Robotics : Applications and Fundamentals

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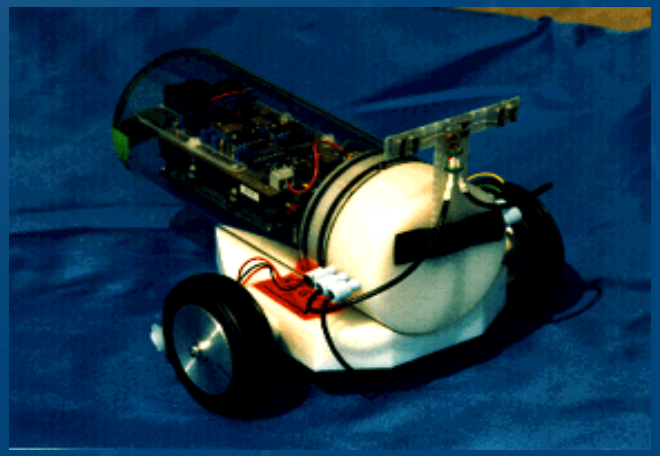
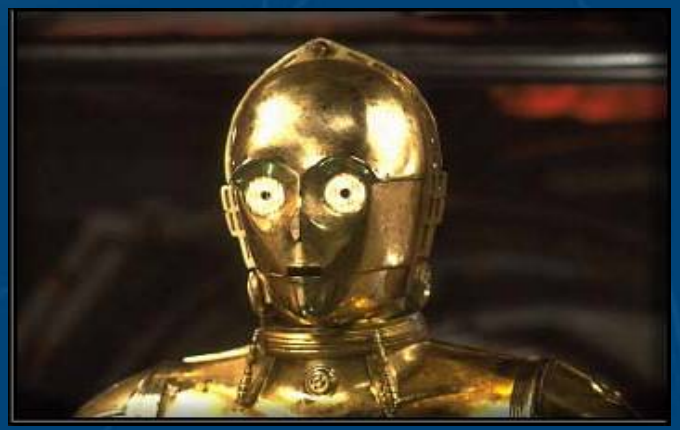


The word “ROBOT”

- In the 1920's, Karl Capek from Czechoslovakia introduced the world's first *robot* on stage. His play was entitled "Rossum's Universal Robots." The theme of the play was *robots* controlling humans in society.
- The word "*robot*," a Czech term for forced labour or serf, was also introduced by a Capek. Karl was wondering what to call the "artificial workers" in his play, and he thought they should be called "labori." His brother didn't like that idea, and muttered that they should be called "*robots*." Then, the term "*robot*" was born.

Hollywood’s Concept

- Many movies show robots as harmful, menacing machines.
- More recent movies. however. like the 1977 "Star Wars". portray robots such as "C3PO" as man's helpers.
- These fictional robots which are made to look human are called "androids...



The Robot Revolution

- In 1941 science fiction writer Isaac Asimov first used the word “robotics" to describe the technology of robots and predicted the rise of a powerful robot industry.
- His prediction has come true. Recently there has been explosive growth in the development and use of industrial robots to the extent that terms like “robot revolution", "robot age" and "robot era" are used.
- "Robotics" is now an accepted word which describes all technologies associated with robots.

The Robot Revolution

- In 1956, George Devol and Joseph Engelberger formed the world's first robot company.
- Devol predicted that the industrial robot would "help the factory operator in a way that can be compared to business machines as an aid to the office worker".
- A few years later, in 1961, the very first industrial robot was "employed" in a General Motors automobile factory in New Jersey.
- Since 1980. there has been an expansion of industrial robots into non-automotive industries.
- The main factor responsible for this growth has been the technical improvements in robots due to advancements in microelectronics ("ME") and computers.

The Robot Revolution

- Today, real, working, sophisticated robots are in use today and they are revolutionizing the workplace. These robots do not resemble the romantic android concept of robots.
- They are industrial manipulators and are really computer controlled "arms and hands". Industrial robots are so different from the popular image that it would not be easy for the average person to recognize one.

Today, most robots are designed to perform specific material handling and manufacturing operations such as welding, spray painting and machining. This large industrial robot can function as a spot welder or a material handler. It has an amazing accuracy of repeating its movements to within 2mm (1/16 in.) !

Flexible Manufacturing System

- For years, automatic machines have been performing labor-saving work and efficiently repeating tasks such as churning out millions of one type of part.
- Unfortunately, automatic machines are not suited to small batch work since physical changes must be made to the machine in order for it to perform a different task. This inflexibility of automatic machines has led to the term "hard" automation.
- Robots, on the other hand, are flexible and can be easily switched to perform different jobs by simply changing the robot control program. This procedure is called "reprogramming". Robots are "soft" automation and make this "flexible manufacturing system" or "FMS" a reality.

Benefits of Robots

- Industrial robots can improve the quality of life by freeing workers from dirty, boring, dangerous, and heavy labor.
- The benefits of robots to industry include improved management control and productivity and consistently high quality products.
- Industrial robots can work tirelessly night and day on an assembly line without any loss in performance.
- Consequently. they can greatly reduce the costs of manufactured goods.
- As a result, industries that effectively use robots will have an economic advantage on world markets.

