Kinematic Design And Analysis Of Six Degrees Of Freedom Manipulator

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Abstract:

Mechanical technology has been a moving subject for educators to instruct and for understudies to learn. One of the significant viewpoints that make it troublesome is the restricted capacity to see and imagine the ideas suitably at the hour of educating. The majority of the modern robots are depicted geo-metrically by their Denavit-Hartenberg (DH) parameters, which are additionally hard to see for understudies. Understudies will locate the subject simpler to learn in the event that they can imagine in 3 measurements. Apparatuses that guide its learning have been created by colleges over the world as alluded somewhere else. This paper proposes RoboAnalyzer, a 3D model based programming that can be utilized to instruct mechanical autonomy subjects to undergrad and postgraduate courses in building schools in India and somewhere else. In the present implementation, it tends to be utilized to learn DH parameters, forward kinematics of sequential robots with revolute joints and permits 3D movement and diagram plots as yield.

Keywords: Kinematic Design, six degree of freedom, Robots, 3D model based programming.

1. Introduction

Mechanical technology is a field identified with the structure, improvement, control and use of robots in industry, training, inquires about, stimulation, restorative applications and so on. It has been advancing at a quicker rate and subsequently it discovers its place in the educational plan of the colleges and is in extraordinary interest.

Apply autonomy course for mechanical building streams generally incorporates the hypothesis of the plan and working of a robot as drawings, pictures of robots and reasonable robots in real life. In spite of the fact that the initial two are simpler to accomplish by numerous colleges, the last can be accomplished by a not many which approach indus-preliminary robots. Without seeing a genuine robot it is hard to fathom its movement in three-dimensional Cartesian space. Consequently, there exists an extraordinary interest for instructing helps that help understudies to imagine a robots development as 3D movements.

2.Kinematics and Jacobian Matrix Modelling

In this area, the forward and opposite kinematics models of the 6R decoupled controller are worked by D-H technique and diagnostic strategy [Chapelle, 2004, González-Palacios, 2013]. At that point the Jacobian grid is inferred by differential change technique. The D-H arrange frameworks of the 6R decoupled controller are appeared in Figure 1 and the relating D-H parameters are appeared in Table 1. The controller's last three back to back joint tomahawks cross at a typical point — fulfilling the Pieper criterion.itude edges of the controller end-effector in X-Y-Z fixed edges organize framework are as following, where are alluded to as move, pitch, yaw edges, separately.2. Kinematics and Jacobian Matrix Modeling In this area, the forward and opposite kinematics models of the 6R decoupled controller are worked by D-H technique and diagnostic strategy [Chapelle, 2004, González-Palacios, 2013]. At that point the Jacobian grid is inferred by differential change technique.

$x=l_1\cos\theta_1+l_2\cos(\theta_1+\theta_2)+l_3\cos(\theta_1+\theta_2+\theta_3)$ ...(1)

$y=l_1\sin\theta_1+l_2\sin(\theta_1+\theta_2)+l_3\sin(\theta_1+\theta_2+\theta_3)$ ...(2)

$\phi=(\theta_1+\theta_2+\theta_3) P_2 = a_3 . S_{23} - a_2 . S_2$ ...(3)

Thus, from eqs.(35) and (36) we find:

$a_3 . C_{23} = P_1 - a_2 . C_2$ ...(4)

$a_3 . S_{23} = P_2 - a_2 . S_2$ ...(5)

Hence from Eqs(37) and (38) we have:

${}^2A_3 = (P_1 - a_2 . c_2) + (P_2 - a_2 . S_2)$ ...(6)

Which yield the following:

$a_3 . C_{23} = P_1 - a_2 . C_2$ ...(7)

$a_3 . S_{23} = P_2 - a_2 . S_2$ ...(8)

Then it clearly follows that:

2.1Forward Kinematics

The D-H arrange frameworks of the 6R decoupled controller are appeared in Figure 1 and the relating D-H parameters are appeared in Table 1. The controller's last three back to back joint

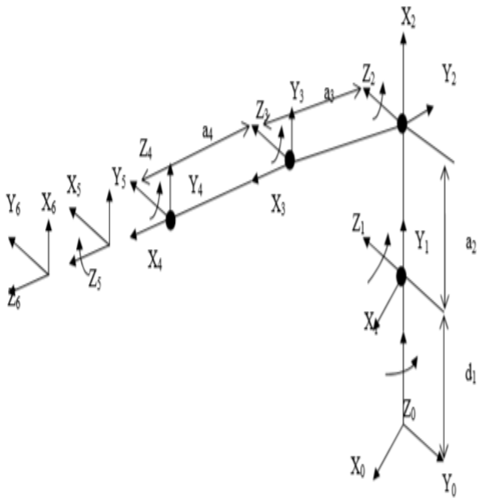


Fig-2: Link frame assignment for MA-2000 Robot with first version of gripper.

