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Automation-Robot Kinematics: A Review

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ABSTRACT

Two contradictory needs of any industrial process are: repetitive tasks and high accuracy. Automation means self-dictated, is the use of control systems, such as computers, to control industrial machinery and processes, replacing human operators. The automation is playing important role in saving human efforts in most of the regular and frequently carried works, includes transfer lines, mechanized assembly machines, feedback control systems, and robots. This article presents literature review on automation, robotics, laws of robotics and different subsystems of robotics and a motion subsystem in detail. There are many gages of performance for this task; including speed, accuracy, and reliability, which all have their own associated difficulties.

Keywords : Automation, Robotics, Manipulator, Actuator, End-effector and Sensor

Introduction:
Automation, which in Greek means self-dictated, is the use of control systems, such as computers, to control industrial machinery and processes, replacing human operators.

Automation is also defined as a technology concerned with the use of mechanical, electronic and computer-based systems in the operation and control of production. This technology includes transfer lines, mechanized assembly machines, feedback control systems and robots.

Robots:
The origin of the word robot can be traced to the Czech word Robota, which means forced or compulsory labour (Saha, 2011). Also it can be defined as a reprogrammable and multifunctional manipulator designed to move materials, parts, or tools, or specialized devices through various programmed motions for the performance of a variety of tasks.

One of the first robots was the "clepsydra or water clock", which was made in 250 B.C. It was created by Ctesibius of Alexandria, a Greek physicist and inventor. The earliest remote control vehicles were built by Nikola Tesla in the 1890s. Tesla is best known as the inventor of AC electric power, radio (before Marconi), induction motors, Tesla coils, and other electrical devices. Other early robots (1940s-50s) were Grey Walter's "Elsie the tortoise" ("Machina speculatrix") and the Johns Hopkins "beast"

Laws of Robotics:
Isaac Asimov in his Science friction stories envisioned the robot as a helper to mankind and postulated three basic rules for robots.
(1) A robot must not harm a human being, nor through inaction allow one to come to harm.
(2) A robot must always obey human beings, unless that is in conflict with the first law.
(3) A robot must protect from harm, unless that is in conflict with first two laws.
(4) A robot may take a human being's job but it may not leave the person jobless.

Robots are broadly classified as Industrial and Non-industrial or special-purpose.

Robotic system generally consist of 3 subsystems, namely

(i) A motion subsystems
(ii) A recognition subsystems
(iii) A control subsystems

A motion system is the physical structure of the robot that carries out a desired motion similar to human arms.

Motion sub-systems can be classified as follows.
(i) Manipulator
(ii) Actuator
(iii) End effector
(iv) Transmission

Manipulator:
It is the physical structure which moves around. It comprises "Links" (also referred as "bodies") and "joints" (also called "kinematics pairs") normally connected in series. Link is either made up of steel or aluminium. The joints are generally of rotary or translatory types. But in the study of robotics and mechanisms, these joints are referred as Revolute and Prismatic joints (Selig, 1992).

The individual joint motions associated with these two categories are sometimes referred to by the term "degrees of freedom", and a typical industrial robot is equipped with 4 to 6 degrees of freedom.

The difference between the two situations is that, in the first instance, the joint has only a single degree of freedom of motion: the angle of rotation in the case of a revolute joint, and the amount of linear displacement in the case of a prismatic joint. In contrast, a ball and socket joint has two degrees of freedom.

Possible joint configuration:
(i) Revolute joints:
They are comprised of a single fixed axis of rotation.

(ii) Prismatic joints:
They are comprised of a single linear axis of movement.

(iii) Cylindrical joints:

Comprise two degrees of movement, revolute around an axis and linear along the same axis.

(iv) Planar joints:
Comprise two degrees of movement, both linear, lying in a fixed plane

(A gantry-type configuration).

(v) Spherical joints:
Comprise two degrees of movement, both revolute, around a fixed point (A ball joint configuration).

(vi) Screw joints:
They are comprised of a single degree of movement combining rotation and linear displacement in a fixed ratio.

However, the last 4 joint configurations can be modeled as a degenerate concatenation of the first two basic joint types. Figure-1 represents the all possible joints.