Service Robots

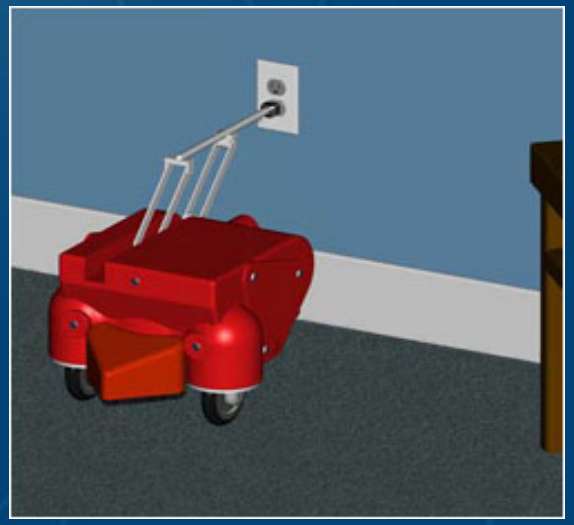
- Recent breakthroughs in robotics are starting to create new roles for robots.
- New mobile robots can perform multiple tasks in a great variety of environments. These non-industrial robots are sometimes called service robots.
- Service robots are used for entertainment, education. personal, and social welfare purposes.

- Prototype units roll down the corridors in hospitals and prisons and serve food and snacks.
- Others navigate in offices and deliver mail to the workers.
- Service robots are ideally suited for working in hazardous areas and have proven valuable for use in dangerous situations such as in bomb disposal and in radio- active and chemically contaminated environments.

The Future

- Future robots will be able to relieve man of many types of physical work.

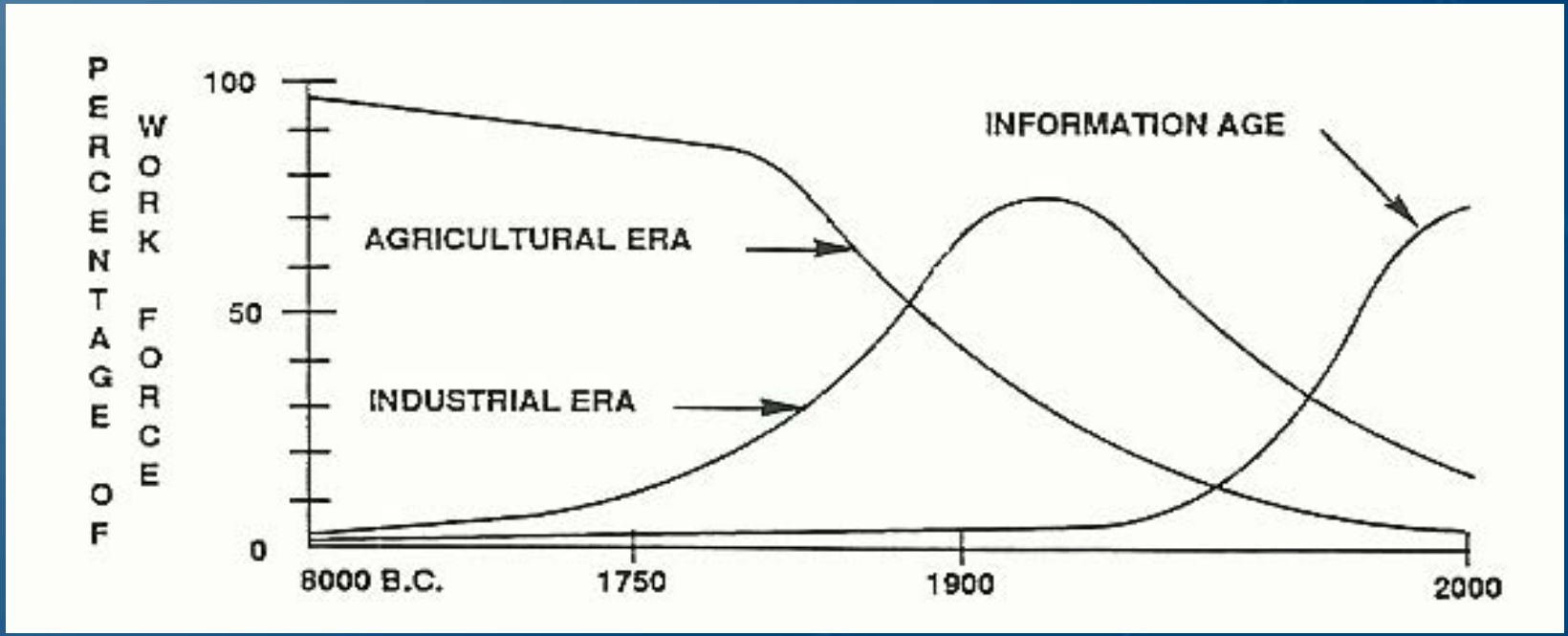
In-home personal/ domestic robot



- When robots enter the public domain, the robot revolution will demand that information age people be “robot literate.”

