ENPM662-INTRODUCTION TO ROBOT MODELING

# Final Project : Gantry Robot


Submitted by:

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# INTRODUCTION

- Gantry robots are mobile manipulator that can move within a fixed frame. It consists of two parts : 1. Crab or Trolley that moved in 2D within fixed frame and 2. Manipulator attached to the crab.
- Gantry robots are used for material handling, welding, tool fixing etc.. .
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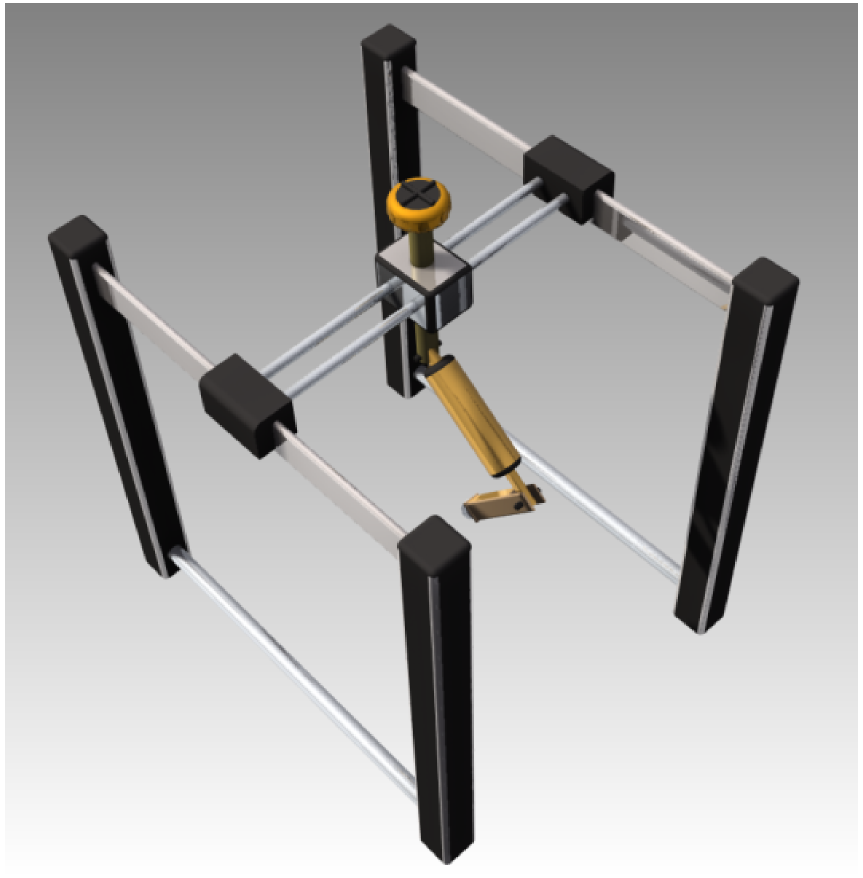

Fig 1: Gantry robot
Image Source: https://grabcad.com/library/gantry-robot-5

# MOTIVATION

- Material storage and material handling is one of the basic operations performed in any Industry. It has a significant impact on productivity and cost of production.
- Overhead crane (Gantry crane) is one of the widely used machines in the industry for material movement. But these are not helpful, if material is to be stored in stacks.
- While ground moving equipment like forklifts and transfer trucks can be used in conjunction with gantry crane, complete utilisation of shop floor is not achieved.
- One of the potential solutions for the above-mentioned problem is to use a “Gantry robot”(if payload is under few hundred kgs).
- Robot manipulator can be attached to the gantry girder and this assembly can be used in place of a gantry crane. Due to its dexterity, it can handle the material which is at the bottom of the stack or rack and thereby eliminating the needs of ground material handling equipment.
- For repeated pick and place operation, Gantry robot can be automated. Moreover, automated material handling is safer than manual handling.

# PROCESS OVERVIEW

Robot specifications selection.

CAD design developement

Forward and Inverse kinematics calculation and programming

Launching model in Gazebo

Prepared Moveit package

Integrated controllers into Moveit packages

Launch file making and launching in gazebo and Rviz

Moving Robot from start to goal position in Gazebo

Forward and Inverse kinematics calculation

# ROBOT DESIGN

To achieve our goal, we propose a gantry robot, where the 6 DOF articulated robotic arm which would be mounted at the bottom of the crab. The gantry comprises 4 structural vertical beams at the corners of the workspace, which are connected by parallel runway beams at the top. The girder mechanism is perpendicular to the runway beams and hosts the crab. Girder mechanism and Crab, possess 1 DOF each in horizontal plane.

| **Robot Manipulator(6 DoF)** | |
|---|---|
| Payload(kg) | 200 |
| Robot Mass(kg) | 2670 |
| H-Reach(m) | 3.507 |
| Joint angles range(degree) | $360^\circ, 180^\circ, 180^\circ, 360^\circ, 180^\circ, 360^\circ$ |
| Material | Mild Steel |
| **Gantry(Frame+girder+crab)** | |
| Dimension | Height - 4 meter<br>Runway beam – 15meter<br>Girder length – 10meter |
| Material | Mild Steel |

A SolidWorks model was created , with the scaled down dimensions.

