A Literature Review on Structural Properties of Different Types of Robots

Rushabh S. Mole
UG Student
Department of Mechanical Engineering
Suman Ramesh Tulsiani Technical Campus, Faculty of Engineering, Khamshet, Pune-410405

Akash M. Rode
UG Student
Department of Mechanical Engineering
Suman Ramesh Tulsiani Technical Campus, Faculty of Engineering, Khamshet, Pune-410405

Ketan N. Phadtare
UG Student
Department of Mechanical Engineering
Suman Ramesh Tulsiani Technical Campus, Faculty of Engineering, Khamshet, Pune-410405

Pavan D. Patil
UG Student
Department of Mechanical Engineering
Suman Ramesh Tulsiani Technical Campus, Faculty of Engineering, Khamshet, Pune-410405

Jitendra B. Satpute
Assistant Professor
Department of Mechanical Engineering
Suman Ramesh Tulsiani Technical Campus, Faculty of Engineering, Khamshet, Pune-410405

Abstract

Nowadays Robots are playing a vital role in all the activities in human life including industrial needs. In modern industrial manufacturing process consists of precise and fastest proceedings. Human operations are needed to perform a various tasks in a robotic system such as set-up, programming, trouble shooting, maintenance and error handling activities. Hazardous conditions exist when human operators interfere into the robotic work zones. Human perception, decision making, and action strategies need to be studied to prevent robot-related accidents. System designers and technology managers they are required to consider the limitations of operator perceptual process in design and layout of robotic system. The ultimate object is to save human lives to increasing productivity and quality of high technology work environments. Effective safety training programs for work with industrial robots should be developed. One of the major areas of Research & Development (R&D) that has made a radical improvement in Computer Science and electronics is “Automation” and “Artificial Intelligence”. Autonomous Systems are self-governed and does not require any manual interventions. The objective of the paper is to study the all types of robots and sate its properties, advantages disadvantages and applications.
Keywords- Types of Robots, DOF, Properties, End effector, Configuration

I. INTRODUCTION

The field of robotics has its origins in science fictions. The word robot comes from the Czech word "robot" means forced labor in 1920. It took another 20 years before the modern technology of industrial robotics have begun. Today, robots are highly automated mechanical manipulators controlled by computers. A robot may appear same like a human being or a simple electro-mechanical device [1]. It may act under the direct control of a human (e.g. the robotic arm of the space shuttle) or under the control of a programmed computer. Robots may be used to perform tasks that are too difficult for humans to implement directly (e.g. nuclear waste cleanup) or may be used to make automate repetitive tasks which can be performed less costly by a robot than by the employment of a human being (e.g. automobile production) or may be used to automate mindless repetitive tasks which should be performed with precision by a robot than by the human such as (material handling, material transfer applications, machine loading and unloading, processing operations, assembly and inspection).[2]

The last 5 decades have a significant advance in the field of robots application. Many more applications are expected to appear in various space exploration, battlefield and in various activities of daily life in the coming years. It is a mechanical device that performs automated tasks and movements, according to either predefined program or a set of guidelines and direct human supervision. Such tasks either replace or upgrade human work, such as in manufacturing, contraction or manipulation of heavy and hazardous material. Robot is an intrinsic part in automating the flexible manufacturing system that one greatly in demand these days [3]. The Robots are now more than a machine, as robots have become the solution of the future as cost labor wages and customers demand. Even though the initial cost of acquiring robotic system is very expensive but as today's rapid development and a very high demand in quality with IS0 standards, human are not capable of such demands. Research and development of future robots is moving at a very high pace due to the constantly improving and upgrading of the quality standards of products.