The Robot in Technological History

- Three major time periods make up technological history: the **agricultural** era, the **industrial** era, and the **information age**. The development of the robot can be seen as logical and important part of this history .



Information Age

- In the middle of the 20th century came new industries based on science. Technological improvements in microelectronics made the electronic computer possible.
- The computer revolutionized the way we process and communicate information.
- Information technology, or “IT”, has a major impact on society. Computers. fiber optics. radio. television and communication satellites are just some examples of devices that have had a tremendous effect on our lifestyle and economy.
- A higher percentage of jobs now require "knowledge workers" and fewer and fewer jobs require "production workers".
- IT has also been responsible for spectacular growth in robot technology.
- As the information era progresses. it is expected that more and more of man's physical work will be done by robots.

Mechatronics

- So what does all this history have to do with ROBOTS?
- Since the introduction of advanced miniature computers in the 1970's, robot technology has made great gains. Modern computers have given a "brain" to the "muscle" of robot mechanics.
- The Japanese have coined a new word, "mechatronics", to describe this fusion.

Robot Numbers Growing

- The year 1980 has been called "the first year of the robot era" because the production value of industrial robots increased more than 80% from the previous year.
- The growth in the total number of industrial robots in use since 1980 is similar to the exponential growth of technological change.
- Japan leads in the use of industrial robots.

Robot Evolution

- **First generation robots** are reprogrammable, arm-type, manipulative devices which are only capable of memorizing repetitive movements.
- A first generation robot has internal sensors which help it to position the mechanics accurately.
- **Second generation robots** (1980's)have external sensors (usually touch or simple visual) which give the robot information (called feedback) about the outside world.
- Second generation robots are also able to make limited choices or decisions and respond to the working environment. These are known as adaptive robots.

Third Generation Robots

The Late 90's and Beyond

- Third generation robots will employ "AI" or artificial intelligence provided by advanced computers.
- "AI" computers can not only "crunch" numbers but also program themselves, make judgements, logically reason and "learn" and "think".
- "AI" will give computers the power to solve problems in intelligent ways and interpret complex Information from advanced visual sensors.
- This will permit the robot to be travel without the aid of human supervisors or pre-marked routes.

What is a Robot?

- Here are some examples of of the many general definitions of a robot:
  - a." A robot is any machine or mechanical device that operates automatically with human-like skill." -Random House Dictionary
  - b. " A machine that in appearance or behavior imitates either a person or a specific action of that person. such as limb movement. " -Robots by Peter Marsh
  - c. " A robot is a machine that does something automatically in response to its environment." -Steve Mendelsohn in Robot Review
  - d. " A robot is a bunch of motors controlled by a programmable computer. " -BERT by Karl Brown
  - e. "A robot is a computer with 'muscles'." -Dr. John Billingsley

Automatons

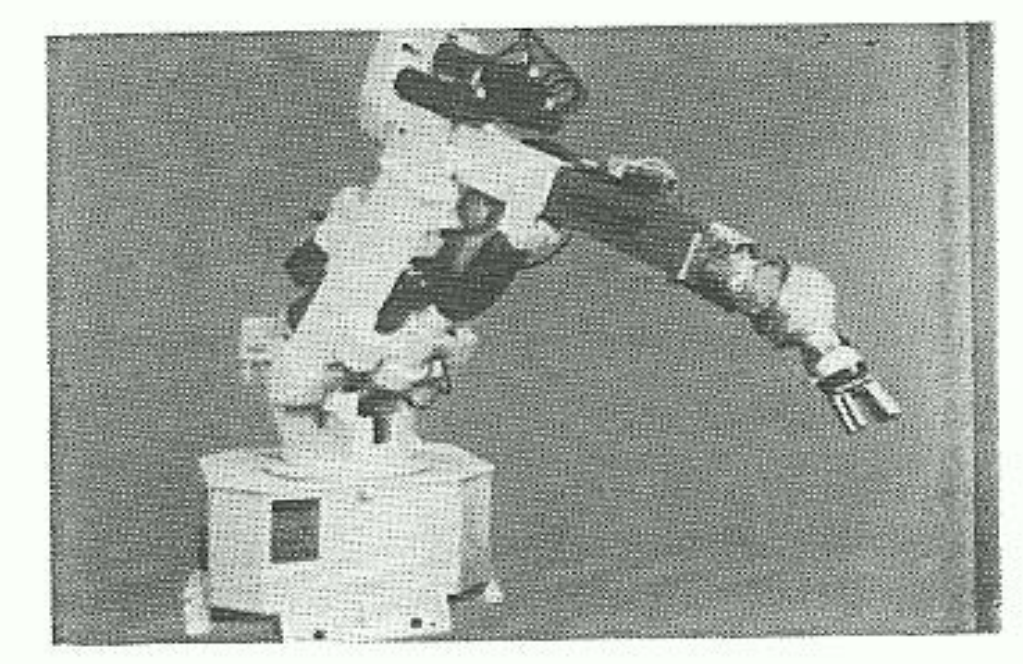
- From the previous definitions it is evident that even the experts do not agree on a general definition of a robot.
- Most agree about the definition of a "non-robot".
- An "automaton" is not a robot
- **Automatons** are machines which carry out a number of mechanical operations under automatic control. A washing machine is an automaton because it automatically washes. rinses and spin dries your clothes but it is not normally considered to be a robot!

