Robotics Introduction -unit 1

Robotics

Introduction to Robotics

UNIT-1

Introduction: Automation and Robotics,
An over view of Robotics – present and future applications – classification by coordinate system and control system. [4 Lect.]

Reference Books:

1. FU K S, Gonzalez RC, Lee CSG; Robotics –Control, sensing, TMH Publ.
2. Saeed B. Niku, Introduction to Robotics, Analysis, Systems, Applications, PHI Publications.
3. S R Dev, Robotics Technology and Flexible Automation, Tata McGraw Hill
4. Spong Mark and Vidyasagar; Robot Modelling and control; Wiley India
5. Ghosal Ashitava; Robotics Fundamental concepts and analysis; Oxford
6. Saha S; Introduction to Robotics; TMH Publications
7. Murphy ; Introduction to AI Robotics; PHI Learning

Automation

Automation is the use of m/c control systems and information technologies to increase/ optimise productivity for the production of the goods and delivery of services.

Automation:

1. Fixed or Hard automation(Ex: sewing m/c, electric iron, fan)

   (a) Adjustable automation (Ex: adjust stitch length, pitch of screw of a lathe m/c etc.)

2. Programmable automation after arrival of computers, NC & CNC m/c, CAM & CIM etc.
3. Flexible automation

Robot is a computer control m/c which is coming under the category of Highest level of autonomy/automations.

Fixed Automation

A manufacturing system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration

Typical features:

- Suited to high production quantities
- High initial investment for custom-engineered equipment
- High production rates
- Relatively inflexible in accommodating product variety

Programmable Automation

A manufacturing system designed with the capability to change the sequence of operations to accommodate different product configurations

Typical features:

- High investment in general purpose equipment
- Lower production rates than fixed automation
- Flexibility to deal with variations and changes in product configuration
- Most suitable for batch production
- Physical setup and part program must be changed between jobs (batches)

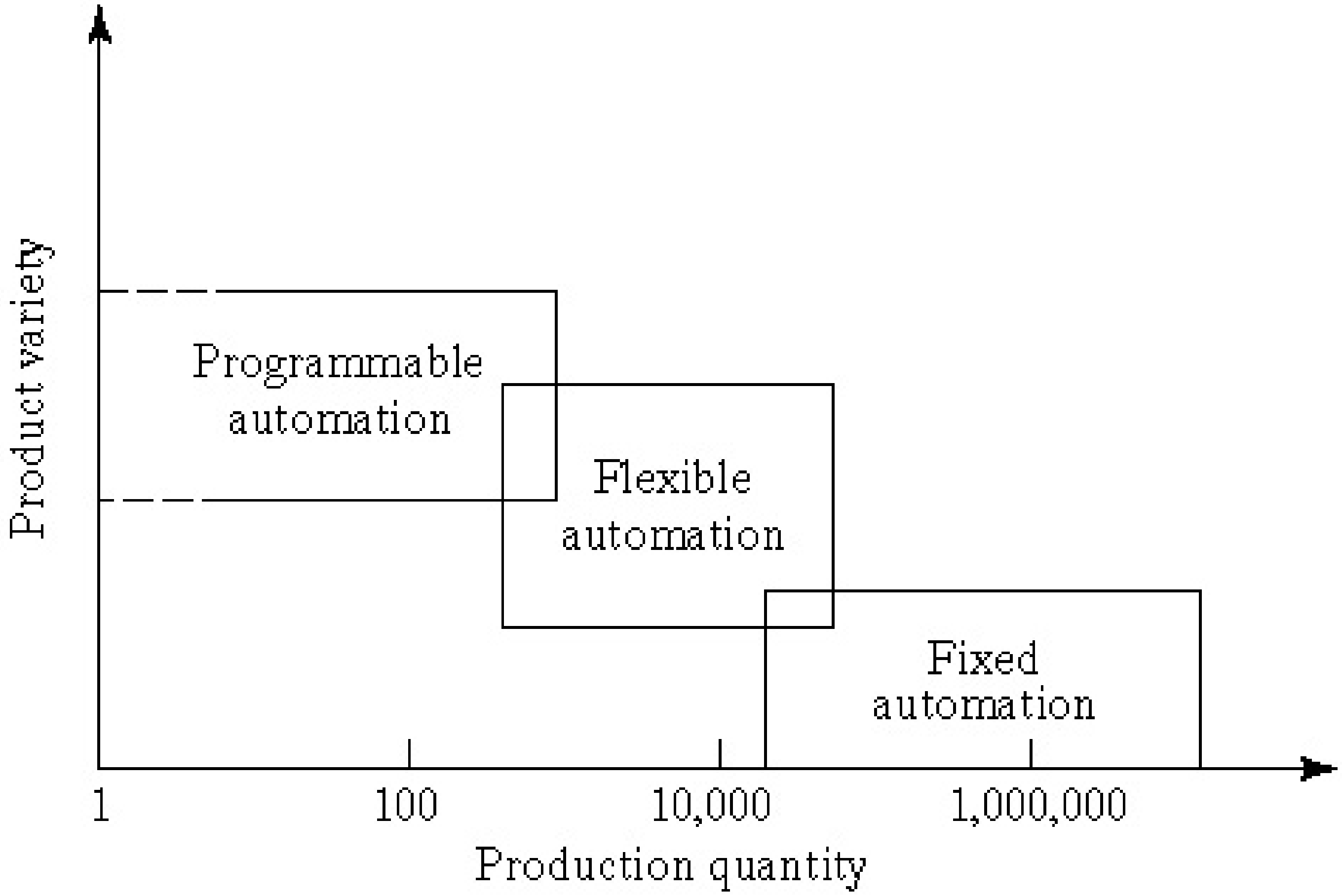
Flexible Automation

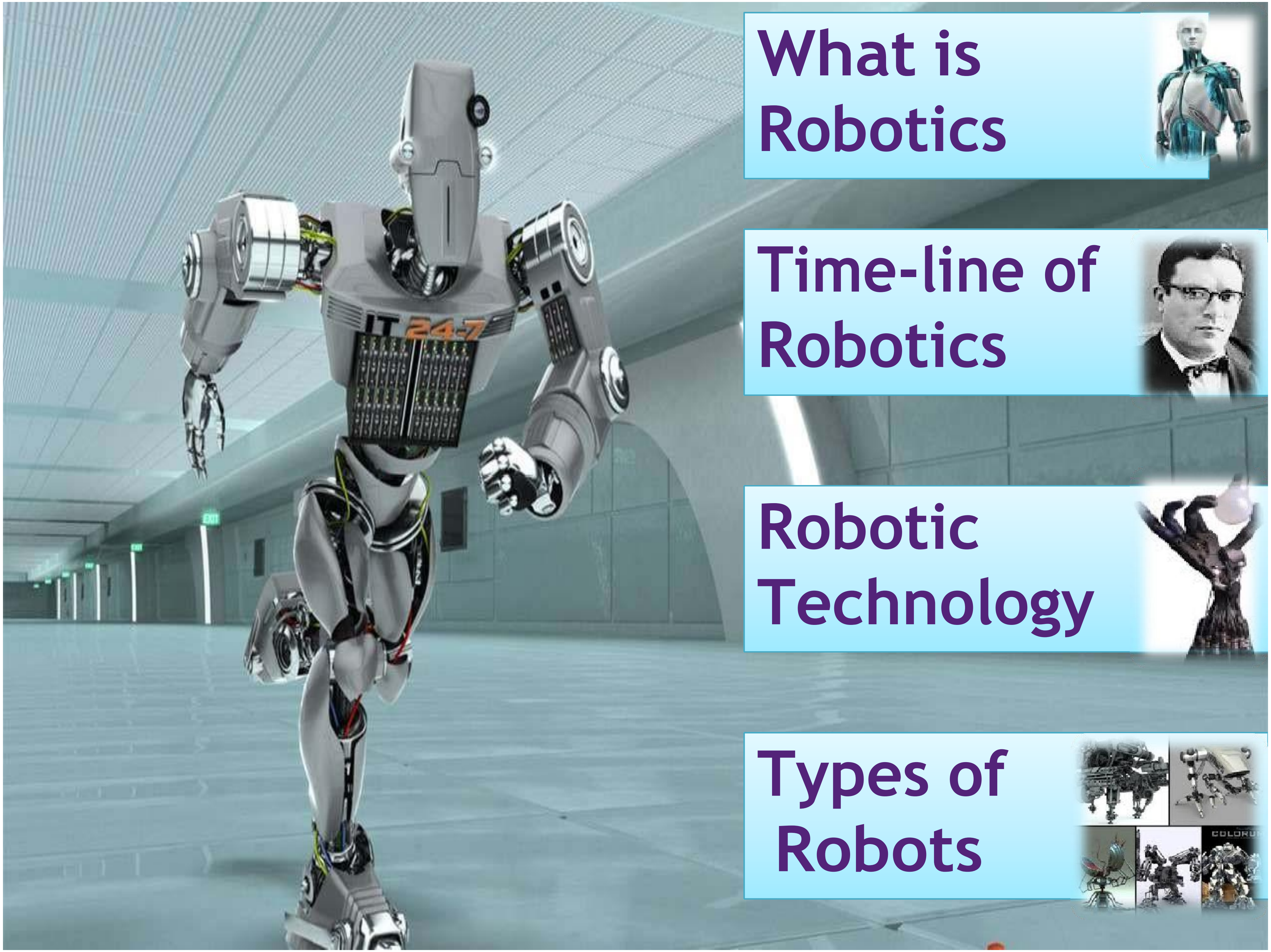
An extension of programmable automation in which the system is capable of changing over from one job to the next with no lost time between jobs

Typical features:

- High investment for custom-engineered system
- Continuous production of variable mixes of products
- Medium production rates
- Flexibility to deal with soft product variety

Product Variety and Production Quantity for Three Automation Types




What is Robotics
Time-line of Robotics
Robotic Technology
Types of Robots

Module-1: Introduction

Robotics: *Definition*

Robotics is science of designing or building an application of robots. Simply ,Robotics may be defines as "The Study of Robots". The aim of robotics is to design an efficient robot.

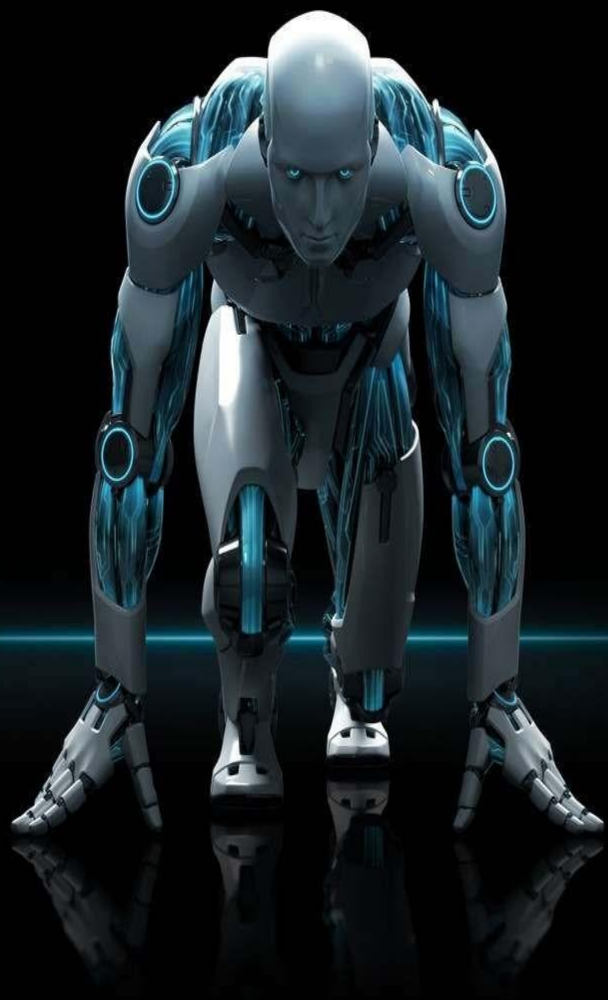
Robotics is the Brach of Technology that deals with design, construction, operations and application of robot & computer system for their control, sensory, feedback & information processing.

These technologies deals with automated machines that can takes the place of human in hazardous or manufacturing process or simply just resemble human.

WHY IS ROBOTICS NEEDED...?

Robotics is needed because:-

- Speed
- Can work in hazardous/dangerous temperature
- Can do repetitive tasks
- Can do work with accuracy



How robot came?

- What can we achieve, if we combine the power of microprocessor with conventional automation systems, and arrived at a very powerful system. That’s why Robot came into picture.
- There are tremendous development in digital electronics & high resolution sensors made the robot highly autonomous.

Why Robotics?

Three factors drive the adoption of robots:

- improved productivity in the increasingly competitive international environment;
- improved quality of life in the presence of a significantly aging society; and
- removing first responders and soldiers from the immediate danger/action.

Economic growth, quality of life, and safety of our first responders continue to be key drivers for the adoption of robots.

Introduction to Robotics

Introduction to Robotics

- Robots have become a subject of great interest nowadays.
- In our imagination, a robot is a machine that looks and acts like a human being.
- Robots are, in fact, defined as man-made mechanical devices that can move by themselves, whose motion must be modeled, planned, sensed, actuated and controlled, and whose motion behaviour can be influenced by “programming”.

What is a Robot...?

A re-programmable, multifunctional, automatic industrial machine designed to replace human in hazardous work. It can be used as :-

- An automatic machine sweeper
- An automatic car for a child to play with
- A machine removing mines in a war field
- In space
- In military , and many more..

What is a Robot ?

- A manipulator (or an industrial robot) is composed of a series of links connected to each other via joints. Each joint usually has an actuator (a motor for eg.) connected to it.

- These actuators are used to cause relative motion between successive links. One end of the manipulator is usually connected to a stable base and the other end is used to deploy a tool.

First use of the word "Robotics"

The word robot was introduced to the public by Czech writer Karel Capek(1890-1938) in his play R.U.R. (Rossum's Universal Robots), published in 1920. The play begins in a factory that makes artificial people called robots . Capek was reportedly several times a candidate for the Nobel prize for his works .

The word "robotics", used to describe this field of study, was coined accidentally by the Russian –born , American scientist and science fiction writer, Isaac Asimov(1920-1992) in 1940s.

History of Robotics

1922: Czech author Karel Čapek's novel, Rossum's Universal Robots, word "Robota" (worker)

1952: NC machine (MIT)

1955: Denavit-Hartenberg Homogeneous Transformation

1963 The 1st vision system was developed.

1967: Mark II (Unimate robot used for paint spraying)

1968: Shakey (SRI) - intelligent mobile robot

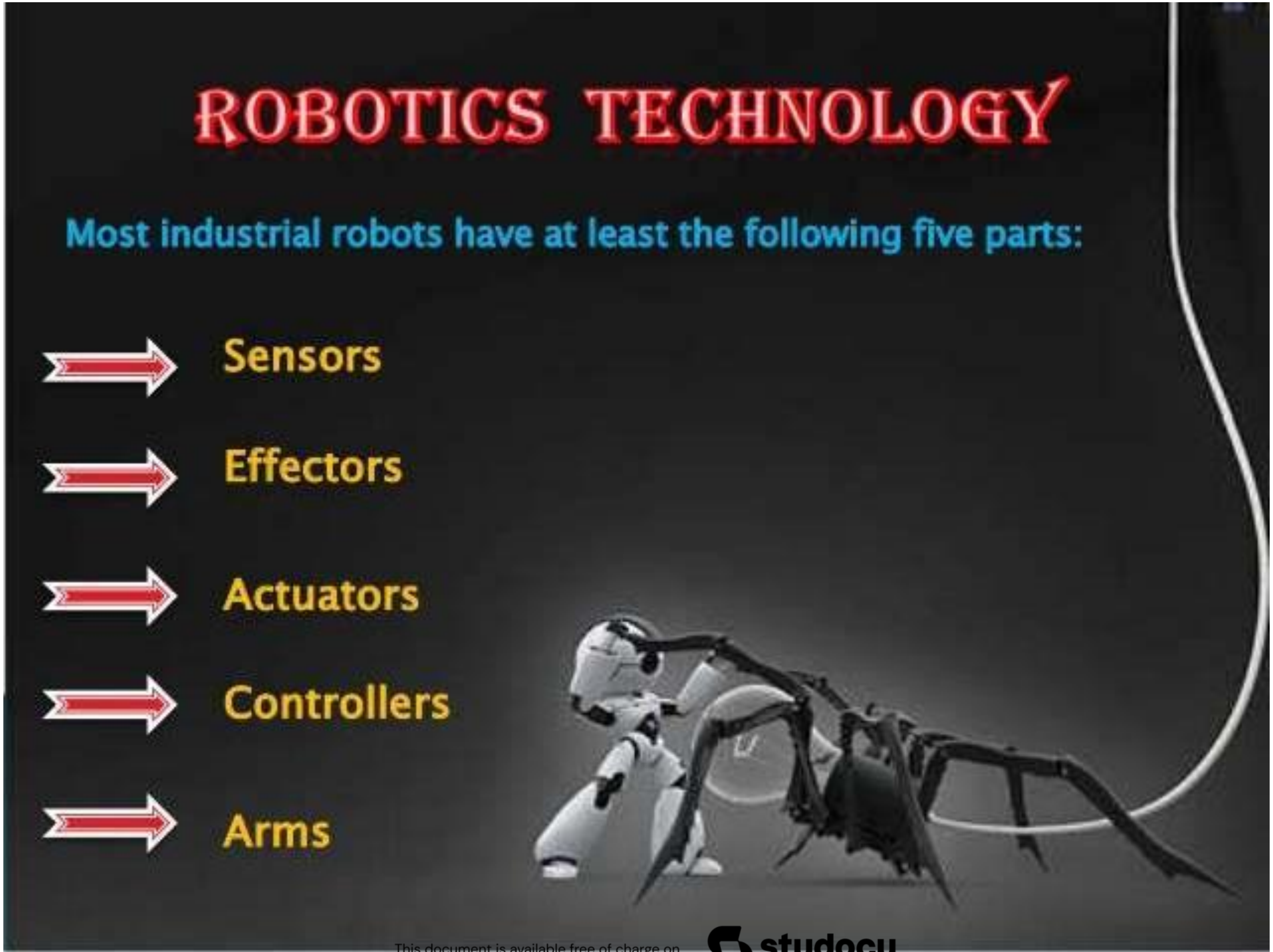
1978: PUMA (Unimation Inc. by General Motors)

21C: Walking Robots, Mobile Robots, Humanoid Robots

The First Robot "UNIMATE"

- After the technology explosion in during world war II in 1956. George C Devol and Josheph F Engelberger made firm Unimation and developed the First Robot, named: Unimate robot.
- Josheph F Engelberger was known as **Father of Robotics.**

Introduction to Robotics



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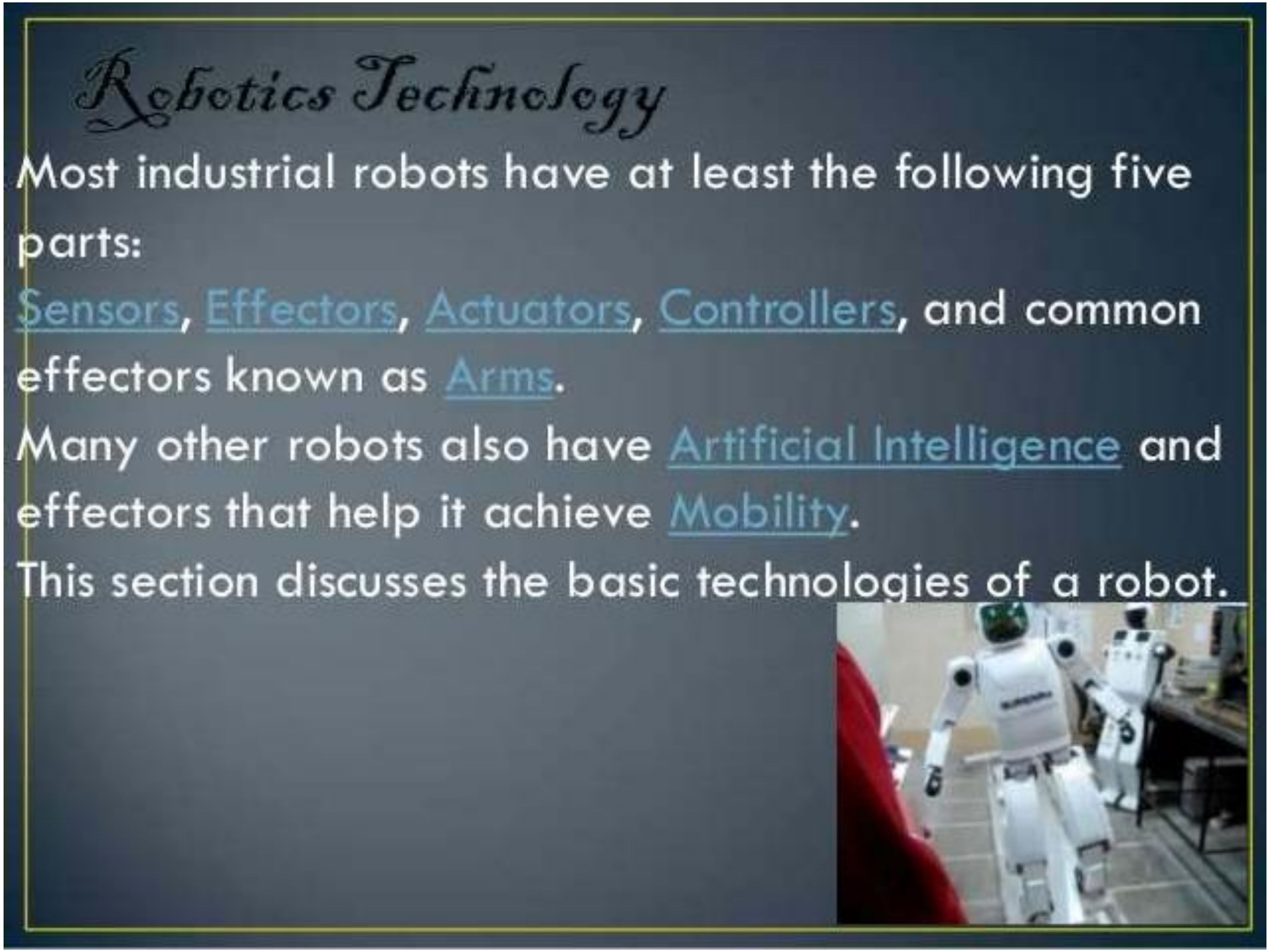

