_2$

Therefore, Mobility of this mechanism = 2 (radial and angular)



Position Analysis (Polar Coordinates):

•Final pen position:

•$x=r(\phi)\cos(\theta)$ $y=r(\phi)\sin(\theta)$

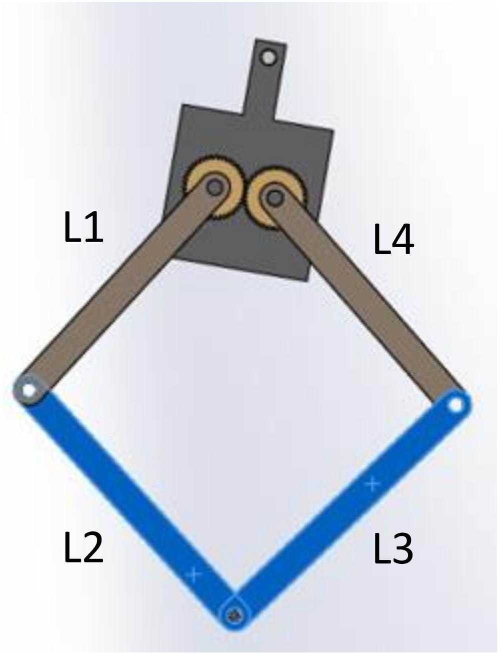
•Radius r determined by the effective extension of the arms driven by gear-coordinated rotation (**ϕ**).

•Angle **θ** controlled by ground motor rotation.

Kinematic Synthesis

Synthesis Goal:
Achieve desired motion output using geared 4-bar linkage to:
•**Control angle (θ):** via synchronized counter-rotating arms.
•**Control radius (r):** via gear-driven extension of links.

To Obtain **θ -** Base Link (Gear Container)
To Obtain **r –** 4-bar Gear Driver Mechanism (Straight Line Mechanism)
To Obtain this r , it is a function of **ϕ** which is the gear rotation r = r(**ϕ**)



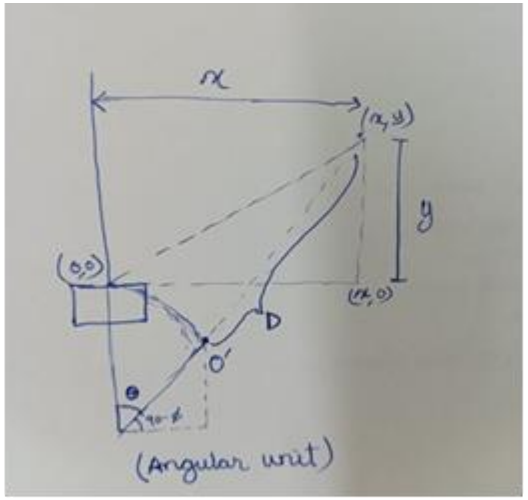
Conditions For a successful mechanism

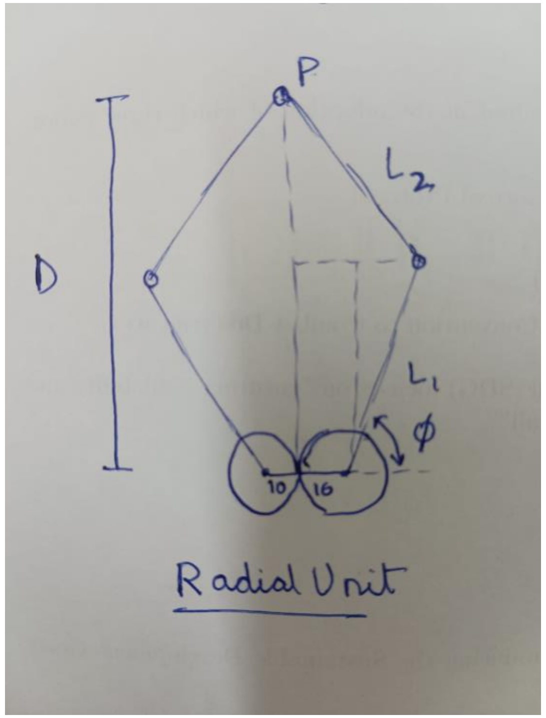
1. To obtain origin the pitch radius If gear is small
2. L1 +L4 + 2(R_p) = L2 + L3
3. Since the pitch center, designation point, pen point should be in straight line i.e after the angular position is set.
   We need symmetry ,
   Therefore L1 = L4 and L2 = L3

MatLab Code

```
% Define link lengths
L1 = 90;
L2 = 100;

n = length(x_coords);
Rang = zeros(n, 1);
ang = zeros(n, 1);

% Define safe square root function
sqrt_safe = @(x) real(sqrt(max(x, 0))); % Ensures real output

% Define time vector (e.g., 0.1s per step)
time_step = 0.1;
time = (0:n-1)' * time_step;

% Loop over each point
for i = 1:n
    x = x_coords(i);
    y = y_coords(i);

    % Compute angle from origin
    fun_ang = @(a) tan(a) - (y / (x - 45 * sin(a)));

    try
        ang(i) = fzero(fun_ang, [-pi/2 + 0.01, pi/2 - 0.01]);
    catch
        ang(i) = 0;
        Rang(i) = 0;
        continue;
    end
```