Human Likeness

- Robots are really "evolved" automatons.
- One important way in which robots differ from automatic machines is that they are generally designed to duplicate the actions and work formerly done by man.
- The human likeness generated by robots mimicking our actions reminds us of ourselves. For example. industrial manipulators look very much like giant human arms.

Human Likeness

- This industrial robot has a human-like arm and wrist which can outperform a human being: it can lift 90kg (200 lb), repeat its actions to within 0.5mm (1/32 in.) and move faster and farther. It is not human-like in that it weights 2700kg (6000 lbs).



Robot Characteristics

- Robots are:
  - machines - mechanical devices designed for doing work.
  - automatic - operations which are executed without external help.
  - reprogrammable - multifunctional and flexible: not restricted to one job but can be programmed to perform many jobs (nearly all robot systems contain a reprogrammable computer).
  - responsive - must be able to react based on their sensory input.

More Specific Definitions

- Robots cover such a broad range of devices that they have been given special definitions by different groups.
- Japanese Industrial Robot Association (JIRA): Robots are "devices capable of moving in a flexible manner analogous to the moving parts of living organisms, with or without intellectual functions, allowing operations in response to human commands".
- Robot Institute of America (RIA): An Industrial Robot is "a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.“
- Implications

Teleoperators

- Teleoperators may or may not be categorized as robots.
- Teleoperators are controlled remotely by a human operator.
- When they are considered robots they are sometimes called "telerobots".
- teleoperators are usually very sophisticated and extremely useful in hazardous environments such as chemical spills and bomb disposal.

Robots are Hard to Define

- As the field of robotics rapidly progresses it is not necessarily a bad thing that everyone has not agreed on a universal definition for a robot
- Robots are likely to outgrow any definition placed upon them.
- Perhaps Joseph Engelberger, father of the industrial robot, summed it up best when he said: "I may not be able to define one, but I know one when I see one."

Types of Robots

- Robots can be classified according to six different characteristics:
  - use
  - mobility
  - motion control
  - Capability
  - arm configuration
  - end effector.

Use

- Industrial robots
  - first used on the factory floor in welding, painting, and materials handling.
  - Most factory robots are primarily fixed location manipulative "arms and hands".
  - Industrial robots are now starting to be outside of the factory in construction, mining, forestry, and agriculture.
- Non-Industrial robots
  - Dangerous environment robots: bomb disposal, chemical spills.
  - Social Welfare robots: assisting nurses and the disabled.
  - Domestic/Personal robots: cleaning, security.
  - Educational robots: to teach and familiarize students and hobbyists with the major concepts of robotics.
  - Show and Entertainment robots: used for advertising, conventions, and fairs, also in television and films.

Mobility

- Fixed Robots
  - Fixed robots can only work within a limited space or area. Until recently all industrial robots were fixed to a pedestal base which was bolted to the floor but now some fixed robots are mounted to provide limited mobility.
- Mobile Robots
  - Mobile robots permit work in a variety of locations. Three main types of land locomotion are used: wheeled, tracked, and legged. Normally, legged robots have four to six legs: two-legged robots are presently very difficult to make. Other types of locomotion include propeller drive systems for submersibles.

Motion Control

- Non-Servo Control
  - Non-Servo robots have their movements set and limited by mechanical end stops. Movement continues until it literally "bangs" in to the end point.
  - cannot accurately stop between end points.
  - useful for simple tasks where movement between two points in space is all that is required.
  - sometimes called "pick and place" or "bang-bang“ robots.

Motion Control

- Servo-controlled robots
  - much more flexible.
  - can be made to stop at any number of points within its working space.
  - built-in sensing ability that constantly "feeds back" the actual position and compares it to the intended position.
  - constant corrections are made automatically to reduce the tracking error.
  - precise movements accurate to less than 2mm (1/16 in.) are made possible!
  - servo-controlled robots permit the complex tracking of perfect straight lines. curves and circles.

Capability

- First Generation Robots include both playback and numerically-controlled (NC) robots.
  - playback robots memorize a route which it has been "taught" by a human operator who physically guides the robot along the desired route. An excellent
    - example of a playback robot is a spray painting robot which has memorized the movements of a human spray painting an object.
  - numerically controlled (NC) machines more advanced
    - no physical teaching is necessary , movements are programmed directly into memory by the programmer .
    - main disadvantage of first generation robots, little or no sensory feedback.
    - If a piece of material to be drilled was incorrectly positioned it would drill it anyway. Or, if a human wandered in front of the robot while it was welding, it would be happy to weld him to the job!

