Review of Forward Kinematic Analysis for Multiple Linkage

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Abstract- **Robot is widely used in industry due to their efficiency and high performance. Optimization of robot is still challenging tasks which require understand of robot's kinematic and dynamic behaviour. This paper present in the forward kinematics analysis of the articulated robot. In forward kinematic analysis found the position of end effector by using the angle of link forward kinematic analysis is used to path tracking of an articulated robot with drilling application.**

I. HISTORY

The word robot was first used in 1921 by Czechoslovakian playwright karel chapek. It is derived from the Czech word robota ,which means forced labour or slave. Robot is defined as " a reprogrammable multifunctional manipulator designed to more material , parts tools or specialized device through variable programed motion for performing a variety of task". Recently robots are increasing and integrated into working task to replace human being to perform the repetitive task. In general robotics can be divided into two part industrial robotics and service robotics[2]

Robots can capable to perform a variety of work and do not require safety and comfort element human needs robots can be reduce the risk involved with human physical interaction[3] Industrial robot are demand high level of energy consumption. Robots provide precision strength and sensing capabilities which can produce high quality end products[4]

Figure 1 robotic arm

II. TYPES OF ROBOT

There are a number of factor that help decide the type of robot required for a specific task. Four major coordinate systems used in the study of robotics are:

1. Cartesian
2. Cylindrical
3. Spherical
4. Articulated[5]

A. Cartesian Workspace

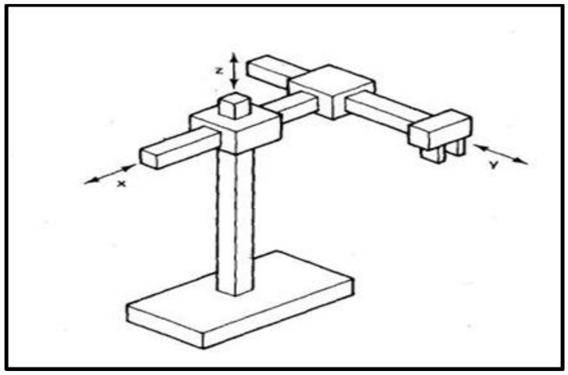

Figure 2 Cartesian workspace

Cartesian robots are used for pick and place work, application of sealant, assembly operation, handling machine tools and arc welding. It's a robots whose arm has three prismatic joints, whose arm axes are coincidental with the Cartesian coordinate. This robots are used for assembly, palletizing and machine tool loading and handle large sized workpieces.[6]

B. Cylindrical Workspace

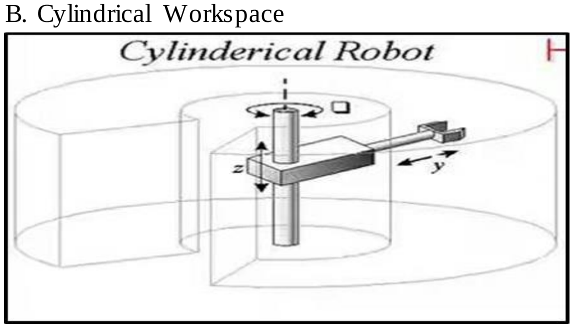

Figure 3 cylindrical workspace

Cylindrical robots have three degree of freedom. It provides two linear and one rotary motion. Cylindrical robots are used in assembly operation; handling of machine tools; spot welding and handling die cast machines. They also have many uses in medical testing. A cylindrical robots is able to rotate along its main axes forming a cylindrical shape. The medical robot is numerous medical application for DNA screening [6]

C. Spherical (polar) Workspace

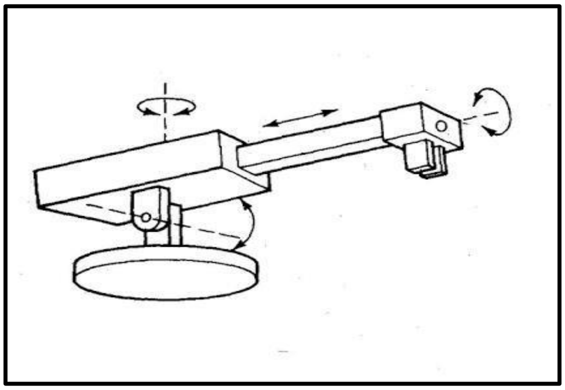

Figure 4 spherical workspace

Spherical robots have three degree of freedom. It provides one linear and two rotary motions. The spherical robots provides spherical work envelope and occupies minimum space. They are generally used in many welding application mainly spot, gas and arc. Polar robots are extremely suitable for reaching into horizontal or inclined tunnels.[6]

