International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Robotic Arm Review

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ABSTRACT:

This is a review paper of robotic arm and their development. It will give some technical research work in this field outstanding open problems and an area of exploration.

There are different types of robotic arms are available commercially some of them are essential to accuracy and repeat-ability. This paper describe the information about robotic arm and the parameters. Types of robotic arm will give us a better idea that which parameter affect the which things.

Key words-Robotic Arm, 6-axis, Dof, Accuracy & Repeat-ability

Introduction:

A robotic arm is a versatile and sophisticated mechanical device designed to replicate the functions of a human arm with a high degree of precision and flexibility. These remarkable machines have revolutionized automation, manufacturing, and a wide range of industries by performing tasks that range from simple pick-and-place operations to complex, delicate procedures. Robotic arms typically consist of a series of joints and links, which can move in multiple degrees of freedom (DOF). They are equipped with various sensors and end-effector, enabling them to interact with their environment and execute tasks with incredible accuracy. The applications of robotic arms are diverse, encompassing industries such as manufacturing, health-care, agriculture, space exploration, and many others. Over the years, robotic arm technology has continued to evolve, incorporating advanced materials, control systems, and artificial intelligence to enhance their capabilities. These machines have become integral to modern automation, enabling higher levels of efficiency, productivity, and precision in a world where technological innovation is reshaping the way we live and work.

A robotic arm is meant a set of rigid jointed bodies able to take different configuration, and to move between these configurations with prescribed limits on velocity and acceleration. Industrial robotic arm differs by the size of the fixed bodies, the type of joint, the sequence in which the joints are connected and the range of motion acceptable at each joint. The individual fixed bodies are called links. Robotic arms are manufactured by using different parameters like number of axis, degree of freedom, working envelope and working space that arm cover, kinematics, payload, speed and acceleration, accuracy and repeat-ability, motion control and drive of an arm etc.

Robotic arm definition

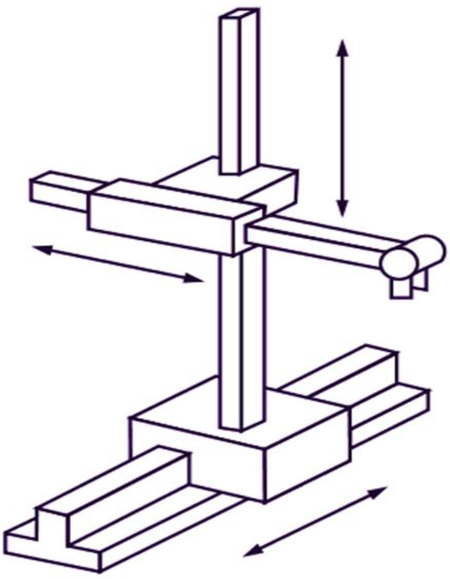
A robotic arm is a robot manipulator, usually programmable, with similar functions to a human arm. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The links of the manipulator can be considered to form a kinematic chain. The business end of the kinematic chain of the manipulator is called the end effectors and it is analogous to the human hand. The end effectors can be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. The robot arms can be autonomous or controlled manually and can be used to perform a variety of tasks with great accuracy. The robotic arm can be fixed or mobile (i.e. wheeled) and can be designed for industrial or home applications.

Types of Robotic Arm:

Based on Kinematics and Design	Cartesian Robotic Arms:
	Cylindrical Robotic Arms:

	Spherical/Polar Robotic Arms
	Articulated Robotic Arms
	SCARA (Selective Compliance Articulated Robot Arm) Robots
Based on Number of Degrees of Freedom (DOF):	4-DOF Robots
	5-DOF Robots
	6-DOF Robots
	7-DOF Robots
Based on Control Method:	Open-Loop Robotic Arms
	Closed-Loop Robotic Arms
Based on Application:	Industrial Robotic Arm
	Medical Robotic Arm
	Space Robotic Arm
	Agriculture Robotic Arm
	Educational Robotic Arm
Based on Payload Capacity:	Light-Duty Robotic Arms
	Medium-Duty Robotic Arms:
	Heavy-Duty Robotic Arms

- **Cartesian Robotic Arm:** Cartesian robotic arms have a linear, block-like design with three perpendicular linear joints, allowing them to move along the X, Y, and Z axes. This design mimics the Cartesian coordinate system, offering precise and straightforward