Capability

- Second generation robots
  - incorporate basic sensory systems to feedback information to the computer controller
  - can respond to their environment.
    - For example, infrared sensors might detect that a human has entered the danger zone. This information is fed back to the computer, a decision is made based on memorized "choices", and the robot is stopped.
  - sometimes called adaptive robots.

Capability

- Third generation robots
  - use artificial intelligence (AI) computers.
  - able to recognize, learn and think.
  - able to program themselves and adapt to new situations not previously known to them.

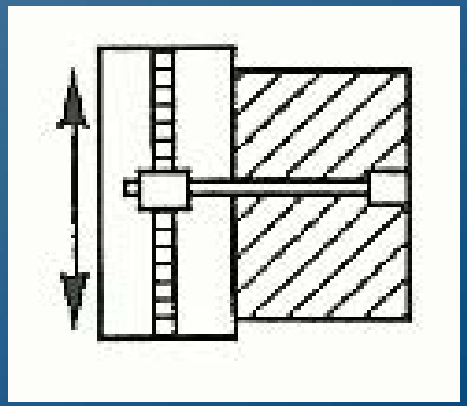
MA RBIII STAR

Arm Configuration

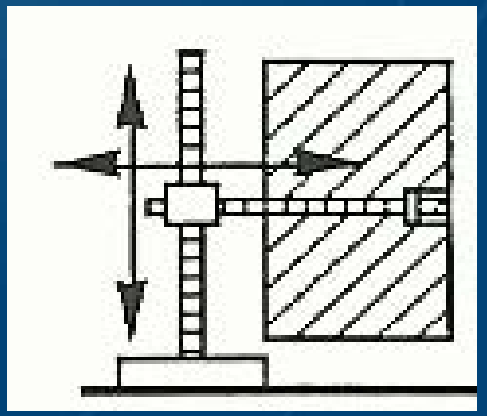
- Robots that have arms:
  - classified according to their arm type configuration
    or
  - classified according to the arrangement and the shape of motion or work envelope (the three dimensional volume of space in which the robot manipulator is capable of working).
  - Each of the five basic work envelopes will be illustrated using a top view and a side view. The combined views make the three dimensional work envelope shape.

Arm Configuration

- Rectangular Coordinate Robot
  - has a cube shaped work envelope. The side view shows that its horizontal arm can rise and fall on the vertical column and also move in and out. The top view shows that it slides back and forth on its base instead of pivoting. These robots are easily programmed. relatively inexpensive. and very precise in operation.



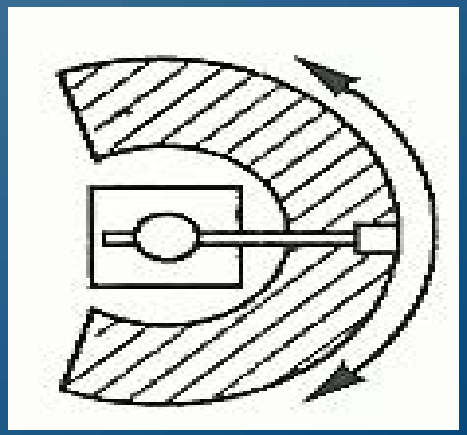
Top view



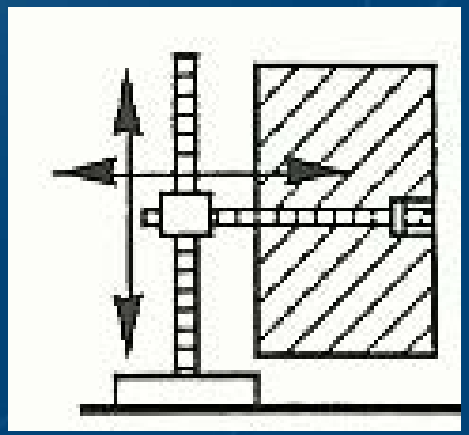
Side view

Arm Configuration

- Cylindrical Coordinate Robot
  - work envelope is a portion of a cylinder. In the side view it can be seen that the arm has the same movements as the rectangular coordinate robot. However . in the top view it can be seen that the entire arm can pivot or rotate around the base, although it cannot rotate a full 360 degrees.