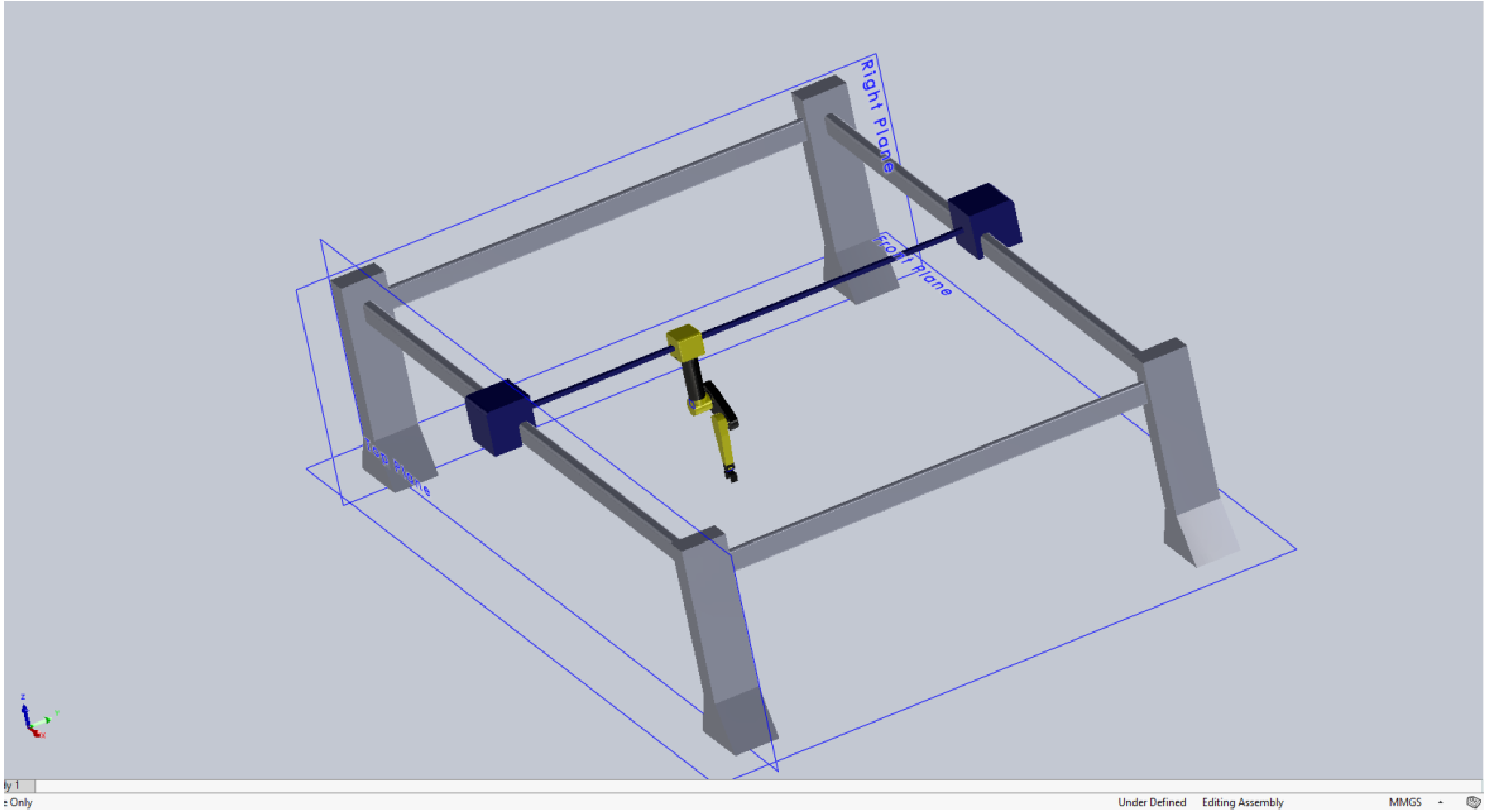


Fig 2: Solidworks model

# DH-Parameter

The DH parameters, were determined for the 6DoF robot manipulator. The orientation of the arm while calculating parameters, is as shown.