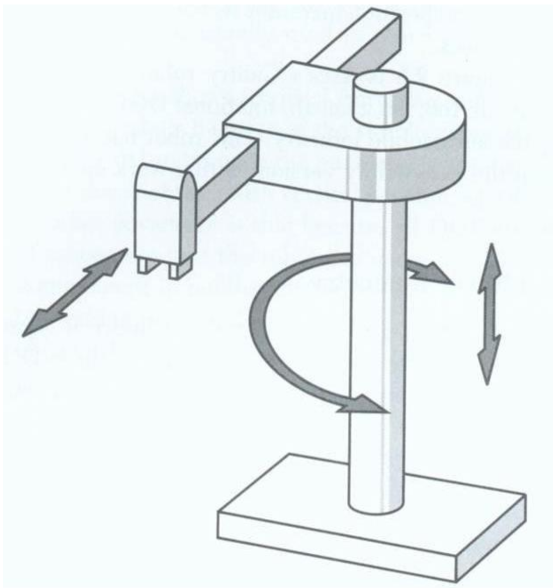


Figure 1 Cartesian Coordinate Robotic Arm

Figure 2 Cylindrical Robotic Arm

rectilinear movements. These robots excel in tasks that require accurate positioning in a three-dimensional workspace. Common applications include 3D printing, CNC machining, pick-and-place operations in electronics manufacturing, and material handling. Cartesian robots are also frequently used for laser cutting and engraving. Their design simplifies programming, as movements are along fixed, orthogonal axes. They are known for their precision, making them suitable for tasks demanding high accuracy. Additionally, they are robust and can handle heavy payloads. The limited range of motion along linear paths is a drawback for tasks requiring complex or curved trajectories. These robots may not be the best choice for applications with intricate, non-linear movements. (Bruno Siciliano, 2009)

- **Cylindrical Robotic Arms:** Cylindrical robotic arms combine rotary and linear joints. They have at least one rotary joint at the base for rotation and one linear joint that provides linear motion. This design allows them to follow a cylindrical path. Cylindrical robots are employed in tasks where both rotational and linear movements are essential. Applications include arc welding, screw driving, and tasks that involve repetitive, circular motions. They are also used in situations where the end-effector needs to be positioned at various points around a circular work-piece Cylindrical robots are efficient for tasks involving cylindrical work-pieces. They provide high precision for repetitive tasks like assembling and drilling holes in circular patterns. They are also known for their simplicity and ease of control. (Spong, 2005)
- **Spherical/Polar Robotic Arms:** Spherical or polar robotic arms have a spherical wrist that allows them to work in a spherical coordinate system. They combine rotary joints with a wrist that provides multi-axis spherical movement. These robots are well-suited for tasks that require the end-effector to reach points in all directions, making them valuable for applications like welding, painting, inspection, and 3D printing. They are often used in situations where versatility is crucial. Spherical robots offer a wide range of motion and can access points in any direction from their base. This flexibility makes them valuable for tasks that demand dynamic and multi-directional movements. Achieving high precision in all directions can be challenging due to the complexity of their kinematics. They may also require more sophisticated control algorithms. (Wu, 2008)

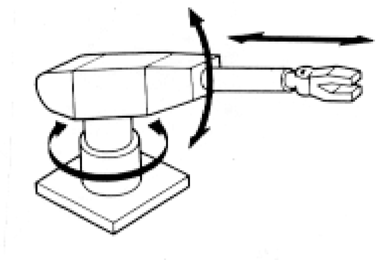


Figure 3 Spherical/Polar Robotic Arm

- **Articulated Robotic Arms:** Articulated robotic arms are characterized by multiple rotary joints (revolute joints), typically six or more, which provide a high degree of freedom and flexibility. These joints allow for complex movements and positioning. Articulated robots are among the most versatile and widely used robotic arms, finding applications in industries like manufacturing, automotive, and aerospace. They perform tasks such as assembly, welding, material handling, and even more delicate operations like surgical procedures. Their high number of degrees of freedom allows them to perform a wide range of tasks with precision. Articulated arms can access a broad workspace and handle diverse work-pieces.The complexity of their kinematics can make programming and control more challenging. They may require more advanced and specialized control algorithms.