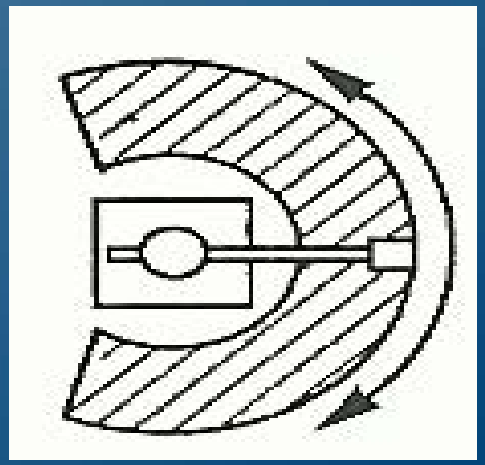
Top view



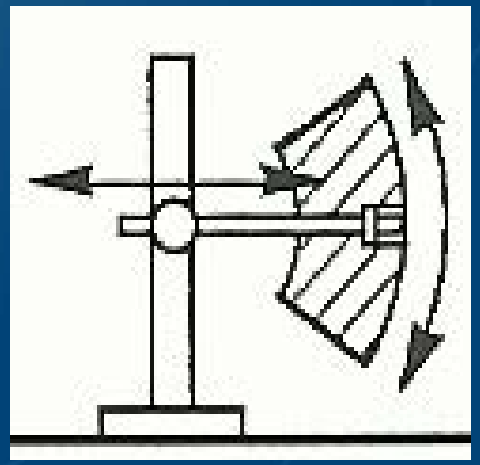
Side view

Arm Configuration

- Spherical Coordinate Robot
  - work envelope shape is a portion of a sphere. In the top view the action is the same as the cylindrical robot. However, In the side view It can be seen that It does not rise and fall on the vertical column but Instead pivots up and down to form an arc.
  - useful for lifting and moving objects.



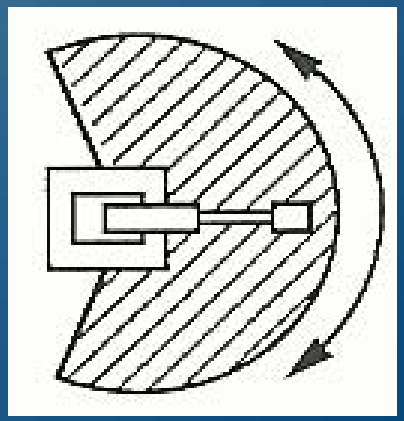
Top view



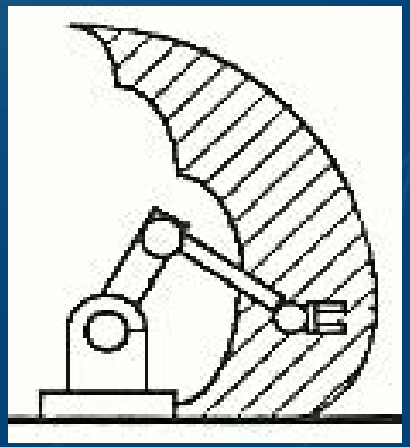
Side view

Arm Configuration

- Jointed Arm Robot
  - work envelope shape is complex because of the action of the joints.
  - resembles the human arm
  - joints are called the waist, shoulder, elbow and wrist.
  - robot arm can reach very low and high and behind itself (side view).
  - used often in industry because of its increased flexibility and strength
  - expensive to produce and requires a complex control system.



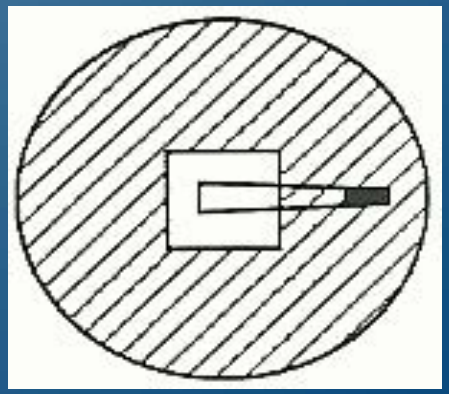
Top view



Side view

Arm Configuration

- Spine Robot
  - "snake like" robot
  - has extraordinary flexibility and has the most complete work envelope of all robots.
  - best suited for work in hard to reach places such as spray painting the inside of a car
  - does not have the same lifting ability of other robots.

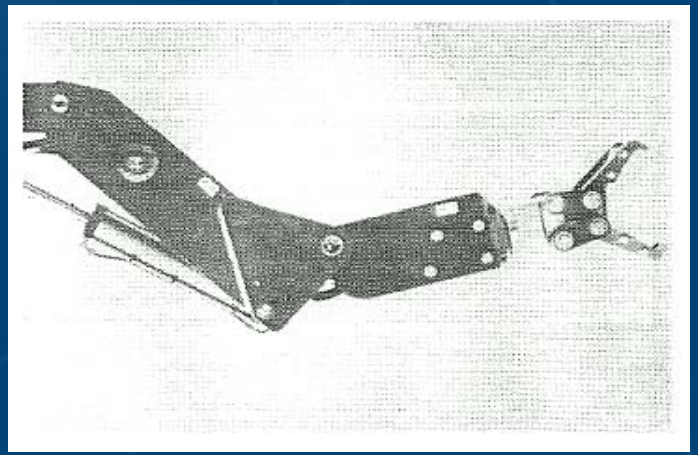


Top view

Side view

End Effectors

- End effectors are the type of tool attached to the end of the robot arm.
  - ability of end effectors to be automatically changed to a different tool is a major factor in robot flexibility.
    - tools could be screwdrivers, wrenches, arc welders, drills, cutters, deburrers, or ladles for moving molten metal.
  - special end effectors are available
    - finger, vacuum, and magnetic grippers.

