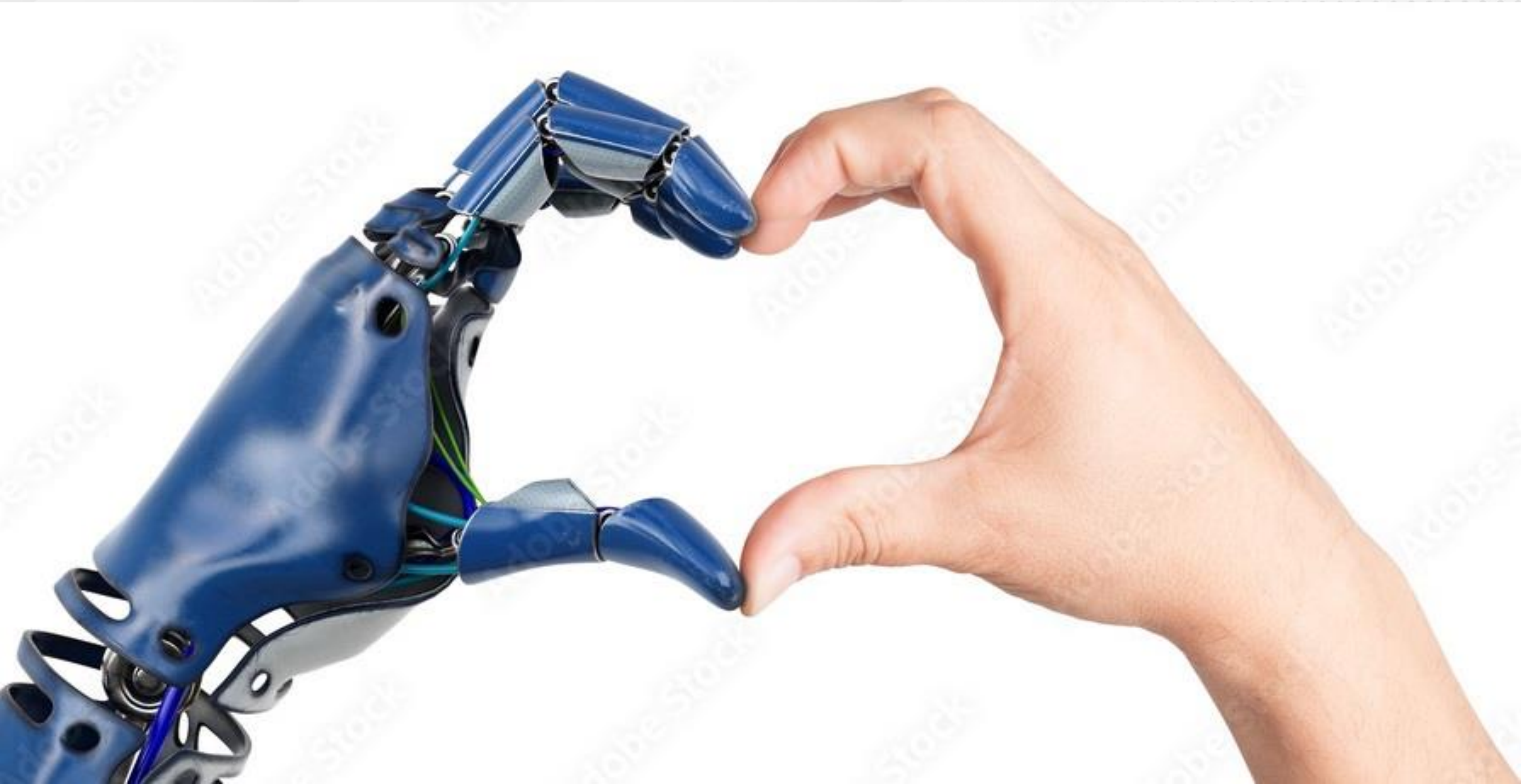
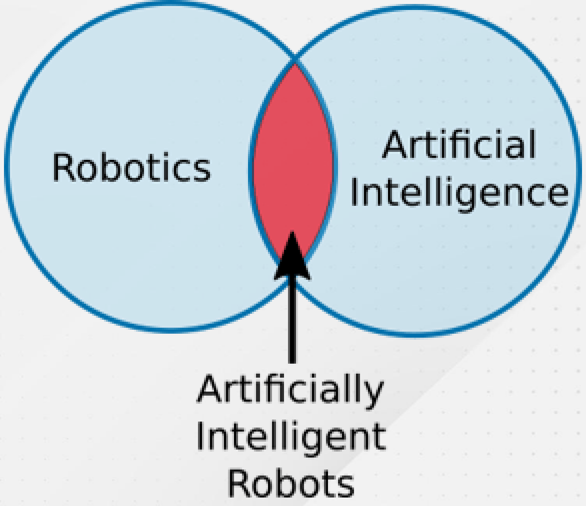
Foundation in Robotics



