Introduction to Robotics

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1 What is robotics?

When mentioning robots, many people will think about machines with hands and feet (Fig. 1a). However, this kind of machines often appears in scientific movies, entertainment, exhibitions and toy stores. They are very different from industrial robots. Industrial robots are abbreviated as IR. Most of them are simple apparatus. Sometimes they are called robotic arms (Fig. 1b). Robotic arms are used in performing simple up-and-down motion, to take and pick out components from machines. However, a lot of machines can be entirely controlled by programs to do different types of jobs, such as, searching, transportation, targeting, assembly and inspection.

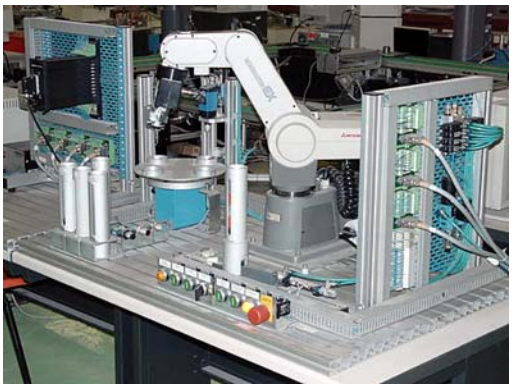


Fig. 1 (a) Robots (b) Robotic arms

In 1979, the American Robots Association has defined robots as '**a multi-functional operator which can be controlled by programs. It moves the materials, components, tools and other special apparatus through control programs to finish a series of work**'. Although many industrial machines do not possess human shapes, they satisfy the criteria and can be called robots.

Robots are being used widely in industries. It is estimated that a lot of industrial robots will be in service in near future. At present, scientists are designing robots with visions so that robots can accomplish more complicated tasks. The study of robots is called robotics.

2 Design of industrial robots

Industrial robots are made up of six basic constituent elements, they are: the dynamic system, the end-of-arm tool, the computerized digital controller, the actuators, the feedback devices and the sensor.

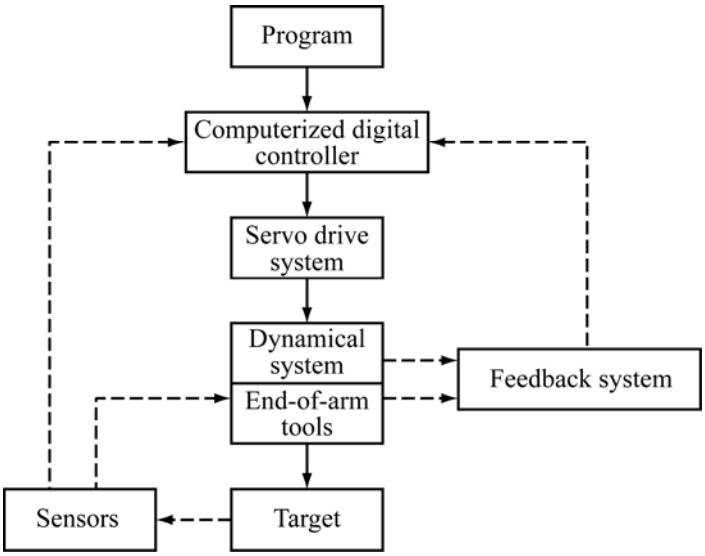


Fig. 2 Six basic elements of robots

(a) Dynamic system

Dynamic system is needed for movement in the working area. The most important of which is the robotic arm. According to the designs of the robots, the main axis will move linearly or rotationally. The number of axes represents the number of directions that a robot can move individually. It can be called 'the degree of freedom'. As shown in Fig. 3, if the volumes of robots are the same, the robot with 3 rotating axes or the highest degree of freedom has the larger working area. A robot usually has 2 to 10 axes, most of the robots have 5 to 6 degrees of freedom.