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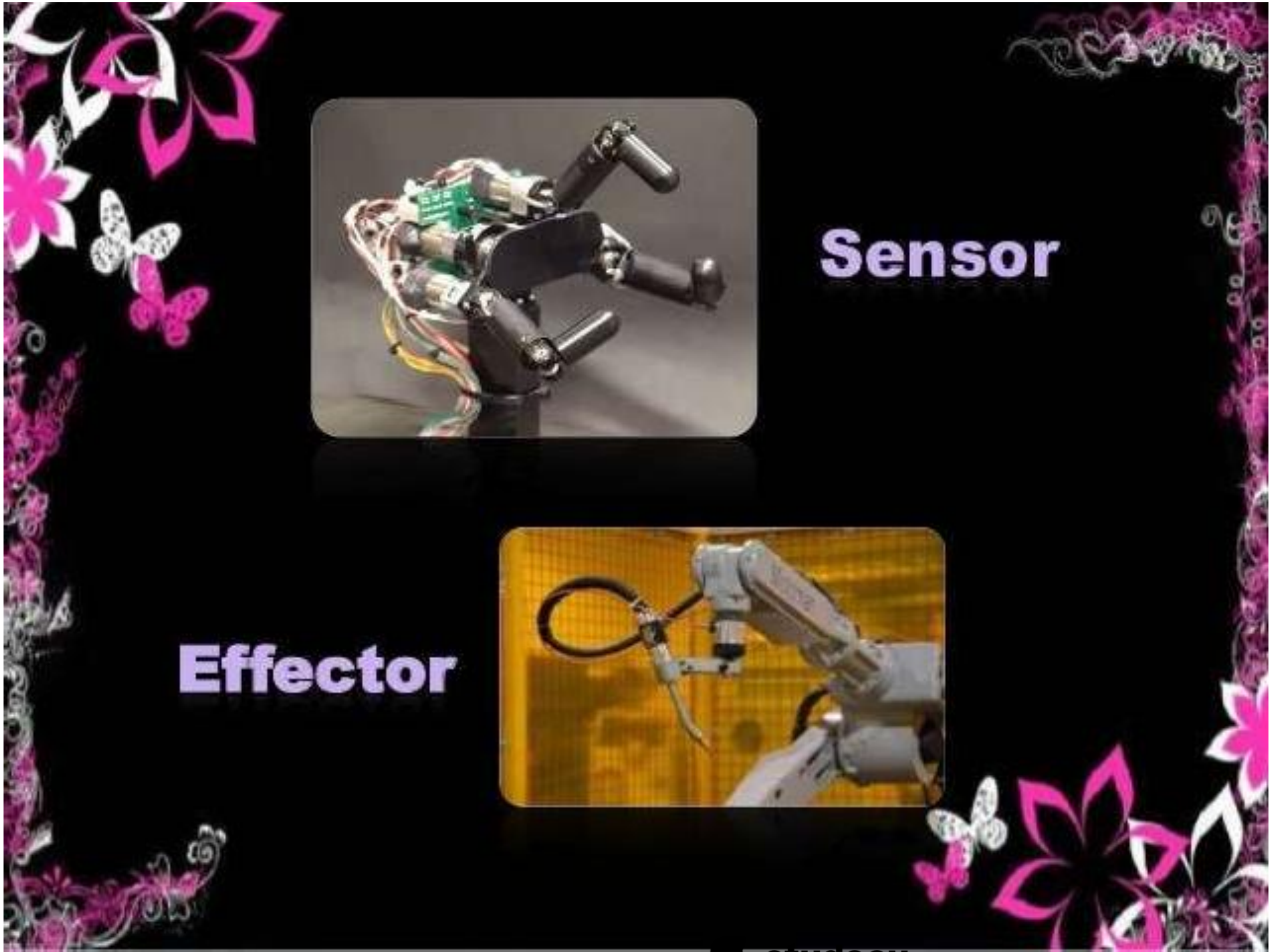

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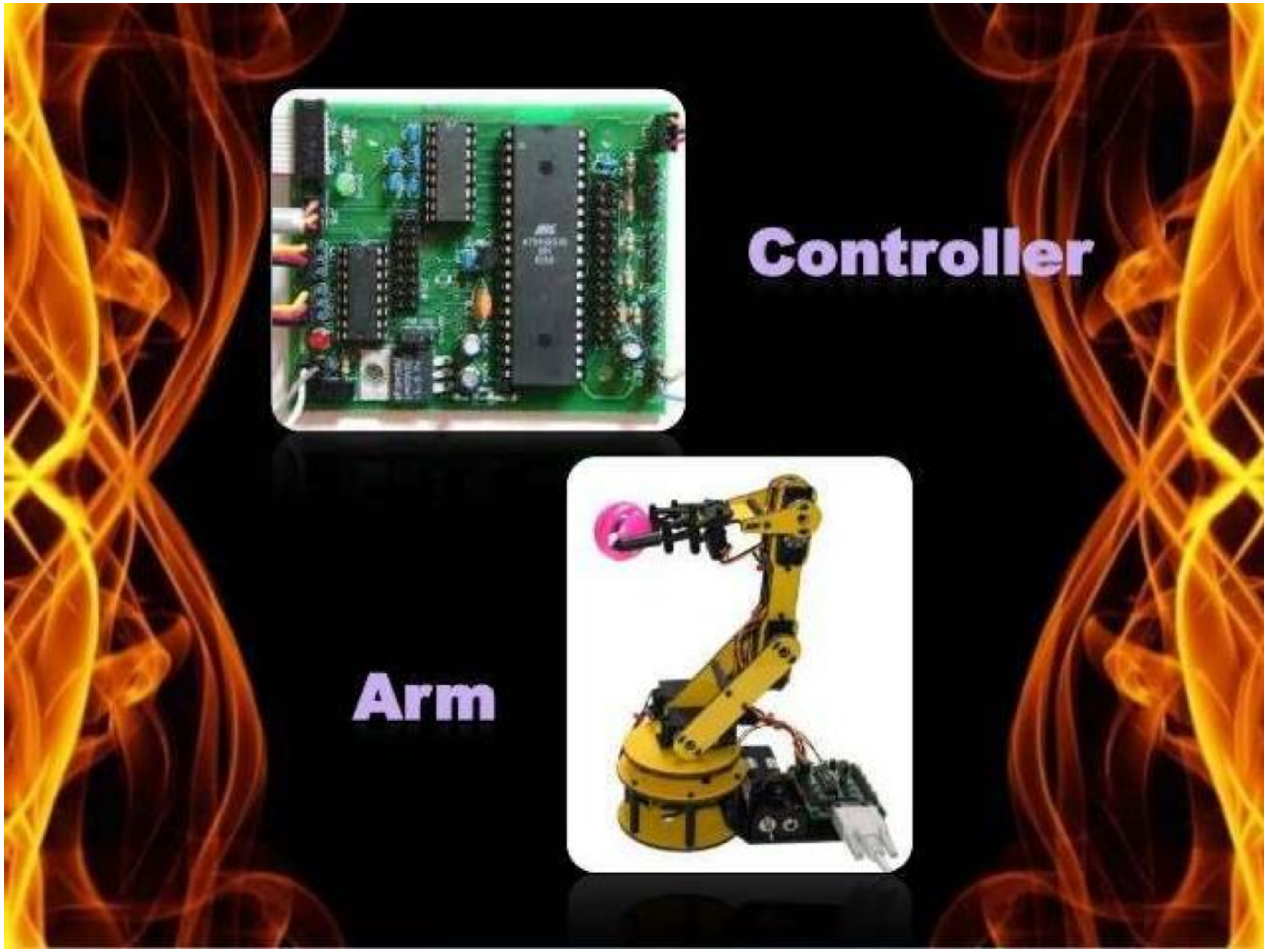

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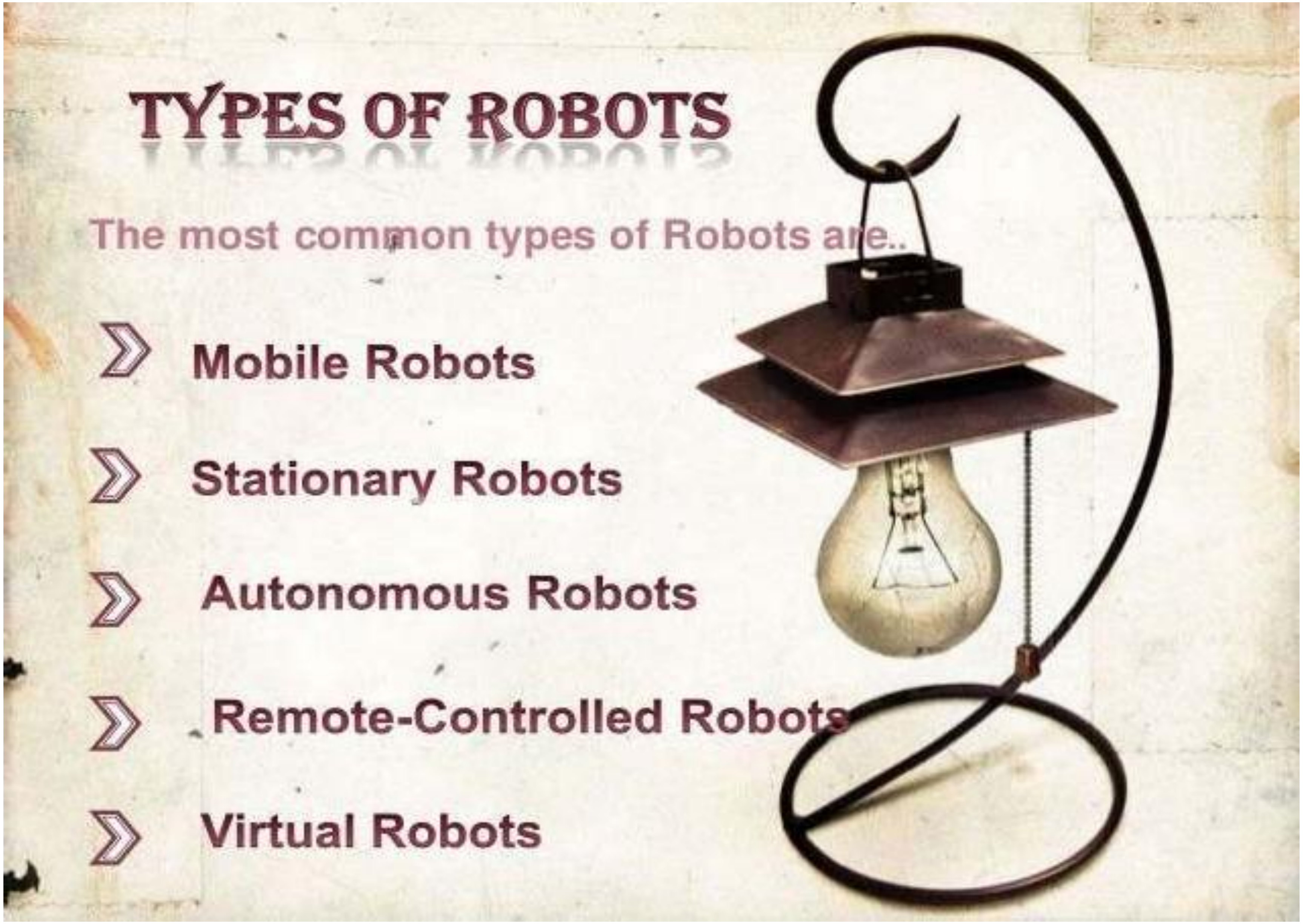

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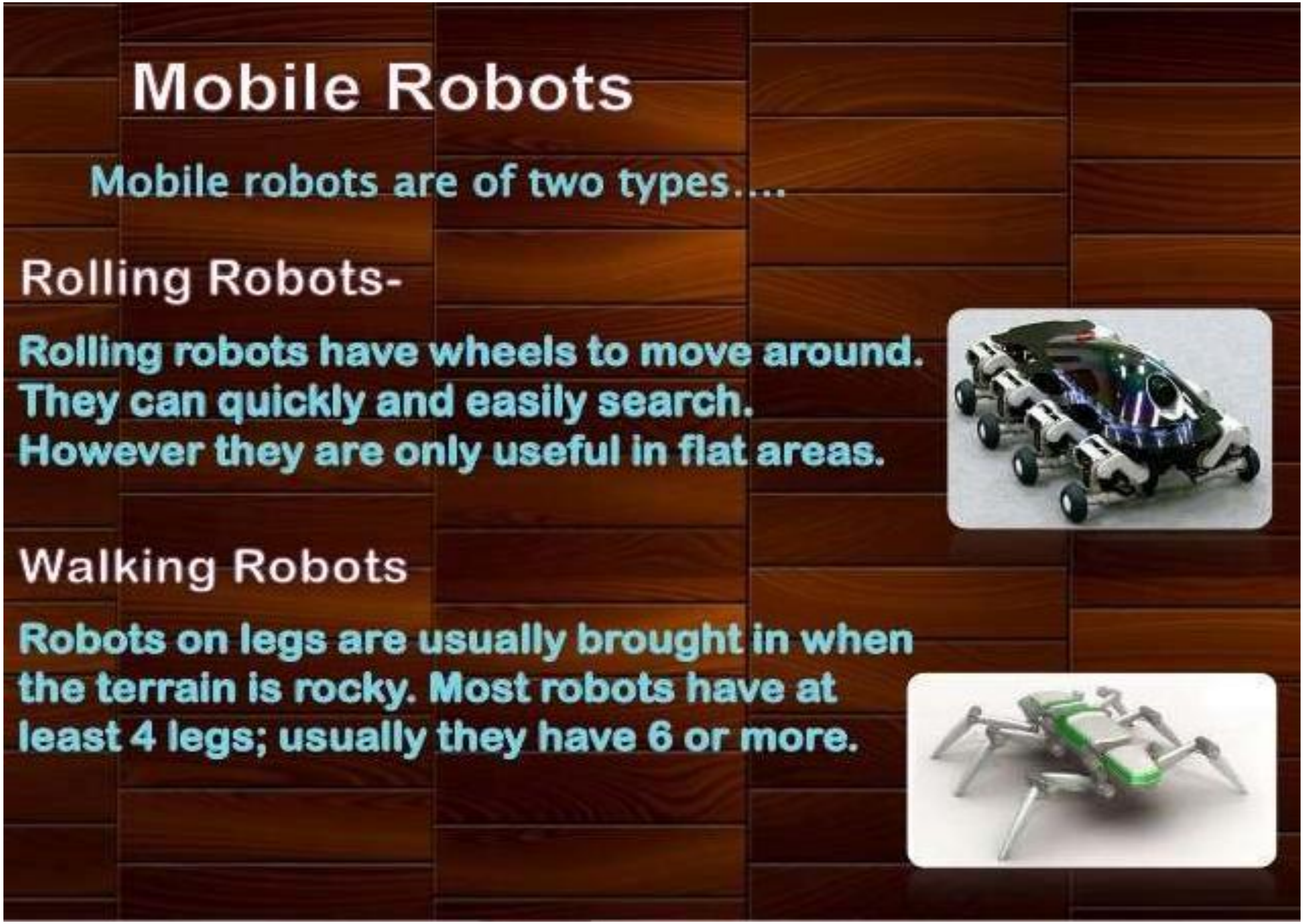


Introduction to Robotics

Stationary Robots

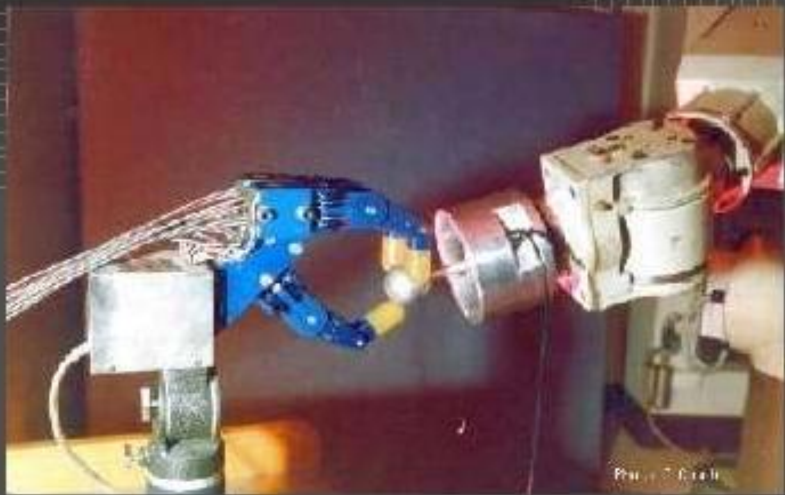
Robots are not only used to explore areas or imitate a human being. Most robots perform repeating tasks without ever moving an inch. Most robots are 'working' in industry settings and are stationary .

Autonomous Robots

Autonomous robots are self supporting or in other words self contained. In a way they rely on their own 'brains'.

Introduction to Robotics

Industrial Robots



- Most of these robots perform repeating tasks without ever moving.
- Most robots are working in industries. Especially dull and repeating tasks are suitable for robots.
- A robot never grows tired; it will perform its duty day and night without ever complaining.

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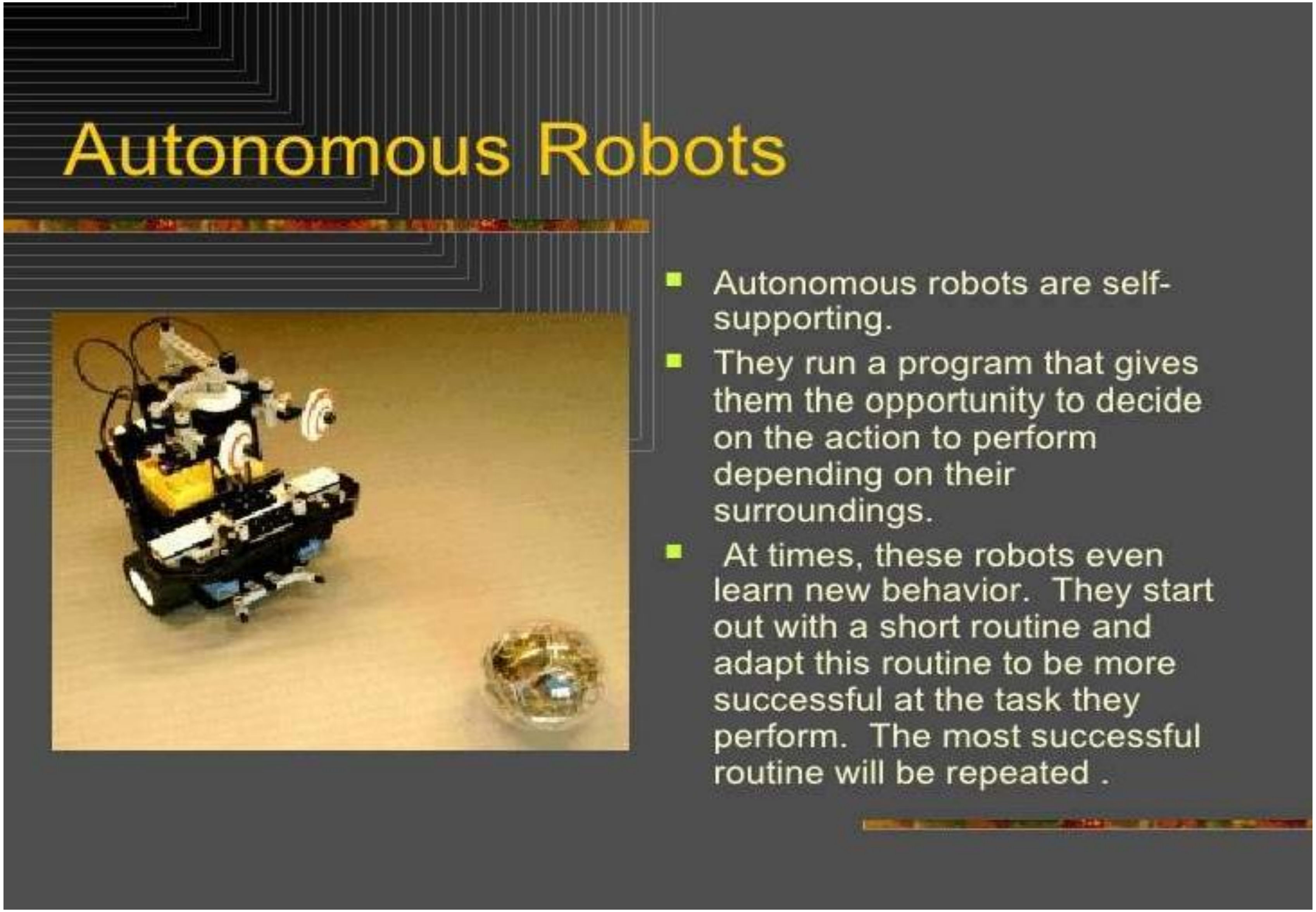

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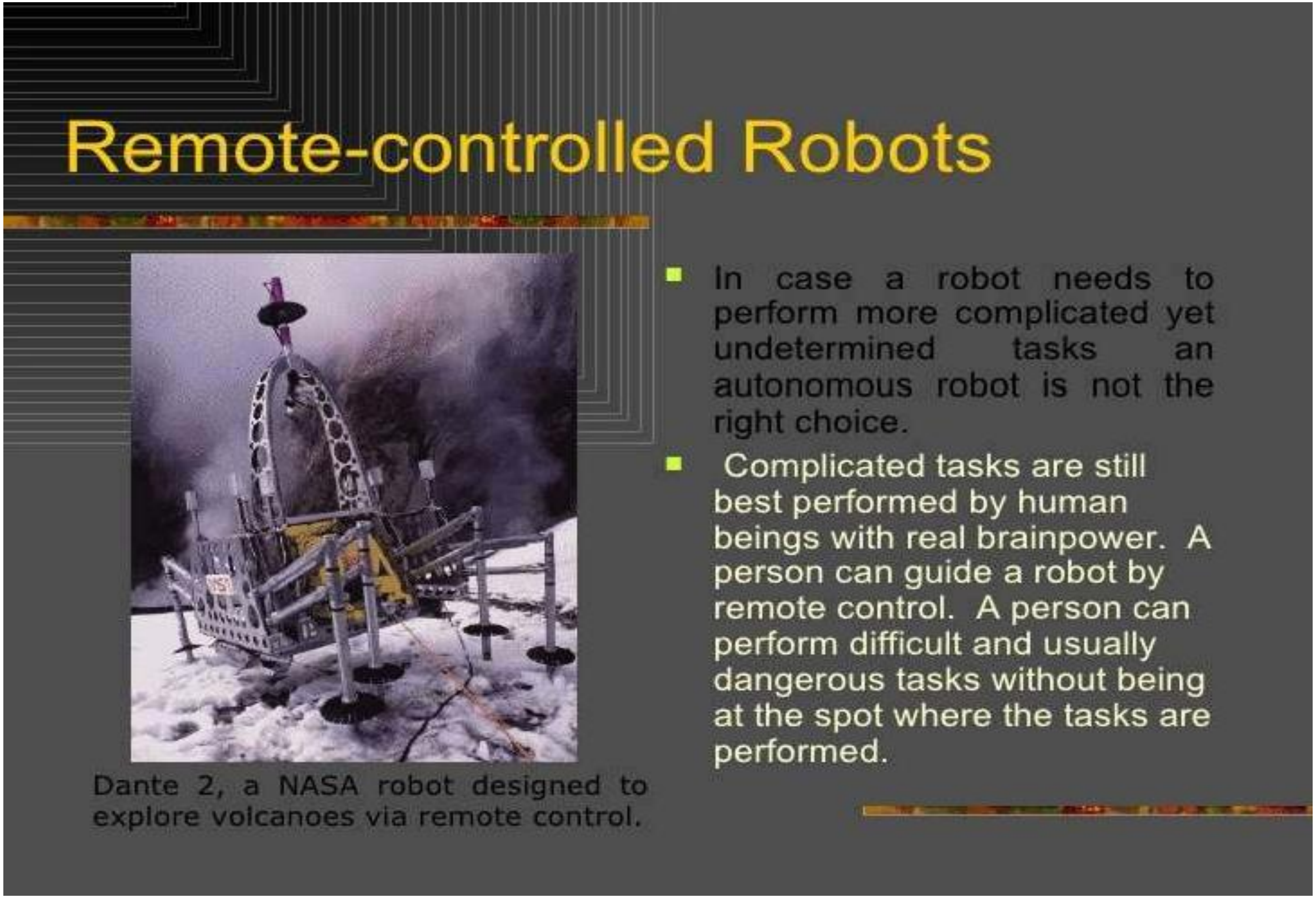

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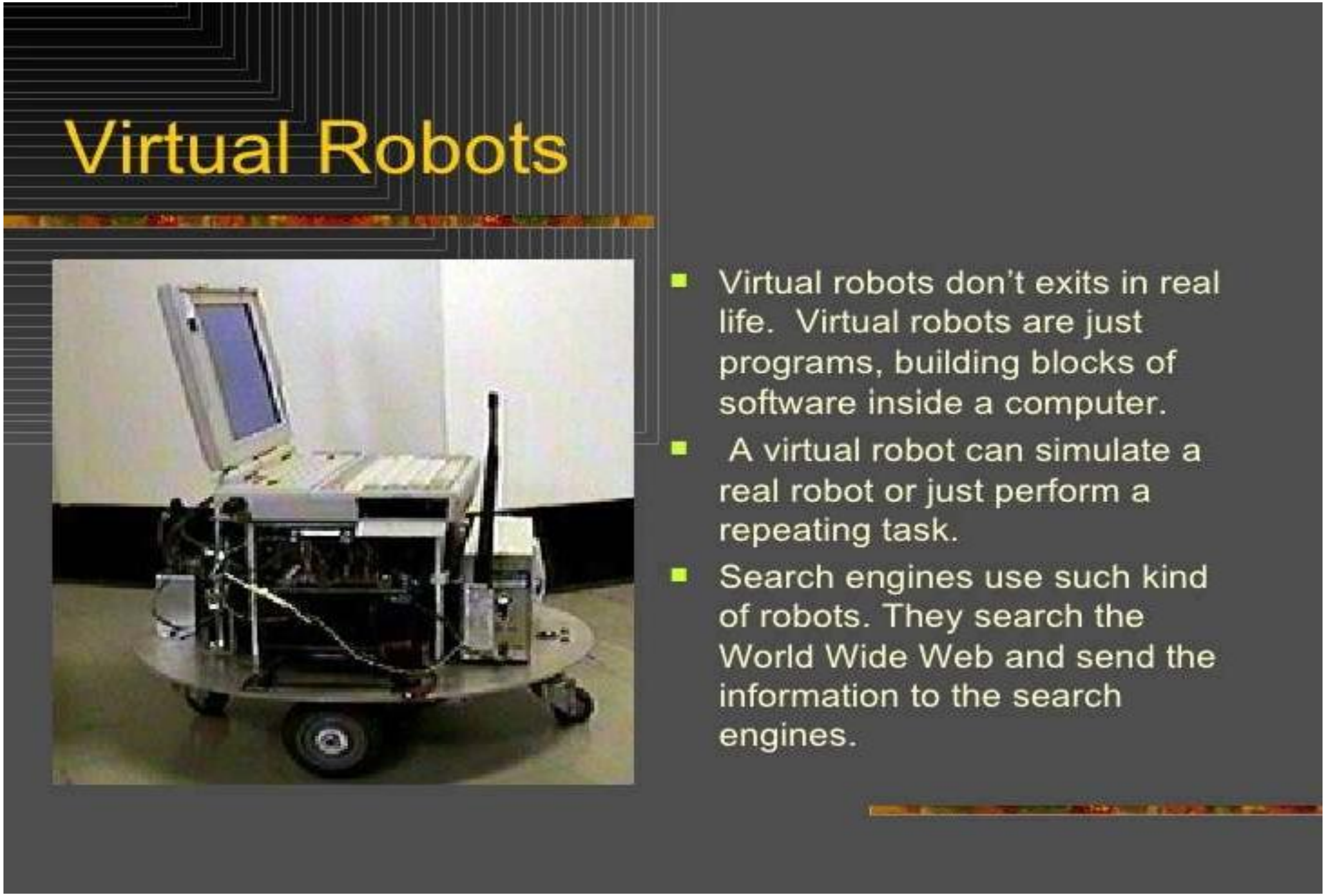


Laws of Robotics

Si Isaac Asimov in his science Friction stories during 1940 envisioned the robot as a helper of human beings and postulates the three basic rules for robotics. Which are later on known as Laws of Robotics.