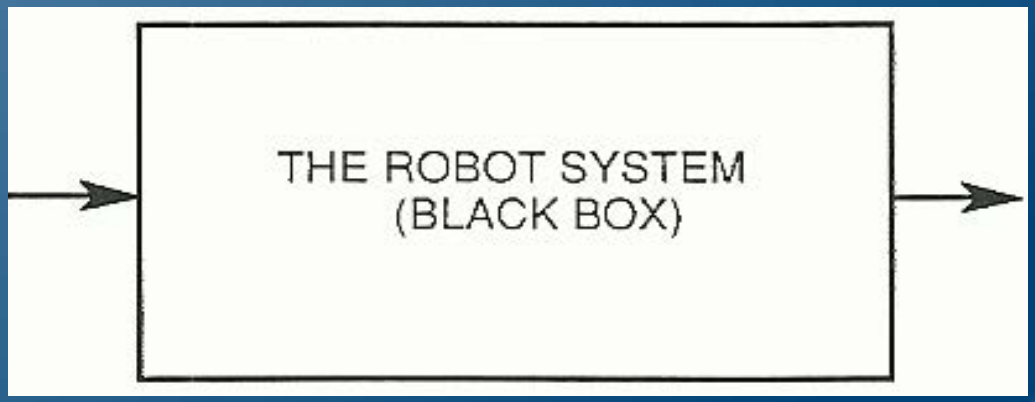


The Robot System

- System Analysis
  - All robots are systems
  - robots are comprised of a set of parts forming a whole.
  - system can be analyzed from general to specific using system analysis.
  - The first stage of system analysis is to consider the system as a "black box".

The Robot System as a Black Box

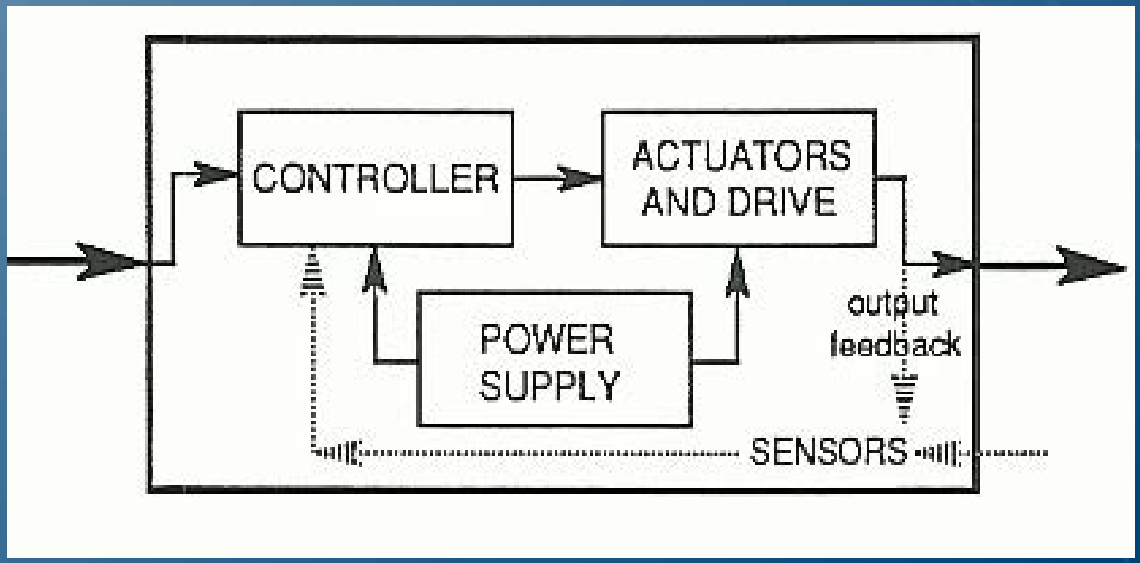
INPUT:
Human
directions



OUTPUT:
Many types of
work done
automatically

Inside the Black Box

INPUT:
Human directions



OUTPUT:
Many types of work done automatically

Four Subsystems (functional units):

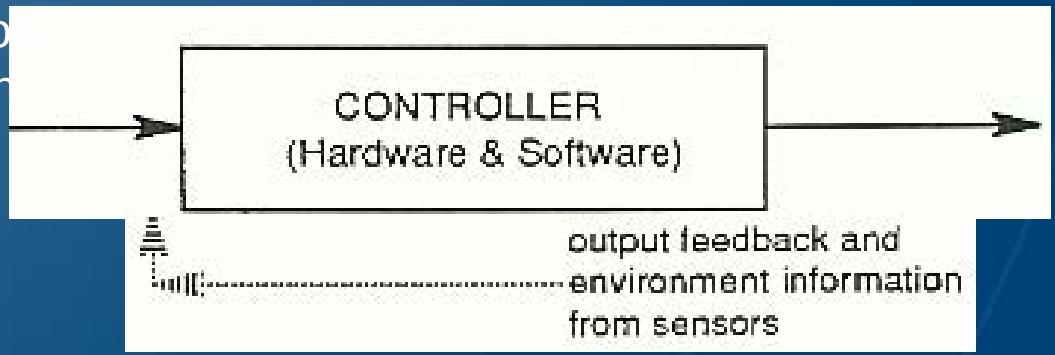
A **Controller** is to govern the operation of the **actuators** (devices that make motion) and **drives** (which modify motion). The **power supply** provides the needed energy for the entire system..

