# Introduction to Robotics ME 639: Industrial Project Presentation 2

# Project Title: Underwater Manipulator’s Control System

**Team Name: Team Pluto**

**Team Members:** Dhvani Shah, Dev Patel, Harsh Shrivastava

**Instructor:** Prof. Harish PM
**Teaching Assistant:** Suraj Borate

# Problem Statement:

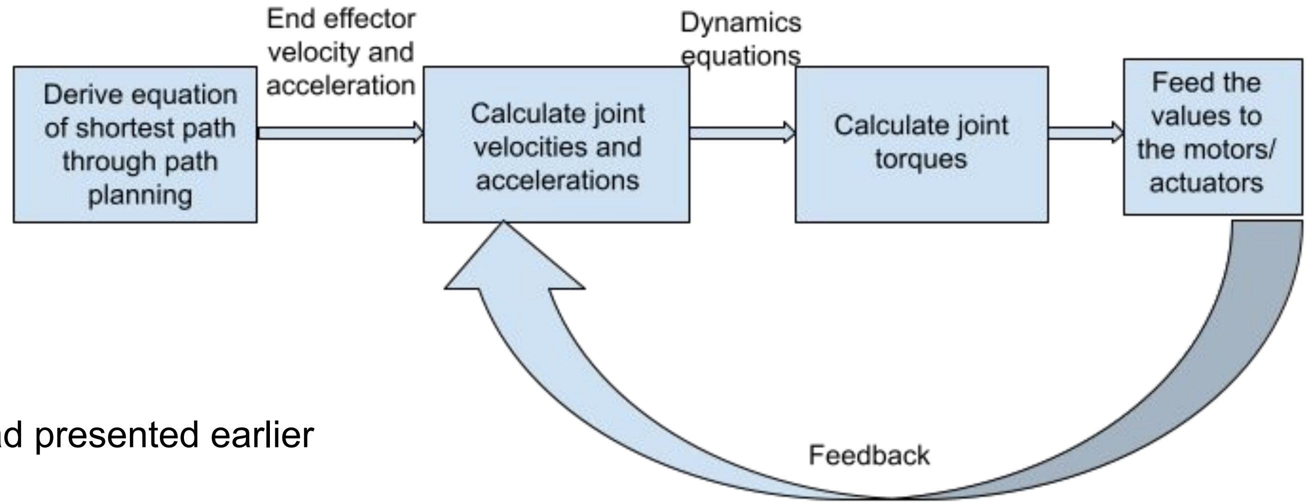
**“ Design a control system for a 2 Dof manipulator of an underwater ROV”**

**Industry name:** **Planys Technologies**

**Objectives:**

- ***Find the shortest path and duration between two readings***
- ***Appropriate value of acceleration and velocity***
- ***Account for underwater dynamics in control system***
- ***Suggestions of suitable actuators***

# Rationale / Approach / Ideas:




What we had presented earlier

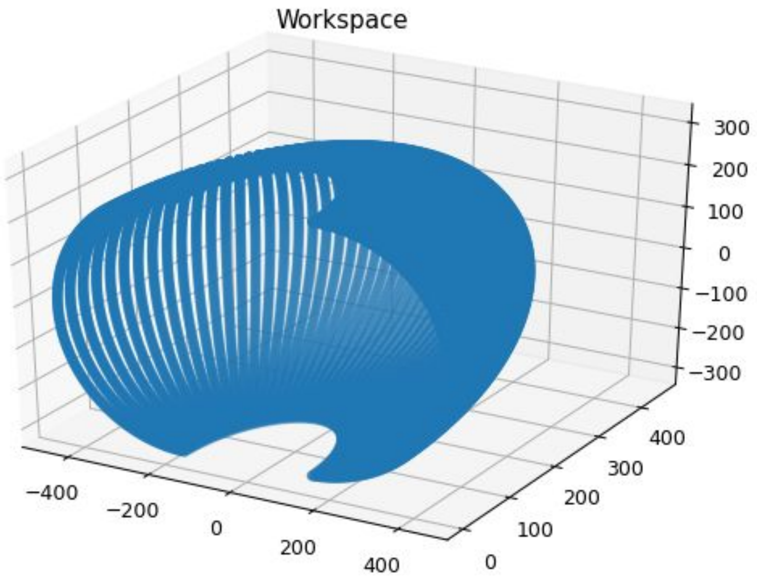
# Rationale / Approach / Ideas:

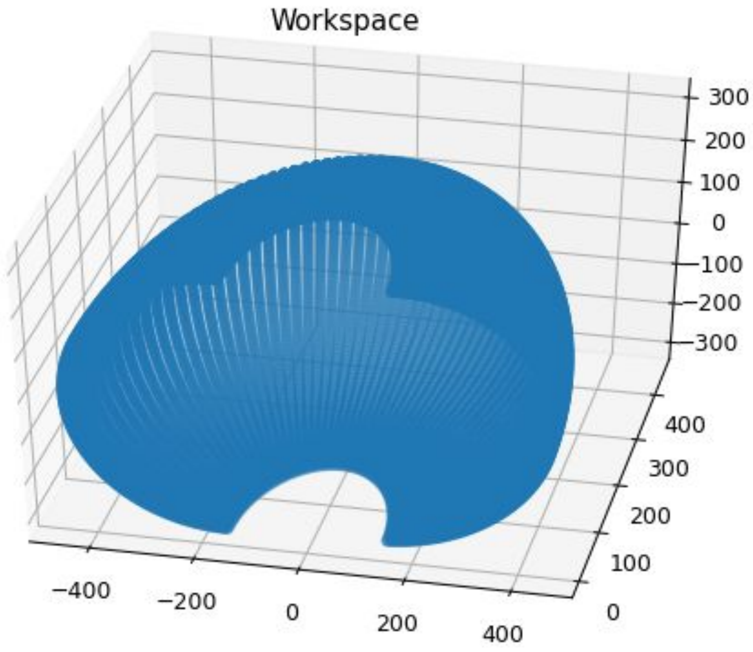
- Deriving the forward and inverse kinematic equation for the manipulator.
- Plotting the workspace
- Looking for the shortest path between two points

- Understanding the underwater dynamics.
- Designing a PID controller for independent joint control.

# Key Results 1:

## Robot Workspace:




**Python Code for Workspace** : [Code.ipynb - Colaboratory (google.com)]()

# How workspace is generated...

1. **Workspace is generated using the joint angles - taking a step of 3° for $q_1$ and 1° for $q_2$.**

2. **The position of end effector is calculated using the dynamic equations and a 3D plot is generated.**

# Insights / Interim Conclusions / Discussion:

1. **As we can see from the workspace, it is impossible for robot to travel in straight line, as most points won't lie in workspace.**

2. **We propose that instead of deriving the shortest path, we will try to reduce the work done by motor, by allowing minimum angular displacement to reach the desired location.**

# Key Results 2:

**Inverse kinematics:**

**We have implemented the inverse kinematics code such that given the two coordinate points, we get the angular orientations of both the joints.**

**Example:**

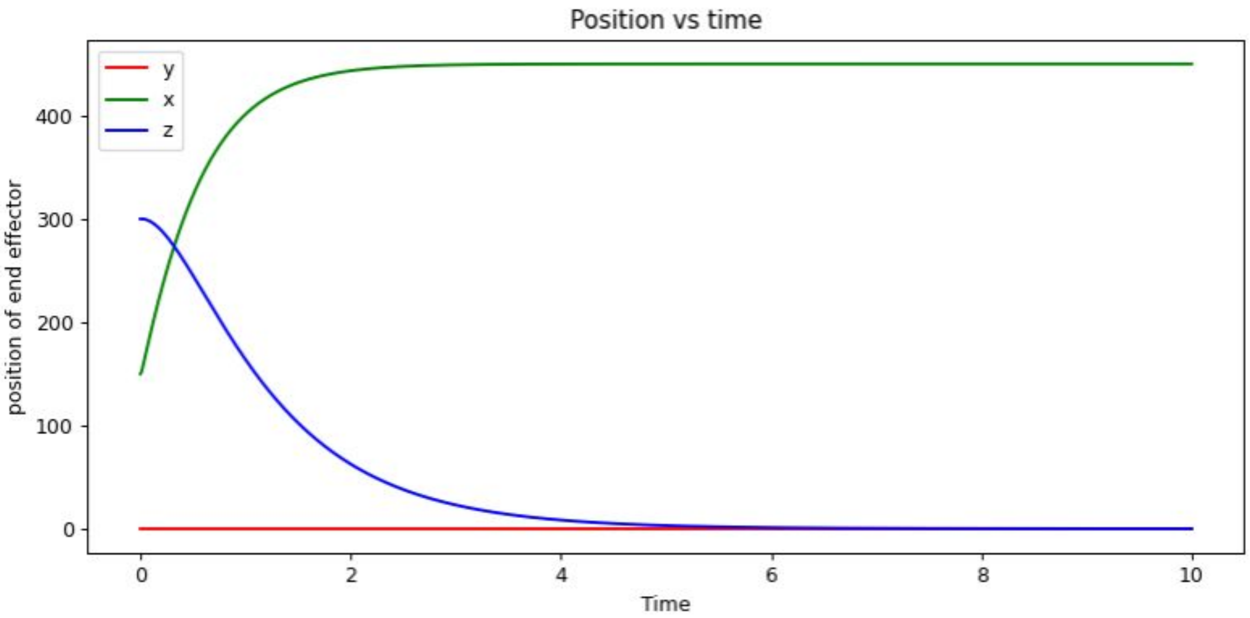
Input:

```
Coordinates of initial point: 150 0 300
Coordinates of final point: 450 0 0
```