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.

2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

Advantages VS. Disadvantages of Robots

Advantages

- Robots increase productivity, safety, efficiency, quality, and consistency of products.
- Robots can work in hazardous environments without the need.
- Robots need no environmental comfort.
- Robots work continuously without experiencing fatigue of problem.
- Robots have repeatable precision at all times.
- Robots can be much more accurate than human.
- Robots replace human workers creating economic problems.
- Robots can process multiple stimuli or tasks simultaneously.
- Greater flexibility, re-programmability, kinematics dexterity
- Greater response time to inputs than humans
- Improved product quality
- Maximize capital intensive equipment in multiple work shifts
- Accident reduction
- Reduction of hazardous exposure for human workers
- Automation less susceptible to work stoppages.

Disadvantages

- Replacement of human labor, creating unemployment

- Robots lack capability to respond in emergencies.

- Robots, although superior in certain senses, have limited capabilities in Degree of freedom, Dexterity, Sensors, Vision system, real time response.

- Robots are costly, due to Initial cost of equipment, Installation costs, Need for Peripherals, Need for training, Need for programming.

Limitations

- Assembly dexterity does not match that of human beings, particularly where eye-hand coordination required.
- Payload to robot weight ratio is poor, often less than 5%.
- Robot structural configuration may limit joint movement.
- Work volumes can be constrained by parts or tooling/sensors added to the robot.
- Robot repeatability/accuracy can constrain the range of potential applications.
- Closed architectures of modern robot control systems make it difficult to automate cells.

Robot Applications

Machine loading
Material Handling: Pick, move and place operations
Fabrication works like; Welding, grinding, cutting, Painting etc.
Sampling,
Manufacturing
Assembly operation: Electronics, automobile and small scale applications.
Inspection and testing, Quality control. Looking for surface, and interior defects
Surveillance
Medical applications
Assisting disabled individuals
Hazardous environments
Underwater, space, and remote locations

Classification of Robots

- JIRA (Japanese Industrial Robot Association)

Class1: Manual-Handling Device (works with multiple DOF)

Class2: Fixed Sequence Robot (Hard to modify)

Class3: Variable Sequence Robot (easy to modify)

Class4: Playback Robot (Human operator performs the task manually, which records the motion for later playback)

Class5: Numerical Control Robot (robot is given a movement program rather than teaching the task manually)

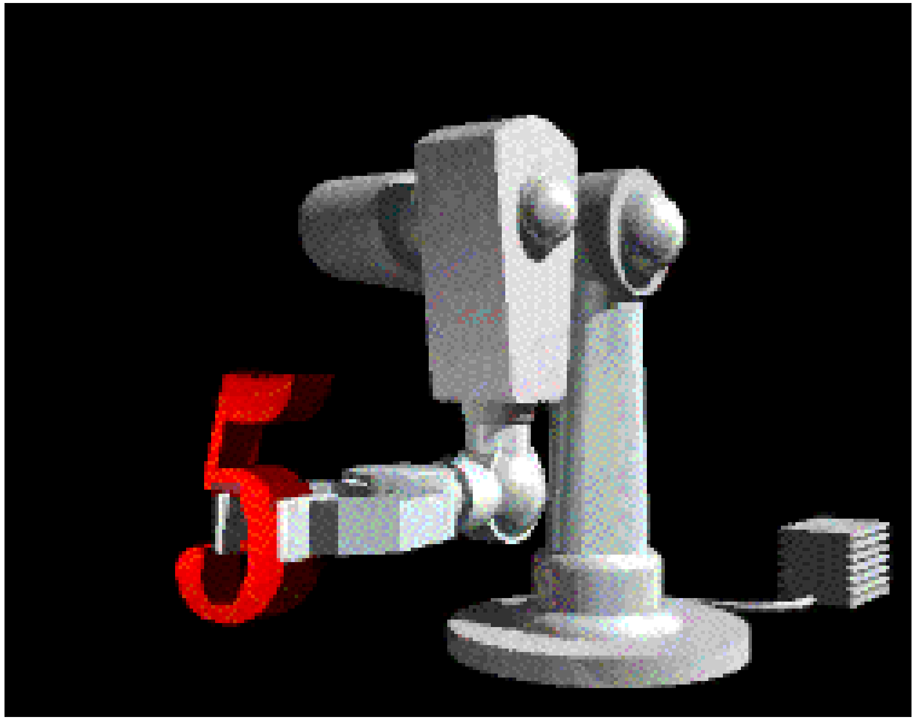
Class6: Intelligent Robot (understand the environment and works accordingly, like human beings)

Classification of Robots

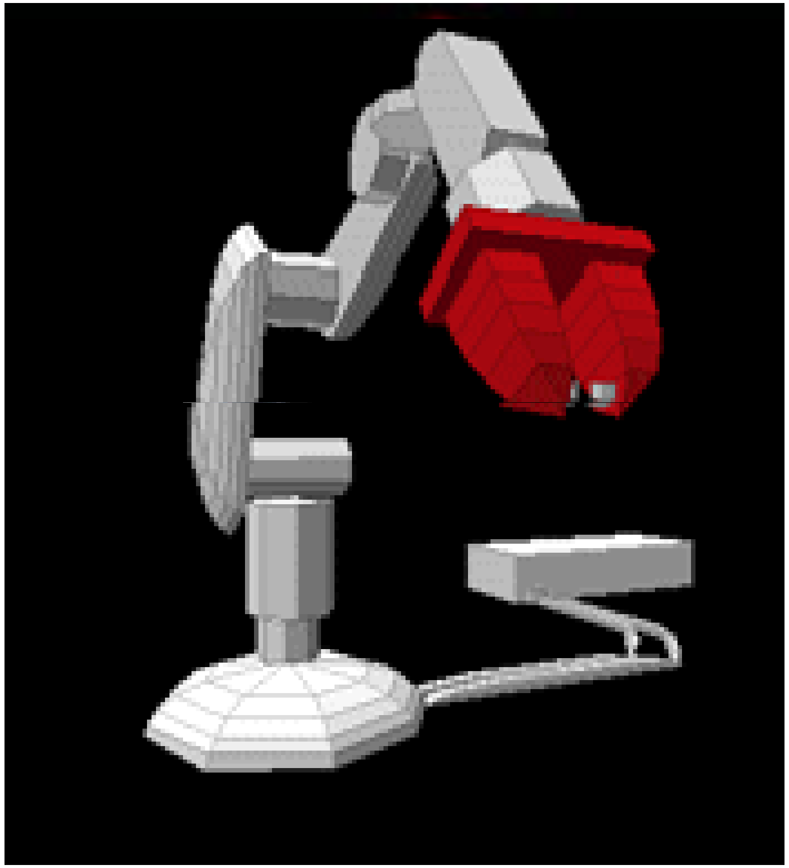
- RIA (Robotics Institute of America)
  - Variable Sequence Robot(Class3)
  - Playback Robot(Class4)
  - Numerical Control Robot(Class5)
  - Intelligent Robot(Class6)

What are the parts of a robot?

- Manipulator
- Pedestal
- Controller
- End Effectors
- Power Source



Manipulator



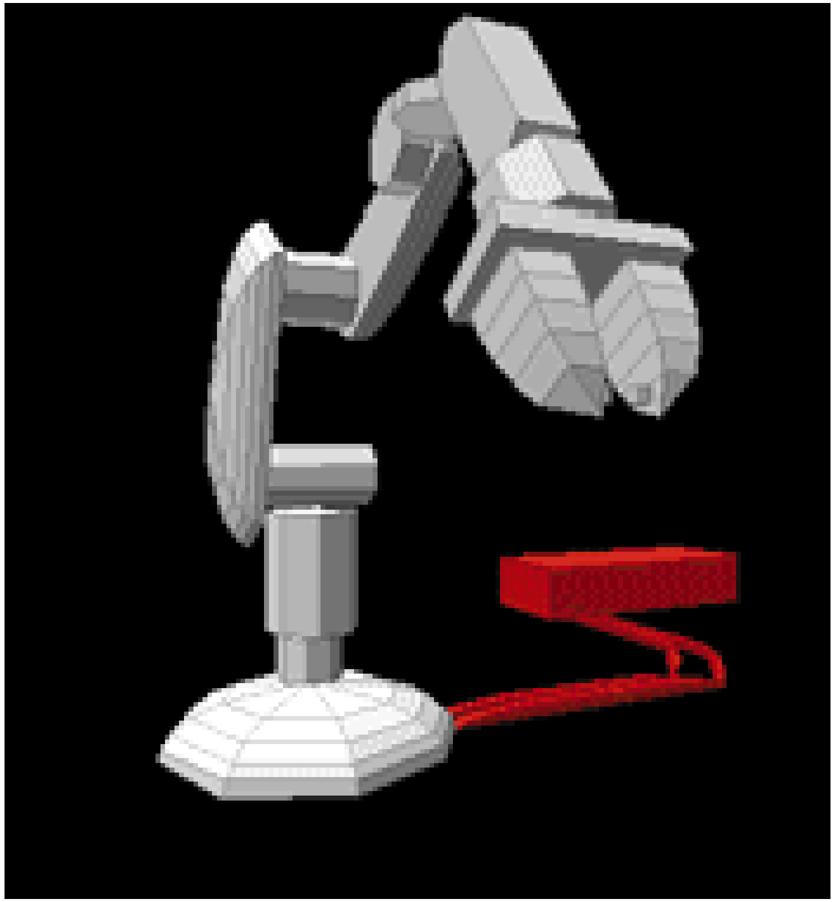
- Base
- Appendages
  - Shoulder
  - Arm
  - Grippers

Pedestal

(Human waist)

- **Supports the manipulator.**
- **Acts as a counterbalance.**

Controller

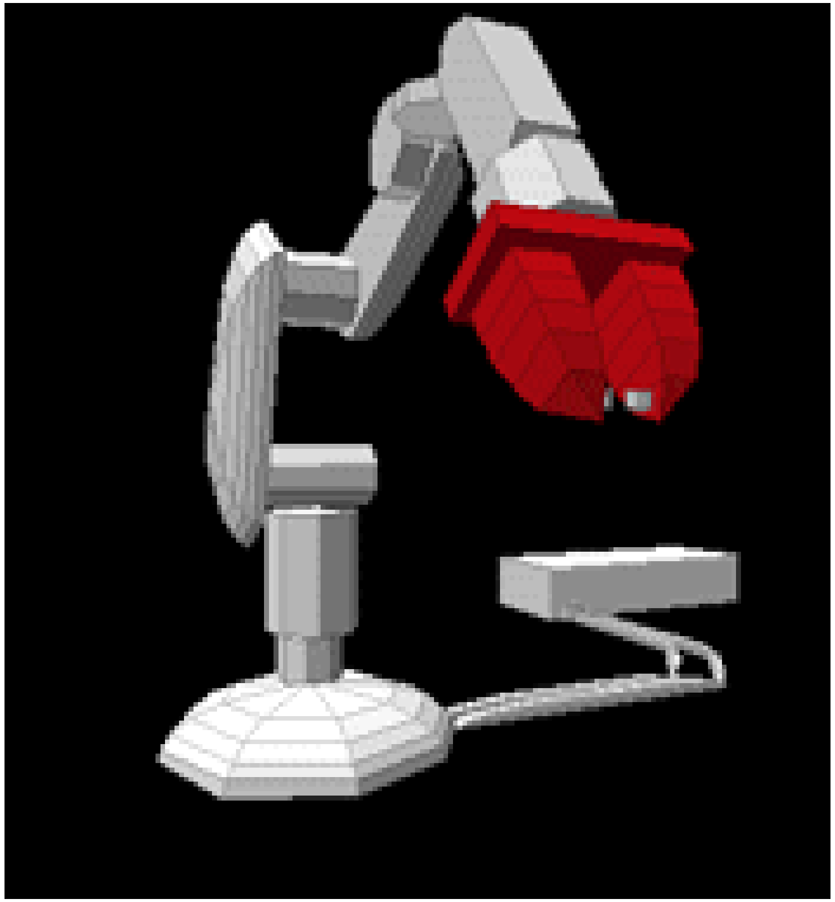


(The brain)

- Issues instructions to the robot.
- Controls peripheral devices.
- Interfaces with robot.
- Interfaces with humans.

End Effectors

(The hand)



- Spray paint attachments
- Welding attachments
- Vacuum heads
- Hands
- Grippers

Power Source

(The food)

- **Electric**
- **Pneumatic**
- **Hydraulic**

Robots degrees of freedom

- Degrees of Freedom: Number of independent position variables which would has to be specified to locate all parts of a mechanism.
- In most manipulators this is usually the number of joints.
- Robot has usually six DOF
- Humans have 42 DOF.

Robots degrees of freedom

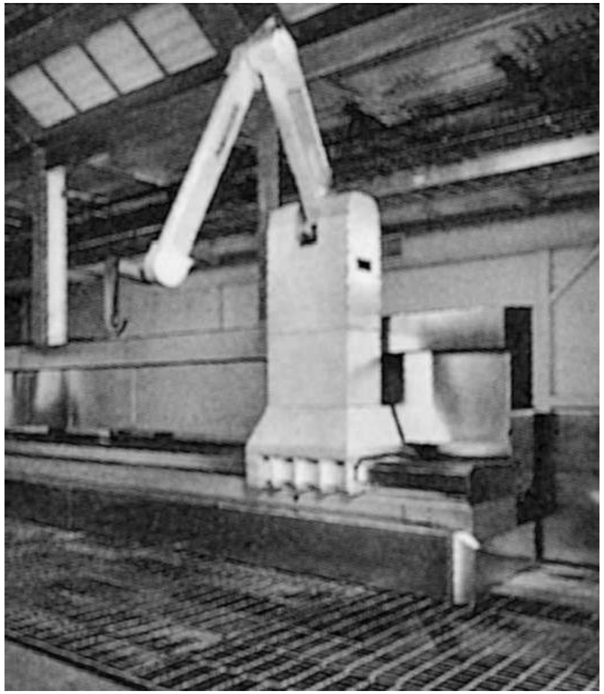


Fig. 1.3 A Fanuc P-15 robot.

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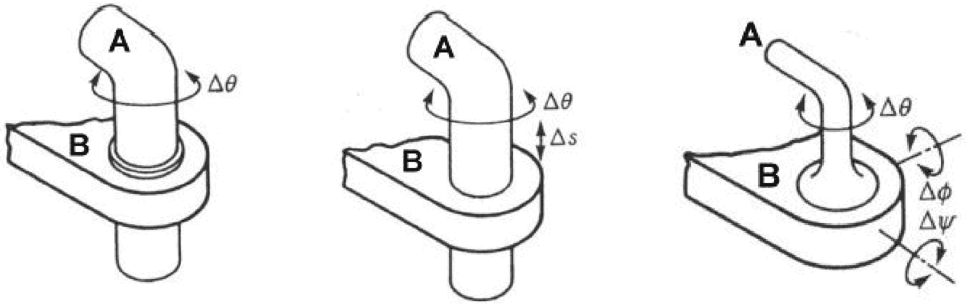
← Consider what is the degree of Fig. 3

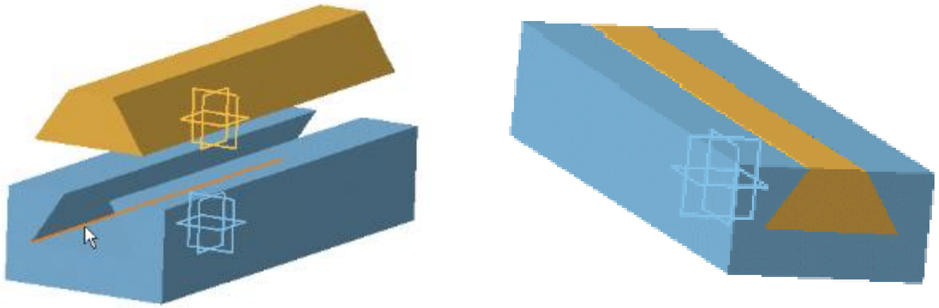


1 D.O.F. 2 D.O.F. 3 D.O.F.

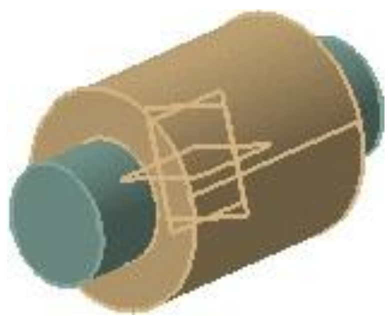
Robot Joints

Prismatic Joint: Linear, No rotation involved.

(Hydraulic or pneumatic cylinder)



Revolute Joint: Rotary, (electrically driven with stepper motor, servo motor)



Robot Coordinates

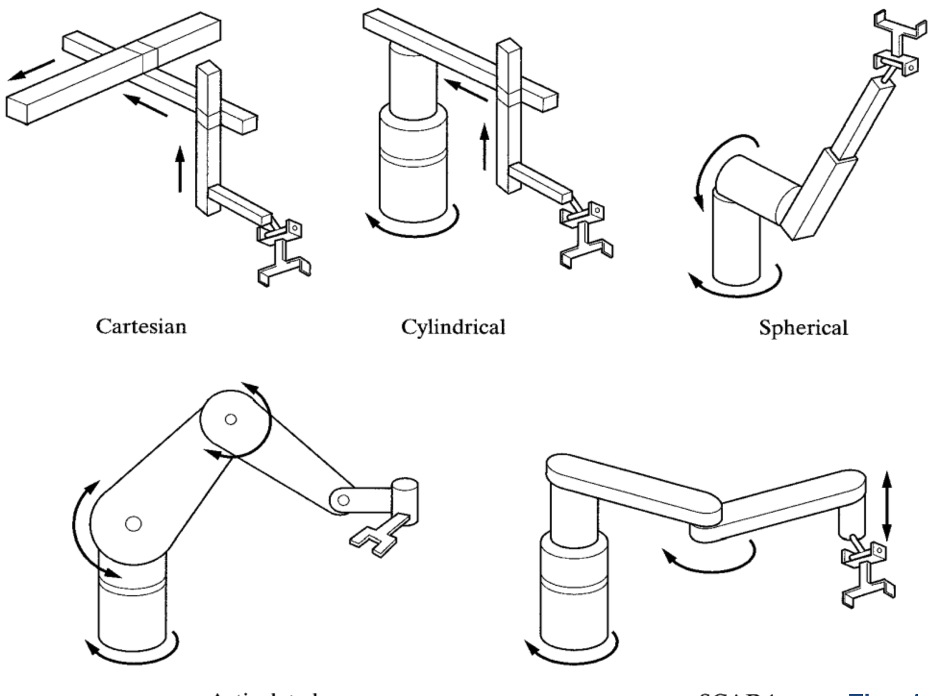
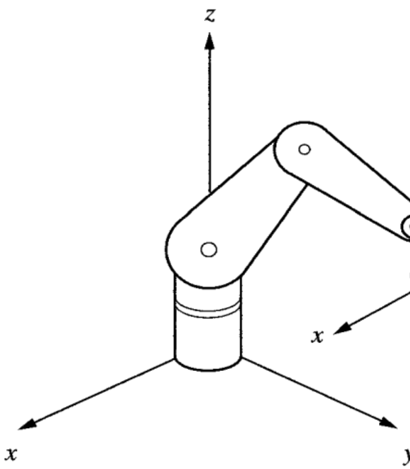


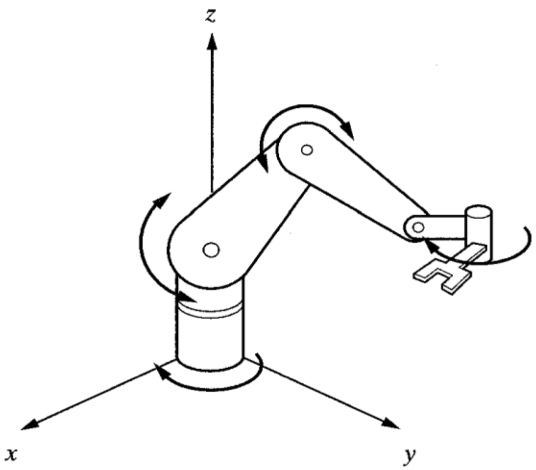
Fig. 1.4

- Cartesian/rectangular/gantry (3P) : 3 cylinders joint
- Cylindrical (R2P) : 2 Prismatic joint and 1 revolute joint
- Spherical (2RP) : 1 Prismatic joint and 2 revolute joint
- Articulated/anthropomorphic (3R) : All revolute(Human arm)
- Selective Compliance Assembly Robot Arm (SCARA):
  2 paralleled revolute joint and 1 additional prismatic joint

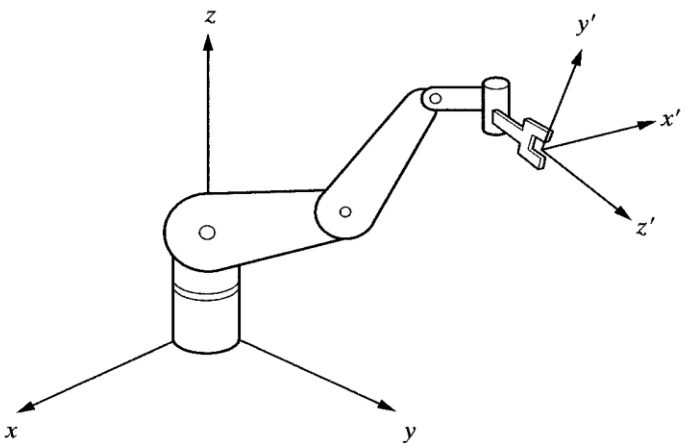
Robot Reference Frames



World reference frame



Joint reference frame



Tool reference frame

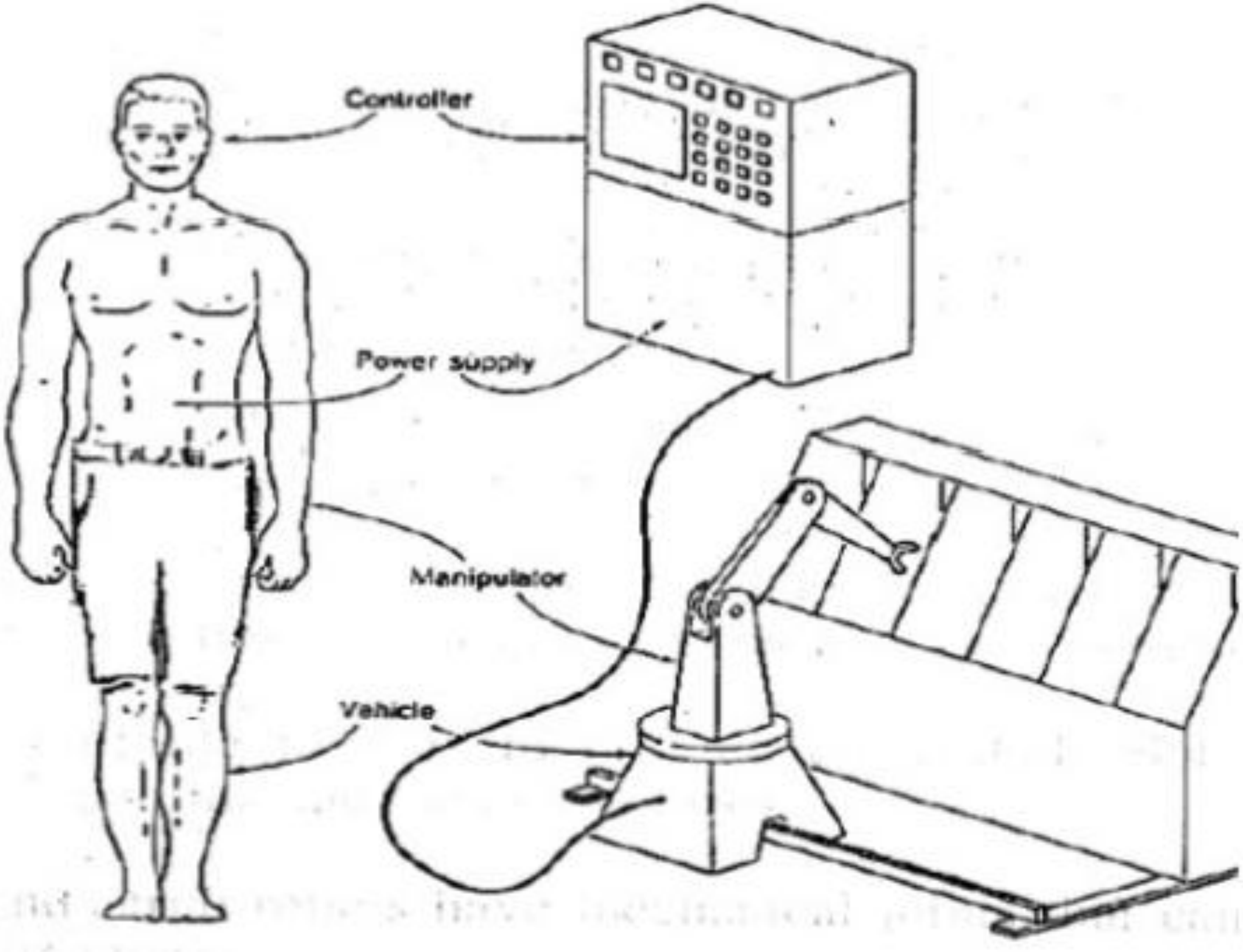
Robot's World, Joint, and Tool reference frames.