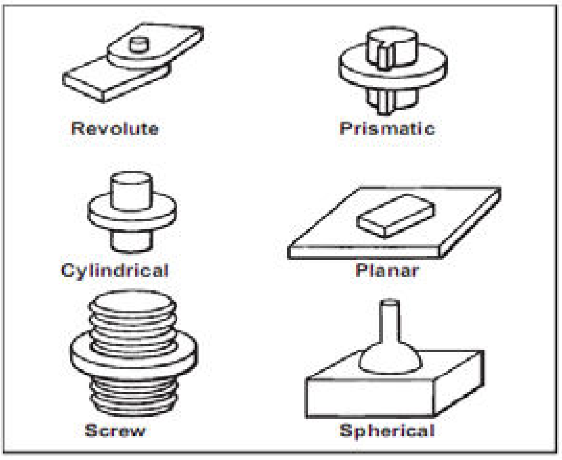

Figure-1 : All possible joint configurations.

Wrist motions:
The wrist movement is designed to enable the robot to orient the end effector properly with respect to the task to be performed. To solve the orientation problem, the wrist is normally provided with up to 3 degrees of freedom.

1. Wrist roll: Also called wrist swivel, this involves rotation of the wrist mechanism about the arm axis.

2. Wrist pitch: Given that the wrist roll is in its center position, the pitch would involve the up or down rotation of the wrist.

3. Wrist yaw: Again, given that the swivel is in the center position of its range, wrist yaw would involve the right or left rotation of the wrist.

Robot Anatomy:

Common Robot Configurations:
The vast majority of today's commercially available robots possess one of five types of commonly used arm configurations.

(i) The Cartesian coordinate:
This robot provide movement to 3 axes movement is X axis, Y axis and Z axis. The advantages of this robot are easy to make a program, accuracy and repeatability high and easy for program off-line. Disadvantage of this robot is need protector from dust and rust, need volume large to operate and it can reach to front only.

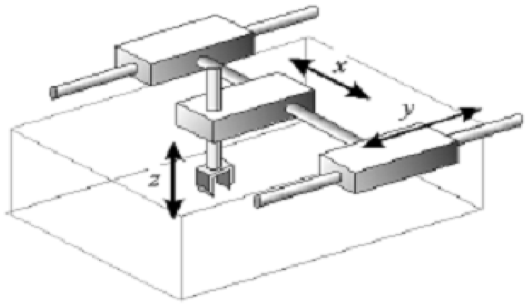

Figure: 2 Cartesian Robot

(ii) Cylindrical coordinate:
This robot provides movement to horizontal axis, vertical axis and rotation axis. It has high accuracy, can operate swiftly, easy to reach, simple structure and easy to make a program. Used for assembly operations, handling at machine tool s, spot welding, and handling at die casting machines. It is a robot whose axes form a cylindrical coordinate system.

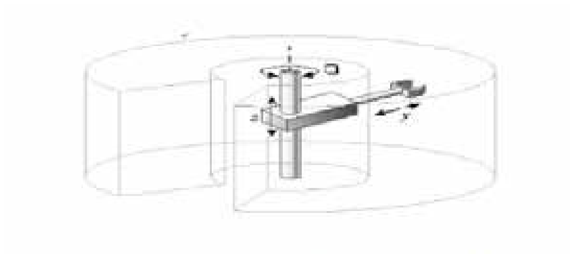

Figure 1.2 Cylindrical Robot

Figure: 3 Cylindrical Coordinate

(iii) Spherical or Polar coordinate:
This robot resemble turret a tank. It combines movement rotation to both vertical and horizontal plane and one movement linear to his arm. It can process heavy mass and also have wide volume from the site that fixed. Disadvantage of this robot is it have complex coordinate and so hard to make a program. Used for handling at machine tools, spot welding, die casting, fettling machines, gas welding and arc welding. It's a robot whose axes from a polar coordinate system.

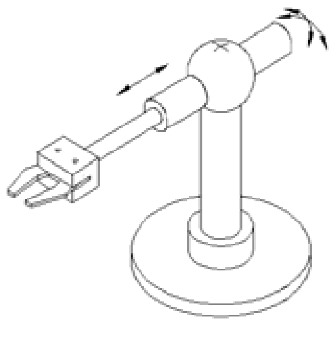

Figure:4 Polar Coordinate

(iv) Articulate robot:
This robot is also known as revolute. Work coverage for this robot is sphere. Advantages for this robot is it can reach almost with base, it capable on obstacle and it also capable to make a complex route. Used for assembly operations, die casting, fettling machines, gas welding, arc welding and spray painting. It's a robot whose arm has at least three rotary joints.