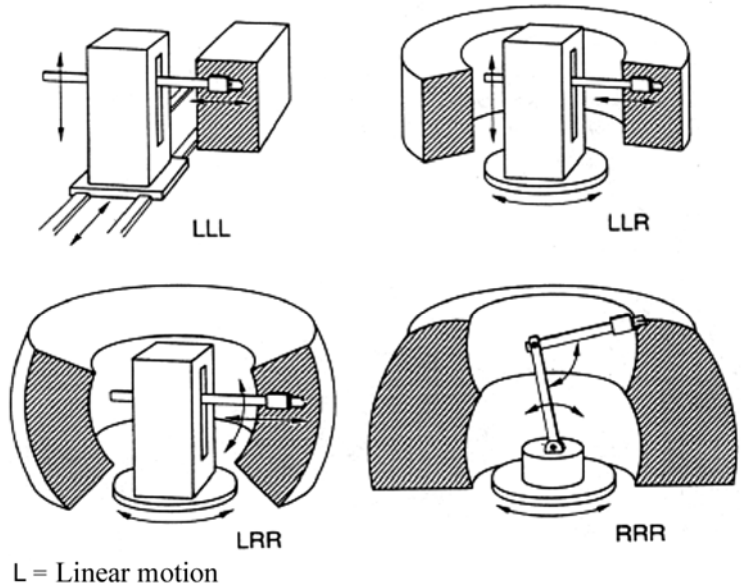


Fig. 3 Triadic structure and working area of industrial robots.

Usually, there are 3 types of drive systems, they are: electrical, hydraulic and pneumatic. Electrical system uses the dynamo to drive the robots. Simple electrical source is needed to provide energy, unlike hydraulic or pneumatic driving system that needs a lot of accessories. The advantages of an electrical system is that it is simple, clean and silent, but it cannot lift or move heavy object. It

is commonly used in middle sized or small sized robots.

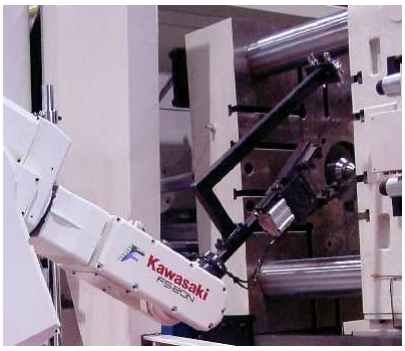
A hydraulic driving system uses the dynamo to pump oil in the storage unit, then compresses the piston to produce a driving force. The storage unit can produce an output driving force shortly with high pressure. So it can produce a larger driving force and can be controlled more easily. However, a hydraulic driving system is expensive and complex in structures. Leakage of oil is easy to occur in between the pipes and the components.

A pneumatic driving system has similar advantages to that of the hydraulic driving system. Pneumatic can produce a rapid movement with a smaller power. Most automatic chemical factories use pneumatic apparatus as the cost is low. However, since air is easier to compress, the accuracy of the movements of robots and the preciseness of moment control are lower. So, pneumatic driving systems usually need some assisting components or special design to determine their positions.

(b) End-of-arm tools

The arms of the robots can be used to install tools like clamps, welding guns, electromagnets, suction pads, hooks or paws, etc., in order to operate any specific procedure. A clamp is a multifunctional robotic arm tool. There are different designs. The clamp can be used to hold tight, keep and transmit components or tools, and make them to direct in a suitable position (Fig. 4). For instance, a clamp with 3 axes can perform complex actions like tilting forward and backward, swirl and swinging from left to right.

(a)



(b)

Fig. 4 Robots using different clamps

(c) Computerized digital controller

The computerized control system in robots controls each part to operate properly. It can input and store different programs where working sequence, linkage and relationships can be determined. In a process system, the computer in the robots may need to control or connect to other machines like the belt, the process machines, etc. Different computers in the robots may use different languages, like VAL, RAPID, etc.

Many robots also use an apparatus called the trainer which is connected to the controller. The trainer can control some of the motions of a robot, for instance, to direct the welding gun in the robotic arm to each welding tip. Robots also record information and store it in the computer, so that the information can be used repeatedly when the robots run. This can save time in programming.

(d) Actuators

Actuators control each of the axes and maintain the direction of moving. Since robots need to handle weights from various components, it has a larger change in motion. Therefore, the motion of actuators is very important. Commands about the direction of movement are sent from the computer of the robots and feedbacks are checked at the same time to ensure the moving parts follow the correct path. This process requires a high-speed computer to send out commands, and reading the machine's motion at reasonable speed.

(e) Feedback system

Feedback devices of a robot measure the position of each axis, moving velocity and its acceleration. Each axis can set any point as zero as the reference point, then relative linear movement can be performed. However, the clamp usually uses absolute measurement values. It is because when the robot begins to operate, the position of the clamp must be ensured.

(f) Sensors

Robots use sensors to identify and evaluate the change in position, difference in patterns and the hinders or failure of external systems. Table 1 lists some commonly used sensors.