Most robots may be programmed to move relative to either of these reference frames.

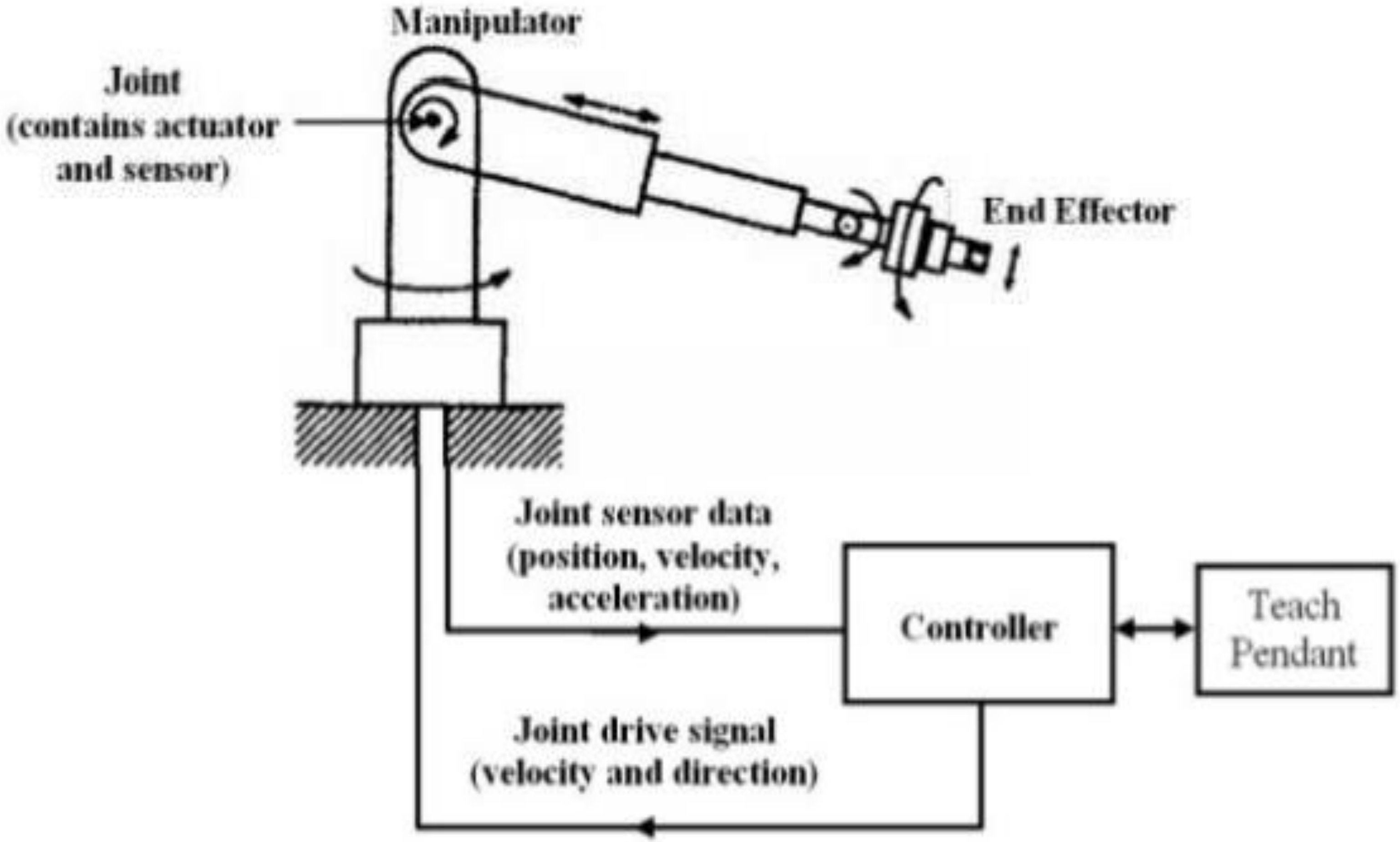
Robot system consists of following components:

- Manipulators or the rover
- End effecter
- Actuators
- Sensors
- Controller
- Processor
- Software

Analogy of Robot with humans



Basic Components..



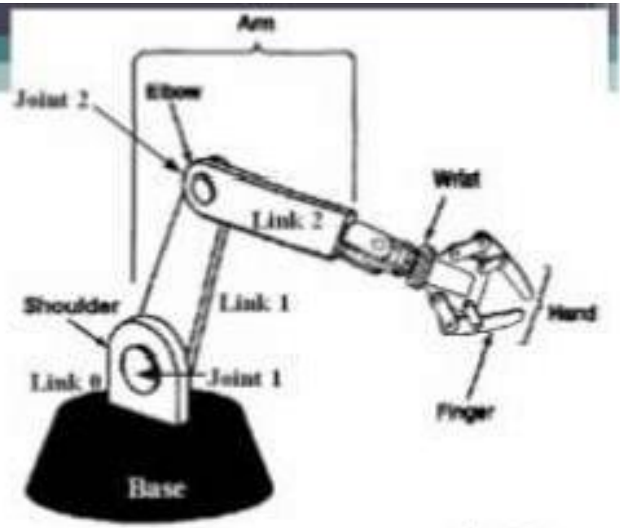
Teach Pendant

- The robot will move to various locations in performing its tasks.
- These locations can be determined by a controller system whenever the robot's working environment is defined.
- However, these locations are usually taught to the robot controller and used by the operator to move the robot to desire locations.
- Teach pendants sometimes can also be used to issue other commands to the robot or to teach a relatively simple program.

Manipulator

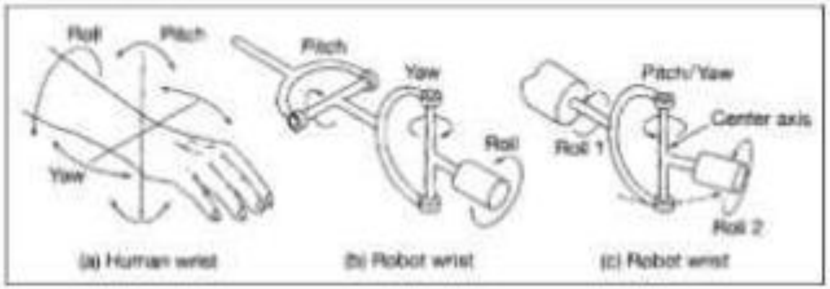
- Manipulator is a main body for the robot and consists of the joints, links and other structural elements of the robot.
- It is a collection of mechanical linkages (or link) connected by joints and included are gears, coupling devices, and so on.
- Generally, joints of a manipulator fall into two classes:
  - revolute (rotary)
  - prismatic (linear).
- Each of the joints of a robot defines a joint axis along which the particular link either rotates or slides (translates).
- Every joint axis identifies a degree of freedom (DOF).
  - ► No. of DOFs = No. of Joints.

Analogy with human hand

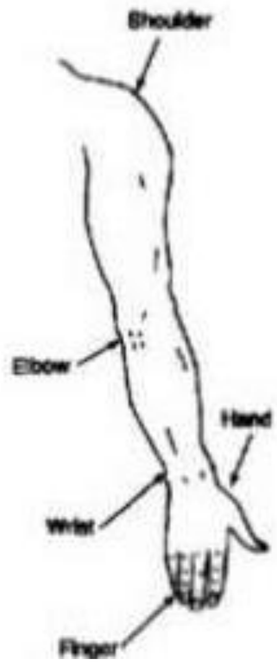


Manipulator..

- Regardless of its mechanical configuration, the manipulator defined by the joint-link structure generally contains three main structural elements as human parts:
  - the arm
  - the wrist
  - the end effector.



- Most robots are mounted on stationary base on the floor and its connection to the first joint as called link 0. The output link of joint 1 is link 1, and so on.



Manipulator...

- Besides the mechanical components, most manipulators also contain the devices for producing the movement of the various mechanical members.
- These devices are referred to as actuators and may be pneumatic, hydraulic, or electrical in nature.
- They are either directly or indirectly, coupled to the various mechanical links or joints (axes) of the arm.
- In the latter case, gears, belts, chains, harmonic drives, or lead screws can be used.
- The interface between the last link and the end effector is called the tool mounting plate or tool flange.

End Effector

- End effector is the part that is connected to the last joint (hand) of a manipulator, which generally handles objects, makes connection to other machines, or performs the required tasks.
- Robot manufacturers generally do not design or sell end effectors; just supply a simple gripper.
- This is the job of a company's engineers or outside consultants to design and install the end effector on the robot and to make it work for the given situation/task.
- In most cases, either the action of the end effector is controlled by the robot's controller, or the controller communicates with the end effector's controlling device such as a PLC.

End Effector..

- The end effectors can include a sensor to determine if a part is present.
- The addition of a simple sensor can make a gripper a relatively intelligent device.
- For example
  - A simple gripper that has a sensor in it which tells if there is something between its jaws
  - This could be as simple as a light and phototransistor
  - If the robot is commanded to go and get a part, the manipulator will position the tool to the correct location and then check the gripper's sensor before closing the gripper.

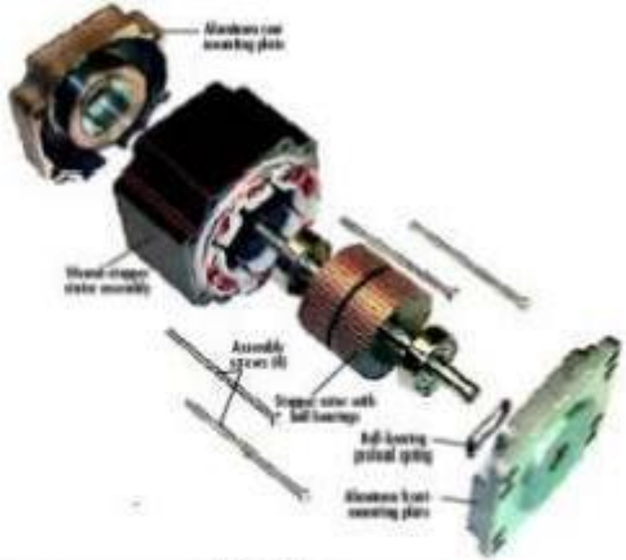
Actuators

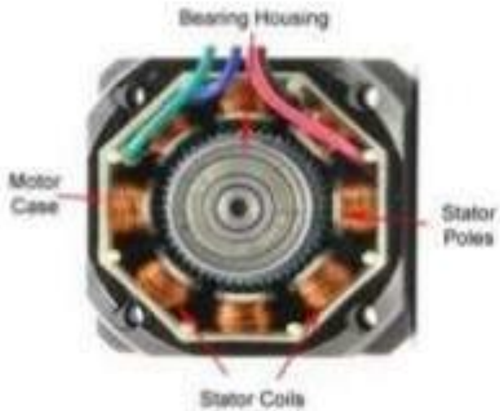
- Actuators are used to move elements of the manipulators.
- It must have enough power to accelerate and decelerate the links and to carry the loads, yet be light, economical, accurate, responsive, reliable, and easy to maintain.
- Each actuator is driven by a controller.
- Common types of actuators are ***electric motors*** (servomotors and stepper motors), ***pneumatic*** cylinders, and ***hydraulic*** cylinders.
- Electric motor especially servomotors are the most commonly used.
- Hydraulic systems were very popular for large robots in the past and still around in many places, but are not used in new robots as often any more.
- Pneumatic cylinders are used in robots that have on-off type joints, as well as for insertion purposes.

Robot system components:

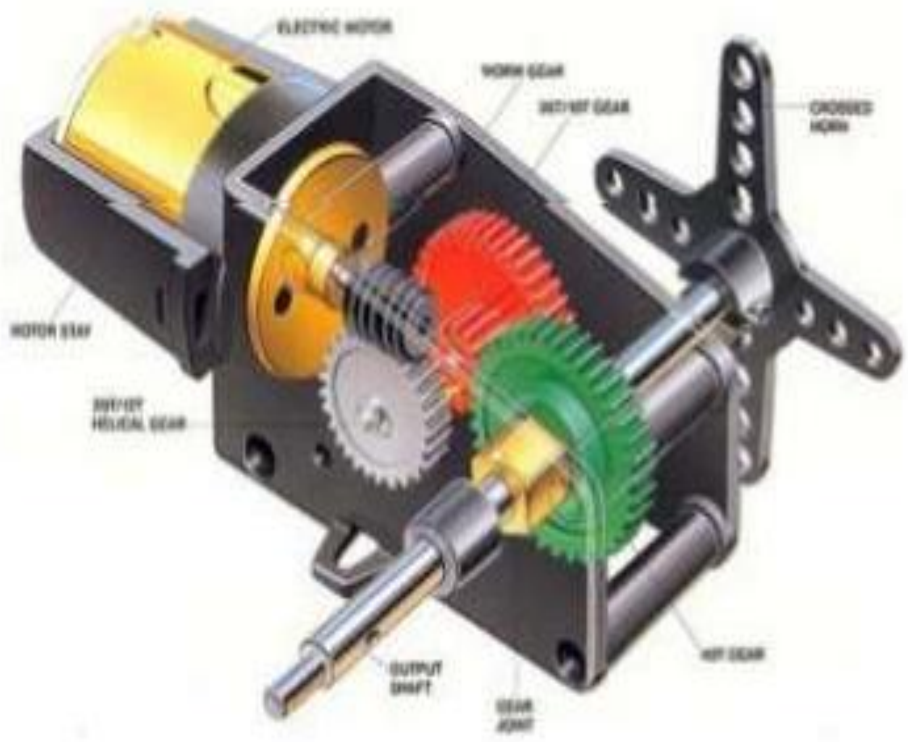
Actuators : Actuators are the muscles of the manipulators. Common types of actuators are servomotors, stepper motors, pneumatic cylinders etc.

Stepper Motor





Servo Motor


ELECTRIC MOTOR
WORM GEAR
CROSSED HORN
MOTOR STAY
HELICAL GEAR
OUTPUT SHAFT
GEAR JOINT

Sensors

- Adding sensors to an industrial robot can increase the range of tasks the robot can perform.
- It also decreases the mechanical tolerances required of both the robot and the robot's environment.
- Sensors can be divided into three categories:
  - **internal sensors**: tell a robot the position of its various joints and report other conditions such as fluid pressure and temperature.
  - **external sensors**: tell the robot what is happening outside.
  - **interlocks**: used to protect both humans and robots. They may possess features of both internal and external sensors.

Sensors..

- If robots are to use sensors in the middle of the electrical noise of a factory, care must be used in transmitting information from them to the robot's controller without interference.
- If the sensor information is being shared with a production computer, the possibility of noise problems is increased.
- Fiber optics or differential drivers may be needed to get the signals to the controller.
- Many sensor devices give an analog signal, while the controller uses digital signals; therefore analog-to-digital and digital-to-analog converter circuits may be required.

Sensors

Accelerometer
Gyro
Metal Detector
Gas Sensor
Piezo Bend Sensor
UV Detector
Resistive Bend Sensors
CDS Cell
Touch Switch
Mechanical Tilt Sensors
Magnetic Sensor
Magnetic Reed Switch
IRDA Transceiver
Solar Cell
Compass
Compass
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Controller

- The controller receives its data from the computer, controls the motions of the actuators, and coordinates the motions with the sensory feedback information.
- Suppose that in order for the robot to pick up a part from a bin, it is necessary that its first joint be at 35°.
- If the joint is not already at this magnitude, the controller will send a signal to the actuator (a current to an electric motor, air to a pneumatic cylinder, or a signal to a hydraulic servo valve), causing it to move.
- It will then measure the change in the joint angle through the feedback sensor attached to the joint (a potentiometer, an encoder, etc.).
- When the joint reaches the desired value, the signal is stopped.

Robot system components:

- **Controller** : The controller receives data from the computer, controls the motions of the actuator and coordinates these motions with the sensory feedback information.

Robot system components:

Energy:

Work Envelope concept

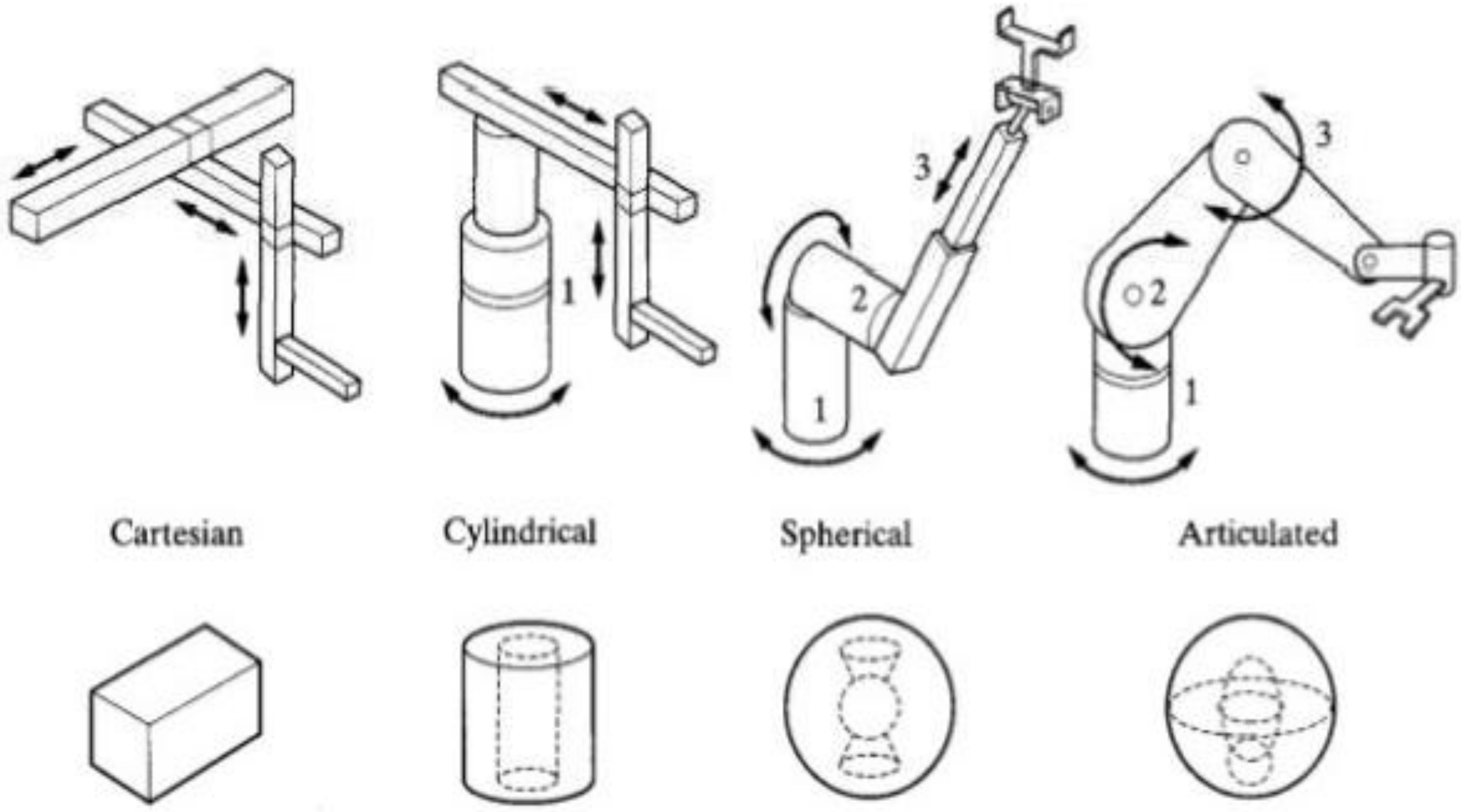
- Depending on the configuration and size of the links and wrist joints, robots can reach a collection of points called a **Workspace**.

- Alternately Workspace may be found empirically, by moving each joint through its range of motions and combining all space it can reach and subtracting what space it cannot reach

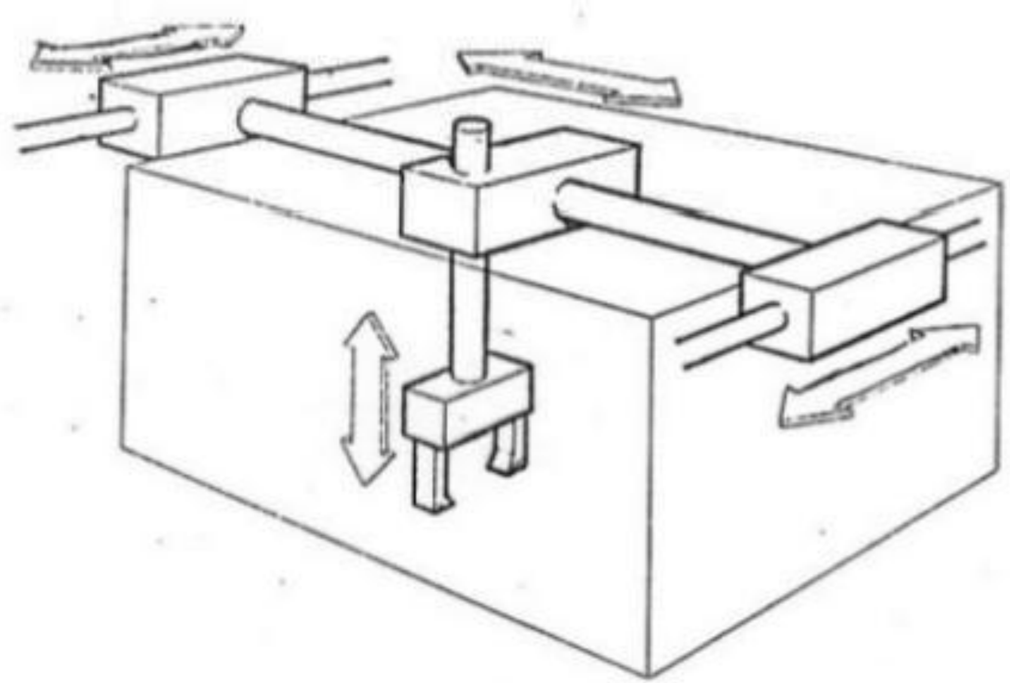
Robot Workspaces

- Workspace or work envelope is an area which robot can reach.
- The shape of the workspace for each robot is uniquely related to its characteristics of robot configuration, links and wrist joints.
- The workspace may be found mathematically by writing equations that define the robot's links and joints and including their limitations, such as ranges of motions for each joint.
- When a robot is being considered for a particular application, its workspace must be studied to ensure that the robot will be able to reach the desired points.