II. REVIEW OF EXISTING ROBOTS

Robots are used in different fields such as industrial, military, space exploration, and medical applications. These robots could be classified as manipulator robots and cooperate with other parts of automated or semi-automated equipment to achieve task such as loading, unloading, spray painting, welding, and assembling.[4]

Generally, articulated robots are designed, built, and controlled via a computer or a controlling device that uses a specific program or algorithm. Programs and robots are designed in a way that when the program changes, the behavior of the robot changes accordingly to resulting in a very flexible task achieving robot. Robots are categorized by their generation, intelligence, structural, application, and operational efficiency. In this study, robots are reviewed according to their structural properties. [5]

- Linear Robots
- Cylindrical Robots
- Parallel Robots
- Spherical Robots
- SCARA Robots
- Articulated Robot Arm

A. Linear Robots

A robot which has linear actuators cooperating with linear motors linked to a linear axis is known as a linear robot (also known as gantry or Cartesian). The above link can be fixed or flexible connections between the actuators and the robot. The linear motor is attached directly to the linear axis. [6]

Robots which use two motors in controlling a linear axis represent gantry robots. Each motor has a limited distance orthogonal to the linear axis. [7] Ball screws follow the same principles which either use linear motors or rotary motors. This kind of robots usually achieve tasks such as palletizing, unitizing and stacking, order grasping, loading, and coordinate measuring.

The manipulator (also known as end-effector) of the linear robots is connected in an overhead way that allows the robot to move along the horizontal plane easily, where each of these movements are perpendicular to each other and are basically represented as x, y for horizontal axis and sometimes z in case of having a vertical axis.

Any action taken by x and y-axis need to have position accuracy of less than ±5.0 mm and repetition of ±1.0 mm. Figure 1 shows Hercules x-y gantry robot made in USA. Figure 1 shows a Cartesian horizontal reach and its symbol where □1, □2 and □3 represent x, y and z axis respectively. [8]

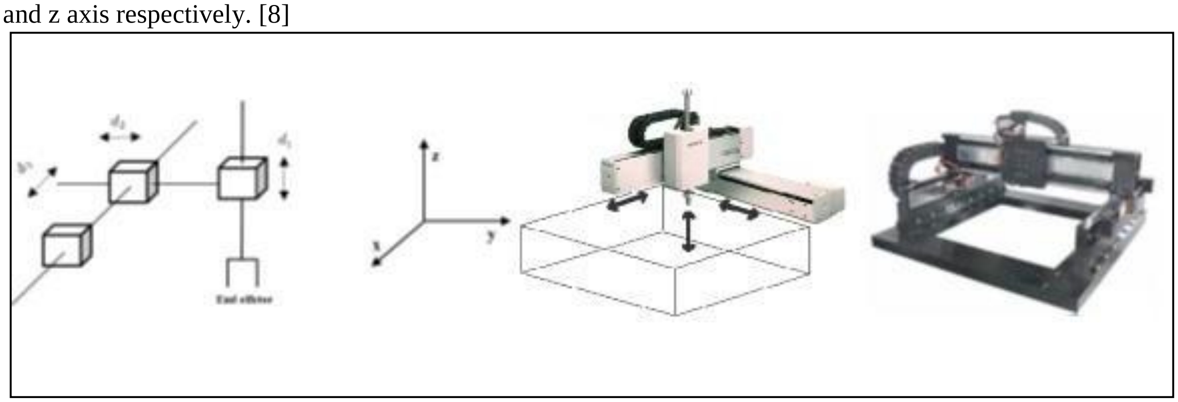


Fig. 1: Cartesian horizontal reach and its symbol (on the right); Cylindrical Robot Arm Configuration; Hercules x-y gantry x-y robot [8]

B. Cylindrical Robots

Cylindrical robots have two prismatic joints which is one rotary joint for positioning task and the end-effector of the robot forms a cylindrical workspace. The main idea of the cylindrical robots is to mount a horizontal arm which moves in forward and backward directions. The horizontal arm is linked to a carriage which moves up and down and is connected to the rotary base. Schematic cylindrical robot and its symbol are shown in Figure 2. [9] Since both of the units move on the base, the workspace is annular space of the cylinder.