Output:

```
Joint angles for initial position:  [0.          1.57079633]
Joint angles for final position:  [0. 0.]
```

# Key Results 3:



# Key Results 4:

**Example 2:**

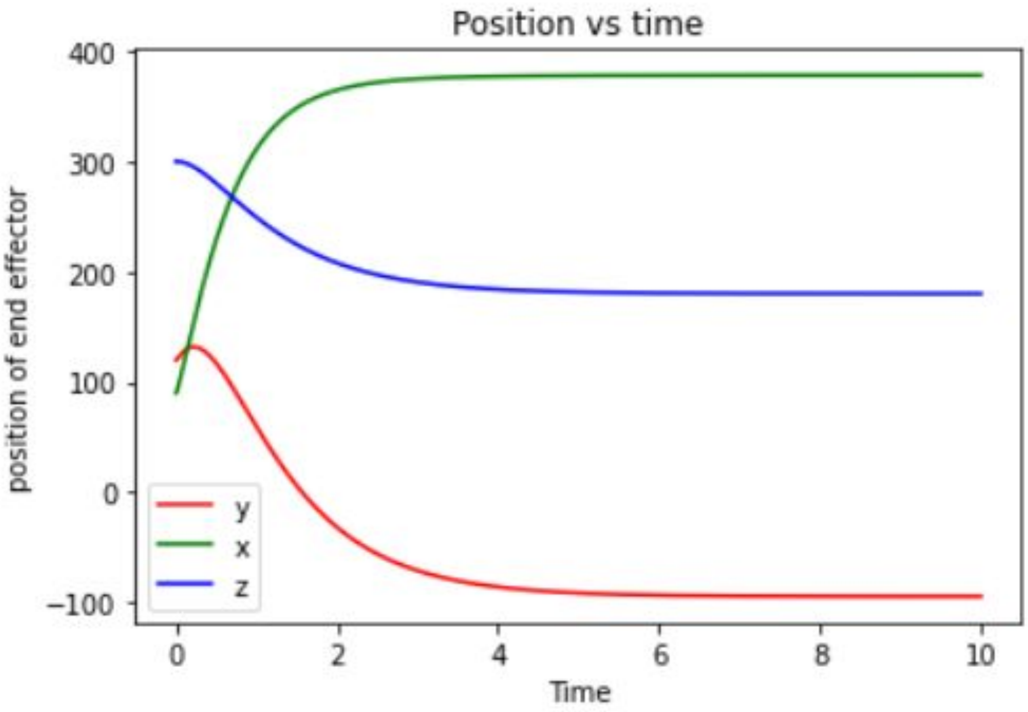
Input:

```
Coordinates of initial point: 90 120 300
Coordinates of final point: 360 -90 180
```

Output:

```
Joint angles for initial position:  [0.92729522 1.57079633]
Joint angles for final position:  [-0.24497866  0.64350111]
```