Agenda – Module I

Introduction



Difference in AI Program and Robot System

1. AI Programs • Usually, we use to operate them in computer-simulated worlds. • Generally, input is given in the form of symbols and rules. • To operate this, we need general-purpose/Special-purpose computers.	2. Robots • Generally, we use robots to operate in the real physical world. • Inputs are given in the form of the analogue signal or in the form of the speech waveform. • Also, to operate this, special hardware with sensors and effectors are needed.	3. Machine learning • To enable a robot to acquire new knowledge or skills through ML algorithms..

Introduction

Definition of Robot:

A robot can be defined as a programmable machine or mechanical device designed to perform tasks automatically, often with a degree of autonomy.

The key characteristics of a robot include:

- **Programmability**
- **Sensing and Perception**
- **Autonomy**
- **Manipulation or Mobility**
- **Repeatability and Precision**
- **Adaptability**
- **Versatility**

The definition and characteristics of a robot can vary based on context, technological advancements, and the specific field of application.

Historical Evolution:

Early Beginnings

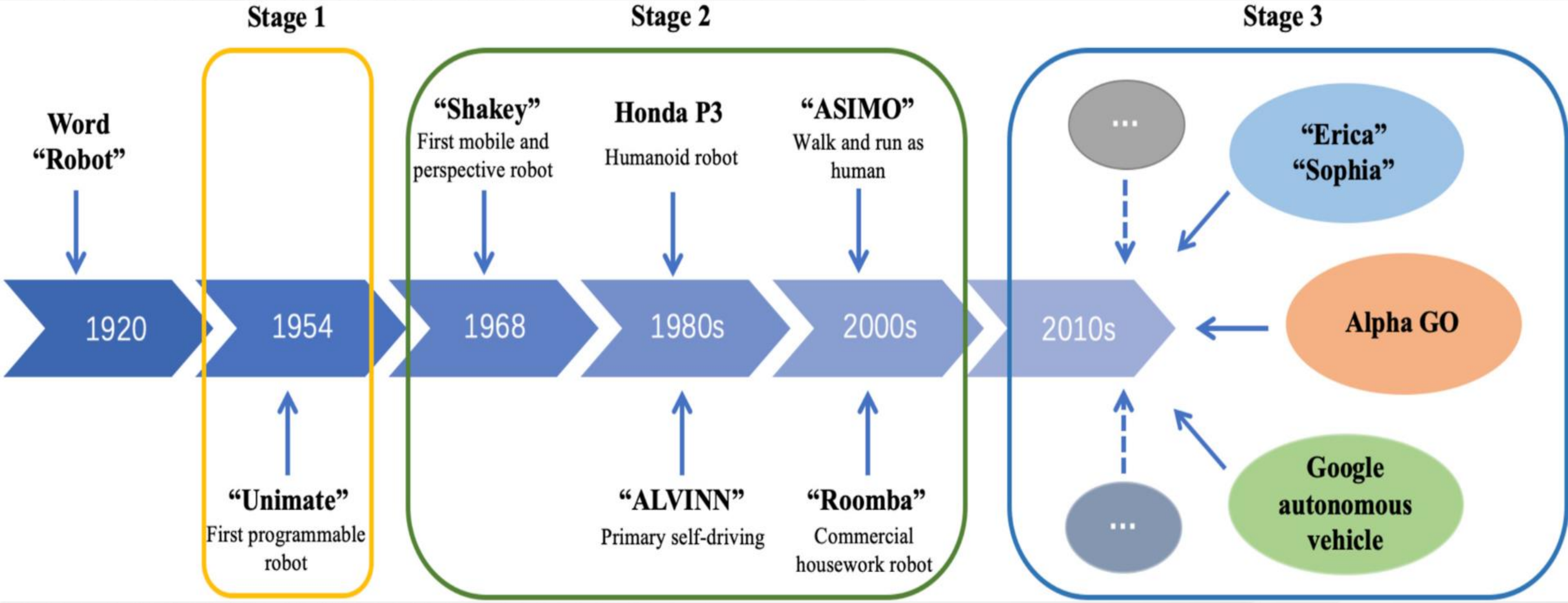
350 BC: Archytas of Tarentum's steam-propelled pigeon.