The base link of the manipulator is fixed. The first rotating joint is frame {0} and end effector frame is {6}.

| | $\theta_i$ | $d_i$ | $a_i$ | $\alpha_i$ |
|---|---|---|---|---|
| 0->1 | $\dot{\theta}_1$ | 26mm | 0 | $-90°$ |
| 1->2 | $\dot{\theta}_1$ | 29mm | 102.52mm | 0 |
| 2->3 | $\dot{\theta}_1$ | -17.5mm | 0 | $90°$ |
| 3->4 | $\dot{\theta}_1$ | 142.49 | 0 | $90°$ |
| 4->5 | $\dot{\theta}_1$ | 0 | 0 | $-90°$ |
| 5->6 | $\dot{\theta}_1$ | 0 | 0 | 0 |

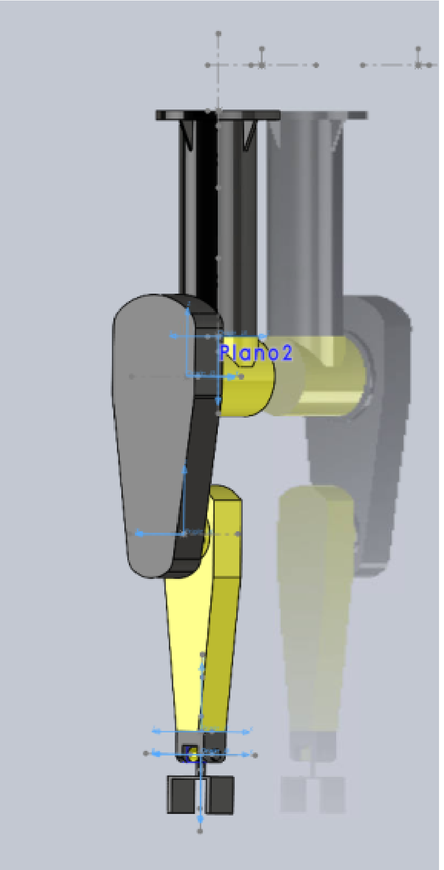


Fig 3: Pose for DH parameters

# Forward Kinematics

Transformation between frames $i-1$ and $i$ , is as follows:

$$T_i^{i-1} = Rot_{z,\boldsymbol{\theta}_i} * Trans_{z,d_i} * Trans_{x,a_i} * Rot_{x,\alpha_i}$$

$$T_i^{i-1} = \begin{bmatrix} \cos\boldsymbol{\theta}_i & -\sin\boldsymbol{\theta}_i . \cos\alpha_i & \sin\boldsymbol{\theta}_i . \sin\alpha_i & a_i . \cos\boldsymbol{\theta}_i \\ \sin\boldsymbol{\theta}_i & \cos\boldsymbol{\theta}_i \cos\alpha_i & -\cos\boldsymbol{\theta}_i \sin\alpha_i & a_i \sin\boldsymbol{\theta}_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Substituting the DH parameters for each transformation between frames. The final transformation between frame {0} and {6} is obtained.
All the calculations are determined using code.

<u>Validation</u>:
For the given joint angle values, the end effector position are determined from both program and simulation and compared. X and Y position are almost equal, however there is a slight variation in Z position. This might be due to different choice of coordinate frame or some other errors..

# Inverse Kinematics

For a given position of end-effector ,the values of joint angles required to achieve it are determined. Jacobian inverse determination was used to calculate this values. As the arm possesses 6 Dof, the Jacobian becomes a square matrix.

$$q_{current} = q_{previous} + J_{inv} * (\Delta x)$$

$q$ is the joint angle
$x$ is the end effector position

<u>Validation</u>:

- The initial values of $q_{initial}$ and $x_{initial}$ are known.
- A set of $q_{goal}$ is inputed to the simulation and final end effector position $x_{goal}$ is determined from simulation.
- Using that $x_{goal}$ as input to the program, a set of $q\grave{}_{goal}$ is found out and compared with $q_{goal}$ .

# PROBLEMS ENCOUNTERED:

1. Errors were encountered with the initially designed model, during urdf conversion and also while launching in gazebo. (Parent-child condition violated.)