Joint	θ_i	α_i	a_i	d_i
1	θ_1	90	0	d_1
2	θ_2	0	a_2	0
3	θ_3	0	a_3	0
4	θ_4	90	a_4	0
5	θ_5	90	0	0
6	θ_6	0	0	d_6

Table-1 : joint parameter for 6-DOF robot with first version

$${}^0T_1 = \begin{bmatrix} C_1 & 0 & S_1 & 0 \\ S_1 & 0 & -C_1 & 0 \\ 0 & 1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$
....(8)

$$ {}^{1}T_2 = \begin{bmatrix} C_2 & -S_2 & 0 & a_2C_2 \\ S_2 & C_2 & 0 & a_2S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad ....(9) $$

$$ {}^{2}T_3 = \begin{bmatrix} C_3 & -S_3 & 0 & a_3C_3 \\ S_3 & C_3 & 0 & a_3S_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad ....(10) $$

$$ {}^{3}T_4 = \begin{bmatrix} C_4 & 0 & S_4 & a_4C_4 \\ S_4 & 0 & -C_4 & a_4S_4 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad ...(11) $$

$$ {}^{4}T_5 = \begin{bmatrix} C_5 & 0 & S_5 & 0 \\ S_5 & 0 & -C_5 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad ...(12) $$

$$ {}^{5}T_6 = \begin{bmatrix} C_6 & -S_6 & 0 & 0 \\ S_6 & C_6 & 0 & 0 \\ 0 & 0 & 1 & d_6 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

tomahawks cross at a typical.

Increasing the networks T1 through T6 and setting the outcome equivalent 0. T yields the accompanying twelve conditions for the assurance to 6 the vector of the joint point

$$ n_x = s_{1.}(c_4s_6 + s_4c_5c_{6.}) - c_{1.}[c_6s_{23}s_5 + c_{23.}(s_4s_6 - c_4c_5c_{6.})]; ...(14) $$

$$ n_Y = s_{1.}(c_4c_6 - s_4c_5s_{6.}) + c_1[s_{23}s_5s_6 - c_{23}(s_4c_6 + c_4c_5s_{6.})]; \quad ...(15) $$

$$ n_Z = -s_1s_4s_{5.} - c_{1.}(s_{23}c_5 + c_{23}c_4s_{5..}); ...(16) $$

$$ o_x = s_{1.}[c_{23}(c_4c_5c_6 - s_4s_{6..}) - s_{23}s_5c_6] - c_{1.}(c_4s_6 + s_4c_5c_{6.}); \quad (17 $$

$$ o_y = s_{1.}[c_{2.}(c_4c_5c_6 - s_4s_6) - s_{23.}s_5c_6] - c_{1.}(c_4s_6 + s_4c_5c_6); \quad ...(18) $$

$$ o_Z = s_1(s_{23.}c_5 + c_{23.}c_4s_5) + c_1s_4s_5; ...(19) $$

$$ a_x = s_{23.}(s_4s_6 - c_4c_5c_6) - c_{23}s_5c_6; \quad ...(20) $$

$$ a_Y = s_{23.}(s_4c_6 + c_4c_5s_6) + c_{23}s_5s_6; \quad ...(21) $$

$$ a_Z = s_{23.}c_4s_5 - c_{23}c_5 \cdot ...(22) $$

$$ p_x = C_1.(d_6.S_5.C_{234} - a_4.C_{234} - a_2.C_2 - a_3.C_{23}) - S_1.C_5\,d_6 ...(23) $$

$$ p_y = S_1.(d_6.S_5.C_{234} - a_4.C_{234} - a_2.C_2 - a_3.C_{23}) + S_1C_5\,d_6 \quad ..(24) $$

$$ p_Z = d_1. + d_6.S_{234}.S_5 - a_3.S_{23} - a_2.S_2 - a_4..S_{234}..(25) $$

3. Inverse Kinematics

Duplicating Eq.(24) by C1 and Eq.(23) by S1 and substituting the subsequent conditions, as coming up next is gotten