When the arm of the robot has a revolute and two prismatic joints, it can operate in z-axis and each point that can be reached by this robot which can be represented by the cylindrical coordinates. As shown in Figure 2, the robot can move in and out in □ direction, can elevate in □ direction and can rotate in □ direction. The arm can move in directions between the specific upper and lower boundaries.[10] It is possible to have additional joints for the end-effector so that the horizontal arm can extend.[11] This kind of robots have a wide use in electronics manufacturing.

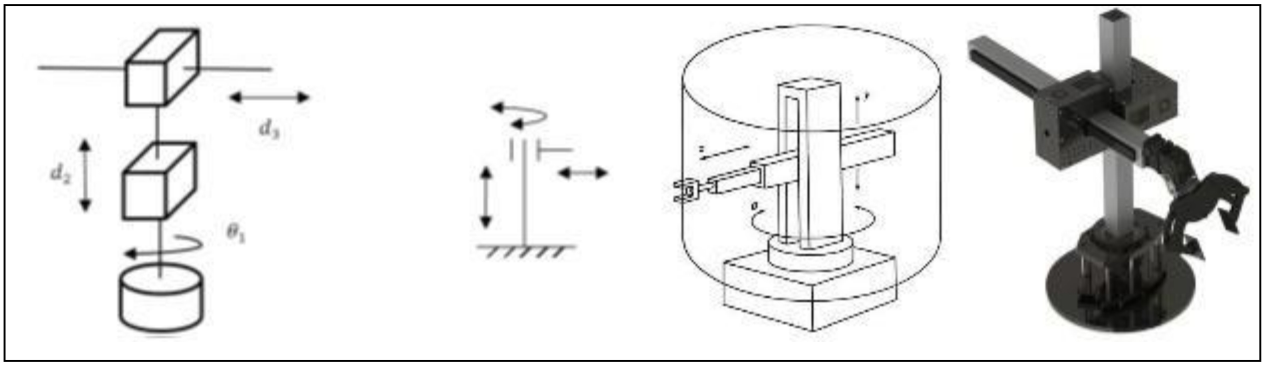


Fig. 2: Cylindrical robot and its symbol (on the right); Cylindrical Robot Arm Configuration; Cylindrical Robot [10]

C. Parallel Robots

A parallel robot has an end-effector with □ DoF which is connected to a fixed base. The connection is done by at least two independent kinematic chains which provide the movements of the robot. A generalized parallel manipulator has a closed-loop kinematic chain mechanism where the manipulator is linked to the base. [12]

There exists different definitions and types of a parallel robots yet the most common properties are as follows [13]

- The end-effector should be supported with at least two chains. Each of the chain should have at least one simple actuator.
- The number of actuators should be equal to the number of DoF of the end-effector.
- There should not exist any mobility of manipulator when the motors are locked.

With having two platforms, parallel robots generally provide relative movement between the moveable platform and the fixed one. Parallel robots have become essential in both industry and academic and likewise, the recent researches on mechanism theories, mobility analysis, dynamics and kinematics modeling, electronics and optimizations have made remarkable developments on the parallel robots. [14]

There are different parallel robot configurations but two kinematic designs have become popular. First design is a parallel robot shown in Figure 3, which has tripod with three axis connecting the end-effector to the movable platform and the base, and has a wrist with 2 or 3 DoF. [15] The second design is a hexapod with six axis which results in full spatial movement as shown in the Figure 3.[16]

Fig. 3: Parallel robot Manipulator; 3 DoF Parallel Robot Arm and configuration; Hexapod with six axis parallel robot [16]

D. Spherical Robots

The spherical robot (also known as polar robot) is big in terms of size and has a telescopic arm. Spherical robot basic movements are rotation at the base and angularly up and down at the arm. [17]

Spherical robots have at minimum two movable joints and one fixed joint. The schematic diagram and symbol of the spherical robot are shown in Figure 4. The motion of the spherical robot consists of the following three movement steps; the 1st movement defines the rotation of the base along vertical axis. The second movement defines the rotation of the arm and finally the third movement defines the in and out motion. [18]