# Key Results 5:

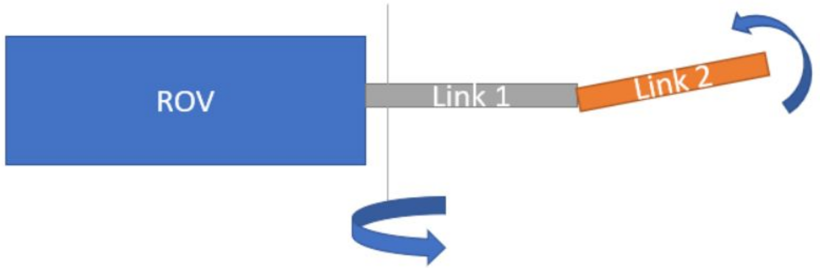


# Appendix 1: Dimensions

**Dimensions:**

$m1 = 1.5$ kg, $m2 = 1$ kg, $m\_probe = 0.5$ kg

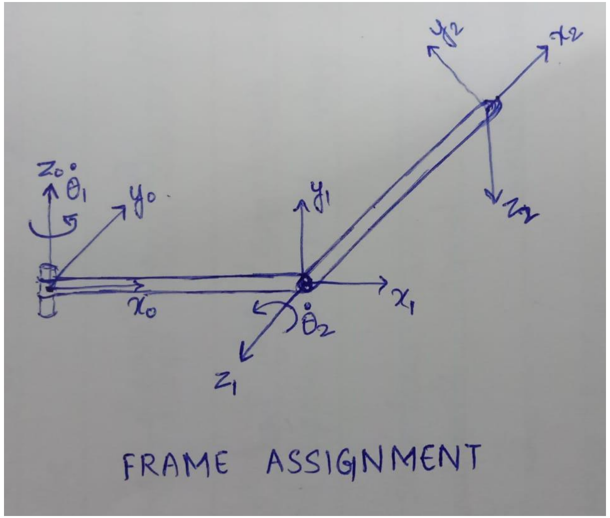
$l1 = 150$ mm, $l2 = 300$ mm




Side View

# Appendix 2: D-H Parameters and Kinematic Equations

| Link | a | d | α | θ |
|---|---|---|---|---|
| 1 | l1 | 0 | 90° | $\theta_1$ |
| 2 | l2 | 0 | 0 | $\theta_2$ |




Forward Kinematic Equations

$$z_p = l_2 \sin(\theta_2)$$

$$y_p = (l_1 + l_2 \cos(\theta_2))\sin(\theta_1)$$

$$x_p = (l_1 + l_2 \cos(\theta_2))\cos(\theta_1)$$

Inverse Kinematic Equations

$$\theta_2 = \tan^{-1} \frac{\frac{z_p}{l_2}}{\sqrt{1 - \frac{z_p}{l_2}^2}}$$

$$\theta_1 = \tan^{-1} \frac{y_p}{x_p}$$

# Deriving the equation of dynamics from DH Parameters

**Keys steps for deriving dynamics:**

1) Use Euler Lagrange's equation

$$\frac{d}{dt}\frac{\partial L}{\partial q*} - \frac{\partial L}{\partial q} = Q$$

Where L= K-V (K= Total Kinetic energy of robot, V= Total Potential energy of Robot)

2) Formulate Matrix D(q); dkj = kth row, jth column element of matrix D(q)
3) Compute Crystoffels symbols, Cijk

$$c_{ijk} := \frac{1}{2}\left\{\frac{\partial d_{kj}}{\partial q_i} + \frac{\partial d_{ki}}{\partial q_j} - \frac{\partial d_{ij}}{\partial q_k}\right\}$$

4) Calculate Torques by,

$$\sum_j d_{kj}(\mathbf{q})\ddot{q}_j + \sum_{i,j} c_{ijk}(\mathbf{q})\dot{q}_i\dot{q}_j + \phi_k(\mathbf{q}) = \tau_k, \quad k = 1, \ldots, n$$

$$\phi_k = \frac{\partial V}{\partial q_k}$$

# Appendix 3: General Dynamic Equation

F is for frictional losses and D is for drag losses.

$$\boldsymbol{\tau} = \mathbf{M}\,(q,q'') + \mathbf{C}\,(q,q')q' + \mathbf{F}(q') + \mathbf{G}(q) + \mathbf{D}(q,q')$$