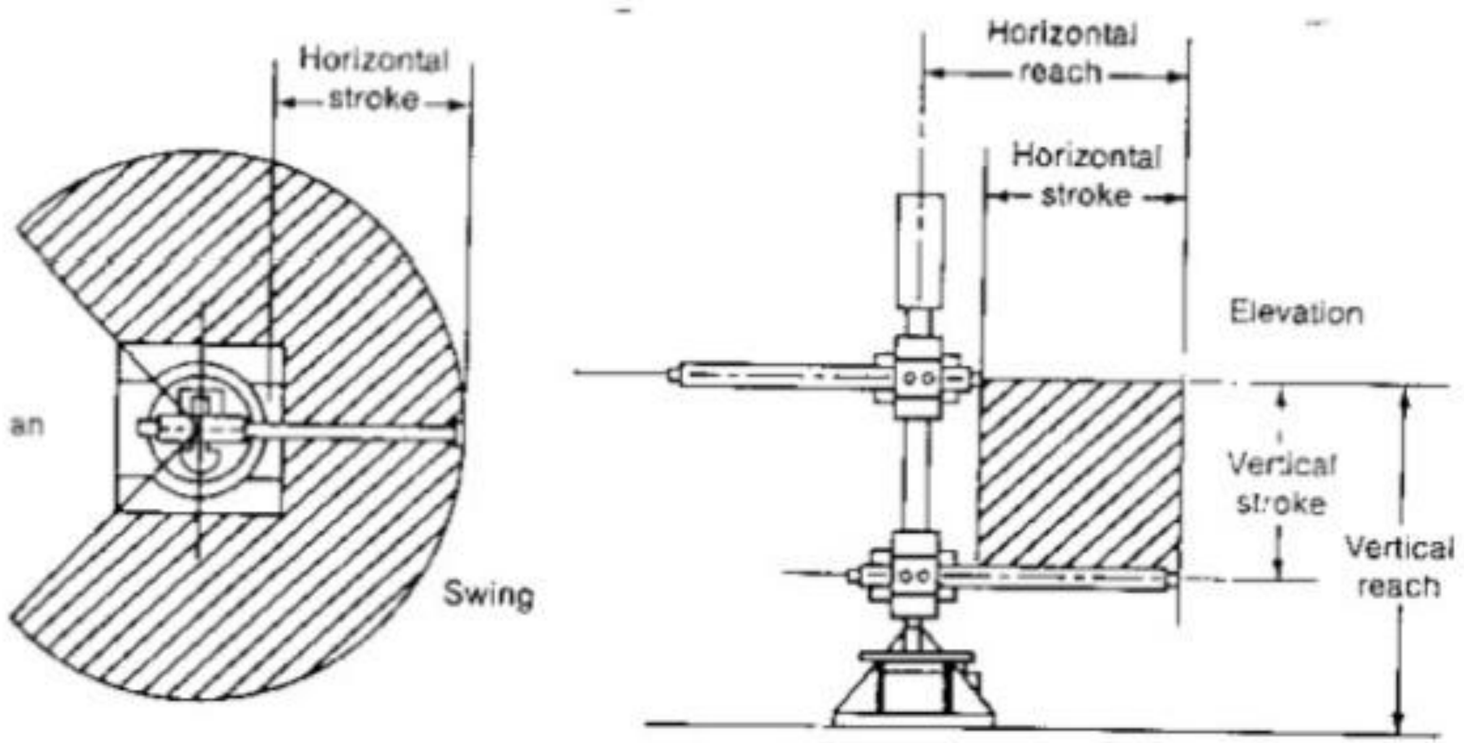
Typical Workspaces for Common Robot Configurations



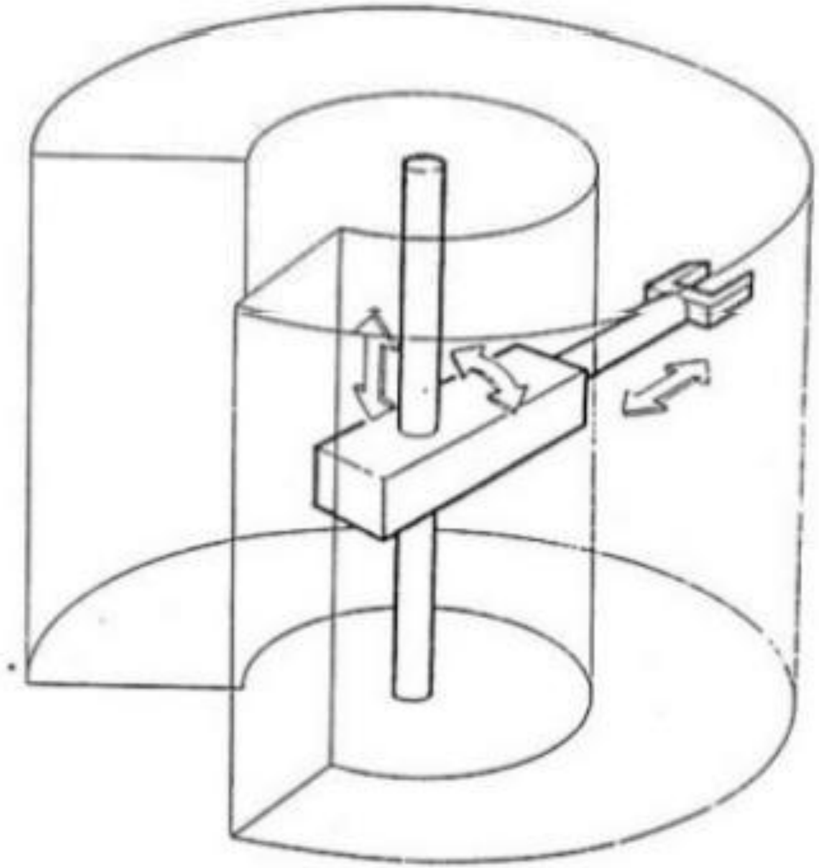
Typical Workspaces for Cartesian Configuration



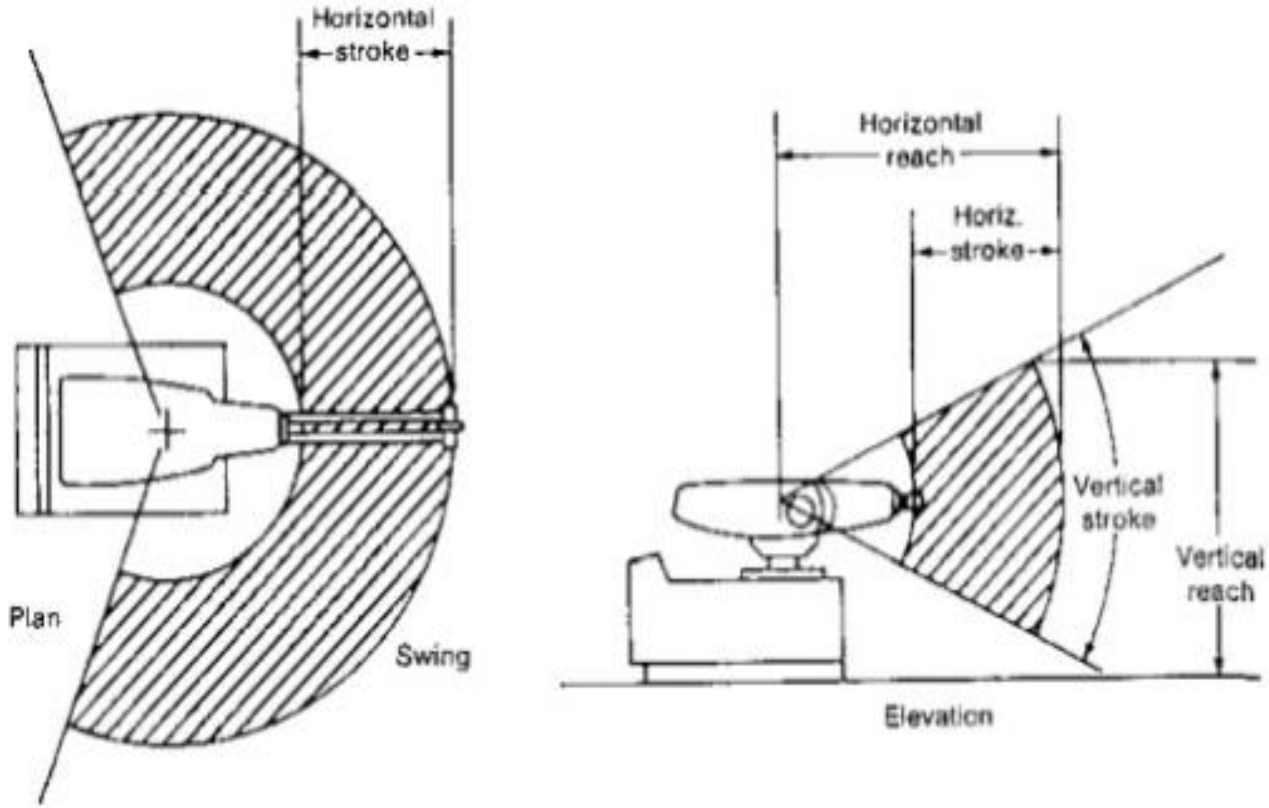
Cylindrical Robot - Work Envelope



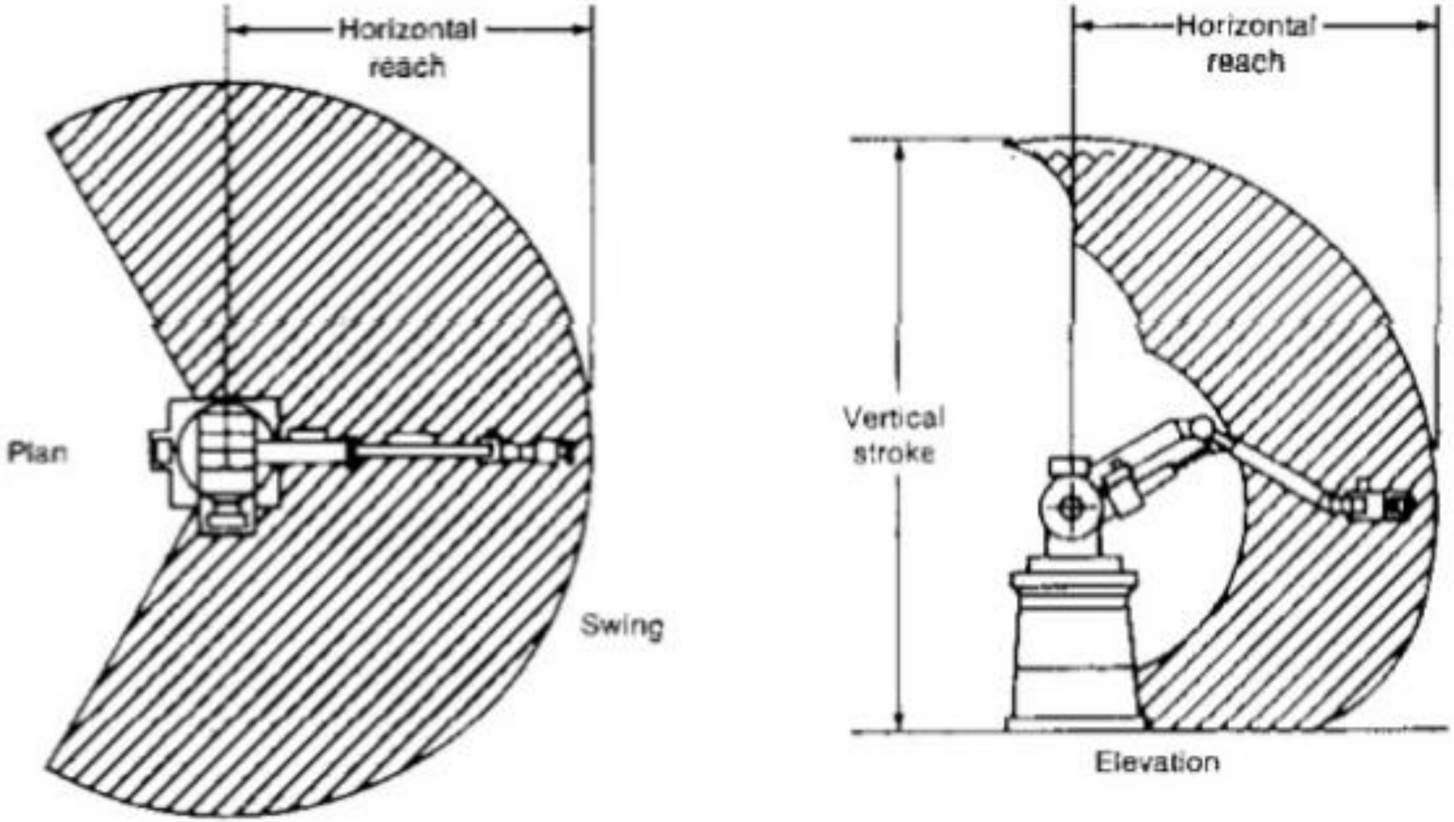
Typical Workspaces for Cylindrical Configuration



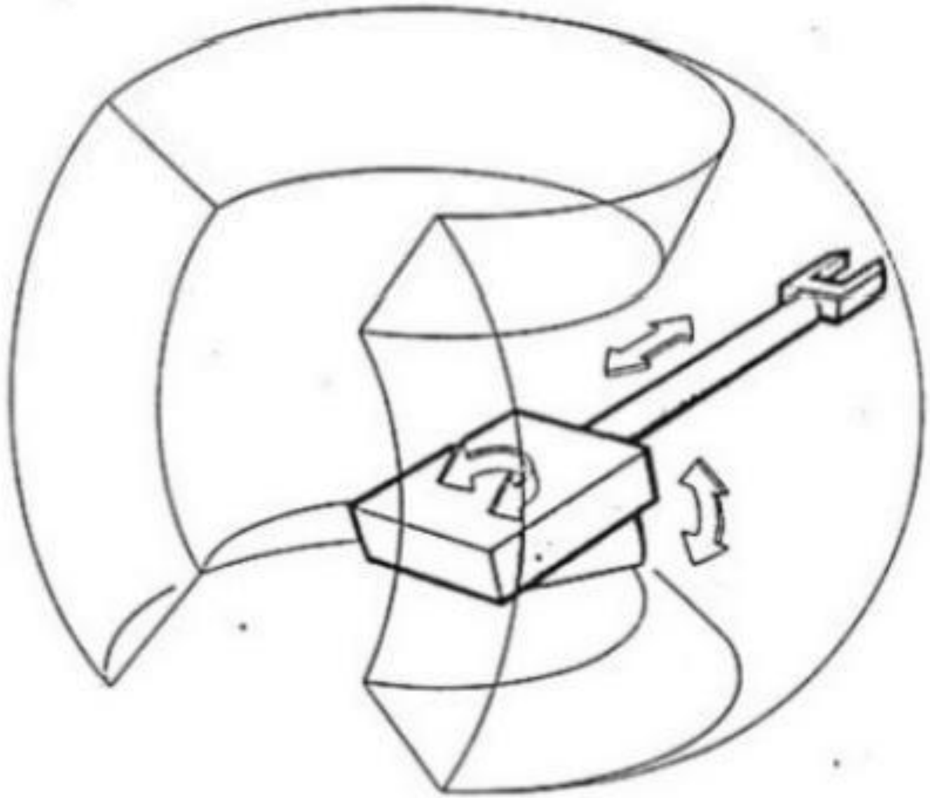
Spherical Robot - Work Envelope



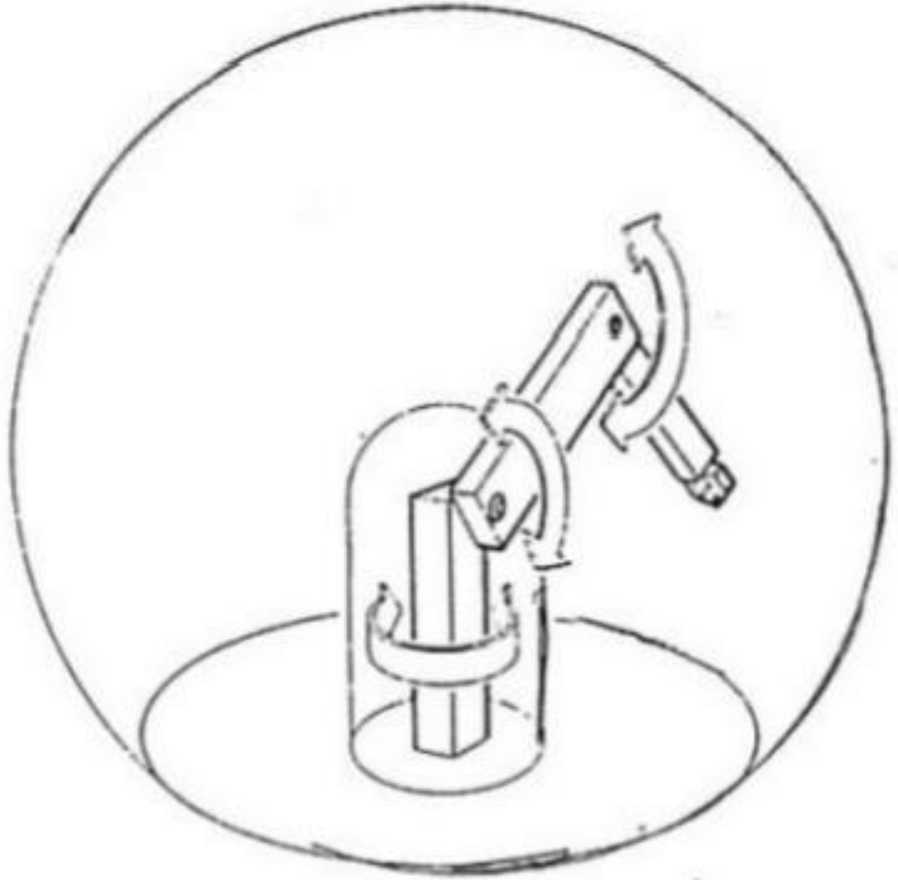
Pure Spherical Jointed Arm - Work envelope



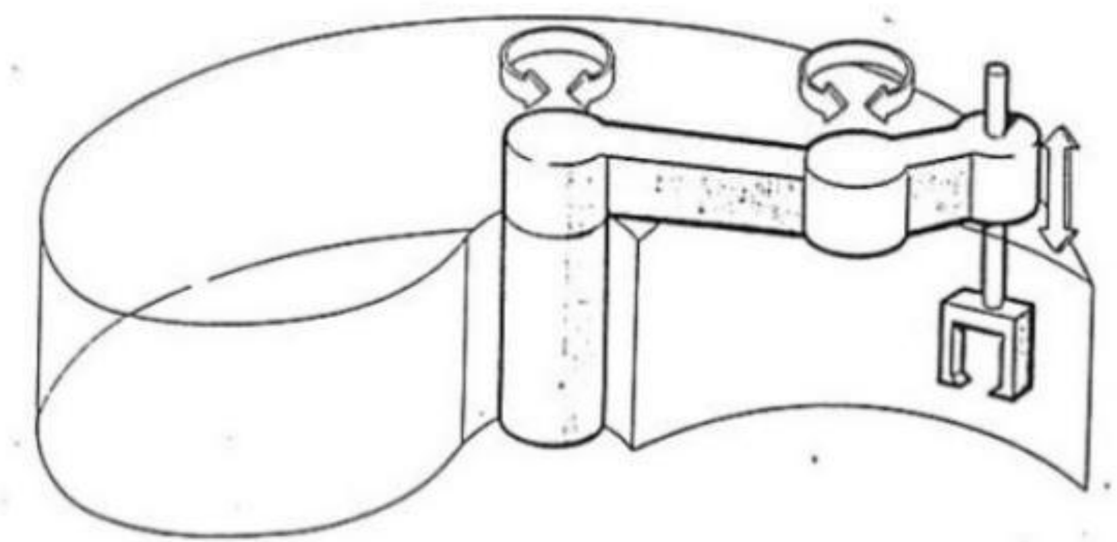
Typical Workspaces for Polar Configuration



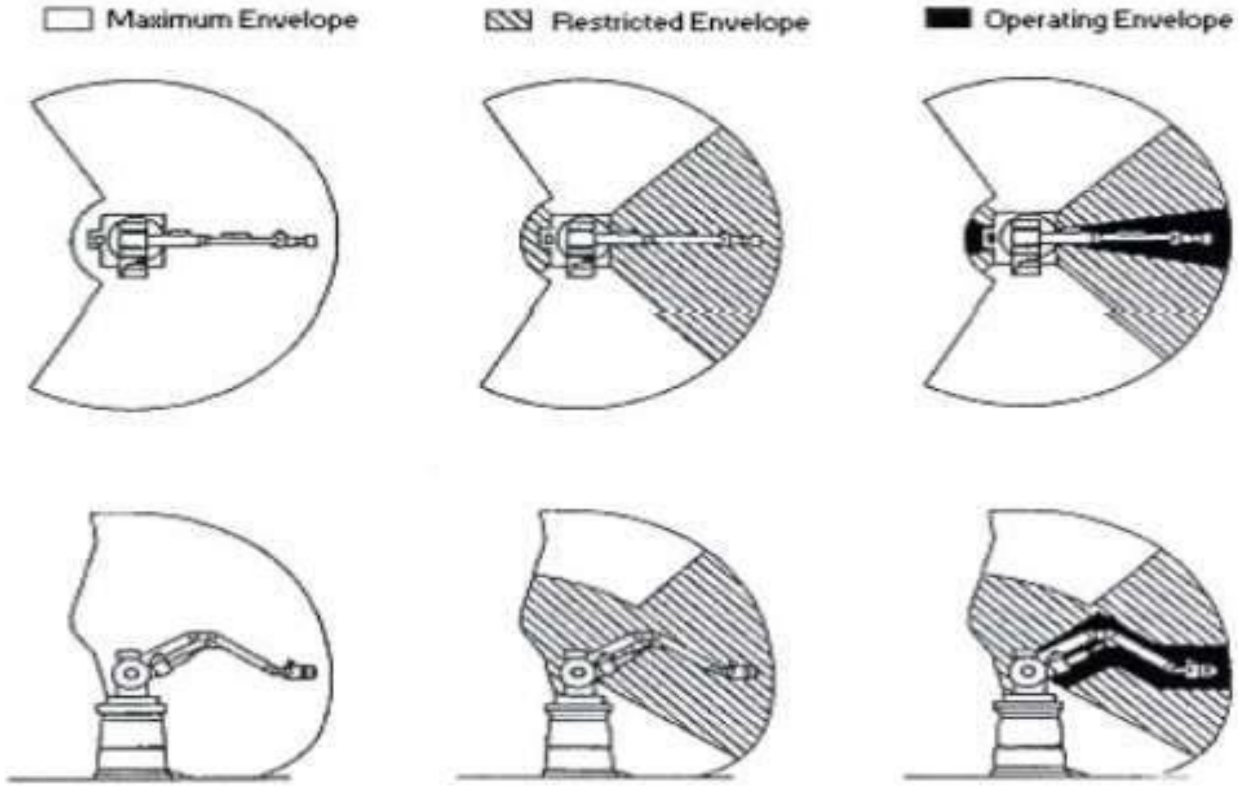
Typical Workspaces for Jointed-Arm Configuration



Typical Workspaces for SCARA
(Selective Compliance Assembly Robot Arm)



Working Envelope



Reachable workspace and Dexterous workspace

The reachable workspace is the volume the manipulator (hand) can reach.

