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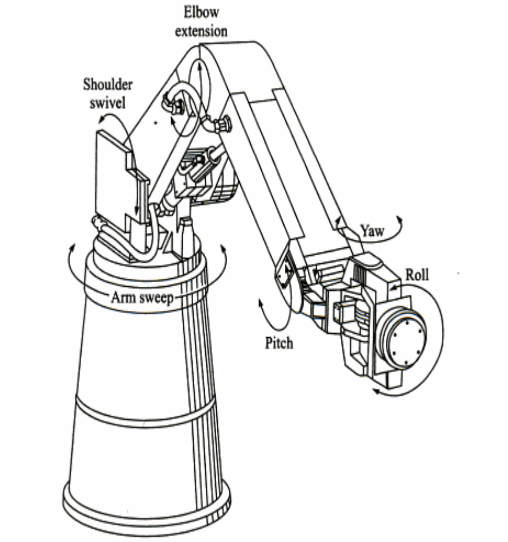
# Kinematic Analysis and Simulation of 6 D.O.F. Of Robot for Industrial Applications

Annamareddy Srikanth[1] Y.Ravithej[2] V.Sivaraviteja[3] V.Sreechand[4]
*IV/IV B.Tech Students, Mechanical Department,*
*K.L.University, Vaddeswaram.*
*Corresponding Author:srikanth.annamareddy@gmail.com*

***ABSTRACT:*** The paper addresses the Kinematic analysis and simulation of 6 D.O.F. of robot for industrial applications. An alternative design of a six-degrees-of-freedom manipulator based on the concept of an in-parallel actuated mechanism is presented. The basic kinematic equations for use of the manipulator are derived and the influences of the physical constraints on the range of motion in the practical design are discussed. We use robo analyzer software for determining the simulation results. Several possible applications which include the in-parallel mechanism as part of the manipulation system are suggested, and we determine D.H.Parameters for design.

## I. INTRODUCTION:

Even though the idea of robots goes back to ancient times of over 3000 years ago in India's Legend of mechanical elephants the first use of the word robot appeared in 1921 in the play Rossum's University robots written by the Czeck writer karel Capek (1890-1938)..A robot s formally defined in the International Standard Of Organization (ISO) as a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable Programmed motions for the performance of a variety of tasks.




## II. MOTION SUB SYSTEM

**Manipulator:** It is the physical structure which moves around. It comprises of links and joints normally connected in series. Each link is made of steel or aluminum. Other materials can also be used depending on the requirements. The joints are generally rotary or translator types. In the study of the robotics and mechanisms these joints are referred as revolute and prismatic joints. A robot manipulator has three parts mainly arm, wrist and the hand. The function of the arm is to place an object in a certain location in the three dimensional Cartesian space, where the wrsit orients it. For 6 DOF robots the first three links and joints form the arm and the last three mutually in intersecting joints made a wrist.

**End effectors:** This is a part attached at the end of the manipulator and so it is named. This is equivalent to the human hand. An end effector could be mechanical hand that manipulates an object or holds it before they are moved by the robot arm. Also specialized tools like the welding electrode, a gas cutting torch attached to the end of the manipulator arm for performing tasks are also considered as end-effectors.

**Actuator:** They actually provide motion to the manipulator and the end effector. They are classified s pneumatic, hydraulic or electric based on the principle of operation. However a pneumatic or a hydraulic system which with or without transmission elements, provides motions to the robot links it is called an actuator not a motor

## III. JACOBIAN MATRIX DERIVATION

It is derived here from the definition of the DeNOC matrices. Note the end effector of the robot manipulator is nothing but a part of the nth body with its position difference from its origin on. It is located at a point denoted by **a**ne from O.

