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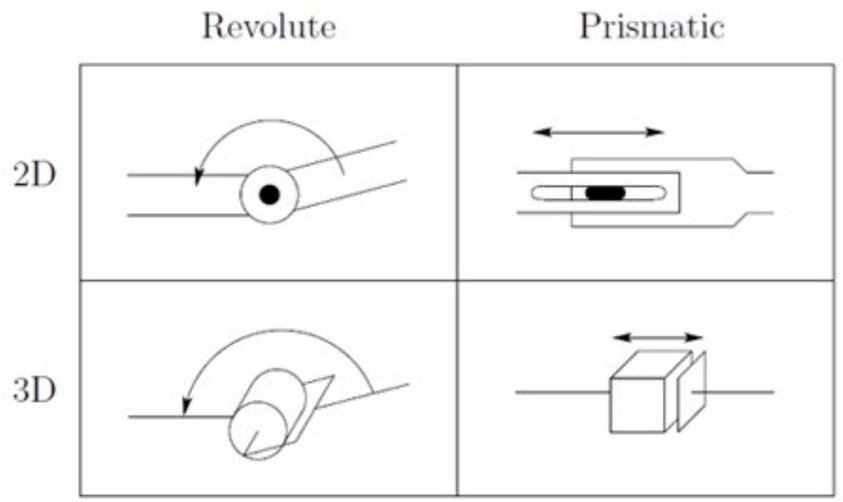
INTRODUCTION TO INDUSTRIAL ROBOTS

Industrial Robots Types

Contents

Initial considerations.

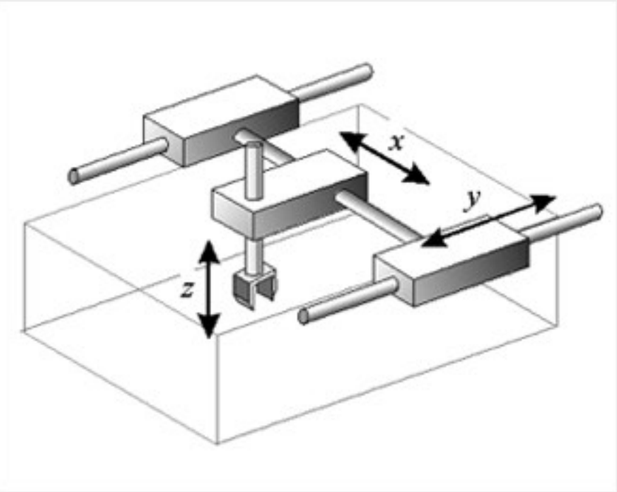


Before we present the different types of robots we must first introduce the concept of “degree of freedom” which is also known as an axis. An axis is a point of rotational (Revolute) or the line of linear movement (Prismatic). For example, a typical CNC milling machine has 3 prismatic axes and industrial robots typically have 6 revolute axes of rotation.

Robotic types

A simpler definition of robotic types can be narrowed down to five types: ***Cartesian, Cylindrical, SCARA, Delta and Articulated.*** Each industrial robot type has specific elements that make them best-suited for different applications. The main differentiators among them are their speed, size, and workspace.