Angular unit

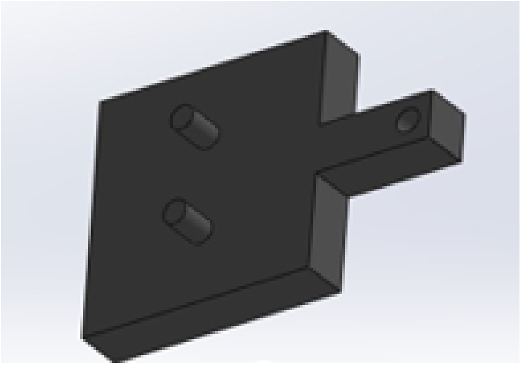


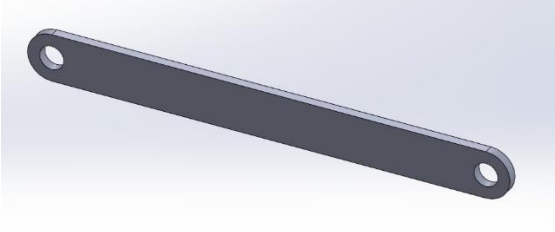


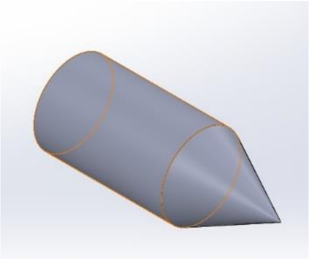
Radial Unit

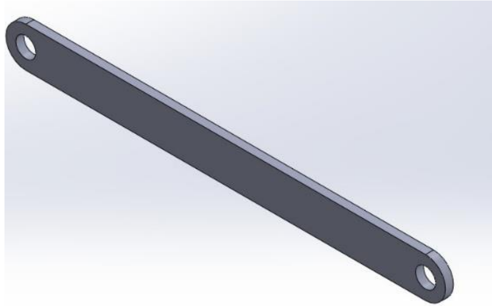
```
a = ang(i);
D = 45 * (1 / cos(a) - 1) + sqrt(y^2 + (x - 45 * sin(a))^2);

fun = @(theta) D - (L1 * sin(theta) + 45 + sqrt_safe(L2^2 - (10 + L1 * cos(theta))^2));
```