1950s: Introduction of the first industrial robot, the Unimate.

Advancements in Industrial Robotics

1960s-2000s: Rapid growth in manufacturing, assembly, and automation.

Integration of computer-controlled systems revolutionizing production.



https://robotics24.net/blog/history-of-robots-origins-myths-facts/

https://www.researchgate.net/publication/331090220_A_Brief_History_of_Industrial_Robotics_in_the_20th_Century

https://www.sciencedirect.com/science/article/pii/S2352864820302881#fig1

Introduction

What is Robotics:

- Intersection of engineering, computer science, and technology.
- Creation of machines capable of autonomous or semi-autonomous tasks.

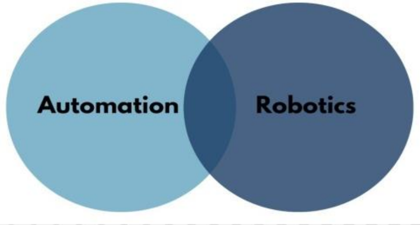
Applications of Robotics and Automation:

Diversification Across Sectors

From manufacturing to healthcare, agriculture, space exploration, and entertainment.

Examples: Medical robots, agricultural drones, and space rovers.

Robots are used these days for everything ranging from security guards, chefs, doctor’s assistants, customer service agents, and even a one-man army in war!



Phases of development in robotics

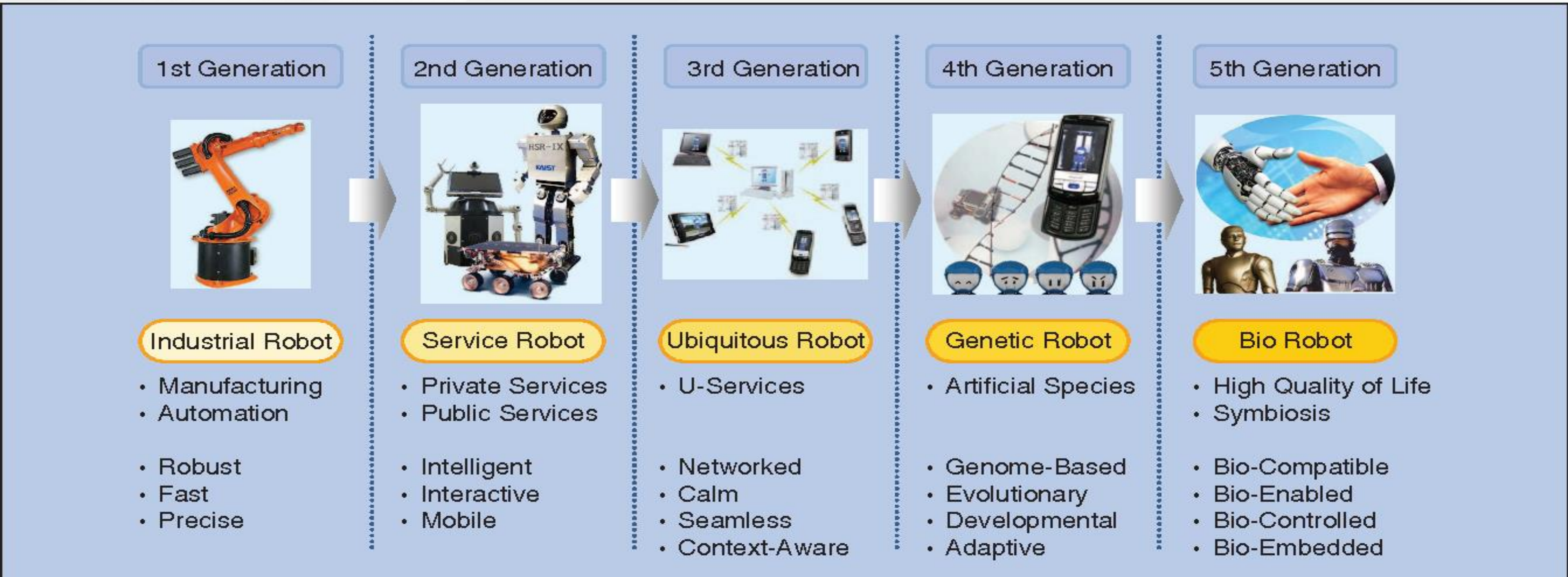
1. Emergence and Industrialization (1950s-1970s):

   Primarily used in manufacturing for tasks like assembly line work and material handling.
2. Advancements in Control and Computing (1980s-1990s):

   Robotic arms and systems became more sophisticated, expanding into industries beyond manufacturing.
3. Integration of AI and Cognitive Robotics (2000s-Present):

   Robots became smarter, capable of learning, decision-making, and adapting to dynamic environments.
4. Human-Centric and Bio-Inspired Robotics (Recent Years and Ongoing):

   Development of robots that can collaborate and interact safely with humans, along with bio-inspired designs mimicking nature for efficiency and adaptability.