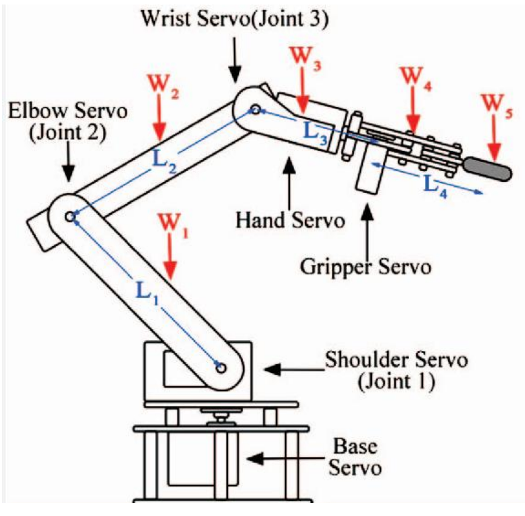
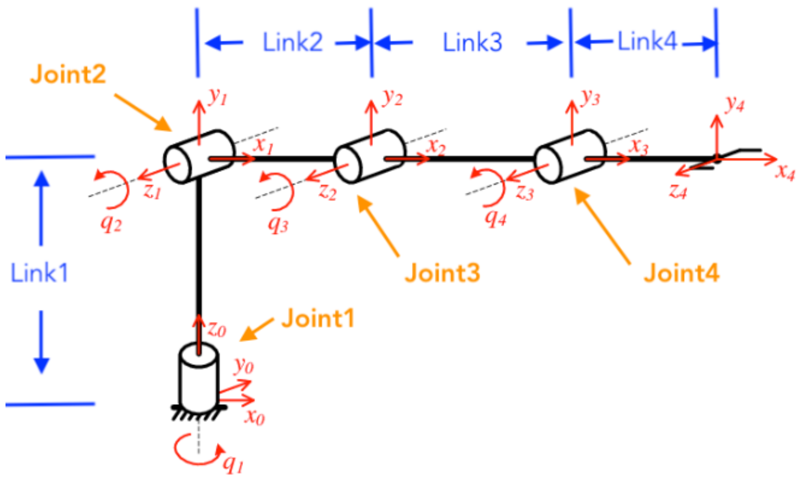


Figure 4 Articulated Robotic Arm

These classifications based on kinematics and design are essential for selecting the right robotic arm for specific applications. Each type offers unique advantages and limitations, making them suitable for different tasks and industries. (Gregorio, 2004)

- **4-DOF (Four Degrees of Freedom) Robots:** 4-DOF robots typically feature four joints that provide movement in four different directions. They are designed to perform tasks with a relatively limited range of motion. These robots are commonly used in applications where a simple and constrained range of motion is sufficient. For example, they might be employed in pick-and-place operations, where objects are moved from one location to another with basic vertical and horizontal motion. 4-DOF robots are often more straightforward to control and program due to their limited range of motion. They are suitable for tasks with less complex spatial requirements. The restricted range of motion can limit the versatility of these robots. They may not be well-suited for tasks that require precise positioning in multiple directions. (Dachang, 2008)



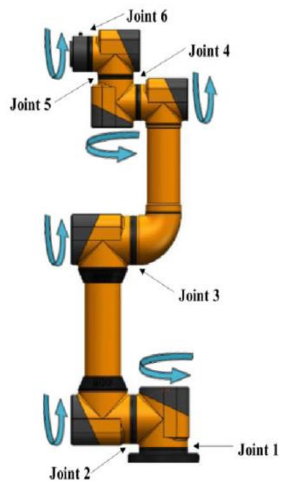


Figure 5 4 Dof Robotic Arm

Figure 6 6 Dof Robotic Arm

- **6-DOF (Six Degrees of Freedom) Robots:** 6-DOF robots are equipped with six joints, providing a more complex range of motion in six directions, often referred to as translation along the X, Y, and Z axes, and rotation around these axes (roll, pitch, and yaw). These robots are highly versatile and can perform a wide range of tasks that demand complex spatial movements and precise positioning. They are commonly used in applications such as advanced assembly, welding, machining, and robotic surgery. The additional degrees of freedom allow 6-DOF robots to handle tasks with intricate and muti-directional movements. They can access a broader workspace and offer superior dexterity. The increased complexity of their kinematics and control systems can make 6-DOF robots more challenging to program and operate. Additionally, they tend to be more expensive than lower-DOF counterparts.
- The choice between 4-DOF and 6-DOF robotic arms depends on the specific requirements of the task. While 4-DOF robots are suitable for relatively simple and constrained tasks, 6-DOF robots are preferred when precision, versatility, and a wide range of motion are essential. The right choice of DOF ensures that the robotic arm can meet the demands of the application effectively.
- **Industrial Robotic Arm:** Industrial robotic arms are advanced mechanical systems designed for automation in manufacturing and industrial settings. These versatile machines have transformed industries by enhancing productivity, precision, and efficiency. Here are the key details about industrial robotic arms:

Articulated Design: Most industrial robotic arms feature an articulated design, characterized by multiple rotary joints (revolute joints). These joints allow the arm to move with multiple degrees of freedom, making them highly flexible and versatile.