D. Articulated Workspace

The Articulated robot have robotics arm made of two pieces which are joined together by turning pair. There are two types of articulated robots:

1. Revolute Robots

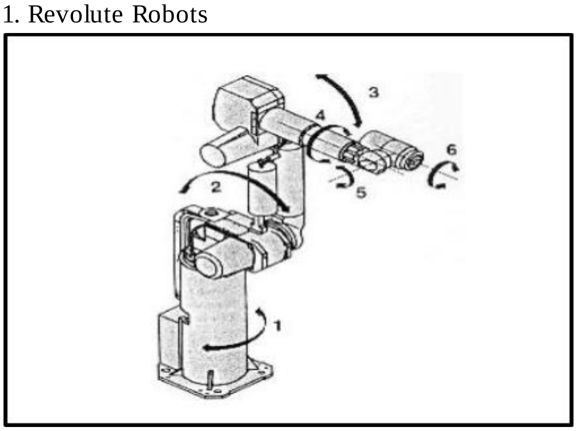

Figure 5 revolute robots

Revolute robot has three degree of freedom. It provides three rotary motions about three manually perpendicular axes. Its configuration is similar to that of human arm. It consist of two straight links, corresponding to the human forearm and upper arm connected by a rotary joint. This robots which provides spherical work envelope, has excellent work area to floor area ratio. The revolute robot, which has highly versatile configuration is used for diverse tasks like: spray painting, of car body seam welding, spot welding, assembly, heavy material handling etc.[6]

2. SCARA (Selective Compliance Assemble Robot Arm) Robots

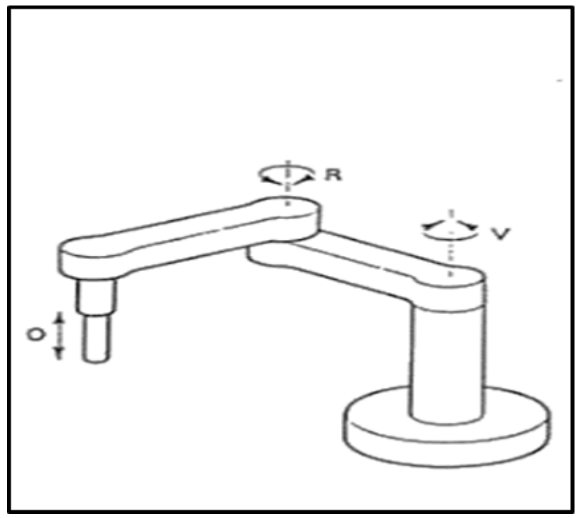

Figure 7 SCARA robots

SCARA robots have three degree of freedom. It provides one linear and two rotary motions. This robots provides cylindrical work envelope. These robots are provided with high speed drive motors. SCARA robot has substantial rigidity in the vertical directions. This makes suitable for assembly operation where it is expected to perform the insertion task.[6]

III. KINEMATICS ANALYSIS

Kinematics and dynamics of robot manipulator are fundamental to robot technologies. The kinematics is the science of motion that does not consider mass and moments of inertia. Dynamics is the science of motion that represent torque of joint and motion of robot. In the kinematics position and orientation, velocity and acceleration of the robot. There are two types of kinematics analysis.

1. Forward kinematic analysis
2. Inverse kinematic analysis

In forward kinematic problem find the position of end effector by using a length of link and joint angle. In reverse kinematic problem find the configuration joint and the joint angle by using the position of end effector and orientation of end effector.