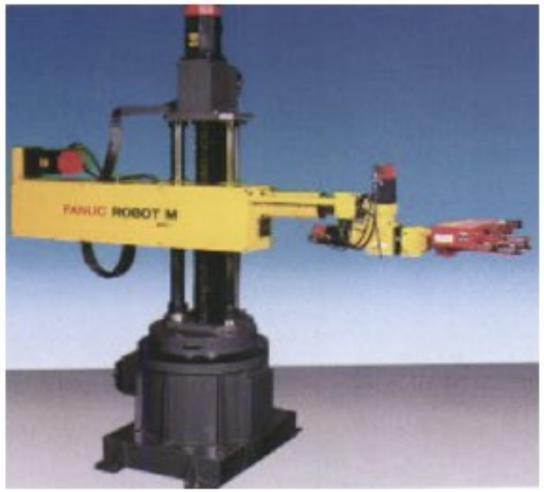
Cartesian

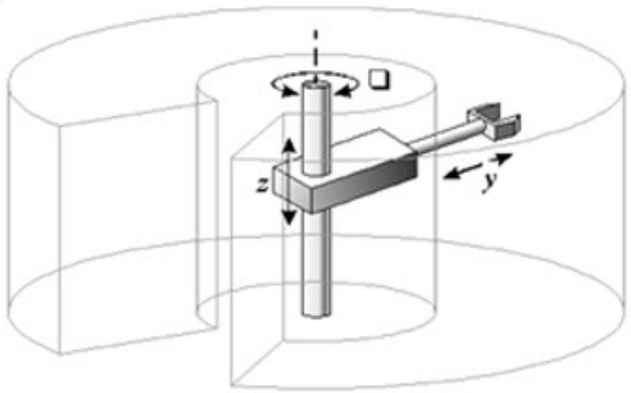


Cartesian robots are also called rectilinear or gantry robots. They are the most common type of robot used in industry. Cartesian robots have three prismatic joints that use the Cartesian coordinate system (X, Y, and Z). They may have an attached wrist to allow for additional rotational movement. The three prismatic joints deliver a linear motion along the axis and the workspace is in the form of a box.

Plant operators often default to this type because they are easy to use and program. The linear movements of the Cartesian elements give the robot a cube-shaped workspace that fits best with pick-and-place applications and can range from 100 millimeters to tens of meters. These robots are also a popular choice because they are highly customizable. Customers can determine the stroke lengths, speed, and precision of the robots because most of the parts arrive separately and are assembled by the machine builders. Overall, plant operators choose this robot design most often for the flexibility in their configuration that allows them to meet specific application needs.

Cylindrical

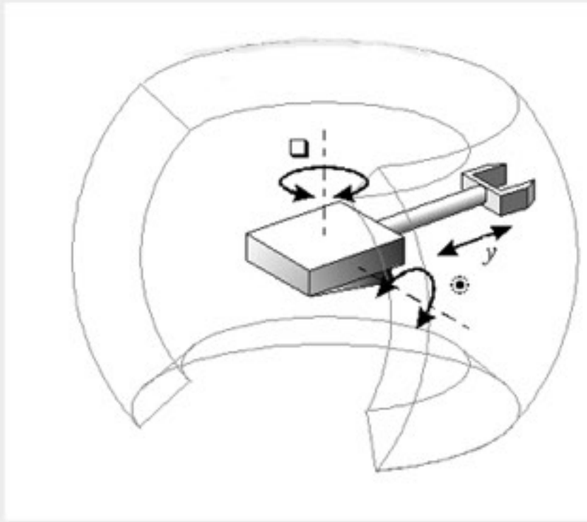




Cylindrical robots are very simple and like Cartesian in their axis of motion. Most Cylindrical robots are made of two moving elements: rotary and linear actuators. Because they have a cylindrical work envelope, machine designers might select them for their economy of space.

The robot can be placed in the middle of a workspace and, because of its rotation element, it can work anywhere around it. Simple applications where materials are picked up, rotated and then placed work best for Cylindrical robots. Installation and use are not complex, and they come as complete solutions with minimal assembly.

Spherical or Polar

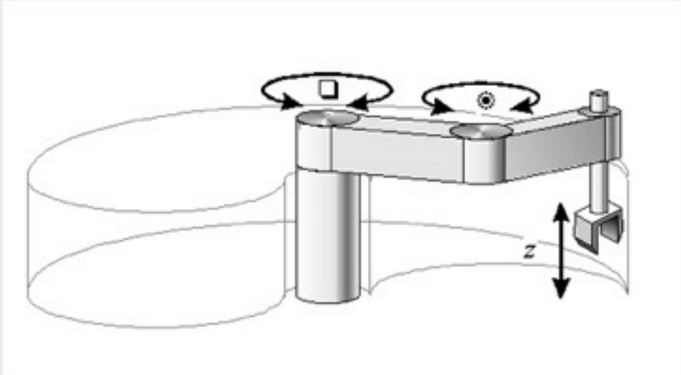


Spherical robots, also known as polar robots, are like cylindrical robots, but instead of having one rotary joint and two linear joints, they have two rotary joints and one linear joint. These robots can be used in some of the most basic robotic such as painting, welding, and assembly.

