

Modeling and Analysis of Puma Robot Using Mat Lab

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Abstract— The PUMA Programmable Universal Machine for Assembly, more popularly known as PUMA is an industrial robot arm. The main objective of this paper is determination of end effectors position for the modified Robot which is same as PUMA robot with different link twist angles using MATLAB. A Mat lab program is developed for different link angles with the help of robot tool kit developed by petercorke. Trajectory of the modified robot is also done using Mat lab. Forward kinematics values are compared with the mat lab values. Modeling of PUMA robot is also done using PRO-E soft ware.

Index Terms—D-H notations, PUMA Robot, MAT LAB, Pro-E, Trajectory planning.

I. INTRODUCTION

A. *Matlab* is powerful and widely used commercial software used statistic analysis and graphical presentation available for a large number of platforms. Specific toolboxes (i.e., collection of dedicated MATLAB functions) have been developed in the past few years for support in research and education, in almost every branch of engineering, such as, e.g., telecommunications, electronics, aerospace, mechanics and control. As far as robotics is concerned, several toolboxes have been presented in the last decade. In this paper computation of MODIFIED PUMA robot along with trajectory planning of MP is represented using the basis of PUMA program used in petercorke robotics toolkit ,focus on modified Denavit and Hartenberg –Transformations and graphical representation of trajectory path of MP.

B. *Matlab analysis of modified puma*: In this paper joint angle, linklength are modified and trajectory planning, was computed using mat lab [3] and justified mathematically with the modeling of Pro-E design.

C. *Forward kinematics*: Forward kinematics is the problem of locating the position and orientation of the end link, given the joint angles. The forward kinematics [4] problem is concerned with the relationship between the individual joints of the robot manipulator and the position and orientation of the tool or end-effector. Stated more formally, the forward kinematics problem is to determine the position and orientation of the end-effector, given the values for the joint variables of the robot. The joint variables are the angles between the links in the case of revolute or rotational joints, and the link extension in the case of prismatic or sliding joint

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Fig 1.Modified PUMA Robot(Pro-E model)

There are two fundamental questions of both theoretical and practical interest in robot arm kinematics:

1. For a given manipulator, given the joint angle vector $q(t) = [q_1(t), q_2(t), \dots, q_n(t)]^T$ and the geometric link parameters, where n is the number of degrees of freedom, what is the position and orientation of the end-effector of the manipulator with respect to a reference coordinate system?
2. Given a desired position and orientation of the endeffector of the manipulator and the geometric link parameters with respect to a reference coordinate system, can the manipulator reach the desired prescribed manipulator hand position and orientation? [2] And if it can, how many different manipulator configurations will satisfy the same condition? The first question is usually referred to as the direct (or forward) kinematics problem, while the second question is the inverse kinematics (or arm solution) problem [10]. Since the independent variables in a robot arm are the joint variables and a task is usually stated in terms of the reference coordinate frame, the inverse kinematics problem is used more frequently

PRO-E: Pro/Engineer is a software design tool for engineers. [11] More specifically, Pro/ENGINEER is a 3D feature-based parametric solid modeler. It enables you to create true 3D solid models of your designs. (There are other similar products on the market that offer similar modeling capabilities. Basic modeling concepts learnt in *Pro/ENGINEER* will apply to other 3D feature-based parametric solid modelers.) Pro/ENGINEER is a core program that can work with many specialist add-on modules and external programs. Pro/ENGINEER enables you to work with:

- Feature based modeling.
- Parametric relationships.
- Associativity

In this investigation we use PUMA Robot which will designed in Pro/E feature based modeling.