Sense	Sensor	Things to be detected
Hearing	Microphones	Sound
Vision	Light dependent resistors	Light
Touch	Thermometer and contact tip	Heat, weight, pressure, shapes, dimensions, position
Smell	Gas or smell detectors	Smell

Table 1 Commonly used sensors.

3 Operation of industrial robots

There is a lot of flexibility in operations of industrial robots, IR can handle demands of different tasks. This is because IRs are controlled by computer programs. Therefore, by changing the program, operations can be changed accordingly. This is similar to numerically controlled machine tools. Both the computer and the numerically controlled machine tools of robots need a lot of memory, repeatable execution programs, program editing apparatus, accessory functions in input and output, and rapid calculating ability.

However, computers in IR required some special functions like input programs for trainers, remain horizontal movement in swinging arms (Fig. 5), and automatic force compensation when holding heavy objects. The operation mode of IR can be classified as: point-to-point and continuous path.

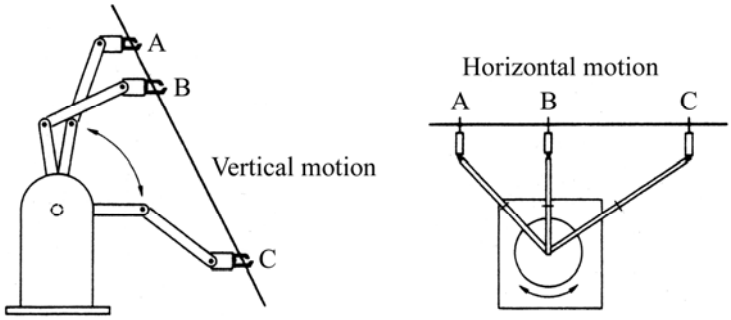
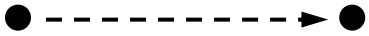


Fig. 5 Clamp is maintained in linear movement

(a) Point to point

When a robot moves in various individual and specific positions according to the instructions in the program, the operation mode is called point to point. This type of robot has a feedback and servomechanism in each of its axis, but the motion and moving path from one point to another is independent of other points. When using this operation mode, programs can be edited by trainer method or manual input. The control system for point to point is relatively simple, so it is more suitable to control components in the numerically controlled machineries.



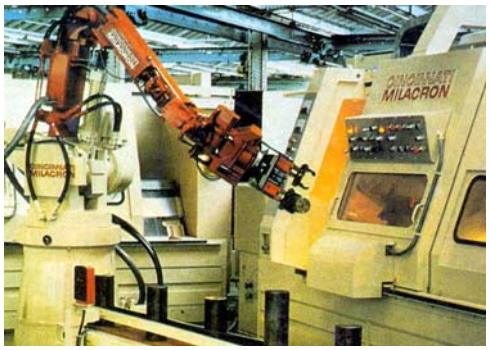
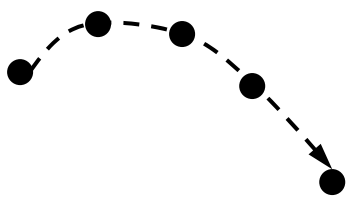


Fig. 6 Point to point operation (b) Handling components

(b) Continuous path

If a robot has to follow the path of the program totally, this operation mode is called continuous path. This type of robot has a feedback and servomechanism in each of its axis. It can also move to any points between the polar positions. Robots with continuous path as operation mode can handle more complicated tasks, like welding of metal in a particular path (Fig. 7), spraying paints on the surface of a car, etc. When using this type of operation mode, it is better to use the method of trainer to write the program.



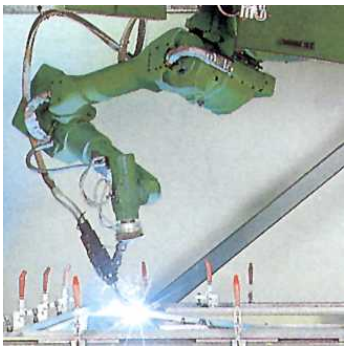


Fig. 7 Continuous path operation (b) Welding

4 Applications of industrial robots

Industrial robots are being used widely in factories, they can be used for tasks like welding, painting, transportation of materials and tools. Table 2 shows the distributions of applications of IR in the year 1990.