You won't find many of this type of robot on the market or in factories today. However, the spherical robot, as pictured above, is the one that started it all. Without spherical robotic technology, we would have never had the Unimate, the first industrial robot produced in the 1960s.

This robot allowed Unimate and other companies to develop advanced robot technologies such as the ubiquitous 6-axis electromechanical driven robots. Though it only had 5-axis, the Unimate robots significantly increased the pace of production for manufacturers to take notice. The industrial robot revolution started with this type of robot and the robot industry and manufacturers never looked back.

Scara



SCARA robots offer a more complete solution than the Cartesian or Cylindrical. It features two parallel joints that provide compliance in one selected plane. They are all-in-one robots, meaning a SCARA robot is equipped with x, y, z and rotary motion (4-axis) in one package that comes ready-to-go, apart from the end-of-arm tooling.

The work envelope is like Cylindrical robots, but it has more degrees of motion in a radius or arch-shaped space. Applications are also like Cylindrical and Cartesian robots, but SCARA robots can move quicker than the other two. They are seen often in bio-medical applications due to their small work area. Because SCARAs have the easiest integration they would appear to be the best solution for most applications, but Cartesians are more common because of their level of customization.

Delta or Parallel

Delta robots are the fastest and often most expensive. These spider-like robots are built from jointed parallelograms connected to a common base. They have a unique, truncated sphere work envelop and their main advantage is their speed and precision with which they operate.

Delta robots are best for fast pick-and-place or product transfer applications like moving small parts from a conveyor belt and placing them in boxes or onto another conveyor belt.

They also come as complete solutions for machine designers but are more complicated in use than the 6-Axis or SCARA robots. This robot configuration is capable of delicate, precise movement so they are heavily used in the food, pharmaceutical, and electronic industries.

Articulated

This robot design features rotary joints and can range from simple two joint structures to 10 or more revolute joints. The arm is connected to the base with a twisting joint. The links in the arm are connected by rotary joints. Each joint is called an axis and provides an additional degree of freedom, or range of motion. Industrial robots commonly have four or six electromechanically driven axes.

The most versatile 6-axis articulated robots operate like a human arm. They can take an object from a table-top and place it into a cupboard, something the other robot types cannot do easily.

6-axis robots can move quickly, come in complete solutions but their programming is more complicated, tedious and costly if you are manually programming the robot (teaching). This last factor has previously limited the economical use of robots to large production runs.

Articulated robots can be utilized for an incredible number of manufacturing processes and can be installed in an unlimited number of configurations using external manipulators (axes) that we are required to discuss them in a separate lesson. These robot types range in size from the very small to huge behemoths that can lift over 1000kg.

4-axis

4-axis articulated robots are primarily used for the transfer of materials (pick & place). Notice the link between first joint and the J3 arm. This keep the handling device always parallel with the base (floor) plate.

5-axis

The odds of any of you actually seeing a 5-axis articulated robot will higher than winning the Lottery. Stäubli introduced 5-axis models of their robot intended as a supplement or replacement of expensive 5-axis CNC machines. They created this model by blocking the J6 and replacing it with a machining spindle.

The idea was economically valid if you were cutting aluminum or composites, but not for steel. Stäubli, who has the reputation for the most accurate robots, discontinued the marketing and production of this model. They quickly discovered that the demand was not there, even with the better precision and rigidity, it was not enough. The production mangers preferd the versatility of 6-axis roubot with a spindle mounted on the J6.

6-axis

There are sub-group types of 6-axis articulated robots with differing joint methods design for specific processes or markets.

Articulated - Types - Subtypes

6-axis Spherical Wrist

The most popular and versatile industrial robot used in manufacturing is the 6-axis articulated spherical joint robot.

6-axis Offset Wrist

An offset wrist and/or offset joint robot has the centerline of the wrist offset from the centerline of the adjacent axis. The offset wrist design is typically used for welding since it allows the placement of a through-arm design.