$C_{1.}{}^{O}P_{Y.}S_{1.}{}^{0}P_{X}=d_{6.}C_{5}$ …(26)

Duplicating Eq.(24) by S1 and Eq.(23) by C1 and substituting the subsequent conditions, as coming up next is gotten

$C_5=C_{1.}a_y-S_1a_x$ ...(27)

From Eqs.(26 and 27) ,we can only obtain

$C_{1.}{}^{O}P_{Y.}S_{1.}{}^{0}P_{X}=d_{6.}C_{1}a_{y}-da_{6.}S_{1}$ ... (28)

Hence

$\theta_1=a\tan 2.(p_y-d_{6..}a_y),(p_x-d_6a_x)$ ...(29)

From eq(27), hence,

$S_5=+\sqrt{1-C_5 2}$...(30)

$\theta_5=a.\tan2(S_5,C_5)$ ...(31)

Now a Eq.(20) by C1 and Eq.(21) by S1 Duplicating and adding the resulting equations yields:

$S_{5.}C_{234}=-(a_{x.}C_1+a_{y.}S_1)$...(32)From Eq.(22) and Eq.(32) find

$\theta_{234}=a\tan2.(-a_z,(a_{x.}C_1+a_{y.}S_1))$

for $\theta_5>0$...(33)

And

$\theta_{234}=\theta_{234.}+\pi$ for θ_5 <0 ...(34)

Duplicating Eq.(23) by C1 and Eq.(24) by S1 and adding result equations results:

$P_1=C_1p_{x6}+S_1p_{y6}+d_{6.}S_{5.}C_{234}-a_{4.}C_{234}$

Where,

$P_1=a_{2.}C_2+a_3C_{23}$ $P_1=a_{2.}C_2+a_{3.}C_{23}$ ...(35)

Rearranging theeq .(25) yields: P2 $=-p_{z6}-d_1+d_{6.}S_{5.}S_{234}-a_{4.}S_{234}$

Where,

$P_2=a_3{}_{.}S_{23}-a_2{}_{.}S_2$ ...(36)

Thus, from eqs.(35) and (36) we find:

$a_{3.}C_{23}=P_1-a_{2.}C_2$ ...(37)

$a_{3.}S_{23}=P_2-a_{2.}S_2$ ...(38)

Hence from Eqs(37) and (38) we have:

${}^{2}A_3=(P_1-a_{2.}c_2)+(P_2-a_{2.}S_2)$ ...(39)

Which yield the following:

$P_{1.}C_2+P_2S_2=P^2+P^2+a^2-a^2{}_{1.}C_2$ ....(40)

Then it clearly follows that:

$\Theta_2=a\tan2(P_2,P_1)+a\tan2(P_1{}^2+P_2{}^2-N,N)$ ...(41)

Consequently that from (37) and (38):

$\theta_{23}=a\tan2(P_2-a_2S_2,P_1-a_{2.}C_2)$ ....(42)

$\theta_3 = \theta_{23} - \theta_2$ ....(43)

And finally

$\theta_4 = \theta_{234} - \theta_{23}$ ....(44)

Duplicating the Eq.(15) by C1 and Eq.(14) by S1 and adding it result yields:

$S_{5.}C_6 = n_y C_1 - n_{x.} S_1$ ...(45)Duplicating the Eq.(17) by S1 and Eq.(18) by S1 and adding it result yields:

$S_5 S_6 = (o_x S_1 - o_y C_1)$ ...(46)

$\theta_6 = a \tan 2((o_x S_1 - o_y C_1), (n_y C_1 - n_x S_1))$... (47)

$\theta_6 = \theta_6 + \pi$ ... (48)

$\theta_1 = a \tan 2.(p_y - d_6 a_y),(p_x - d_6 a_x)$ ... (49) $\theta = a \tan 2.(P , P) + a \tan 2(\sqrt{a \tan 2(P, P)\ a \tan 2}$,N ... (50)

$\theta_{23} = a\tan 2.(P_2 - a_{2.} S_2, P_1 - a_{2..} C_2)$ ...(51)

$\theta_3 = \theta_{2..3} - .\theta$ ...(52)

$\theta_4 = k - .\theta_{23}$ ... (53) $\theta_5 = 0$ ... (54)

From Eqs.(16) and (19) and further yield:

$C_6 = n_{z.} S_{234} C_5 - o_{z.} C_{234}$ ... (55)