$$\mathbf{t}_e = \mathbf{A}_{en}\,\mathbf{t}_n$$

Where the 6*6 matrix Aen id given by

$$\mathbf{A}_{en} \equiv \begin{bmatrix} \mathbf{1} & \mathbf{O} \\ \mathbf{a}_{en}\times\mathbf{1} & \mathbf{1} \end{bmatrix} = \begin{bmatrix} \mathbf{1} & \mathbf{O} \\ -\mathbf{a}_{n}\times\mathbf{1} & \mathbf{1} \end{bmatrix}$$

Vector is defined as similar to the vector $\mathbf{a}_{i+1,i} \equiv -\mathbf{a}_{i,i+1}$ substituting the expression of tn from the generalized twist expression can be re-written as

$$\mathbf{t}_e = \mathbf{A}_{en}\,\mathbf{N}_{ln}\,\mathbf{N}_d\dot{\boldsymbol{\theta}}$$

Where the 6*6n matrix is as follows:

$$\mathbf{N}_{ln} \equiv [\mathbf{A}_{n1}\ \mathbf{A}_{n2}\ \cdots\ \mathbf{A}_{n,n-1}\ \mathbf{1}]$$

Substituting the expression of Nin we obtained

$$\mathbf{t}_e = \mathbf{A}_{en}\,[\mathbf{A}_{n1}\mathbf{p}_1, \mathbf{A}_{n2}\mathbf{p}_2, \ldots, \mathbf{A}_{n,n-1}\mathbf{p}_n, \mathbf{p}_n]\dot{\boldsymbol{\theta}}$$

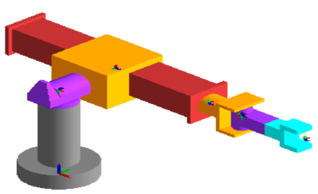
Using the twist propagation matrix property the equation can be written in the form

$$\mathbf{J} = [\mathbf{A}_{e1}\mathbf{p}_1, \mathbf{A}_{e2}\mathbf{p}_2, \ldots, \mathbf{A}_{en}\mathbf{p}_n, \mathbf{p}_n]$$

J is the jacobian matrix. Depending up on the requirement any of the expressions for the jacobian matrix may be used to the user's advantage for example to achieve efficiency to get the better physical interpretations etc.

**DENAVIT AND HARTENBERG (DH) PARAMETERS:** The Denavit-Hartenberg parameters (also called DH parameters) are the four parameters associated with a particular convention for attaching reference frames to the links of a spatial kinematic_chain, or robot_manipulator
Joint offset (b): length of intersections of common normal on joint axis
Joint angle (θ): angle between the orthogonal projections of te common normal to the plane normal to the joint axes.
Link length (a): measured as the distance between the common normals to the axis.
Twist angle (α): the angle between the orthogonal projections of the joint axes onto a plane normal to the common normal.
So for the given type of joint i.e. revolute or prismatic one of the DH parameters is variable which is called the joint variable, whereas the other three remaining parameters are constant and are called link parameters

**PATH BY USING ROBO ANALYZER**



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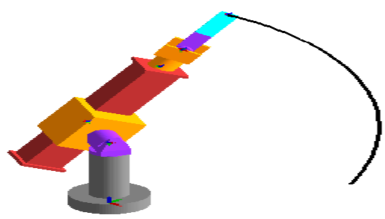
**FORWARD KINEMATICS**



**LINK MATRIX FOR ALL 6 LINKS:**

**LINK 1**

$$\begin{bmatrix} 0.500006 & 0 & -0.866022 & 0 \\ 0.866022 & 0 & 0.500006 & 0 \\ 0 & -1 & 0 & 762 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

**LINK 2**

$$\begin{bmatrix} -0.866022 & 0 & 0.500006 & 0 \\ -0.500006 & 0 & -0.866022 & 0 \\ 0 & -1 & 0 & 393.412 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

**LINK 3**

$$\begin{bmatrix} 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 734.999342 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

**LINK 4**

$$\begin{bmatrix} 0.500006 & 0 & -0.866022 & 0 \\ 0.866022 & 0 & 0.500006 & 0 \\ 0 & -1 & 0 & 226.8 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