Second generation robots have **sensors** which receive **output feedback** from the actuators and pass the information to the controller to provide error correction. External environment information can also be received by the sensors and sent back to the controller to make necessary adjustments in operation.

The Controller

- the controller is to direct the operation of the robot actuators.
  - input is information received from people and sensors.
  - output consists of electrical commands sent to the actuators.
- today. virtually all robots are controlled by computers.
  - two very important sections: the hardware (the actual parts) and the software (the coded instructions). Good hardware and good software are required in effective robot controllers

INPUT: informatio
entered by human
beings

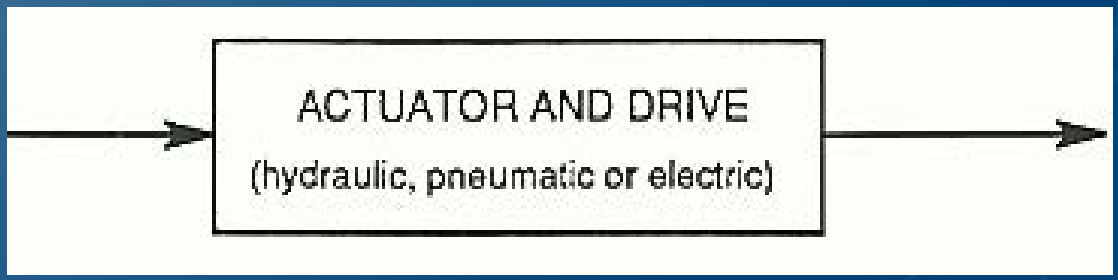


OUTPUT:
electrical command
signals sent to
actuators

Actuators and Drives

- Actuators receive as their input the command signals from the controller. As their output they give physical movement. The drive mechanically modifies the motion into a convenient form such as a slower speed.
- There are three basic types of actuators: hydraulic, pneumatic, and electric.

INPUT:
energy from an external source



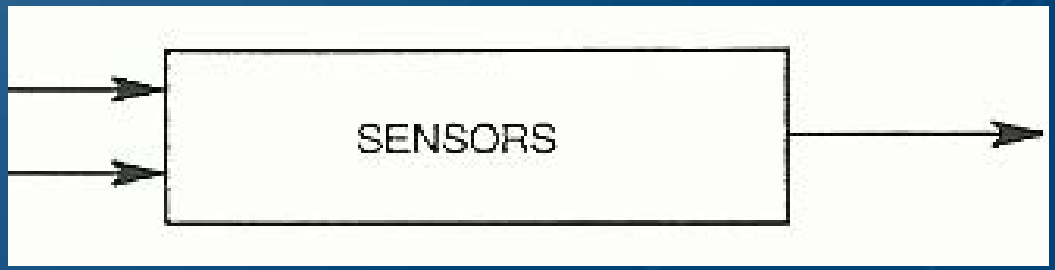
OUTPUT:
Motion (robot arm, end effectors, wheels, legs, etc.

Sensors

- critical components of all modern robots
- provide output and environmental feedback needed for the robot to correct itself. fall into
- two general categories of sensors:
  - direct contact
    - include all types of touch sensors which use mechanical switches. strain gauges and pressure sensors
  - non-contact.
    - detect objects at a distance and include infrared beam, sound, light, ultrasonic, radar, sonar, laser beam, and visual.

INPUTS:
feedback from actuators

Environmental information



OUTPUT:
Signals sent to controller for error correction and responsive action

The Mini-Andros

RETURN

Robobug III

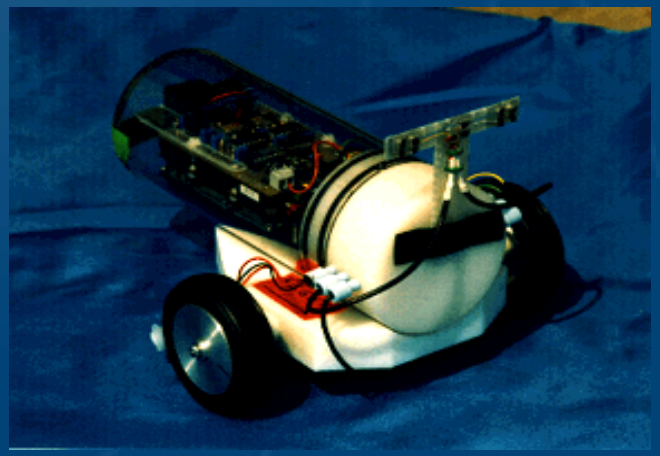
RETURN

Star

RETURN

رباتیک:تاریخچه و مقدمه، کاربرد ها، اصول پایه

ارائه دهندگان :
هومن حسین خان ناظر ، سید سینا راستاد کوچصفهانی
عضو قطب علمی طراحی، رباتیک و اتوماسیون دانشگاه صنعتی شریف



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