$S_6 = o_{z.} S_{234.} C_5 - n_{z.} C_{234}$ ...(56)

$\theta_6 = a.\tan 2(S_6, C_6)$ ... (57)

$s_1 = \sin\theta_1$, $s_{12} = \sin(\theta_1 + \theta_2)$, $s_{123} = \sin(\theta_1 + \theta_2 + \theta_3)$

$c_1 = \cos\theta_1$, $c_{12} = \cos(\theta_1 + \theta_2)$, $c_{123} = \cos(\theta_1 + \theta_2 + \theta_3)$

Velocity Analysis

When controlling a robot to move between various positions, it isn't just enough to choose the joint and end effector bearings of the goal position. It may be essential to constantly control the course or the path taken by the robot as it pushes toward the goal position. This is fundamental to avoid impediments in the workspace. Even more altogether, there are assignments where the bearing of the end effector is fundamental. For example, when welding, it is essential to keep up the mechanical assembly at a perfect bearing and a fixed decent ways from the work piece while moving uniformly5 along a perfect way. In this way one needs to control the speed of the end effector or the device during the development. Since the control action occurs at the joints, it is only possible to control the joint rates. Consequently, there is an ought to have the alternative to take the perfect end effector speeds and figure from them the joint velocities. This requires an inexorably point by point kinematic assessment, one that tends to speeds or the pace of progress of bearings instead of the past zone where we just looked or encourages

x

$\dot{x} = -l_1 \dot{\theta}_1 s_1 - l_2(\dot{\theta}_1 + \dot{\theta}_2) s_{12} \ldots - l_n(\dot{\theta}_1 + \ldots + \dot{\theta}_n) s_{123\ldots n}$

$$\dot{y} = -l_1\dot{\theta}_1 c_1 - l_2(\dot{\theta}_1+\dot{\theta}_2)c_{12} \ldots\ldots - l_n (\dot{\theta}_1 + \ldots\ldots + \dot{\theta}_n)c_{123\ldots n}$$

$$\dot{\phi} = \dot{\theta}_1 + \dot{\theta}_2 + \dot{\theta}_3 + \ldots\ldots\ldots \theta_n$$

Where we have used the short hand notation:

$s_1=\sin\theta_1$, $s_{12}=\sin(\theta_1+\theta_2)$, $s_{123}=\sin(\theta_1+\theta_2+\theta_3)$

$c_1=\cos\theta_1$, $c_{12}=\cos(\theta_1+\theta_2)$, $c_{123}=\cos(\theta_1+\theta_2+\theta_3)$

This one denotes the joint speed for the ith joint or time derivative of ith joint angles and $\dot{x}$ $\dot{y}$ ↦ $\dot{\phi}$