Technologies and their implications on the field of robotics

Emergence of AI in Robotics

21st century advancements: Integration of AI and machine learning.

Adaptive robots capable of learning from environments and making decisions.

Challenges and Future Prospects

Challenges

Ethical considerations, job displacement, safety in AI-powered robots.

Balancing technological advancements with ethical implications.

Future Trends

Predictions: Collaborative robots (cobots), swarm robotics, human-robot interaction.

The potential impact of robotics on various industries and everyday life.

https://www.techadvisor.com/article/724821/a-brief-history-of-robotics-and-ai.html

Introduction

What are Artificially Intelligent Robots

- Artificial intelligent robots connect AI with robotics.
- AI robots are controlled by AI programs.
- Usually, most robots are not AI robots, these robots are programmed to perform repetitive series of movements, and they don't need any AI to perform their task. However, these robots are limited in functionality.
- AI algorithms are necessary when you want to allow the robot to perform more complex tasks.
- A warehousing robot might use a path-finding algorithm to navigate around the warehouse.

Introduction

What are the advantages of integrating Artificial Intelligence into robotics

1. social care.

2. Robotics also helps in Agricultural industry.

3. In Military industry

4. Robotics also employed in volcanoes, deep oceans, extremely cold places, or even in space where normally humans can't survive.

5. Robotics is also used in medical and healthcare

Introduction

Asimov's laws of robotics

Asimov proposed three laws of robotics, they are:

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

Law 2: A robot must obey orders given to it by human beings, except where such orders would conflict with the first law.

Law 3: A robot must protect its own existence as long as such protection does not conflict with the first law.

Types of robots




1. **Industrial**
2. **Mobile**
3. **Medical**
4. **Military**
5. **Aerospace**
6. **Aquatic**
7. **Autonomous car**
8. **Domestic**
9. **Educational**
10. **Humanoid**
11. **Exoskeleton**
12. **Drones**

Industrial Robots

Various works such as Welding, material Handling, Improving Productivity, Inspection are carried out by robots.

There are various types of industrial robots as below:

1. Articulated
2. Cartesian
3. Cylindrical
4. Polar
5. SCARA
6. Delta

Mobile Robots

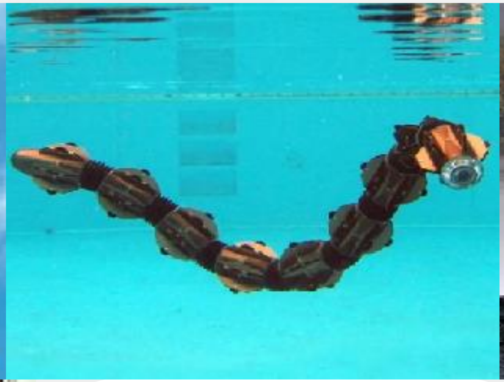
Robots that move around legs, tracks or wheels. There are types of robots that can even handle radio active material.

Types of mobile robots are

1. Land based wheeled, tracked, legged robots
2. Air based robots –plane, Helicopter
3. Water based – Submarines

Combinational robots

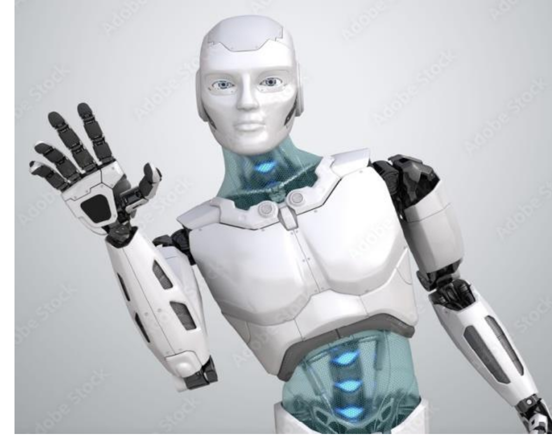
Types of robots



Educational Robots
Robots that are used in education. They are abled to bring schools to students who cannot be able to present Physically.
Types of educational robots are:
1. Root
2. Cubelets
3. Dash and dot
4. Ozobot bit
5. Mbot

Domestic Robots
There are two types :
1. To perform household tasks and
2. The other one is modern toy that performs tasks like talking, walking etc .