II. THEORETICAL MODELLING

2.2 Theoretical Calculations

D-H coordination system:

Denavit and Harienberg put forwards to a matrix method to build the attached coordinate system for each link in the joint chains of the Robot for describing the relationship of translation or rotation between the contiguous links in 1955 Denavit and Harienberg [1]. For the rotation joint, only the joint angle is the joint variable while the others are constant. For the translation one, only the offset is the variable while others are constant. The Endeffector of the manipulator is required to move in a particular fashion to accomplish a specified task[6]. Denavit and Hartenberg notations are used to represent the transformations from link1 to link6[7]

The D-H matrix is ${}^{i-1}L_i$ is given by

$$\begin{bmatrix} \cos \theta_i & -\sin \theta_i \cos \alpha_i & \sin \theta_i \sin \alpha_i & a_i \cos \theta_i \\ \sin \theta_i & \cos \theta_i \cos \alpha_i & -\cos \theta_i \sin \alpha_i & a_i \sin \theta_i \\ 0 & \sin \alpha_i & \cos \alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

For Link 1:

$$\theta_1 = 90; d_1 = 0.67; a_1 = 0; \alpha = 90$$

$$= \begin{bmatrix} \cos 90 & -\sin 90 \cos 90 & \sin 90 \sin 90 & 0 \cos 90 \\ \sin 90 & \cos 90 \cos 90 & -\cos 90 \sin 90 & 90 \sin 90 \\ 0 & \sin 90 & \cos 90 & 0.67 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0.67 \\ 0 & 0 & 0 & 1 \end{bmatrix} \rightarrow {}^0T_1$$

For link 2:

$$\theta_2 = -90; d_2 = 0; a_2 = 0.4318; \alpha_2 = 0$$

L(2)=

$$\begin{bmatrix} \cos(-90) & -\sin(-90)\cos 0 & \sin(-90)\sin 0 & 0.4318\cos(-90) \\ \sin(-90) & \cos(-90)\cos 0 & -\cos 90\sin 0 & 0.4318\sin(-90) \\ 0 & \sin 0 & \cos 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 0 & 1 & 0 \\ -1 & 0 & 0 & -0.4318 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \rightarrow {}^1T_2$$

For link 3:

$$\theta_3 = -90; d_3 = 0.15005; a_3 = 0.4318; \alpha_3 = -90$$

L(3)=

$$\begin{bmatrix} \cos(-90) & -\sin(-90)\cos(-90) & \sin(-90)\sin(-90) & 0.4318\cos(-90) \\ \sin(-90) & \cos(-90)\cos(-90) & -\cos 90\sin(-90) & 0.4318\sin(-90) \\ 0 & \sin(-90) & \cos(-90) & 0.15005 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & -0.04318 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \rightarrow {}^2T_3$$

For link 4:

$$\theta_4 = 0; d_4 = 0; a_4 = 0; \alpha_4 = 90$$

L(4)=

$$\begin{bmatrix} \cos(0) & -\sin(0)\cos(90) & \sin(0)\sin(90) & 0\cos(90) \\ \sin(0) & \cos(0)\cos(90) & -\cos 0\sin(90) & 0\sin(90) \\ 0 & \sin(90) & \cos(90) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \rightarrow {}^3T_4$$

For link 5:

$$\theta_5 = 0; d_5 = 0; a_5 = 0; \alpha_5 = -90$$

L(5)=

$$\begin{bmatrix} \cos(0) & -\sin(0)\cos(-90) & \sin(0)\sin(-90) & 0\cos(-90) \\ \sin(0) & \cos(0)\cos(-90) & -\cos 0\sin(-90) & 0\sin(-90) \\ 0 & \sin(-90) & \cos(-90) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \rightarrow {}^4T_5$$

For link 6:

$$\theta_6 = 0; d_6 = 0; a_6 = 0; \alpha_6 = 0$$

Now, substituting all these matrices into the equation:

$${}^0T_1 \times {}^1T_2 \times {}^2T_3 \times {}^3T_4 \times {}^4T_5 \times {}^5T_6$$

$$\begin{bmatrix} 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0.67 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & -0.4318 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & -0.4318 \\ 0 & -1 & 0 & 0.15005 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times$$

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0.8636 \\ 0 & 1 & 0 & -0.1500 \\ 0 & 0 & 1 & 0.6700 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The solution is obtained from mat lab is as following which is equal to the theoretical solution

>> fkine(mp,x)

$$\begin{bmatrix} 1 & 0 & 0 & 0.8636 \\ 0 & 1 & 0 & -0.1500 \\ 0 & 0 & 1 & 0.6700 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$d=0.6700$

Link _i	θ _i	d _i	a _i	α _i
L(1)	90	0.67	0	90
L(2)	-90	0	0.4318	0
L(3)	-90	0.15005	0.4318	-90
L(4)	0	0	0	90
L(5)	0	0	0	-90
L(6)	0	0	0	0