The workspace of the spherical robot depends on the volume of globe of the sphere. The workspace of the robot is the space between two concentric hemispheres. When the arm is fully retracted, the reach of the arm is the inner hemisphere and when the arm is fully straightened, the reach is the outer hemisphere. A typical spherical robot configuration in shown in Figure 4.[19]

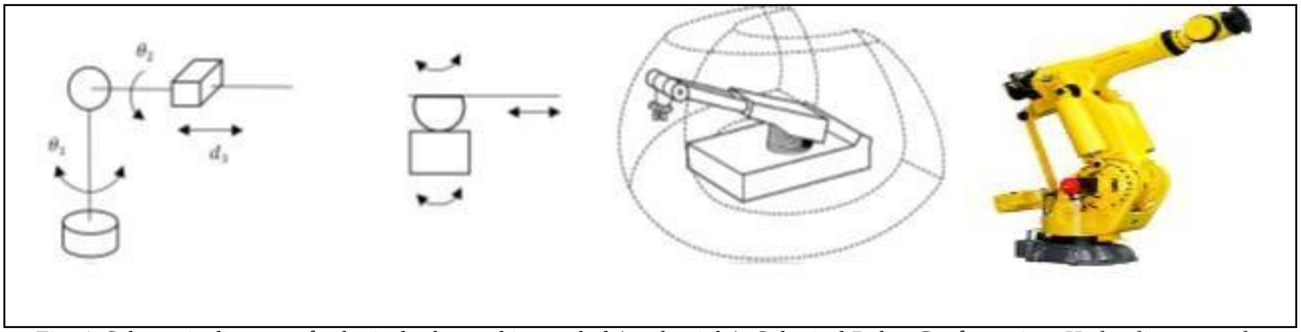


Fig. 4: Schematic diagram of spherical robot and its symbol (on the right); Spherical Robot Configuration; Hydraulic powered spherical robot [19]

E. SCARA

Selective Compliance Assembly Robot Arm (SCARA) was 1st designed and invented in early 1960s in Japan. SCARA robots are perfect for the applications which require high speed and repetitive point to point movements. This is why SCARA is used widely in assembly operation.[20] Special end-effector movement makes SCARA ideal for the tasks which require uniform motion and accelerations in a circular form.[21]

SCARA consists of two parallel rotary joints and a prismatic joint. The rotary joints can move along the horizontal plane and the prismatic joint moves along the vertical plane. The special characteristic of SCARA is that the robot is smooth while operating on □ and □-axis but very strong versus the z-axis. Figure 5 shows the schematic diagram of SCARA.

An especial design of SCARA which was built in Sweden which is known as Spine robot, is designed in a way that it consists of several discs which are linked together via two pairs of hydraulic cable actuators. Each robot has at least four cables in each rigid part which results in total of eight cables with four DoF.

The robot operates when these cables are pulled by the cylinders which are placed in the base of the spine robot.[20] SCARA arm is able to pick up a part vertically from a horizontally placed table and move along the horizontal plane to a desired point and attain the assembly task by lowering the arm and placing the part at its proper location. Figure 13 shows a typical SCARA robot.