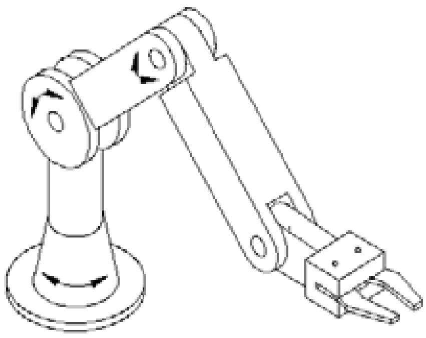

Figure: 5 Articulate robot

(v) Self Compliant Automatic Robot Assembly (SCARA):
Scara is short form to "selective compliance assembly robot arm". Work coverage for this robot is cylindrical. This robot has high accuracy, simple to make a program and it also can operate swiftly. But the work coverage that limited. Used for pick and place work, application of sealant, assembly operations and handling machine tools. It's a robot which has two parallel rotary joints to provide compliance in a plane.

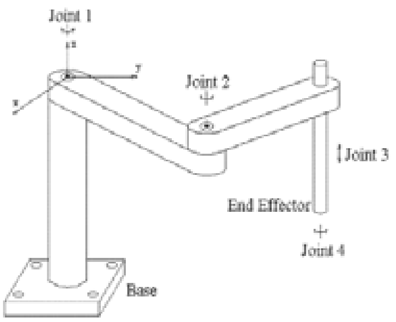

Figure: 6 Scara Robot

About 90% of the robots in the world nowadays are found in industries which may be either stationary or mobile itself. The pick and place robot was invented to be used as hardware to solving and accomplishing most of task that cannot be done by human being and also to be faster and pinch the production time.

Industrial robot:
The official definition of an industrial robot as provided by the Robotics Industries Association (RIA) is:

An industrial robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or special devices through variable programmed motions for performance of a variety of tasks.

Actuators (Drive Systems):
The drive system determines the speed of the arm movements, the strength of the robot, and its dynamic performance. Commercially available industrial robots are powered by one of three types of drive systems. Comparative study of these three systems is as follows: (Harshe, 2006).

Electrical Actuator	Hydraulic Actuators	Pneumatic Actuators
Moderate Payload capacity	High payload capacity	Low payload capacity
High power to weight ratio	Moderate power to weight ratio	Low power to weight ratio
Highly accuracy and precision	Moderate accuracy and precision	Low accuracy and precision
Highly reliable and requires low maintenance	Low reliable and requires high maintenance	Moderate reliable and requires moderate maintenance
Low cost	High cost	Moderate cost
Can work in narrow speed range	Moderate range of speed	Wide speed range

Table:1 Comparison of different drive systems

End Effectors:
The end effector represents the special tooling that permits the general-purpose robot to perform a particular application. This special tooling must be designed specifically for the application. End effectors can be divided into two categories: (Tian-Soon, Angjri & Kah-bin, 1997).

(i) Grippers
(ii) Tools.

Grippers could be utilized to grasp an object, usually a workpart, and hold it during the robot work cycle. There are a variety of holding methods that can be used in addition to the obvious mechanical means of grasping the part between two or more fingers. These additional methods include the use of suction cups, magnets, hooks, and scoops.

A tool would be used as an end effector in applications where the robot is required to perform some operation on the workpart. These applications include spot welding, arc welding, spray welding, and drilling. In each case, the particular tool is attached to the robots wrist to accomplish the application.

Robotic Sensors
Sensors used as peripheral devices in robotics include both simple types such as limit switches and sophisticated types such as machine vision systems. Sensors are also used as integral components of the robots position feedback control system. The sensors used in robotics include the following general categories:

1. Tactile sensors: These are sensors which respond to contact forces with another object. Some of these devices are capable of measuring the level of force involved.

2. Proximity and range sensors: A proximity sensor is a device that indicates when an object is close to another object but before contact has been made. When the distance between the objects can be sensed, the device is called as range sensor.

3. Miscellaneous types: The miscellaneous category includes the remaining kinds of sensors that are used in robotics. These include sensors for temperature, pressure, and other variables.

4. Machine vision: A machine vision system is capable of viewing the workspace and interpreting what it sees.

These systems are used in robotics to perform inspection, parts recognition, and other similar tasks. Sensors are an important component in work cell control and in safety monitoring systems (Craig, 2005).

Denavit-Hartenberg Notation:
Denavit-Hartenberg notation looks at a robot manipulator as a set of serially attached links connected by joints. Only joints with a single degree of freedom are considered. Only prismatic and revolute joints are considered. All other joints are modeled as combinations of these fundamental two joints. The links and joints are numbered starting from the immobile base of the robot, referred to as link 0, continuing along the serial chain in a logical fashion. The first joint, connecting the immobile base to the fi rst moving link is labeled joint1, while the first movable link is link1. Numbering continues in a logical fashion. The geometrical configuration of the manipulator can be described as a 4-tuple, with 2 elements of the tuple describing the geometry of a link relative to the previous link.