If you look closely at the welding torch in the above example you will notice that the welding torch power and wire feed cables feed through the center of the final axis and through the upper arm. A through-arm design results in a slimmer manipulator without exterior cables or conduits to impede movement or snag in hard to reach or crowded areas.

6-axis Offset Joint

This type of 6-axis articulated robot has each axis offset from the adjacent axis. The smaller drive motors are in the interior of the arm/joint. The offset joint robots are widely used in machine loading tasks due their lower costs, ease of teaching and the integrated torque control sensor on each axis. This configuration will stop the robot movement if it collides with an object or more importantly, a person.

The torque sensors allow the user to easily manipulate the robot by pushing/pulling the J6 joint manually in space. Once you have the position the robot you can record the position on the control. For this reason, they are often called collaborative robots.

Articulated - Types - Subtypes

6-axis Three Roll, Hollow or Lemma Wrist Robots

These types of robot are typically found in paint spraying facilities where the robot must be sealed tightly against contamination or to prevent explosions.

7-axis

Some robot manufacturers add an additional joint between the 2nd and 3rd axis.

The redundant 7-Axis design provides increased freedom of motion and helps achieve optimum robot posture in difficult configurations, especially welding in tight places.

External axes & manipulators

Rotary Tables

A 6-axis robot can be assembled with a single rotary table or a 2-axis combination table as pictured. A rotary table allows the production team to rotate the part while keeping an optimal robot configuration.

External rotary tables are typically used in robotic welding since it allows the user to position the part where the robot and welding torch are in their optimal positions. A good example of this is keeping the torch position vertical while the table moves the part relative to the vertical welding torch with minimal robot movement.

Rotary tables come in many forms, configuration and sizes. They can be 1-axis, 2-axis, vertical, horizontal or even mounted on a single axis horizontal positioner. The motion of the rotary tables can be indexed (stationary while welding) or synchronous (rotating while the welding) if they have the correct motors and the control capability. For large object welding there are robust 2-axis rotary tables mounted on arm that be positioned vertically.

The programming of rotaries, if the part is held in one position (indexing), is not very difficult and can be done by manual programming (teaching) the robot. If the table must move in a synchronous movement with the torch it is extremely difficult or impossible to manually program economically. This type of production requires a very powerful off-line programming system.

External axes & manipulators

Gantries, Rails or Linear Axes

6-axis robots can be attached to linear axis rails to extend the robot's workspace envelop. A robot mounted on a single linear axis provides the advantage of working on long objects or workspaces while keeping the robot in an optimal configuration. The rails can range from 2m to 30m or more.

Robots mounted on overhead rails can easily do machine loading without wasting valuable workspace. Notice in the above photo how the J1 joint has an extended arm to facilitate the machine loading.

Production managers working on large objects can install a robot onto a 2 or 3 axis gantry configuration. This allows the production of large parts with the robot being able to reach into extremely variable positions.

A few large part welding shops will even combine a single horizontal axis or a 2-axis rotary table with a 3-axis gantry. This combination gives the production team the possibility to complete a wide range of complex parts.

The 2-axis rotary/3 axis gantry configuration absolutely requires a powerful off-line programming system to be operated efficiently and profitably.

Hybrid Robots

Combining the best of each

Kuka-China has developed an interesting hybrid robot that combines the versatility of a robot wrist and the accuracy and large workspace of a gantry cartesian robot.

They replaced the J1, J2 and J3 rotary joins with a precision linear axis gantry and combined with a robot, versatile J4, J5 and J6 wrist joints on the end of the Z-linear axis.

Robots come in many shapes, sizes and utility. Hopefully, you can understand why the 6-axis medium payload robots are typically the perfect choice for the versatile handling of large and heavier workpieces. They are the popular choice for machine tending, welding, grinding, polishing, deburring, laser/plasm/water-jet cutting, adhesive deposition and low accuracy machining (+- 0.2mm) applications, etc.

Robots are used in a wide range of industrial applications that provide process solutions for material handling, material joining, paint dispensing and spot welding, just to name a few. Robotic systems are seen everywhere in industry including the food and beverage, consumer goods, automotive, air and space, plastics, wood, and pharmaceutical industries.