Application	Percentage
Welding	26%
Handling materials	22%
Load-and-unload of cutting machineries	17%
Assembling components	15%
Cast treatment	11%
Painting and surface treatment	8%
Others	1%

Table 2 Distributions of applications of IR in 1990

(a) Welding

There are various types of welding, including spot welding, electrical welding and wind welding, etc. IR is often used to operate spot welding. Spot welding is suitable for joining two pieces of steel plates. Its working principle is that the two pieces of steel plates are first joined by two electrodes, a large current is produced when pressure is added. As the electrical energy of the current melts the metal on the joints, they are then joined together rapidly. Generally, there are more than several thousands of welding joints in a car. If the process is done manually, the quality may be unstable. Therefore, robots are more suitable for this kind of repetitive work (Fig. 8).

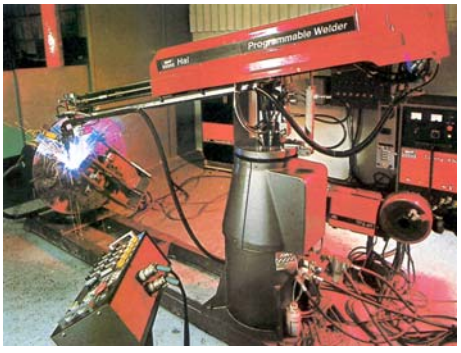


Fig. 8 Robotic arm in welding machines

Fig. 9 Robots handling materials

(b) Handling materials

Robots can be used to handle materials, for instance, put and pick out materials from the machineries and transportation of materials (Fig. 9) etc. Robots can also take materials out from the production line, move machinery vehicles in a factory automatically and stack up the goods (materials, semi-finished goods, components, etc).

Take press brake machining procedure as an example, the metal foils are pressed into different shapes, like the outer case of the car, the case for circuits, etc. Since these procedures are very dangerous, it is necessary to use robots to replace workers. Robots are responsible for picking up the metal foil and put it on the suitable position in the press brake machine. The finished products will be selected and stacked together and delivered to the next step of the product line.

(c) Load and unload of cutting tools

If a worker is responsible for the loading and unloading of cutting tools, the machines and the connected parts has to stop to ensure the safety for the worker. If a robot works with the machineries instead, only the clamp tip has to stop operating. Other procedures can continue to operate. If the load and unload commands are preset in the program of the robots, the robots can take out the cutting tools quickly, replace the cutting tools on the clamp tip and put the old ones back to the cutting tools storage. This process only takes about a few seconds (Fig. 10). After replacing the cutting tools, the machineries can start again. Therefore, the use of robots has shortened the time of changing cutting tools.

Fig. 10 Robotic arm in load-and-unload cutting tools procedure

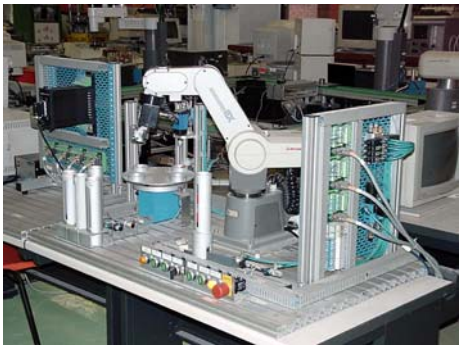


Fig. 11 Robot for assembling components

(d) Assembling components

Besides handling materials, robots are used to assemble components (Fig. 11). For instance, robots can use the suction pad to assemble the window on the car. Using robots to assemble the machines has a lot of advantages. For example, robots can maintain stable production. They ensure the hygiene and can work under dangerous circumstances.

(e) Cast treatment

Moulding is the process of injecting the melting metal into a mould. When the metal cools down, the desired product is produced. Since the materials for moulding and the product are very hot, the workers may get hurt. Therefore, robots are used to pour the melted metal, handle the finished products and carry out initial treatment of the surface. Robots can work 24 hours a day, so the production cost is lower though the machineries are very expensive.

(f) Painting

Spray painting is the use of gas to spray the paint as dots and scatter them evenly on the surface of the finished products. However, frequent inhalation of paint affects the health of the workers. Therefore, it is better to use robots to do the routine spraying task (Fig. 12). For instance, a robot paints cars in the production line with a spray gun. Using robots with continuous path operation mode, robots can spray the paint quickly and evenly on the car, so it can improve the quality of the cars.

