Workspace Analysis and Mounting Height for 3DOF Delta Robot

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***Abstract*—This Paper demonstrates an approach to figure out both the effective workspace and the mounting height of a delta parallel manipulator. Recently, this type of robotic arms have witness a significant and rapid growth in several industrial applications specially in pick and place applications, due to the fact that, it is stiff, light weighted, and its remarkable speed and accuracy.**

I. Introduction

The delta parallel manipulator's workspace is developed using the approach in [1], which depends on solving the forward kinematics problem following the equations found in [2], for numerous sets of active joints angles then illustrating the retrieved solutions in the three-dimensional space using MATLAB 2016a. It can be easily seen that the workspace is a homogeneous and uniform shape, as shown in Figure 1 below.

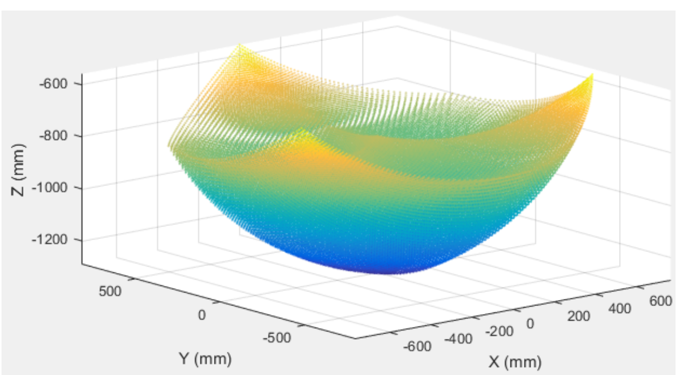

Fig. 1. Delta robot's ideal workspace.

It should be also mentioned that this approach neglect the maximum allowable angle of the ball joints that act as the passive joints in each leg of the delta robot,meaning that there are invalid sets of points that could damage the robot, if they were reached, hence further investigation must be done.

II. Effective Workspace

In order to develop the effective workspace, two measures should be taken. Firstly, the maximum allowable angle that the horizontal link, which forms the small sides of the parallelogram in each leg, can move before colliding with the body of the ball joint, must be found. Secondly, eliminating the points that violates this restriction.

A. Ball Joint Maximum Allowable Angle

Both the link and the ball joint were drawn with their precious dimensions for a PHS 8 and a link of 8 mm diameter using SOLIDWORKS 2016, then assembled together to observe the movement, finally their motion was restricted to the XZ plane, and the maximum angle between the axis of the link and the XY plane was measured and found to be 28^0 as shown in the Figure 2

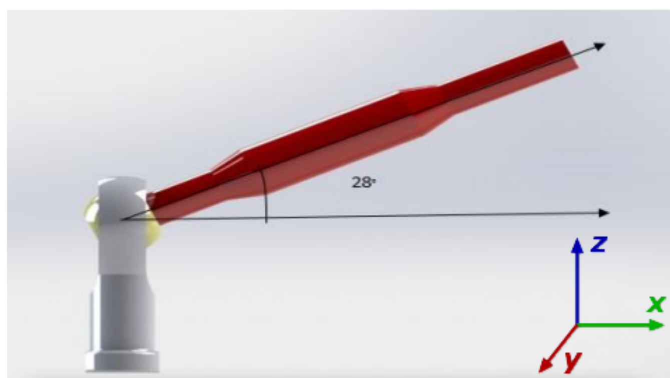

Fig. 2. Maximum Allowable angle before collision occurs.

B. Passive Joints Motion Constraints

The key to find the effective workspace is to test all the obtained set of points from the ideal workspace, then eliminate those, which should be avoided during path planning. The equation which dominates this process is as follows [3],[4].

$$\theta_{3i} = cos^{-1}\left(\frac{xcos(\phi_i) - ysin(\phi_i)}{L_2}\right) \tag{1}$$

where
$[x, y]$: are the position of the end effector.
L_2: the length of the forearm.
ϕ_i: instillation angle [0 , 2pi/3 ,-2pi/3].
θ_{3i} is the complementary angle of that measured above, hence

the equation which governs the developing of the effective workspace is as follows

$$62 \leq \theta_{2i} \leq 118 \tag{2}$$

Testing all the generated sets of points from solving the forward kinematics problem with this equation, results in the three-dimensional volume shown in Figure 3, which is approximately the same as the ideal except for that its corners are clipped.