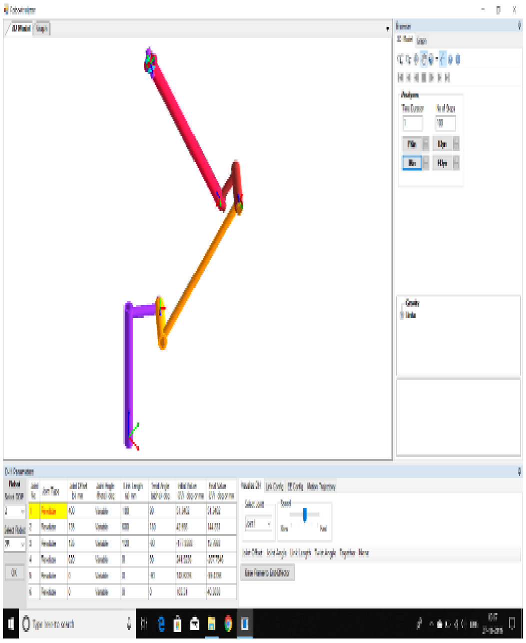


Figure 1:Sixrevolute arm

Figure 2: The joint variables and link lengths

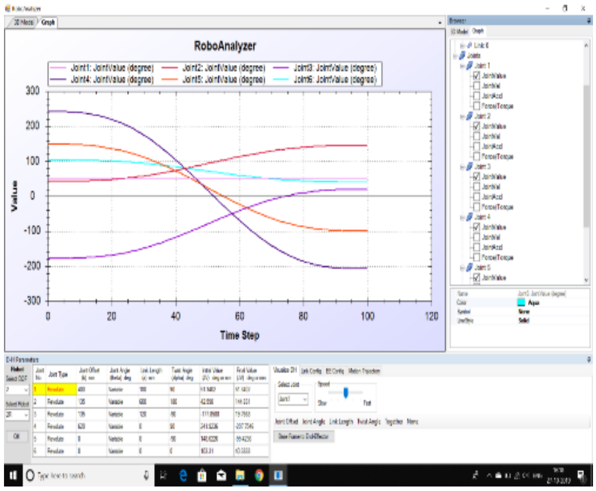


Figure 3: Inverse kinematics graph of 6 revolute robotic arm

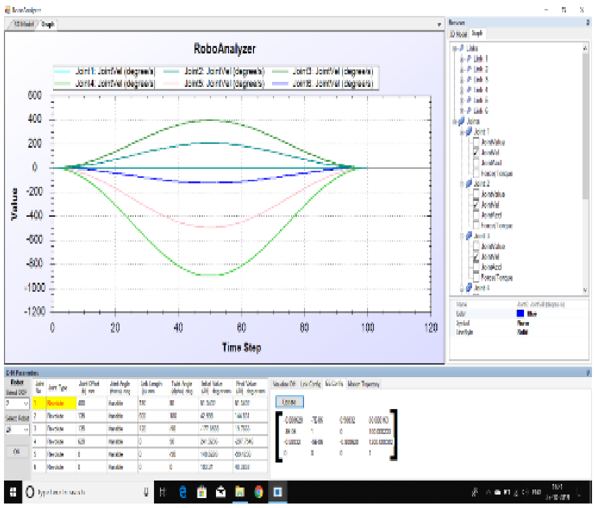
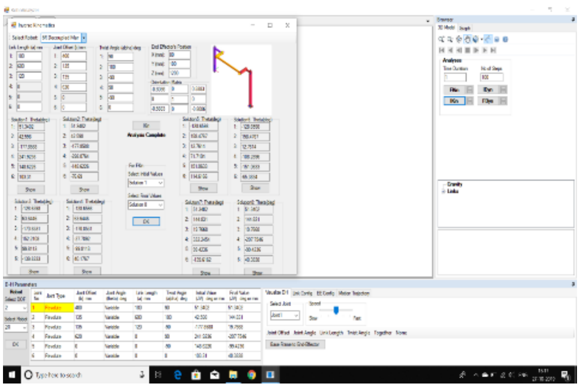


Figure 4: Velocity graph of 6 revolute robotic arm

Conclusions

This present work oversees Kinematic structure and speed examination of 6 revolute mechanical consecutive controller for given association lengths l1, l2, l3, l4, l5, l6 by considering the particular point P1 (x,y) .In the workspace the joint evacuations for position are dictated by using these joint movements the jacobian is resolved which would be the essential idea for calculating the speed

A 3D-model based programming to learn mechanical self-sufficiency thoughts is presented in this paper. It is made using Visual C# and OpenGL that takes the portrayal of a consecutive robot with revolute joints using DH parameters as data. An understudy using this item can learn DH parameters and forward kinematics through "Model to Concept" approach, likewise bypassing the showing of robot which is required in the business programming. FKin examination can be performed among starting and last estimations of joint elements and the amusement data can be used to vivify all of the associations of the robots all the while. Accommodating outline plots of end-effector position can in like manner be drawn inside the item and moreover be conveyed to a spreadsheet for further getting ready if important. The present interpretation is made available through a site (http://www.roboanalyzer.com) and used by around 30 understudies in mechanical innovation courses. In perspective on the contributions of the customers, as point by point in Section 2.5, improve-ment of the present features and extension of new modules are in progress and will be represented in future



Future Scope

- The machine will be of extraordinary use to perform repetativetasks of pick and putting of little articles in present day creation line
- Its usage can be expanded and abused by hardly any changes in accordance with do difficuilt and hazardous endeavours for current applications
- It might be used to do little social affair work capably in light of its extra viability for course of action of parts
- Because of high potential resoluteness, high precision and high stacking cutoff points of parallel controllers, reach and structure of various consecutive controllers in building thes are played out even more successfully in endeavours
- A certifiable proto sort with PC controlled UI is to be made. The dynamic examination of the segment is a critical endeavour in future
- RoboAnalyzer will be furthermore made to improve the present features and incorporate new features, for instance,
- Kaleidoscopic joints, Inverse kinematics, Inverse components, Forward components, Trajectory orchestrating, Analysis of shut circle and tree–type structures Import 3D CAD model into the item

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