**LINK 5**

$$\begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 0.173648 & -0.984808 & 0 \\ 0 & -0.984808 & -0.173648 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

**LINK 6**

$$\begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 431.8 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

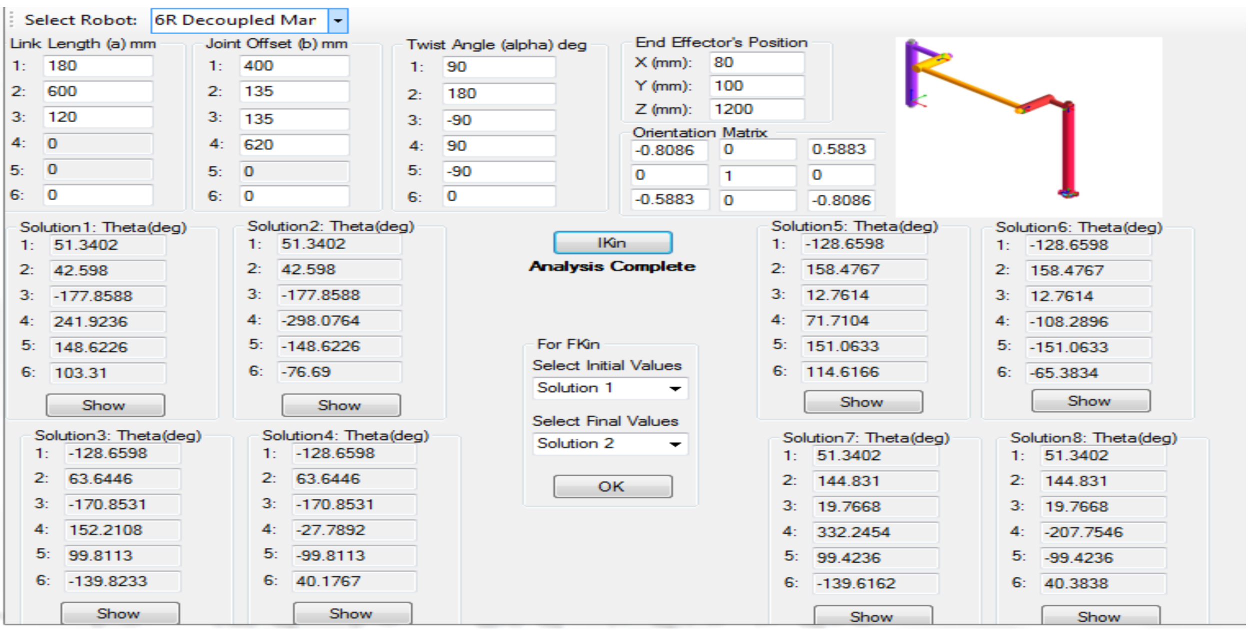
**EE CONFIGURATION:**

$$\begin{bmatrix} -0.808018 & 0.568792 & 0.153569 & -33.936592 \\ -0.399505 & -0.72055 & 0.566748 & 857.904972 \\ 0.433016 & 0.396591 & 0.809452 & 1944.46075 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

## INVERSE KINEMATIC ANALYSIS

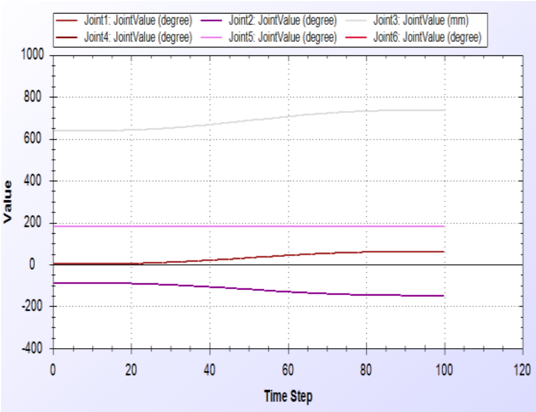
The reverse process that computes the joint parameters that achieve a specified position of the end effector is known as inverse kinematics. Inverse kinematics refers to the use of the kinematics equations of a robot to determine the joint parameters that provide a desired position of the end-effector. Specification of the movement of a robot so that its end-effector achieves a desired task is known as motion planning. Inverse kinematics transforms the motion plan into joint actuator trajectories for the robot. The movement of a kinematic chain whether it is a robot or an animated character is modeled by the kinematics equations of the chain. These equations define the configuration of the chain in terms of its joint parameters. Forward kinematics uses the joint parameters to compute the configuration of the chain, and inverse kinematics reverses this calculation to determine the joint parameters that achieves a desired configuration. For example, inverse kinematics formulas allow calculation of the joint parameters that position a robot arm to pick up a part. Similar formulas determine the positions of the skeleton of an animated character that is to move in a particular way.