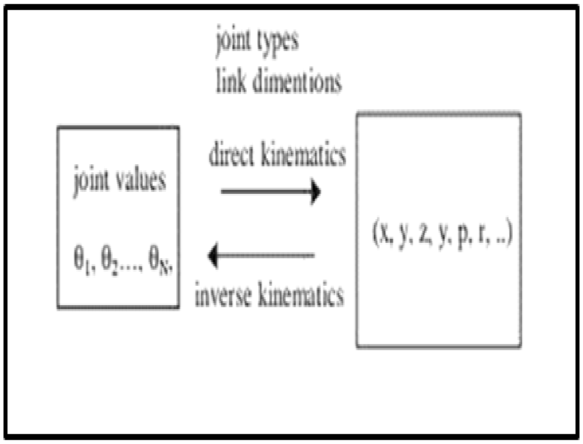

Figure 6 forward kinematics

A. One link of forward kinematics analysis

Shown in figure is a one link articulated robot. Is there Forward kinematic of one link articulated robot by geometric method. The position of end effector is

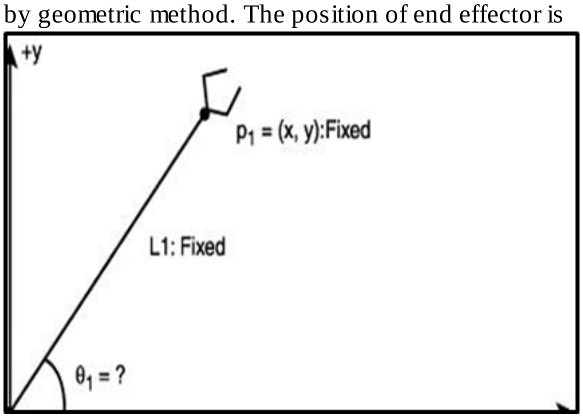

Figure 8 one link forward kinematics

X=L1cosθ

Y=L1sinθ

$$[T]=\begin{bmatrix} L1cos\theta & 0 \\ 0 & L1sin\theta \end{bmatrix}$$

B. Two link of forward kinematics analysis

In to dimension one clearly needs two degree of freedom to reach and arbitrary point within a given work space. let us first study a simple two link manipulator with rotational joint. Define vectors corresponding two the two link. The position of the tip found simply by vector addition.

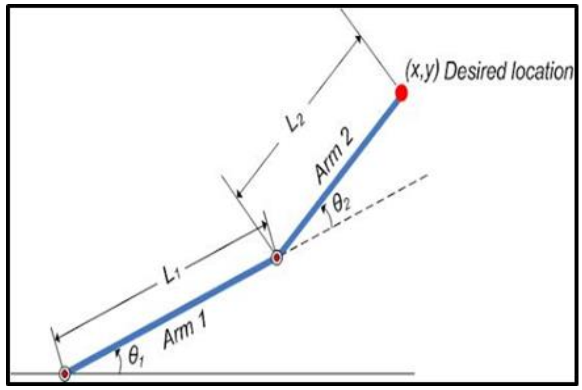

Figure 9 two link forward kinematics

X= L1cosθ1+L2cos $(\theta 1 + \theta 2)$

Y= L1SINθ1+L2SIN $(\theta 1 + \theta 2)$

Ø= $\theta 1 + \theta 2$

In the end effector position in geometric transformation,

$$\begin{bmatrix} \mathrm{T1} \\ \mathrm{T2} \end{bmatrix}=\begin{bmatrix} \mathrm{L1cos}\theta 1 + \theta 2 & -\mathrm{L1sin}\theta 1 + \theta 2 \\ \mathrm{L1sin}\theta 1 + \theta 2 & \mathrm{L1cos}\theta 1 + \theta 2 \end{bmatrix}$$

C. Three link of forward kinematic analysis

X=L1COSθ1 + L2COS $(\theta 1 + \theta 2)$ +L3COS $(\theta 1 + \theta 2 + \theta 3)$

Y= L1SINθ1 + L2SIN $(\theta 1 + \theta 2)$ +L3SIN $(\theta 1 + \theta 2 + \theta 3$