Link length, a i-1:

Considering the shortest distance between the axis of link i-1 and link i. This distance is realized along the vector mutually perpendicular to each axis and connecting the two axes. The length of this vector is the link length ai-1 (Wang & Lien, 1989).

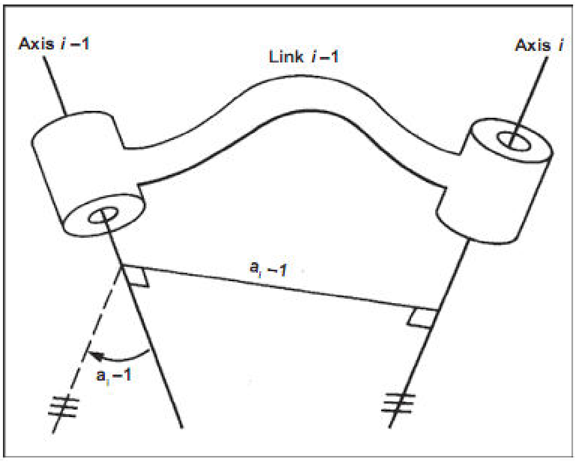

Figure: 7 Link length

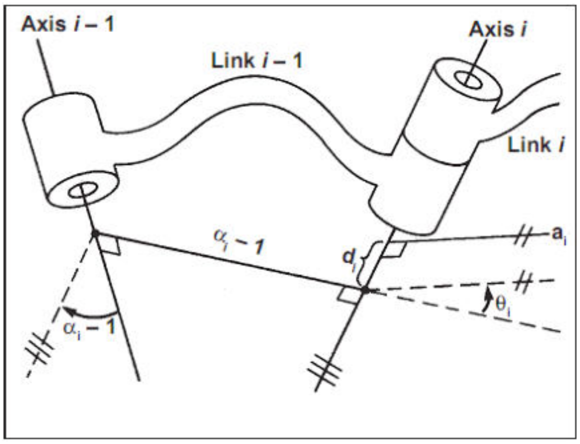

Figure: 8 Representation of link off-set

Link Twist, α i-1:
Consider the plane orthogonal to the link length a i-1. Both axis vectors of joint i-1 and i lie in this plane. Project the axes vectors of joints I and i-1 onto this plane. The link twist is the angle measured from joint axis i-1 to joint axis i in the right-hand sense around the link length a i-1. Direction of a is taken as from axis i-1 to i.

Link Offset, di :
On the joint axis of joint I consider the two points at which the link lengths a and ai are attached. The distance between these points is the link offset, measured positive from the ai-1 to ai connection points.

Joint Angle, θi :
Consider a plane orthogonal to the joint axis i. By construction, both link length vectors a and ai lie in this plane. The joint angle is calculated as the clockwise angle that the link length ai-1 must be rotated to be co-linear with link length ai. This corresponds to the right-hand rule of a rotation of link length ai-1 about the directed joint axis.

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

Conclusion:
A robotic manipulator is designed to perform a task in the 3-D space. The tool and end effector is required to follow a planned trajectory to manipulate objects or carry out the task in the workspace. This requires control of position of each links and joint of manipulator to control both the position and orientation of the tool. Kinematic model describe the spatial position of joints and links, and position and orientation of end effectors. This paper deals with the automation, basics of robot, laws of robotics, robot anatomy, robotics subsystems, sensors and Denavit-Hartenberg Notation.

REFERENCES

1. Craig, J. J. (2005). Introduction to robotics Mechanics and Control. Pearson Education International. | 2. Harshe, M. (2006). An innovative multti- DOF robotic arm assembly for press Shopes. Pune University. | 3. Saha, S. K. (2011). Introduction to robotics. New Delhi. Tata McGraw Hill. | 4. Selig, J. M. (1992). Introductory robotics. London. Prentice Hall International. | 5. Tian-Soon, S., Angjri, M. H. & Kah-bin, L., (1997). Compliant end-effector coupling for vertical assembly: design and evaluation, Robotics & Computer- Integrated Manufacturing, 13, 21-30. | 6. Wang, K. & Lien T. K., (1989). The structure design and kinematics of a robot manipulator theory, Robotics & Computer-Integrated Manufacturing, 5,153-158.