## RESULTS FOR INVERSE KINEMATICS:

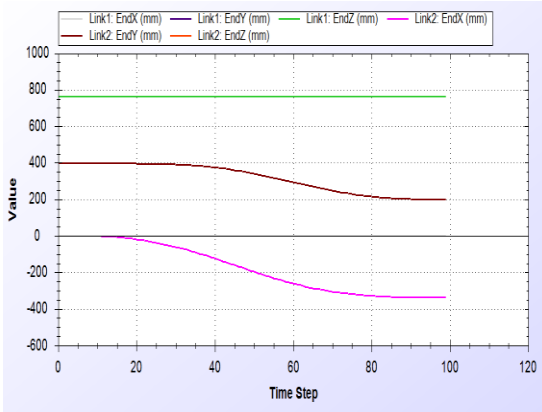


**GRAPHS OBTAINED FOR JOINT VELOCITIES:**

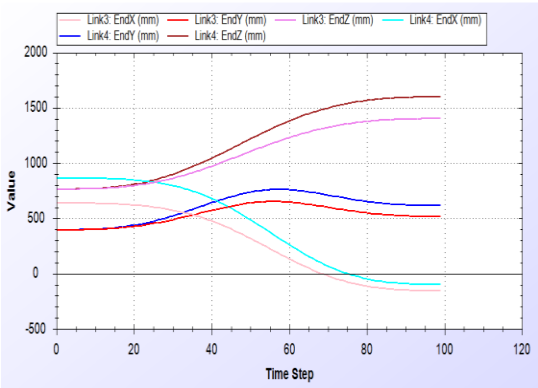
**JOINT VELOCITIES:**



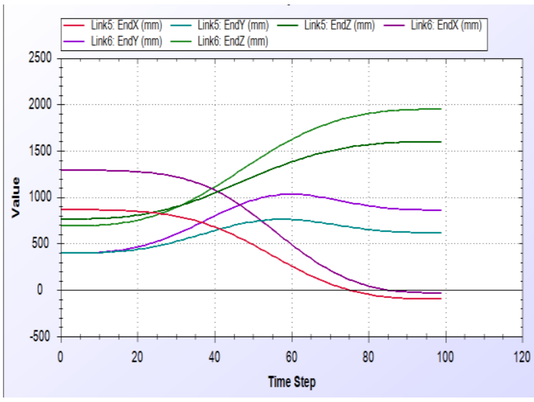

**LINK 1 & 2:**




**LINK 3 & 4:**




**LINK 5 & 6:**




These graphs give us the details regarding links velocity, acceleration. Whereas the joint graphs give us the info on joint velocity, joint value, joint acceleration and force with torque.

**CONCLUSION:** Design of a six-degrees-of-freedom manipulator based on the concept of an in-parallel actuated mechanism is presented. We introduced jacobian matrix for simulation, the basic kinematic equations for use of the manipulator are derived and the influences of the physical constraints on the range of motion in the practical design are discussed. We use robo analyzer software for determining the simulation results. Several possible applications which include the in-parallel mechanism as part of the manipulation system are suggested, and we determine D.H.Parameters for design and we obtained the results.

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