$\emptyset = \theta 1 + \theta 2 + \theta 3$

While we could process to solve the forward kinematics problem of finding position of end effector from the angle of joint with the use of geometric method. One can easily solve the position of joint 2,

X2=X-L3cosø

Y2=Y-L3sinø

This can be written in matrix form

$$\begin{bmatrix} T1 \\ T2 \\ T3 \end{bmatrix}\begin{bmatrix} -(L1S1 + L2S12 + L3S123 & (L1C1 + L2C12 + L3C123) & 1 \\ -(L2S12 + L3S123) & (L2C12 + L3C123\ ) & 1 \\ -(L3S123) & L3C123 & 1 \end{bmatrix}$$

D. 6 Link of forward kinematic analysis

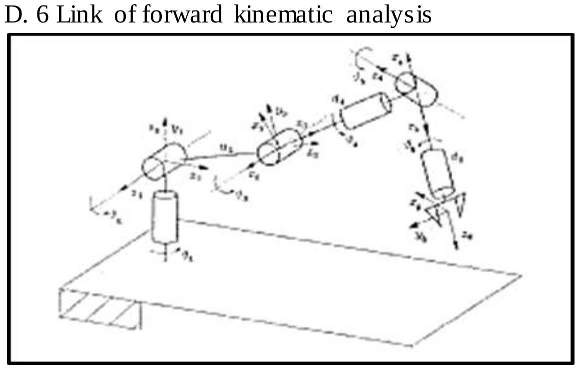

Figure 10. 6 link forward kinematics

By using the geometric method the transformation matrix for each joint and have one 3*3 rotational matrix that show the orientation of the end effector and have one 1*3 type matrix which show the position of the end effector.

$$A1=\begin{bmatrix} C\theta1 & 0 & S\theta1 & a1C\theta1 \\ S\theta1 & 0 & -C\theta1 & a1S\theta1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A2=\begin{bmatrix} C\theta2 & -S\theta2 & 0 & a2C\theta2 \\ S\theta2 & C\theta2 & 0 & a2S\theta2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A3=\begin{bmatrix} C\theta1 & 0 & S\theta1 & 0 \\ S\theta1 & 0 & -C\theta2 & 0 \\ 0 & 1 & 0 & d3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A4=\begin{bmatrix} C\theta4 & 0 & -S\theta4 & 0 \\ S\theta4 & 0 & C\theta4 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A5=\begin{bmatrix} C\theta5 & 0 & S\theta5 & 0 \\ S\theta5 & 0 & -C\theta5 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A6=\begin{bmatrix} C\theta6 & -S\theta6 & 0 & 0 \\ S\theta6 & C\theta6 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

It can be started with the first joint and then transform to the second joint then to the third until to the arm end of the robot and eventually to the end effector. The total transformation between the base of the robot the hand by multiplying these equation we can get the final equation for forward kinetics and compare the value with equation one and finally get the kinematic equation [8]

${}_0T^6$=A1*A2*A3*A6*A4*A5*A6

$${}_0T^6=\begin{bmatrix} nx & ox & ax & px \\ ny & oy & ay & py \\ nz & oz & az & pz \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

nx=C1[C23(C4C5C6-S4S6S23S5C6]+S1(S4C5C6+C4C6)

ny=S1[C23(C4C5C6-S4S6)-S23S5S6]-C1(S4C5C6+C4S6)

nz= S23(C4C5C6-S4S6)+C23S5S6

ox=C1[-C23(C4C5C6+S4C6)+S23S5S6]+S1(-S4S5S6+C4C6)

oy=S1[-C23(C4C5C6+S4C6)+S23S5S6]-C1(-S4C5C6+C4C6)

oz=-S23(C4C5C6+S4C6)-C23S5S6

ax=C1[C23C4S5+S23C5]-C1S4S5

ay=S1[C23C4S5+S23

az=S23C4S5 – C23C5

px=C1(C2a2+a1)+S1d3

py=s1(C2a2+a1)-C1d3

pz=S2a2

IV. CONCLUSION

To conclude that paper proposed mathematically approach for solving the forward kinematics foe one, two, three and six DOF robotic manipulator. This technique is used to determine the position and orientation.

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