The dextrous workspace is a subset of that in which the manipulator can move with every degree of freedom.

Just think about the furthest points you can touch with your fingertips, that's the outer boundary of your reachable workspace.

The dextrous workspace is made up of all the points where you could grab a stationary object and still move all your joints as you usually could.

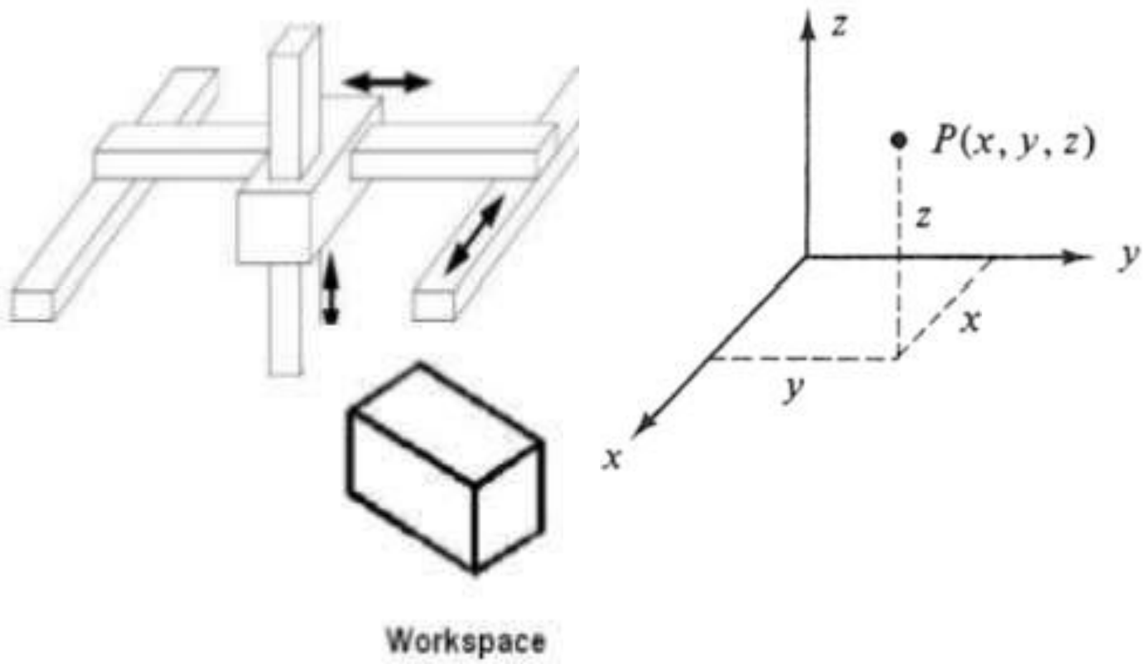
Types of Robots (Based on Coordinate systems)

There are five types of robots which are:

- Cartesian robot
- Cylindrical
- Spherical
- Articulated/Anthropomorphic robot
- SCARA

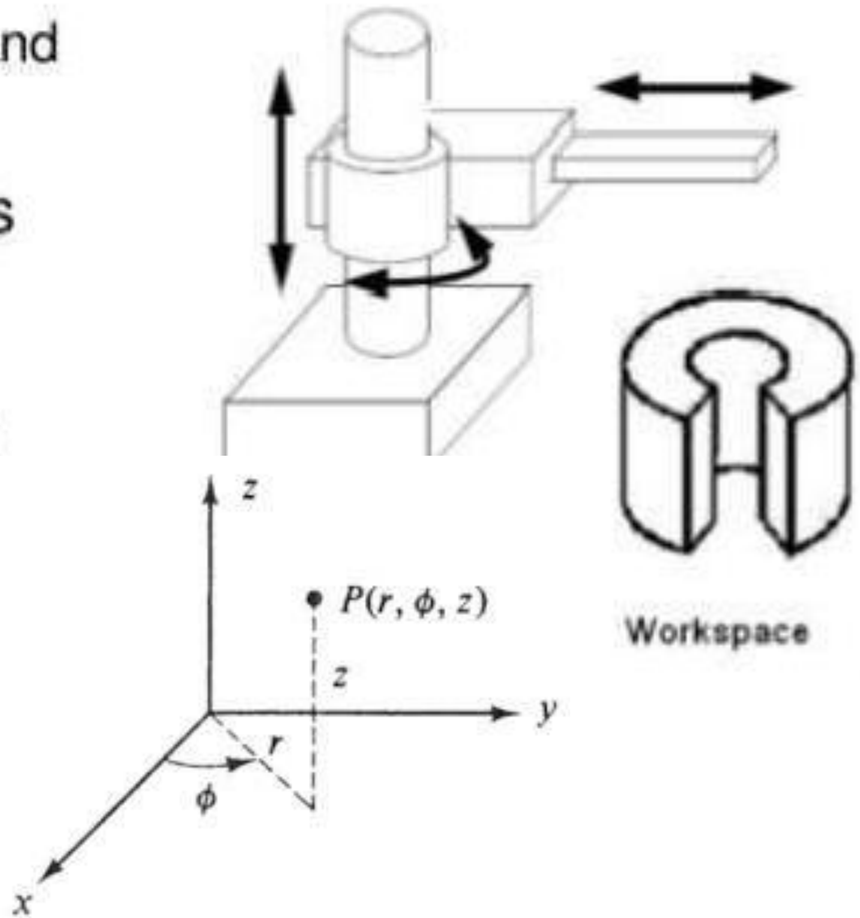
Cartesian Robot (3P)

- A Cartesian robot, also known as a Cartesian coordinate robot, is a common type of industrial robot. It has three "arms" that each function along linear axes of control. Each of these axes is at a right angle to the other two.
- Motions available:
  1. Forward/Reverse if horizontal
  2. Up/Down if vertical

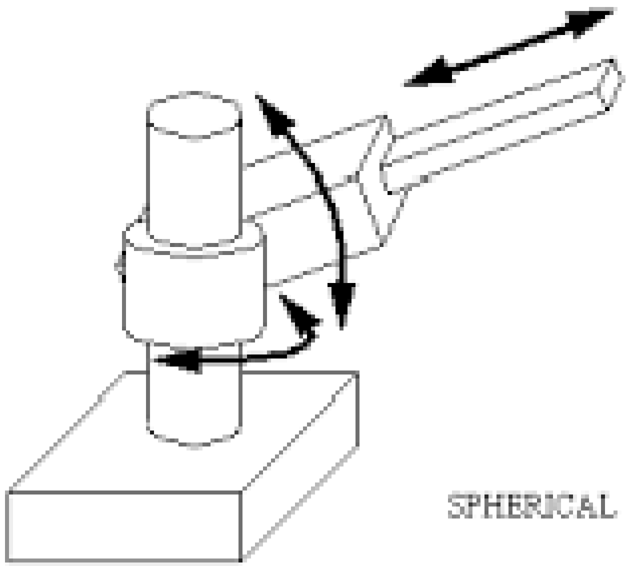


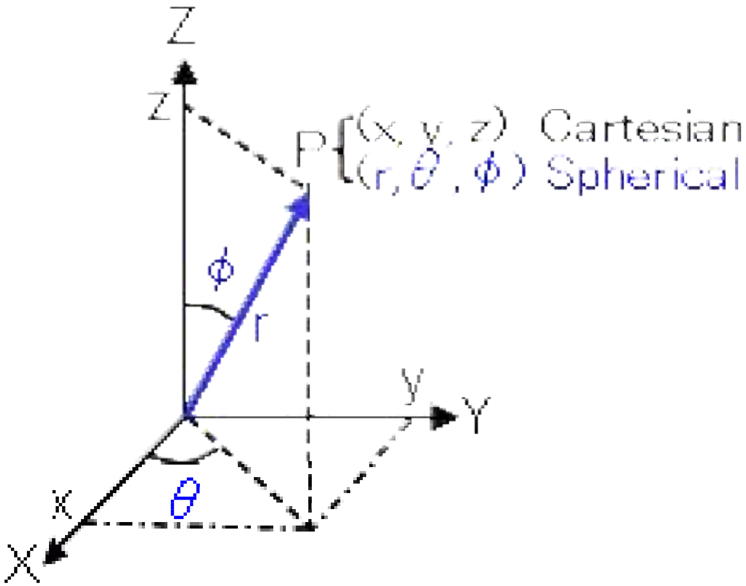
Cylindrical Robot (R2P)

- It has three axes of movement -
  - two of which are linear and
  - one - circular.
- So, usually robots of this type can move along Z and Y axes and rotate along Z axis. Therefor it forms a cylindrical coordinate system



Spherical Robot (2RP)





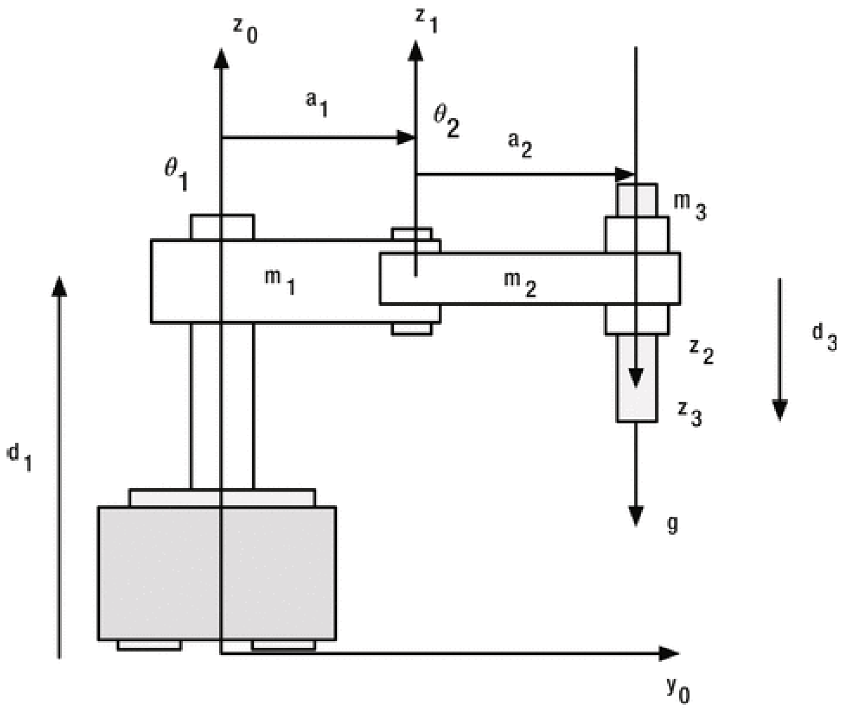
Spherical coordinate robot has one prismatic joint and two revolute joints to positioning parts/objects. These are extensively used in industries in FMS.

r ⟶ z
b ⟶ y
g ⟶ y

Articulated/ Anthropomorphic Robot (3R)

- The articulate or jointed arm robot (or sometime called Anthropomorphic arms) closely resembles the human arm.
- The mechanical structure has
  - three rotary joints which forms a polar coordinate system.

Selective Compliance Assembly Robot Arm (SCARA) developed in 1981, (2RP)



- Commonly used for assembly operation in industries.

- Their specific characteristics is that they are more compliant in x-y plane, but very stiff along the z-axis.and thus selective compliance.

Types of Robots

1. Based on Coordinate systems
   (a) Cartesian Coordinate robot
   (b) Cylindrical Coordinate robot)
   (c) Spherical Coordinate robot)
   (d) Articulated Or Anthropomorphic robot)
   (e) Selective Compliance Assembly Robot Arm (SCARA) robot

2. Based on Power source
   (a) Electric powered, (b) Hydraulic powered, (c) Pneumatic powered

3. Based on methods of control
   (a) Servo Control (b) Non-servo control

4. Based on sequence of operations
(a) Fixed sequence and (b) Variable sequence

5. Based on Trajectory Control: Point to point control and continuous control robot.

6. Based on sensing system: Active robot and Passive robot

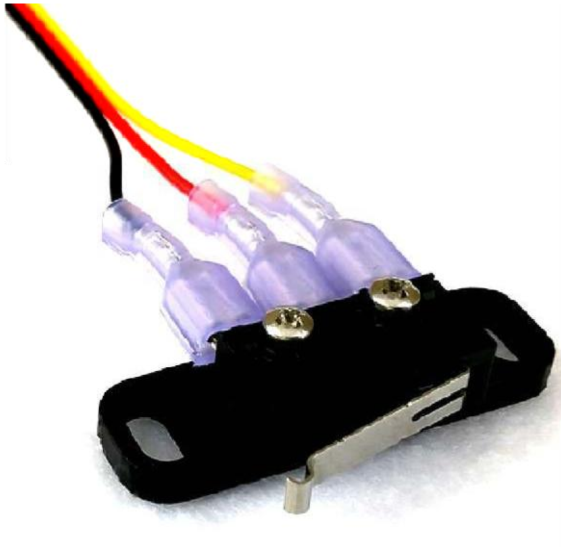
Note:-

** Hydraulic and pneumatic actuators are generally suited for driving prismatic joints. Since they produce linear motion directly. They are often referred as linear actuators.

**Electric actuators which produce rotation are most suited to drive revolute joints. However, various mechanisms are required to convert rotary to linear motion or vice-versa.

Limits Switch

Limit Switch Sensor Signal: The limit switch sensor is a physical switch. It can tell the robot whether the sensor's metal arm is being pushed down or not.



Robot Characteristics

- The following characteristics are typically used to describe commercial industrial robots:
  - Payload
  - Reach
  - Precision (validity)
  - Repeatability (variability)

Robot Characteristics

- **Payload**
  - Payload is the weight a robot can carry and remain within its specifications.
  - If load capacity larger than its specified payload, it may become less accurate, may not follow its intended path accurately, or may have excessive deflections.
  - The payload of robots compared with their own weight is usually very small.

  >> Fanuc Robotics LR Mate™ robot has a mechanical weight of 86 lbs and a payload of 6.6 lbs.

M-16i robot has weight =594lbs and a payload of 35lbs.

Robot Characteristics

- **Reach**
  - Reach is the maximum distance a robot can reach within its work envelope.
  - Many points within the work envelope of the robot may be reached with any desired orientation (called dexterous).
  - However, for other points, close to the limit of robot's reach capability, orientation cannot be specified as desired (called non-dexterous point).
  - Reach is a function of the robot's joint lengths and its configuration.

○ **Many points within the work envelope of the robot may be reached with any desired orientation (called as dexterous point).**

○ **Reach is a function of robot's joint length and it's configuration.**

Robot Characteristics

- **Precision (validity)**
  - Precision is defined as how accurately a specified point can be reached.
  - This is a function of the resolution of the actuators, as well as its feedback devices.
  - Most industrial robots can have precision of 0.001 inch or better.

Robot Characteristics

- **Repeatability (variability)**
  - Repeatability is how accurately the same position can be reached if the motion is repeated many times.
  - Suppose that a robot is driven to the same point 100 times. Since many factors may affect the accuracy of the position, the robot may not reach the same point every time, but will be within a certain radius from the desired point.
  - The radius of a circle that is formed by this repeated motion is called repeatability. Most industrial robots have repeatability in the 0.001 inch range.
  - Repeatability is more important than precision. If a robot is not precise, it will generally show a consistent error, which can be predicted and thus corrected through programming.
  - As an example, suppose that a robot is consistently of 0.05 inch to the right. In that case, all desired points can be specified at 0.05 inch to the left, and thus the error can be eliminated. However, if the error is random, it cannot be predicted and thus cannot be eliminated.

Repeatability and Accuracy

The repeatability and accuracy of an industrial robot have a direct impact on the effectiveness during the execution of its tasks.

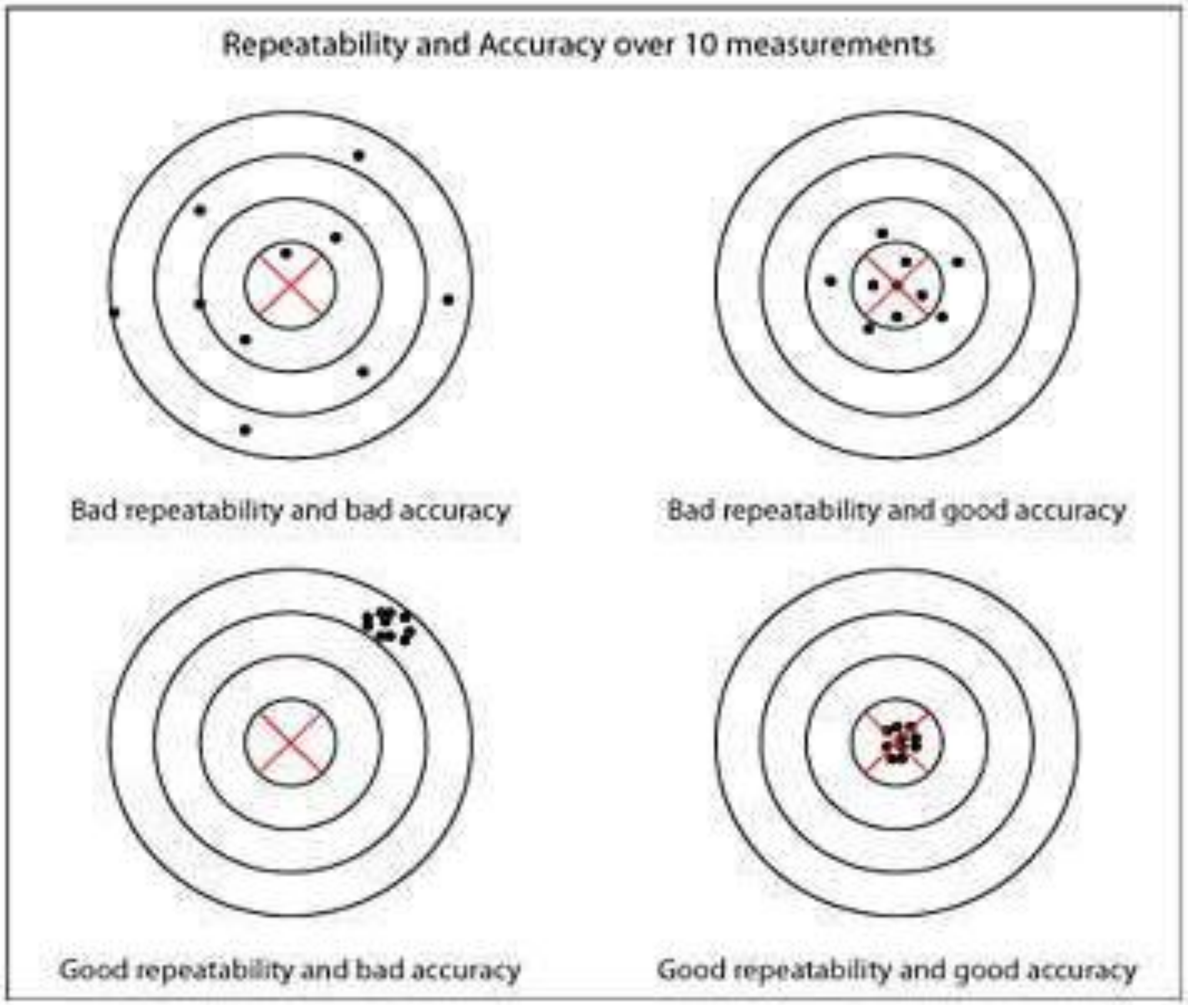
The repeatability of a robot can be defined as its ability to achieve repetition of the same task (point).

On the other hand, accuracy is the difference (i.e. the error) between the set task and the obtained task (i.e. the task actually achieved by the robot).

So, repeatability is doing the same task over and over again, while accuracy is hitting your target each time.

The typical value of repeatability for revolute joint robot is 0.1mm, while for **Staubli robot** it is 0.02mm.

Repeatability and Accuracy



Programming Modes

- **Programming Modes**

1. Lead Through Programming
2.Teach Mode: Teaching Pendant/ Playback/p-to-p Programming
3. Textual Programming using computer: Use of feedback information

Robot Languages

Microcomputer Machine Language Level: the most basic and very efficient but difficult to understand to follow.

Point-to-Point Level: Funky® Cincinnati Milacron's T3©
It lacks branching, sensory information.

Primitive Motion Level: VAL by Unimation™
Interpreter based language.

Structured Programming Level: This is a compiler based but more difficult to learn.

Task-Oriented Level: Not exist yet and proposed IBM in the 1980s.

Holonomic and Non-holonomic Robot

- A holonomic robot means that the number of degrees of freedom (for example 3 parameters of translation in 3D space and 3 parameters of rotation) equal the number of controllable degrees of freedom. However, non-holonomic means the number of controllable degrees of freedom is less than the number of degrees of freedom which the robot experiences.
- Example:
- The number of DOF of this robot is 3: it acts in a 2D plane with additional rotation. However, the actual mechanism controlling the motion only has two DOF (degrees of freedom) because it is moving in the 2D plane as can be controlled but it can’t rotate.

- A car is another non-holonomic mechanism. You can’t directly position a car in space which is why parallel parking is not the easiest thing in the world.
- In comparison, omni-wheels are mechanical structures that direct control over the motion in 3DOF space (2 translation and a a single rotation).

- In simpler terms, a **holonomic** system is when the number of controllable degrees of freedom is equal to the total degrees of freedom.

- Holonomy refers to a restriction (or not) among translational axes. If a robot is holonomic with respect to N dimensions, it's capable of moving in any direction in any of those N physical dimensions available to it. If it's nonholonomic, it's restricted in which directions it can move in.
- For example, in a one-dimensional space, there is only one axis in which something can move. If you pretend that axis is a railroad track, a train would be considered holonomic because it could potentially move in either direction. If you took some object that could only move in one direction on the tracks, that object would be nonholonomic.
- If, however, you expanded that space into two dimensions such that there were two axis with one still being railroad tracks, a train would no longer be considered holonomic, because it could still only move along one predefined axis, and is not capable of moving along the other axis physically available for movement otherwise in (trains can't move sideways!).
- From the point of view of robotics, you can refer to humans as holonomic within our two-dimensional space (we can't fly). If you built a robot that could move in any direction like a human can, it would also be holonomic. If you built a robot that could only move forward, or sideways, or backwards, that robot would be nonholonomic.
- Holonomic system where a robot can move in any direction in the configuration space.
- Nonholonomic systems are systems where the velocities (magnitude and or direction) and other derivatives of the position are constraint.