6 Degrees of Freedom (6-DOF): A typical industrial robotic arm has six degrees of freedom, enabling it to move in all directions within its workspace. These 6-DOF arms provide precise control over position and orientation.[1]

Industrial robotic arms use feedback control systems to ensure accurate and precise movements. Encoders and sensors provide real-time information about the arm's position and orientation, allowing for adjustments during operation. These arms are programmed using specialized software. Programming languages like RAPID (used in ABB robots) or KRL (KUKA Robot Language) are common. Some modern robots also support graphical programming interfaces, making it easier to program tasks. Robotic arms are extensively used in welding applications, such as arc welding and spot welding. They offer high repeatability and can work in hazardous or challenging environments. Industrial robotic arms excel in material handling tasks, where they transport and manipulate objects in manufacturing processes, distribution centers, and logistics. Robotic arms are employed in assembly lines for tasks like inserting components, fastening screws, and assembling complex products with precision and speed. In industries like automotive manufacturing, robotic arms are used for painting and applying coatings to achieve consistent quality and finish. Robotic arms automate the packaging and palliating of products, increasing efficiency and reducing manual labor in the packaging industry. Industrial robots are used in CNC (Computer Numerical Control) machining to perform tasks like milling, drilling, and grinding with precision. Vision systems integrated with robotic arms inspect products for defects and ensure quality control in various manufacturing processes.Industrial robotic arms have significantly transformed the manufacturing landscape by automating various processes, improving product quality, and enhancing efficiency.

Figure 7 Industrial Robotic Arm

Industrial robotic arms have significantly transformed the manufacturing landscape by automating various processes, improving product quality, and enhancing efficiency. They continue to play a crucial role in industries worldwide and are expected to evolve further with advancements in control systems and artificial intelligence.

Mechanical components:

A mechanism is a device transforms motion to desired patterns and making very low forces and creates little power. A machine usually contains mechanisms designed to provide significant forces and power. If a mechanism involves light forces and slow speeds, it is sometimes treated as a kinematic device that is analyzed without regard to forces. Machines, on the other hand, must be first treated as mechanisms. Their velocities and accelerations must be analyzed and then be treated as dynamic systems. Their static and dynamic forces caused by accelerations are kinematic-ally analyzed. Most applications in robotic involve motions at lower speed with low or moderate forces. [1] A wheel axle assembly is particularly useful when gears and belts are taken into account. Gears can change the direction or speed of movement, but modifying the speed of rotation affects the force transmitted reversely. A small gear meshed with a larger one will turn more rapidly, but with less strength. Spur gears, rack and pinion gears, bevel gears and worm gears are the four basic types of gears. Spur gears are the most common. In bevel gears, two wheels intermesh at an angle, which changes the direction of rotation because the axles are not parallel; the speed and force can be customized, if desired. Worm gears involve one wheel gear (better known as a pinion) and one shaft with a screw thread wrapped around it. Worm gears change the motion's direction, speed and force. Belts work like spur gears, with the difference that they can't change the direction of the motion. In gears and belts alike, the way to change the speed and force is through the size of two interacting wheels. In any pair, the bigger wheel will rotate slower but with greater force. This comes between the force and speed from the difference in the distance between the rotation point and the axle between the two wheels. The big and small gear has the same linear velocity at the contact point with the wheels. Otherwise, if it were to be unequal, one gear would spin faster than the other and would promptly rip off its teeth. As the parameter of the larger gear is greater, a point on it must cover a longer distance than a point on the smaller one to complete a revolution as a result of having the same linear speed. Therefore, the smaller gear completes more revolutions than its counterpart in the same time span. The force applied to the outer surface of each wheel needs to be equal or one of them would accelerate faster than the other which, again, would break the teeth of the other wheel. However, the forces being applied to the outer surfaces of the wheels are not of interest. Rather, the forces on the axles. The concept of levers allows us to know that the distance at which the force is applied affects the force yielded, and a wheel and axle work in the same fashion as a lever.