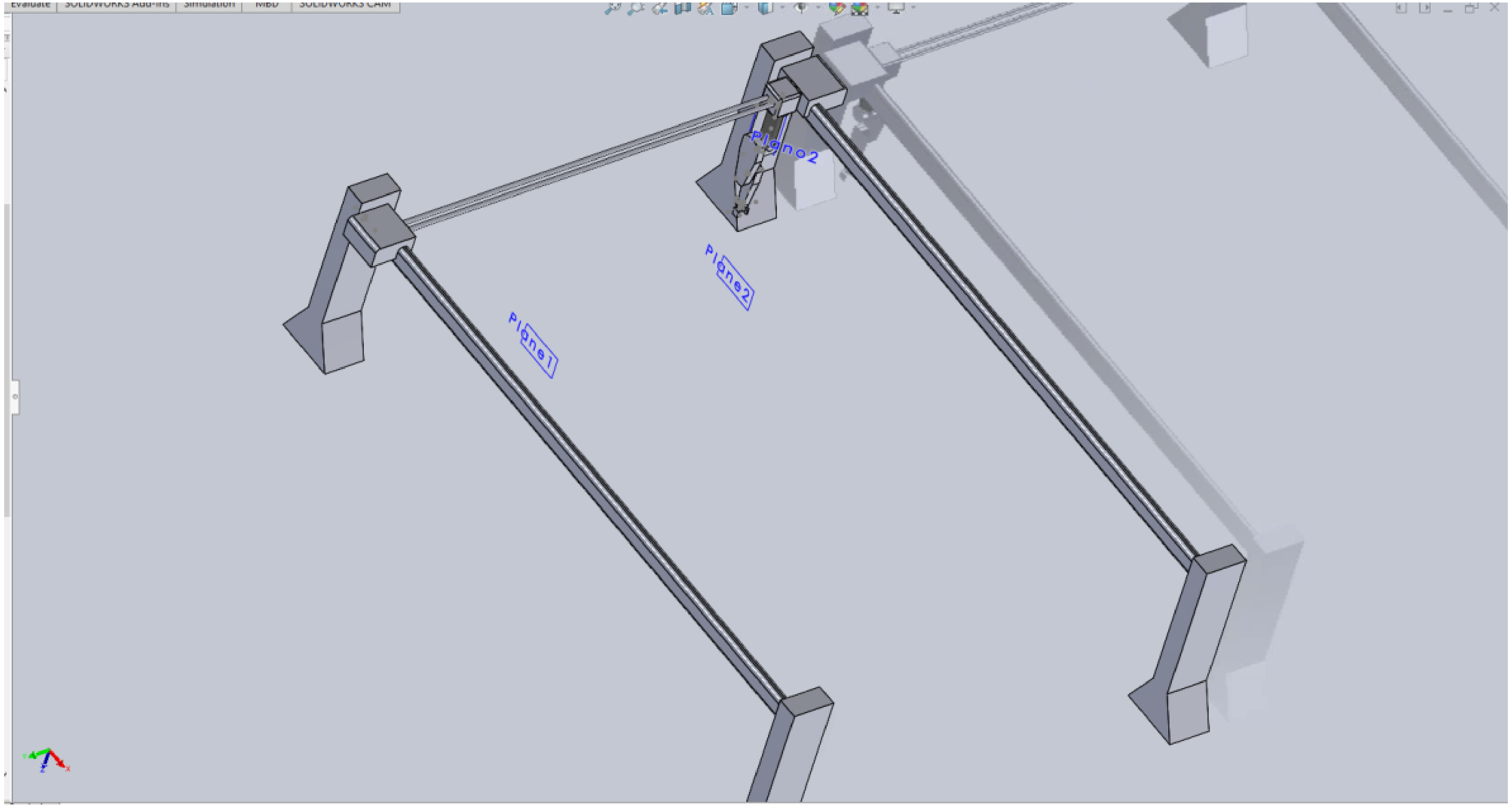


Fig 4: Initial Design

2. Torque limit and velocity limit were zero in urdf, so robot was not moving.
3. Model is not launching in correct orientation in gazebo.(This might be due to frame assignment during urdf export.)

# RESULTS

The video of simulation achieved as of now, is provided in the link:

https://drive.google.com/file/d/1X6COeCyQYrSfKaMGjnmouMJRvSmIHpbM/view?usp=shari
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# CONCLUSIONS

- A gantry robot for pick and place operation has been proposed and modelled.
- The forward and inverse kinematics of the manipulator arm have been carried out.
- Implementation of the path planning in Gazebo is carried out and forward and inverse kinematics values are verified. There is slight difference in z values which might be due to different choice of coordinate frame or some other errors.

# INDIVIDUAL CONTRIBUTIONS

- Jeffin – Build Solidworks and exported urdf. And also assigned DH parameters.
- Pradip – Inverse Kinematics and simulation part.

# REFERENCES:


1. https://www.robots.com/faq/what-are-gantry-robots
2. https://www.robots.com/robots/fanuc-m-900ia-200p
3. FANUC-M-900iA-Series-Large-Payload-Robot-Brochure