Active and Passive Robot

Robotics: Past, Present and Future

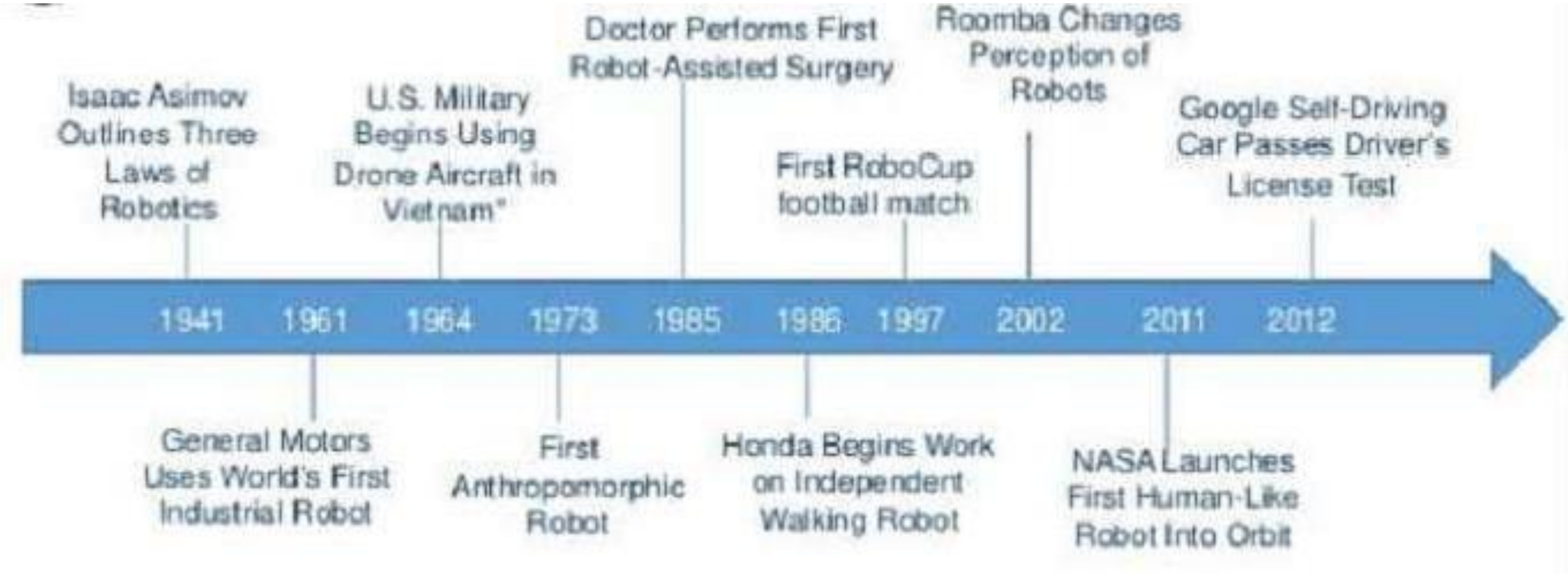
- What is Robot and AI
- Milestones of Robotics
- Types of Robotics today
- AI and robotics Intelligence
- Issues and challenges of AI Robotics in Future

What is a robot ?

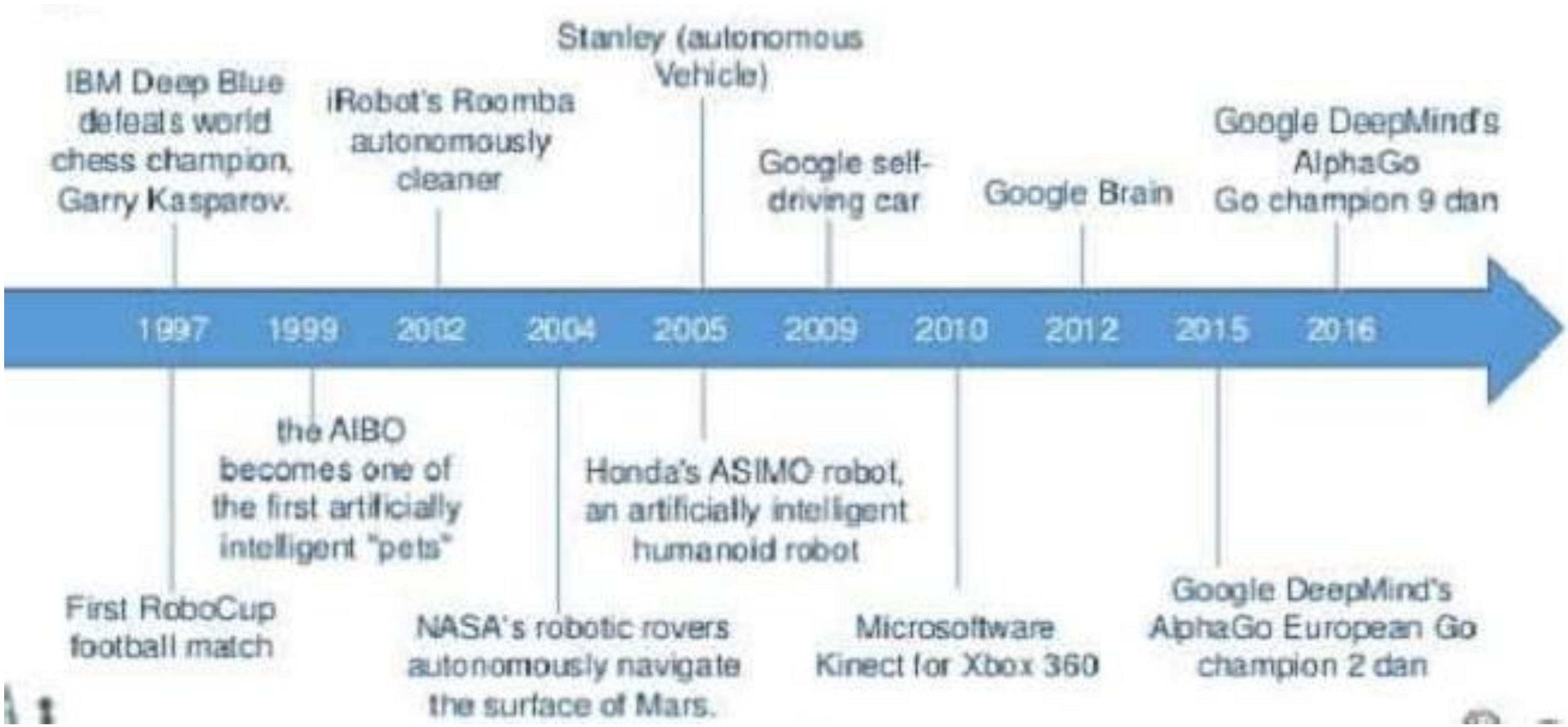
A robot is...

- "An active artificial agent whose environment is the physical world"
  --*Russell and Norvig*
- "A programmable, multifunction manipulator designed to move material, parts, tools or specific devices through variable programmed motions for the performance of a variety of tasks" --*Robot Institute of America*
- *An active artificial agent, which exists in the physical world, autonomously senses its environment and intelligently acts in the environment for a specific purpose as human expects.*

Ten Milestones of Robotics



History of AI (1993-2016)

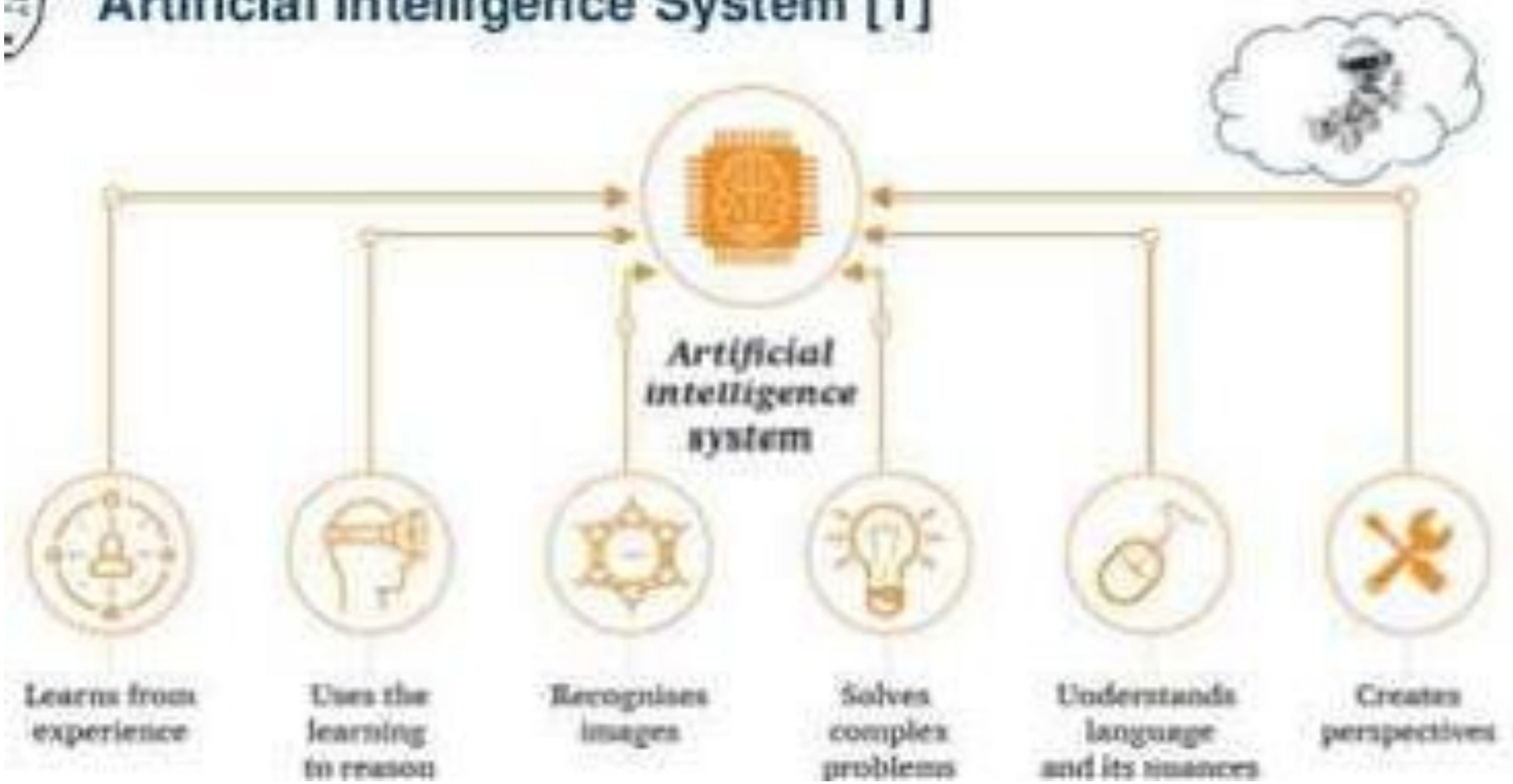


What is AI ?

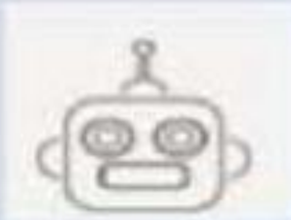
Artificial intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs.

--- John McCarthy, father of AI at MIT, 1956

Artificial Intelligence System [1]



Artificial Intelligence Today [1]

	Human in the loop	No human in the loop
Hardware/Specific System	**Assisted intelligence:** Helping people to perform tasks faster and better.	**Automated intelligence:** Automation of manual/cognitive and routine/nonroutine tasks.
Adaptive Systems	**Augmented intelligence:** Helping people to make better decisions.	**Autonomous intelligence:** Automating decision making processes without human intervention.
		

Robots in Terms of the 4 AI Forms

Assisted intelligence:	**Automated intelligence:**
Medical robots (surgery robots)	Manufacturing machines Industry arms/hands/robots
Augmented intelligence:	**Autonomous intelligence:**
Machine translators Entertainment robots (AlphaGo) Domestic robots (home care robots) Robotic nurses/doctors (cannot replace human doctors) [3]	Entertainment robots (Robot Football) Service robots Domestic robots (robotic cleaner) Mobile robots Space robots Military robots

Artificial Intelligence - Rise Beyond Human Intelligence

Disciplines Used in Robotics

- Robotics merges many technical disciplines:
  - Mechanical Engineering
  - Electrical Engineering
  - Computer Science
  - Bio-Medical Engineering
  - Ethics and Legal Issues

(Mechanical Engineering, Electrical Engineering, Computer Science) → *Mechatronics*

Military/Government Robots

Soldiers in Afghanistan being trained how to defuse a landmine using a PackBot.

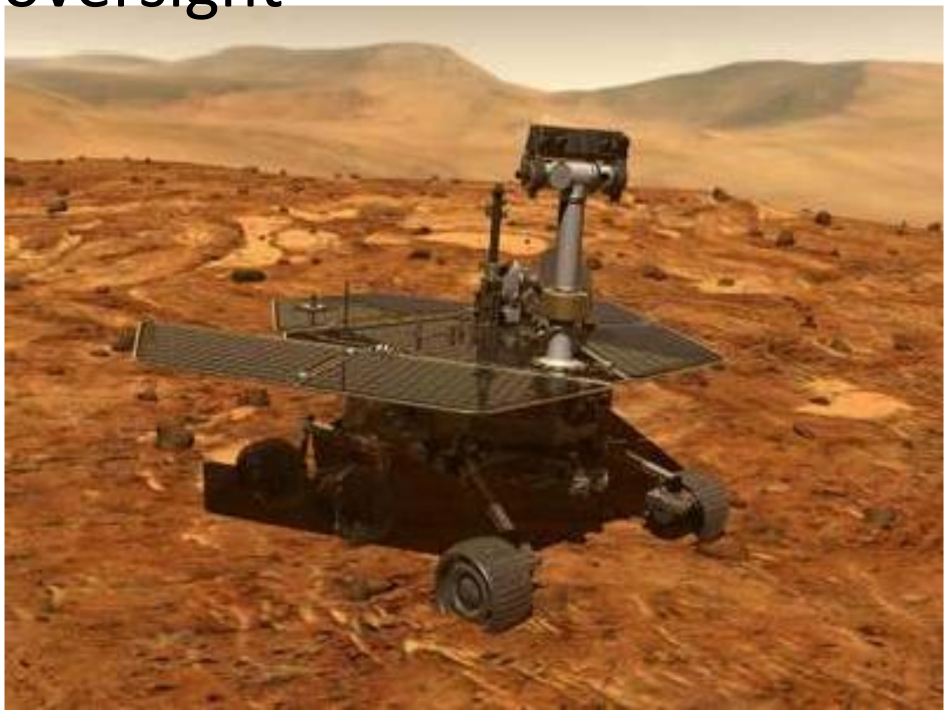
Military Robots

- Aerial drones (UAV)

- Military suit

Space Robots

- Mars Rovers – Spirit and Opportunity
  - Autonomous navigation features with human remote control and oversight



Laboratory Applications

Drug discovery

Test tube sorting

Medical/Healthcare Applications

DaVinci surgical robot by Intuitive Surgical.

St. Elizabeth Hospital is one of the local hospitals using this robot. You can see this robot in person during an open house (website).

Japanese health care assistant suit (HAL - Hybrid Assistive Limb)

Also... Mind-controlled wheelchair using NI LabVIEW

Medical robots

Manufacturing Robots


Domestic Robots





Service robots

Entertainment robots

Massive robot dance - Guinness World Recor

Space robots

Mobile robots

ROBOTICS IN FUTURE WARFARE

- Second order impacts (Cont.)
  - Robotics – military and civilian – will become ubiquitous in peace and war
  - There will be almost no human combatants on the battlefield
  - Robots will generate $12 trillion in annual U.S. revenue (2009 dollars) – approximately the U.S. GDP in 2007

Introduction to Robotics

The Future of Robotics

- To demonstrate advances in research and stimulate scientists, a RoboCup soccer competition is held a few times every year.
- Recognizing teammates, the goals, the ball is a difficult task for the robots. Thus, it becomes a challenge for them.
- Thus, constant advances are being made in robotics and robots are bound to revolutionize Humanity

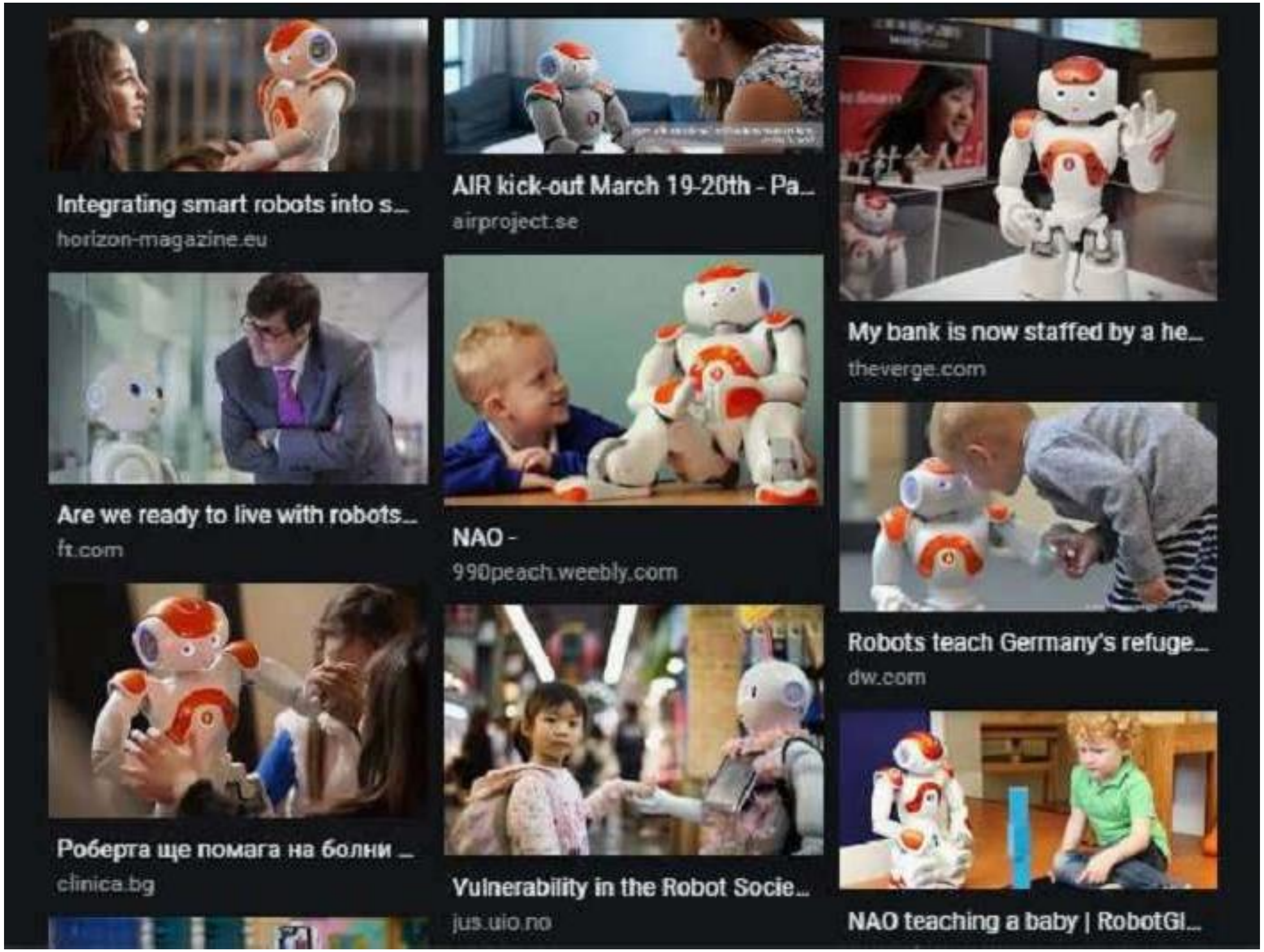
The robots' influence, and their future

❖ In the future, people and robots can go side by side in their lives in each area. In several areas they are irreplaceable now already.

❖ Replace many hard-working human workers with robots.

❖ Who knows exactly how this term "human and robots" will be translated into future. Humans and robots that complement each other – they prosper together and live together. However, Complicated tasks are still best performed by human beings with real brainpower.

Emotional Robot



Robotic Humanity:
Sophia -- the First Robot to Receive Citizenship of a Country

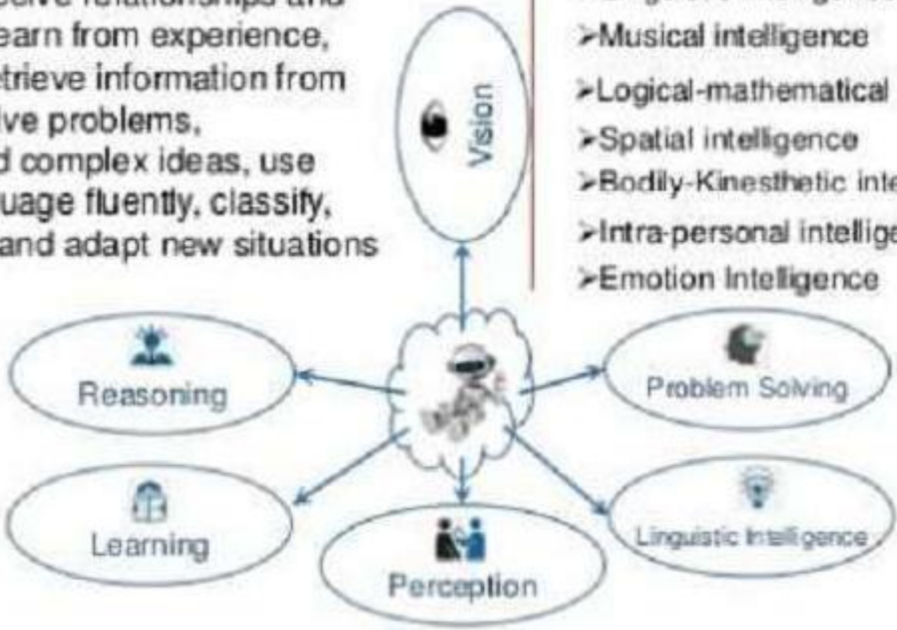
- ✓ Sophia is a social humanoid robot, able to display more than 62 facial expressions, and developed by Hong Kong-based company Hanson Robotics.
- ✓ In Apr. 2015 , Sophia was activated;
- ✓ In Mar. 2016, Sophia first appeared at South by Southwest Festival in Austin, Texas, USA.
- ✓ In Jun. 2017, Sophia presented at the AI for GOOD Global Summit, International Telecommunication Union, Geneva;
- ✓ In Oct. 2017, Sophia became a Saudi Arabian citizen;
- ✓ In Nov. 2017, Sophia was named the United Nations Development Programme's first ever Innovation Champion, the first non-human to be given any United Nations title.
- ✓ Sophia has been covered by media around the globe and has participated in many high-profile interviews.