Parameters:

a) **Axis:** Axis are used for movement indication, one use for a line, two for a plane and three for a point at anywhere in space. (a robotic arm with lables, 2015) (Shirkhodaie, 1987) Roll pitch and yaw control are the main factors of a robotic arm axis, use for full control. Robotic arm working in 3 axis, 4axis, 5axis, 6axis, 7axis & muti-axis robotic arm is available. Figure 6 (Huang, 1997)shows a six axis- robotic arm. Freely moving are good for a three dimensions, rotating axis arm must be positive interactive for good stability. Mass of arm should be less for less force of inertia at different joints, lighter arm performs more dynamically than bulky arms at same stability level (Z. Kuijing, 2010). Industrial robotic arms are using bulky tool and weight of arm also very high, use for big construction. Robots may become flexible and less in weight by using multiple axis arms. (A. Bejo, 2009)

b) Degrees of Freedom: Robotic arm control all points (directionally) using their degrees of freedom. A human arm control by seven degrees of freedom, articulated arms typically have up to six degree of freedom (A. Bejo, 2009) (C.-H. Kuo, 2008). We can understand by n joint coordinates also known as internal coordinates. All coordinates depend on joints and describe the relative motion of beside links.

c) **Kinematics:** Robotic arm have a different joint of Cartesian, articulated, spherical and parallel etc., we arrange them for controlling a motion of a robotic arm (C.-H. Kuo, 2008). Robot kinematics is use for finding the movement of multi-axis and multi-degree of freedom. A chain of kinematic is used for making structure of robot; Figure 7 show arm kinematics and motion planning. (F. Zacharias, 2007) The priority of structure is different parts (rigid bodies) are properly connected at joint to provide excellent rotation, robotic kinematics use for know about velocity, acceleration and position of all rigid body part in the robotic system and decided all control movement. It also calculate exact force, torque, decide the role of motion, inertia and mass at every part of a robotic arm for making an efficient arm. (Atkeson, 2002)

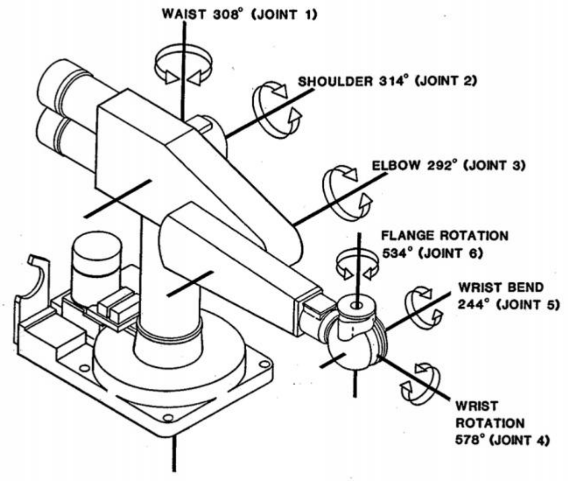


Figure 8 Kinematics of Robotic arm

a) **Payload:** A payload is a simply the weight that arm can be able to carry and movement possible with weight, Figure 8 show weight lifting robotic arm. It is important to maintain payload at the time of arms implementation and check how much weight arm can be lifted. It also includes weight of the entire arm with tools and dependent on a use of an arm in industries robotic arm use for heavy works so it should be high in industry arm and for normal use payload is 1 to 10 kg (H. Ueno and Y. Saito, 1996). range. Some tools are used for proper weight calculation. The robotic arm have maximum payload 500gm,the arm able up to maximum payload 7kg. industries arm having more payload than others.

b) **Speed and Acceleration:** It defines by each part and total, linear and angular movement. In this paper flexible and active motion obtain by using a visual result of present task due to this perform real time highspeed catching, high-speed vision camera system and generate fast result during an experiment. Robotic arm can be reached speed movement with a max velocity of 8m/s. Robotic arm all joint can work at very high joint speed of 360degree/s, they make arm and finger high speed. The closure of the fingers depend on the robot catches flying objects at different speed. The starting times for finger motion varies with the incoming object speed, i.e., approximately 33 ms (top) versus 50 ms (Bottom).

Conclusion

Discussed robotic arm and there different parameters. Understand which factor affect the performance of a robotic arm and how it change a robotic arm in work efficient arm. Know how multiple axis uses to change the mass of an arm, DOF increased by simply by adding joints and acceleration vary in different works, accuracy and repeat-ability is the important factor for any robotic arm. Also, use diagrams for making proper understanding of robotic arm. Then discussed gaps in research and issues, its use as a guideline for future research work, at last give suggestions how we try to improve a robotic arm by working on effective algorithms and simulations.

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