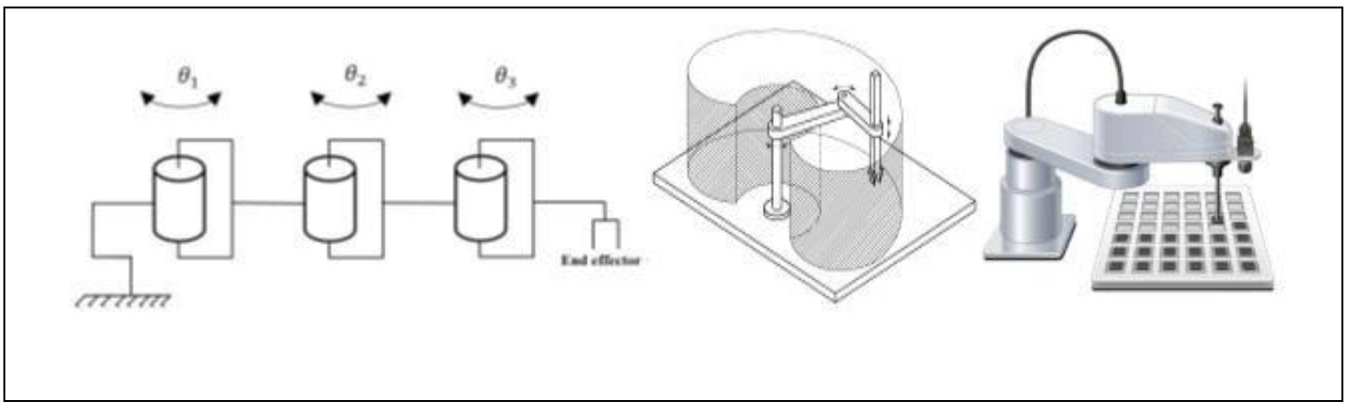


Fig. 5: Schematic diagram of SCARA robot; SCARA Robot Configuration; SCARA robot [20]

F. Articulated Robot Arm

Articulated robots (also known as revolute robots) have three fixed axis connected to two revolute base. All joints of an articulated arm are revolute and most likely it represent the human arm. Figure 6 shows the schematic diagram and symbol of an articulated robot. [21]

The moving rigid objects are called links, revolute joints which are also called hinges and prismatic joints are called sliding joints. Each joint defines the relative motion of the other two object it links which determines the subset of the whole configuration space. Each configuration member is a different position for each link. These members are simple to measure by considering a distance or an angle with each joint.

A robotic arm can be said to be a typical example for articulated robot. An important matter which should be considered is that the dimension of the configuration space increases with the number of joints however the operation speed is limited due to the different payloads at the manipulator and nonlinear environment. [22]

Almost 80% of the registered robots are articulated and up to 20% are linear robots. Figure 6 shows a typical articulated robot. [23]

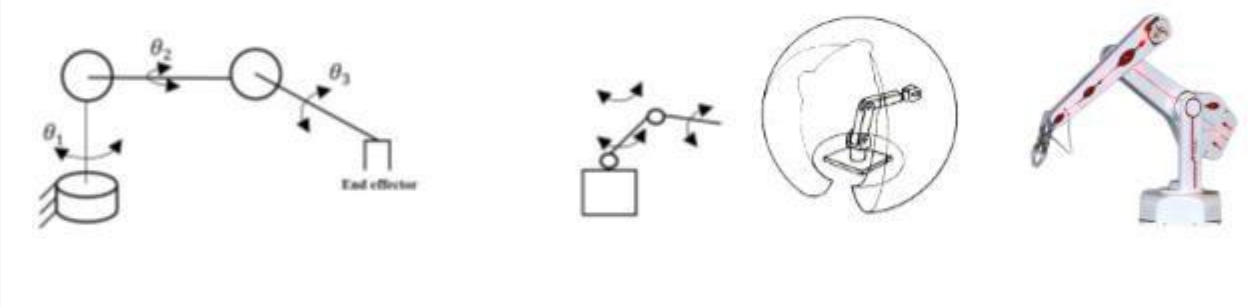
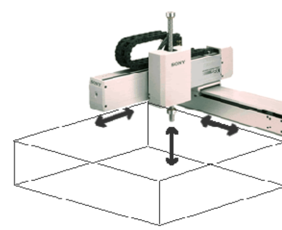
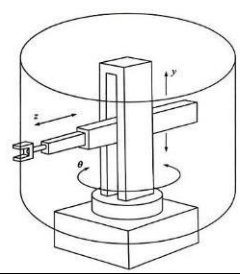
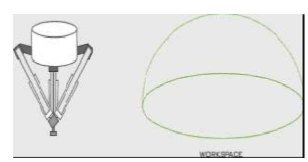
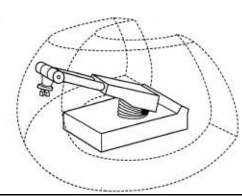
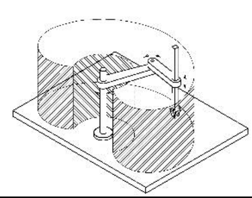
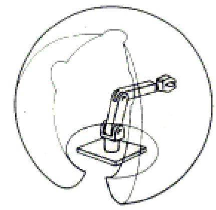