Artificial Intelligence → Robotic Intelligence

The ability of a system to calculate, reason, perceive relationships and analogies, learn from experience, store and retrieve information from memory, solve problems, comprehend complex ideas, use natural language fluently, classify, generalise, and adapt new situations

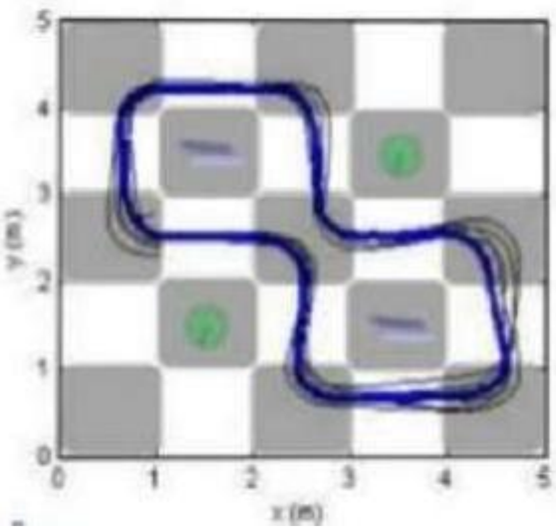
Types of Intelligence:

- Linguistic intelligence
- Musical intelligence
- Logical-mathematical intelligence
- Spatial intelligence
- Bodily-Kinesthetic intelligence
- Intra-personal intelligence
- Emotion Intelligence



Learning from Experience

A case study: Robot Route Learning with a Linguistic Decision Tree



- Human drives robot along a path for several times
- Record the data from laser sensor, which scan the environment when robot is driven
- Robot has four basic actions: turn left, turn right, forward and backward

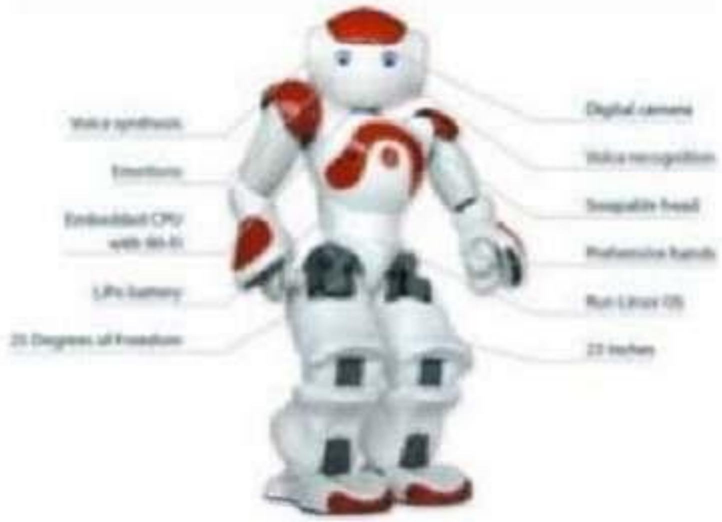
Functions of Robotics

Implementation of Robot Intelligence

- ❑Sensors
- ❑Effectors
- ❑Framework of information fus
- ❑Information Propagation

AI-enabled Robots

Interfacing a Humanoid Robot: Nao



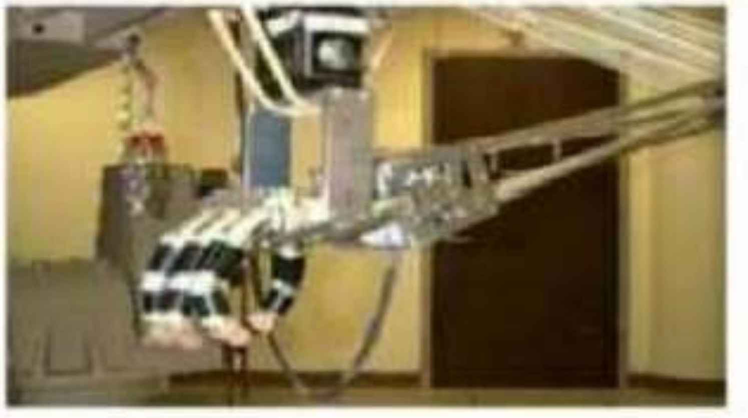
Sensors

- ❑Force-sensing
- ❑Tactile-sensing
- ❑Sonar
- ❑Laser scanner
- ❑Visual (camera)
- ❑Proprioceptive (GPS)

Drone with camera attached

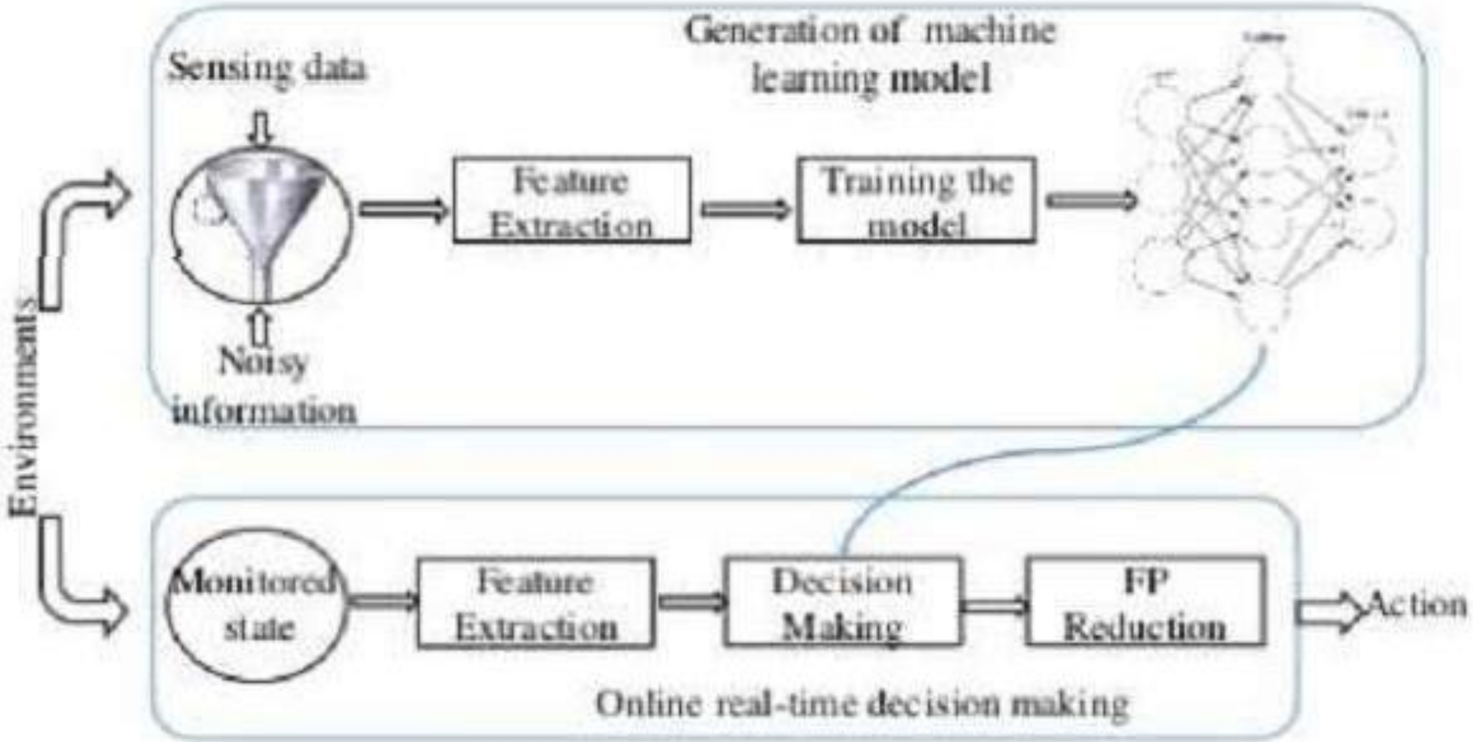
End Effectors

- ❑Effector vs. Actuator
- ❑Degrees of freedom (d.f.)
  - 6 d.f. for free body in space
- ❑Locomotion
  - Statically stable vs. Dynamically stable
- ❑Manipulation
  - Rotary vs. Prismatic motion
  - End Effector

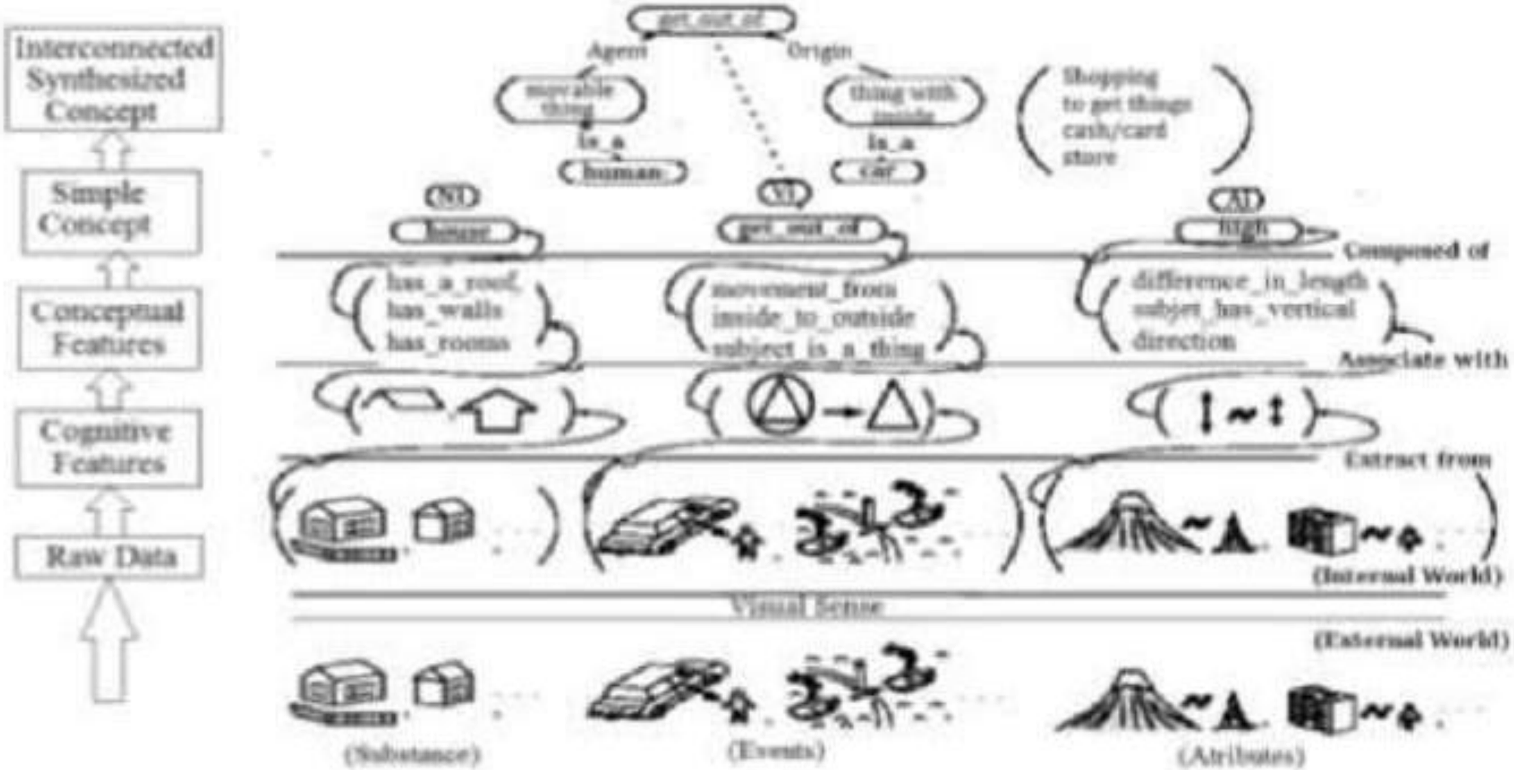


Four-finger Utah/MIT hand

A Framework of Perception



Information Propagation – still a long journey



Will robot Take our Job ? (BBC News)

- About 35% of current jobs in the UK are at high risk of computerisation over the following 20 years, according to a study by researchers at Oxford University and Deloitte.
- Narrative Science chief scientist Kristian Hammond has previously said that in 15 years' time, 90% of news will be written by machines but, he told the BBC, that didn't mean that 90% of journalist jobs would go.

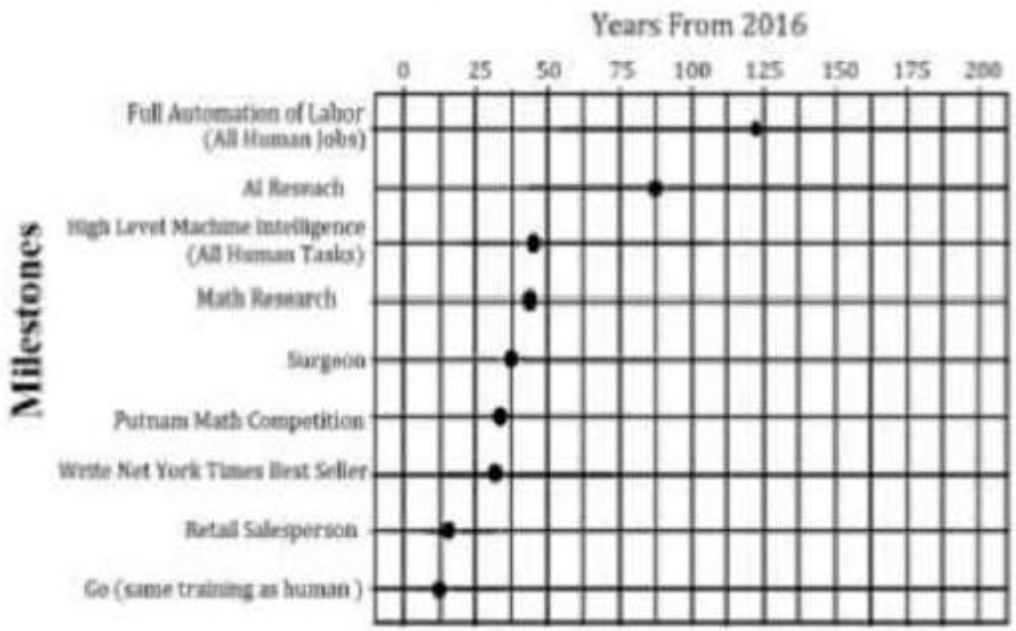
Rank*	Job title	Automation Risk
1	Telephone salesperson	99.0%
2	Typist or related keyboard worker	98.5%
3	Legal secretary	97.6%
4	Financial accounts manager	97.6%
5	Weigher, grader or sorter	97.6%
5	Routine inspector and tester	97.6%
7	Sales administrator	97.2%
8	Book-keeper, payroll manager or wages clerk	97.0%
8	Finance officer	97.0%

When Will robot Take our Job ?

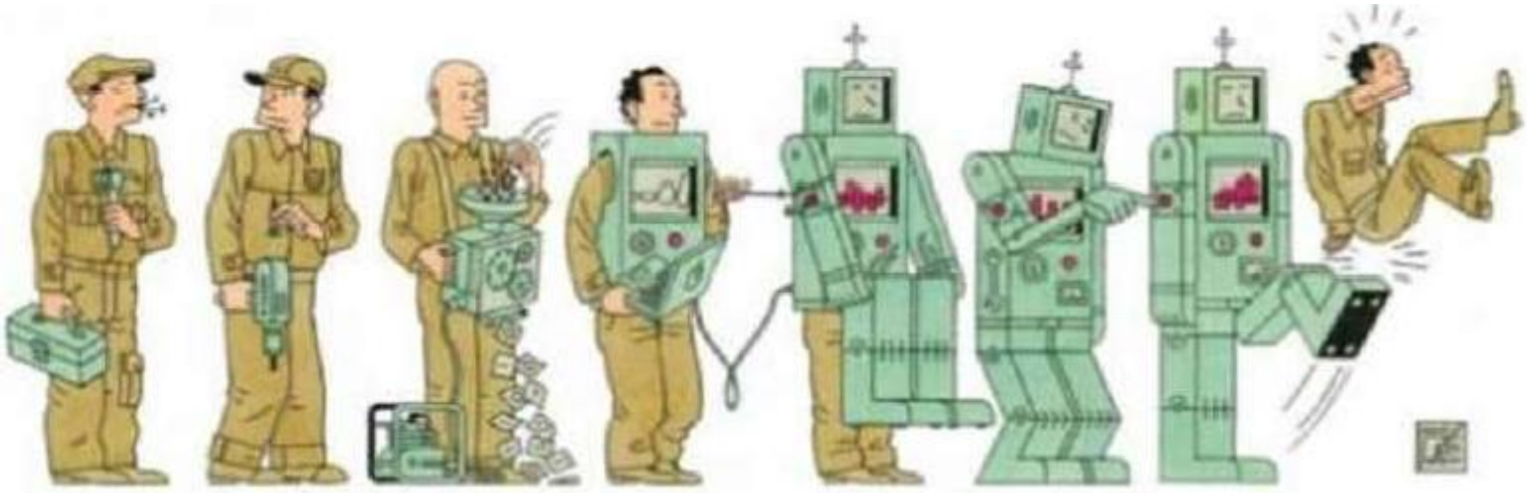
Survey from 352/1634 leading AI academics and industry experts By University of Oxford

In near future, AI is expected to outperform humans in:

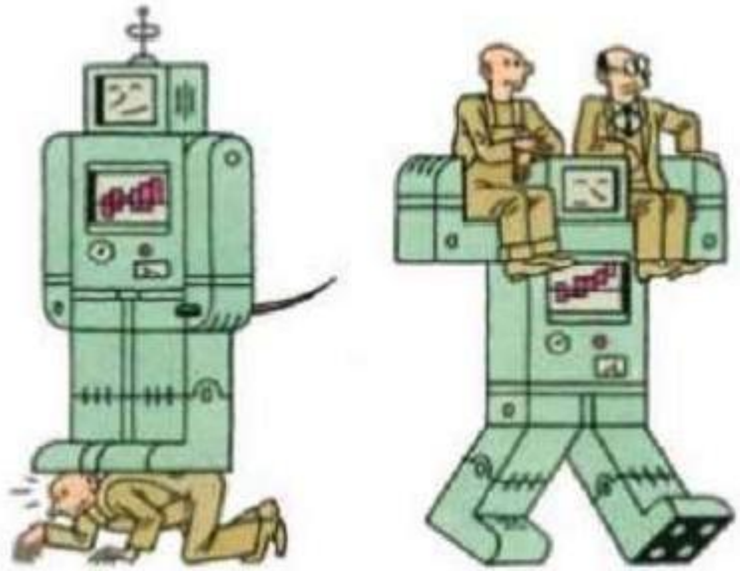
- ❑ translating languages by 2024,
- ❑ writing high-school essays by 2026,
- ❑ driving a truck by 2027,
- ❑ retail by 2031,
- ❑ writing a bestselling book by 2049)
- ❑ working as a surgeon by 2053.

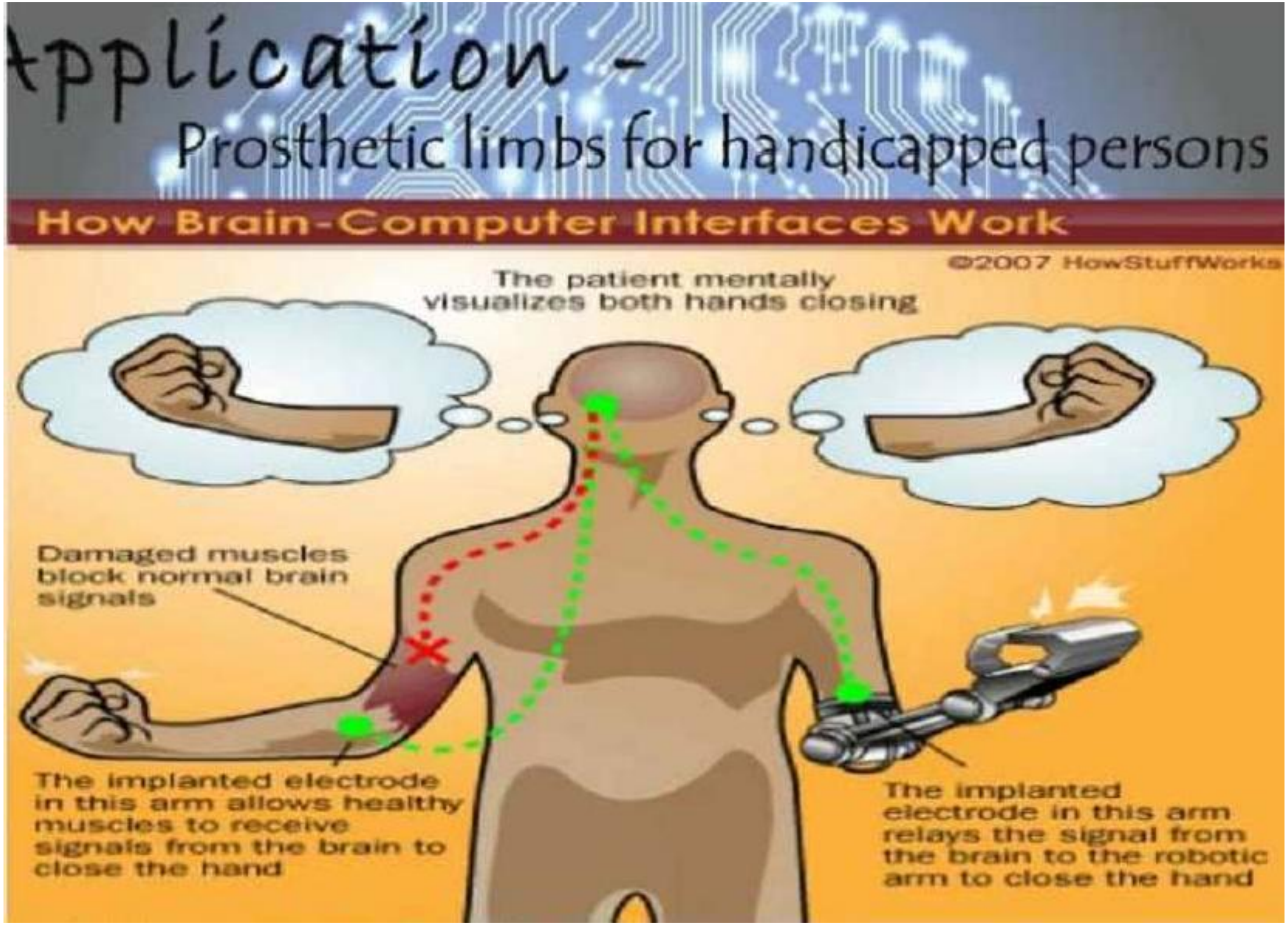


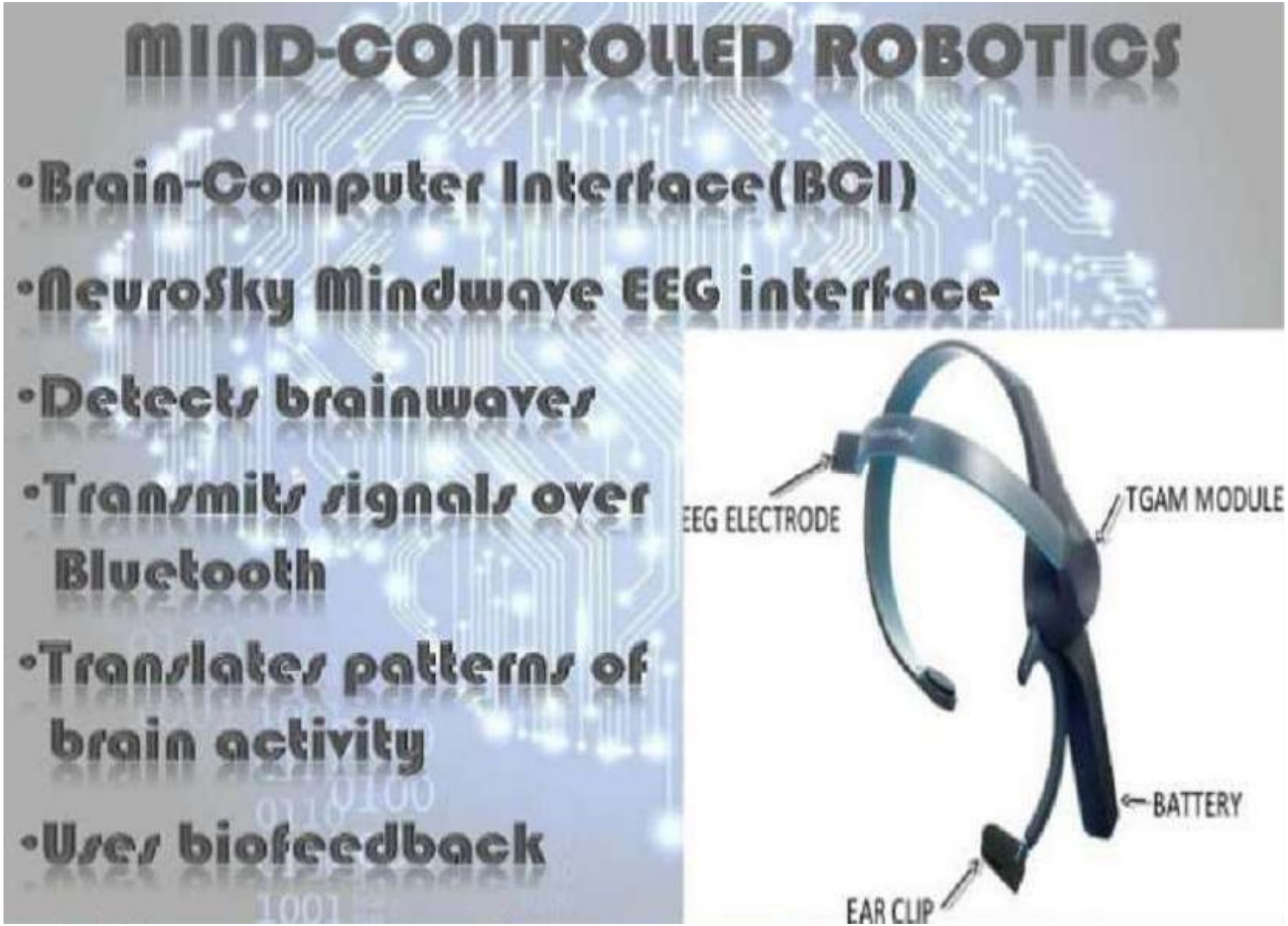
Who own the Future robot



Which Case Will Be Happened in Future?




Application -
Prosthetic limbs for handicapped persons
How Brain-Computer Interfaces Work
©2007 HowStuffWorks
The patient mentally visualizes both hands closing
Damaged muscles block normal brain signals
The implanted electrode in this arm allows healthy muscles to receive signals from the brain to close the hand
The implanted electrode in this arm relays the signal from the brain to the robotic arm to close the hand


MIND-CONTROLLED ROBOTICS
•Brain-Computer Interface(BCI)
•NeuroSky Mindwave EEG interface
•Detects brainwaves
•Transmits signals over Bluetooth
•Translates patterns of brain activity
•Uses biofeedback
EEG ELECTRODE
TGAM MODULE
BATTERY
EAR CLIP


Thank You!