Table 1. D-H parameters for PUMA Robot

3. Trajectory planning simulation

The execution of specific task requires the manipulator to move in preplanned path, goal of trajectory is to describe the requisite motion of the manipulator as a time sequence of locations which are generated by interpolating or approximating the desired path. the joint space planning, the Cartesian space planning, the kinematics and inverse kinematics [2], the simulation of trajectory planning is executed for six-DOF Robot by using the MATLAB software on the computer, which supply the basic trajectory datum for the subsequent motion simulation analysis. [5]Several positions of manipulator derived from this simulation are represented on Fig 2.

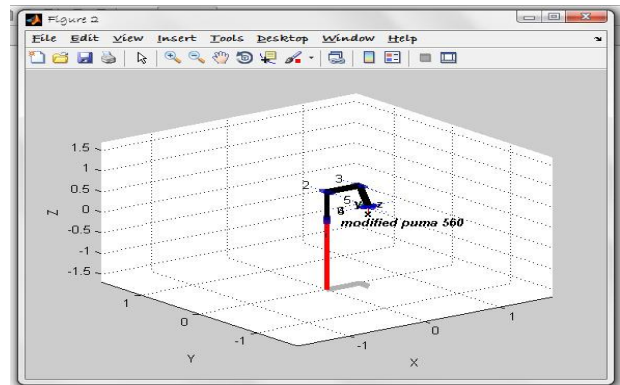


Fig 2(a&b). Simulation of joint space trajectory

III. RESULTS AND CONCLUSIONS

Analysis of PUMA Robot in MATLAB gives 75% of the results in an optimized way; the theoretical computations are approximated in Mat lab[8&9]]. By changing the link parameters in transformations link length and angle is better results are computed in Mat lab it also includes graphical representation of link joints path with respect to time. The actual parameters of puma robots link and joint parameters were theoretically verified with the actual values .Then the link and joint parameters were modified and simulated in the MAT LAB[3] and further they are theoretically verified.

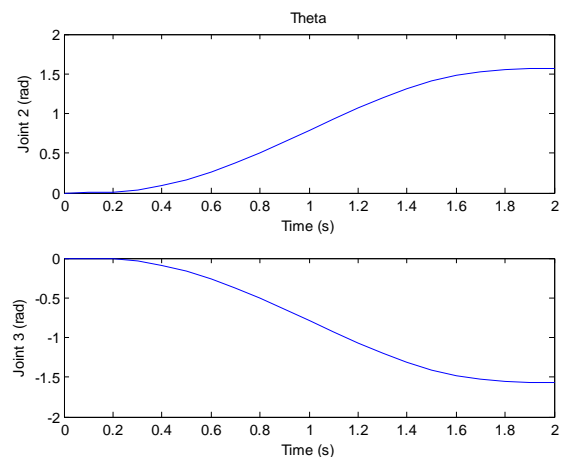


Fig 3. Joint angles θ2 and θ3 against time

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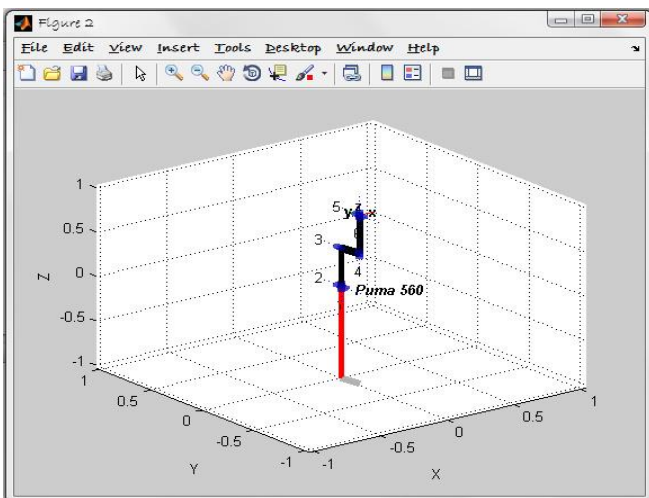


Fig 2(a)