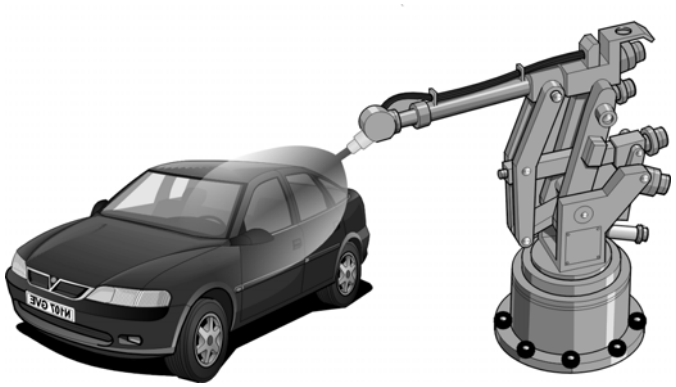


Fig. 12 Spraying the paint on the casing of the car by the use of robotic arm

5 The advantages of robots

Robots are widely used because they have several advantages:

1. Robots can carry out simple and repetitive work for human beings.
2. Robots do not take rest and so can work continuously for a longer period. The productivity is raised.
3. They can be used in assembly work with high precision and density. The quality of products is enhanced.
4. Robots can replace workers without laboring cost, and robots can achieve stable production rate as robots will not be late to work, resign, take day off or strike.
5. The program can be modified easily so robots can increase the flexibility in manufacturing.
6. They can work in unfavourable circumstances, e.g. removing the high-temperature artifact from a casting machine, welding task, spraying task, transportation of chemicals, etc., such work will affect the health of the workers.
7. The manufacturing speed can be increased and the cost be reduced when robots are used.
8. Using robots may minimize the wasting of materials.
9. Using robots can improve the quality of a product by its ability to assemble precise components.

6 The restrictions of robots

Despite the advantages in using robots, there are a lot of restrictions as well:

1. There are limitations in the senses of robots. Therefore, it is difficult for them to accomplish tasks with a lot of observations, like identifying different materials.
2. Robots cannot do tasks which are too precise or delicate, for instance, grinding of small gold jewelry and making pottery, etc.
3. The abilities of a robot can be fully expressed under a good mechanical technician and operator.
4. The cost for setting up a robot for industrial use is very high. Medium scale and small-scale factories may not be able to afford.
5. It is very time consuming to compile the operation programs for robots. Each degree of freedom should be tested repeatedly and the position should be set. Therefore a robot is more suitable to be used in large scale production line. It is not suitable for production in small quantity.
6. The space for factories using robots must be large enough for them to work to avoid accidents.

7 Safety precautions in robots

To ensure safety, the following safety precautions should be noted when using robots:

1. Use protective cover to prevent workers from being in contact with the robots in operation or working area.
2. Robots should be equipped with safety precautions like alarms, flashes and shields, etc.
3. Understand the tensile strength of the robot and avoid overloading.
4. Take measures to avoid bug or failure of the software, for instance, robots equipped with several processors; auto disconnection when computer cannot be connected with the robots for a long time; two computers working simultaneously to check the data, etc.
5. Always test and maintain to avoid the malfunction of robots. For instance, addition of sensors to test and track information of voltage, pressure, temperature, velocity and acceleration, etc. Backup hardware should be added to prevent malfunction, for instance, when carrying load, more operating machines should be used, so as to avoid accidents when one of them fails to function properly and drops the heavy load.
6. Use multi-safety design to ensure the robots can stop when malfunction, such as an emergency brake and automatic halt during prolonged use.
7. Training should be given to operators to ensure they have adequate knowledge to handle sudden changes or accidents caused by the robots.

Interactive Information

	Website	Content in brief	Language
1.	http://www.lego.com/dacta/tobolab/default.com	Introduces components of LEGO robots	English
2.	http://www.sciencekits.com/robots1.html	Introduces components of robots for beginners	English
3.	http://www.ljkamm.com/robots.htm	Contains article about robots	English

Exercise

1. What are the three basic driving modes in the dynamic system of industrial robots?
2. What kind of tools can be installed at the end of a robotic arm?
3. What is the use of the actuator in a robot?
4. What are the uses of the touch sensors in robots?
5. What are the six basic elements of industrial robots?
6. Write down the definition of a robot by the American Robots Association.
7. What is the degree of freedom of a robotic arm?
8. List those merits and limitations associated with the use of pneumatic system in driving robots.
9. What are the two main operational modes of industrial robots? Briefly describe two operational modes.
10.

(i) What are the welding procedures that a welding robot can do?

(ii) Explain and describe the working principles of a spot welding robot.

(iii) In what industrial field is a spot welding robot widely used? Compare the merits of spot welding by robot and manual welding.