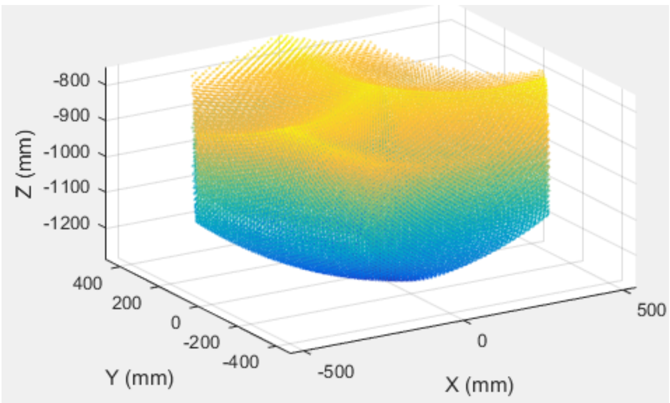

Fig. 3. Effective workspace.

III. Mounting Height

In pick and place applications, the mounting height of the parallel manipulator is a key parameter as it decides the proportion of the workspace that would be used during the operation, because the arm is meant to cover the area of the conveyor belt or the table underneath it, hence depending on the height of the picked object and other parameters the mounting height is calculated.

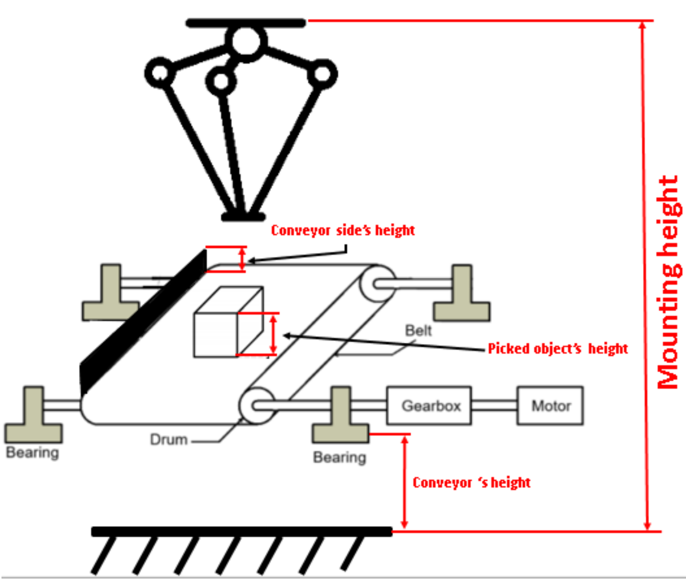

Fig. 4. Parameters affecting the mounting height of delta robot.

It can be easily seen that the work space gets narrower as the robot descends, therefore optimizing the slice of the workspace to provide maximum volume of reach is a necessity. The thickness of this slice is essential factor as it must ensure that the robot does its main functions correctly from picking, transporting over the conveyor's side, if exists, to placing the object at its destination,hence its thickness can be calculated as follows

$$Thickness = (h_{object})_{max} - (h_{object})_{min} + h_{conveyorside} \tag{3}$$

Investigating the workspace's slice of the given thickness, which has the largest volume or the maximum number of point in other words, results in the shape shown in Figure 4, which should be utilized for path planning problem, neglecting the rest volumes of the workspace.

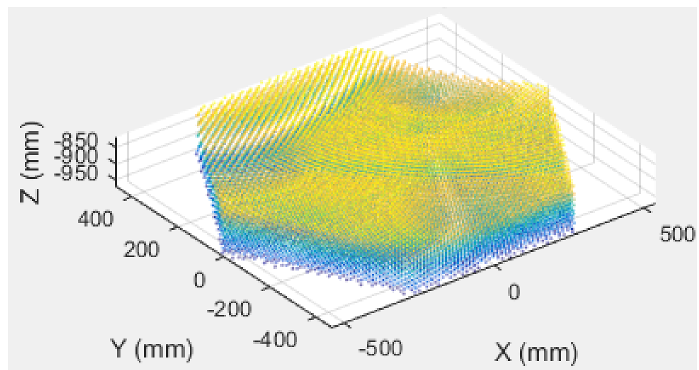

Fig. 5. The used proportion of the workspace during operation.

As for the mounting height, it can be calculated by extracting the least z index of that worksapce, which indicates how low the end effector can reach, then substituting it in the following equation, the mounting height can be calculated preciously.

$$h_{mounting} = |z_{min}| + (h_{object})_{min} + h_{conveyor} \tag{4}$$

IV. Conclusion

This study has proposed an approach to define the optimal proportion of the workspace, which gives the robot the largest reach to complete its functions, and an approach to calculate the height on which the robot should be hanged further investigation should be dedicated to the structure that hold the robot in both structural analysis and vibration in order to ensure system mechanical stability.

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