Fig. 6: Schematic diagram of an articulated robot and its symbol (on the right); Articulated Robot Arm Configuration; Articulated Robot Arm [22]

Table 1: Comparison of fundamental robot arms

CONFIGURATION	*ADVANTAGES*	*DISADVANTAGES*	*APPLICATIONS*	*WORK ENVELOP*
Linear Robots Cartesian (Three linear axes) x: base travel y: height z: reach[6]	*Easy to visualize Rigid structure Easy off-line programming Easy mechanical stops*	*Reach only to front and back Requires a large floor space Axes are hard to seal Expensive*	*Appling sealant to mating faces of the case Appling of adhesive agent to drum. Used in the sheet metal processing unit*	
Cylindrical Robots (1 rotating and two linear axes) Θ: base rotation Φ: height z: reach[9]	*Can reach all around Rigid y,z-axes Θ- axis easy to seal*	*Cannot reach above itself Less rigid Θ-axis y-z-axes hard to seal Won't reach around obstacles Horizontal motion is circular*	*Used in assembly operations Used in handling at machine tools Used in Spot welding Used for handling die casting machines*	
Parallel Robots (3 rotating axes) Θ: base rotation Φ: elevation angle Ψ: reach angle[12]	*Can reach all around Maximum vertical reach*	*Cannot reach above itself Expensive Used in Spider Cam*	*It is used in medical applications*	
Spherical Robots (2 rotating and one linear axes) Θ: base rotation Φ: elevation angle z: reach[15]	*Can reach all around Can reach above or below obstacles Large work volume*	*Cannot reach above itself Short vertical reach*	*It is used in Electronic industry to pick and place object*	
SCARA Robots (2 rotating and one linear axes) Θ: base rotation Φ: elevation angle z: reach[18]	*Can reach all around Can reach above or below obstacles Large work volume*	*Cannot reach above itself Short vertical reach*	*It is used for Screw Tightening Used to transfer heavy workpieces Used for inspection*	
Articulated Robot Arm (3 rotating axes and 3 linear axes) Θ: base rotation Φ: elevation angle Ψ: reach angle	*Can reach above or below obstacles Largest work area for least floor space*	*Difficult to program off-line Two of more ways to reach a point Most complex robot*	*It is used in packaging industry It is used in hazardous working area Mostly it is used in Automobile Sector*	

x: base travel *y: height* *z: reach[22]*				

III. CONCLUSION

The purpose of this review is to view the trends in Robots within the past hundred years and learn about the properties of different types of robots. In last hundred years lots of inventions are made to make fewer efforts for the humans. The safeties of the humans are also considered in the hazardous working areas so the Robot is the ultimate solution for it. It is also used to detect any fault in system or any danger in industry.

Today we find most robots working for people in industries, factories, warehouses, and laboratories. Robots are useful in various ways. For instance, it boosts economy because businesses need to be efficient to keep up with the industry competition. Therefore, having robots helps business owners to be competitive, because robots can do jobs superior and faster than humans can, e.g. robot can built, assemble a car. Yet robots cannot perform every job; today robots are also playing an important roles include assisting research and industry. Finally, as the technology improves, there will be new ways to use robots which will bring new hopes and new potentials. [23]

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