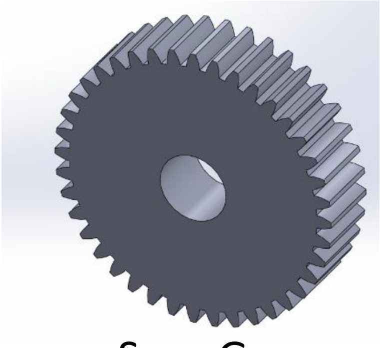
Computer Aided Design

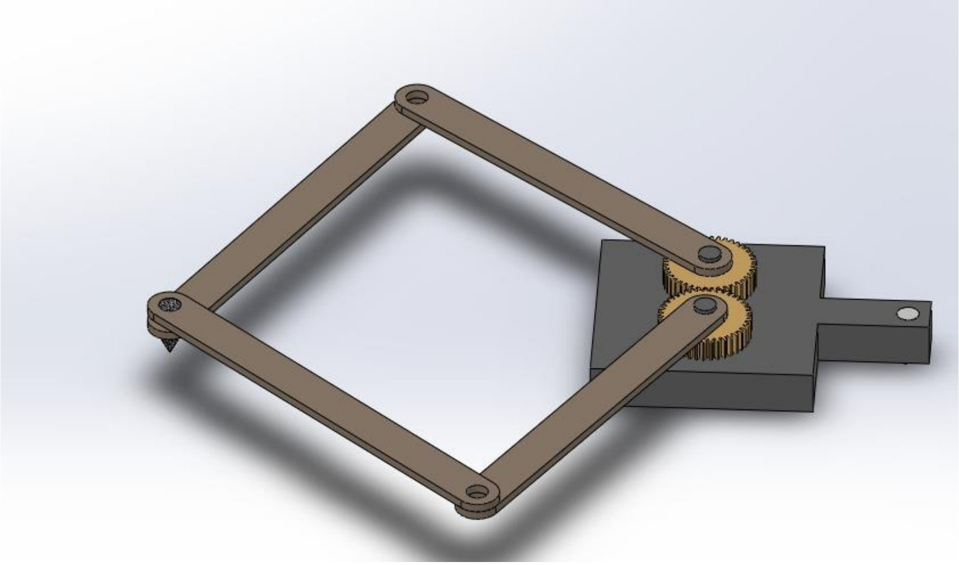

Gear Mounting Box


Back Link

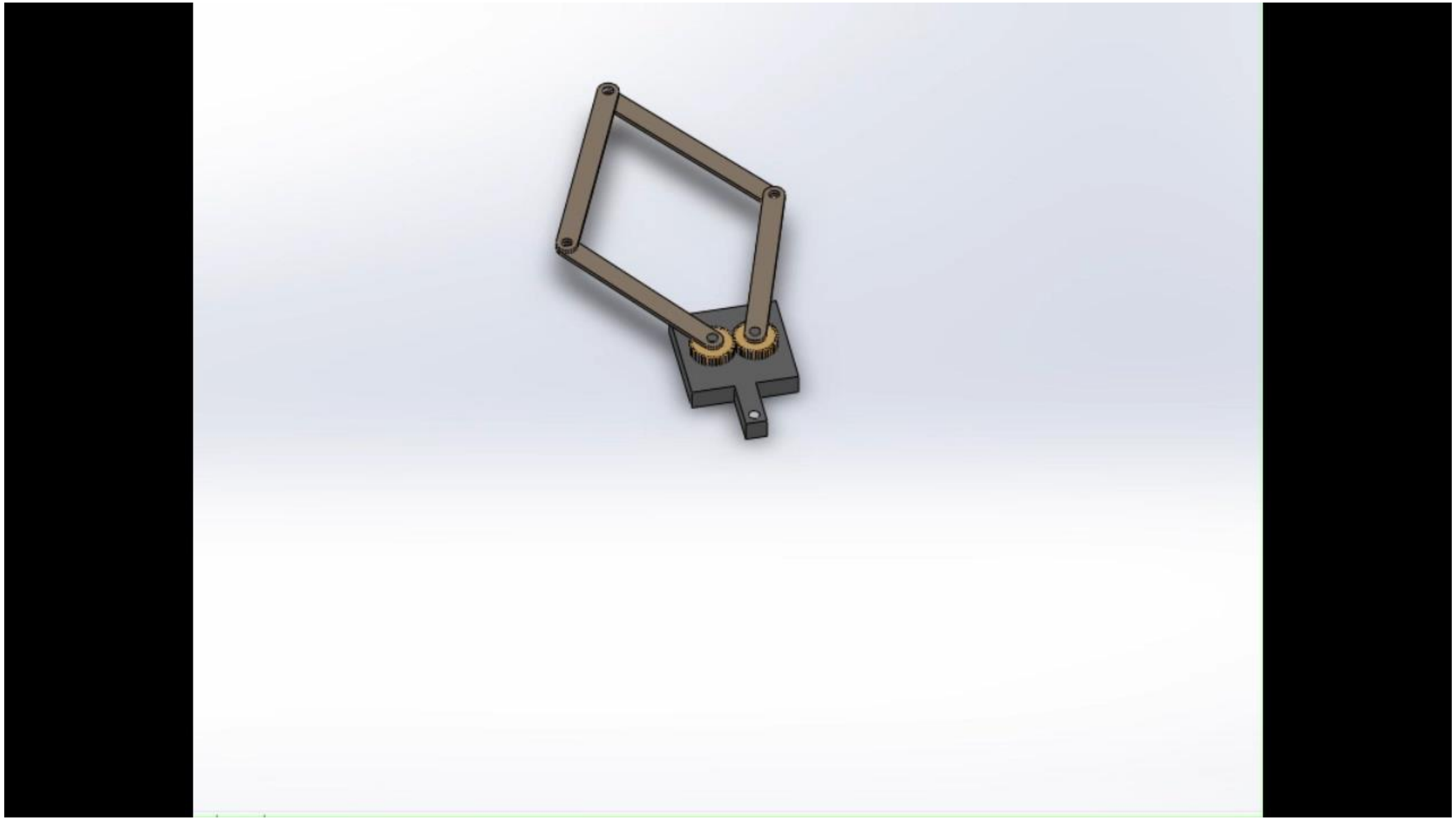

Pen Tip


Front Link


Spur Gear


Assembly

Motion Analysis / Study



Conclusions

Flow chart of design: → **1.Input Image → MATLAB** → → Extract contour points (x,y)

→ **2.Contour Points (x,y)(x, y)(x,y)** → → Converted to **Polar Coordinates** (r,θ) → **3.Inverse Kinematics** → Compute **Angular Position (θ)** and **Radial Angle (ϕ)**

→ **4.Base Link Motor** → Sets final **Angular Position (θ)** of pen → **5.Gear-Driven 4-Bar Mechanism** → Rotates by **Radial Angle (ϕ)** to adjust **Radial Distance (r)** → **6.Linkage Alignment (ϕ)** → Aligns **Pitch Center**, **Pen Tip**, and **Target Point**

→ **7. Mechanism Output** → Draws desired image on surface

Individual Components of the mechanism are done including the extraction of points etc, but integration and functionality has not been checked which can be done in the future.

Thank You