Introduction



Future Robots----???????

- Bio-robotics: emulating biology, Micro, Nano.
- Exoskeletons: wearable devices.
- Neuro robotics: cyborgs, aneroids.
- Robotic drugs : nano robots for curing diseases, surgery.
- Assistive / Rehabilitation robotics.
- Outer space / nuclear applications
- Defense: soldier, autonomous armaments.
- Replacement of body functions: artificial muscles.
- IOT, CPS
- ????

Introduction

Future Robots----???????

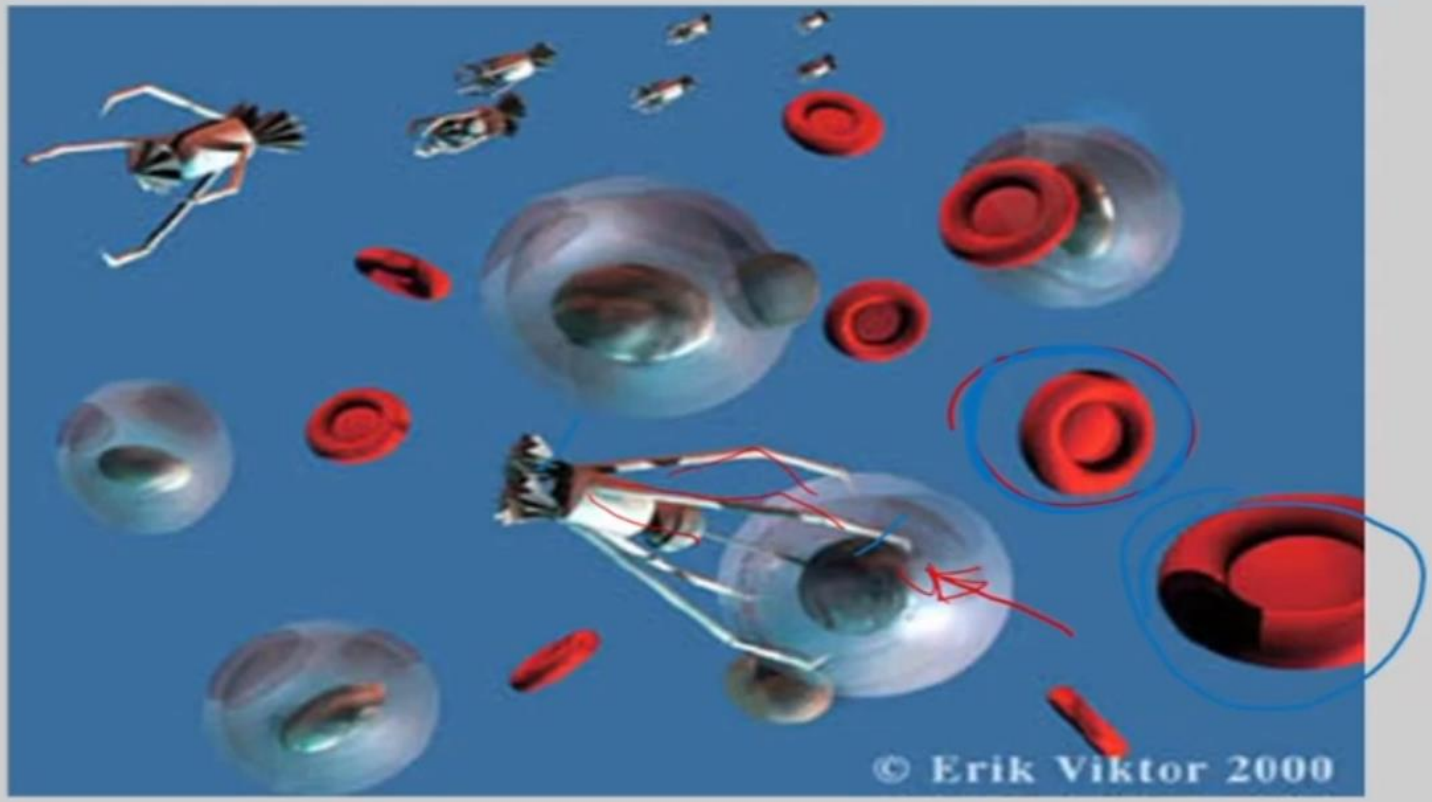
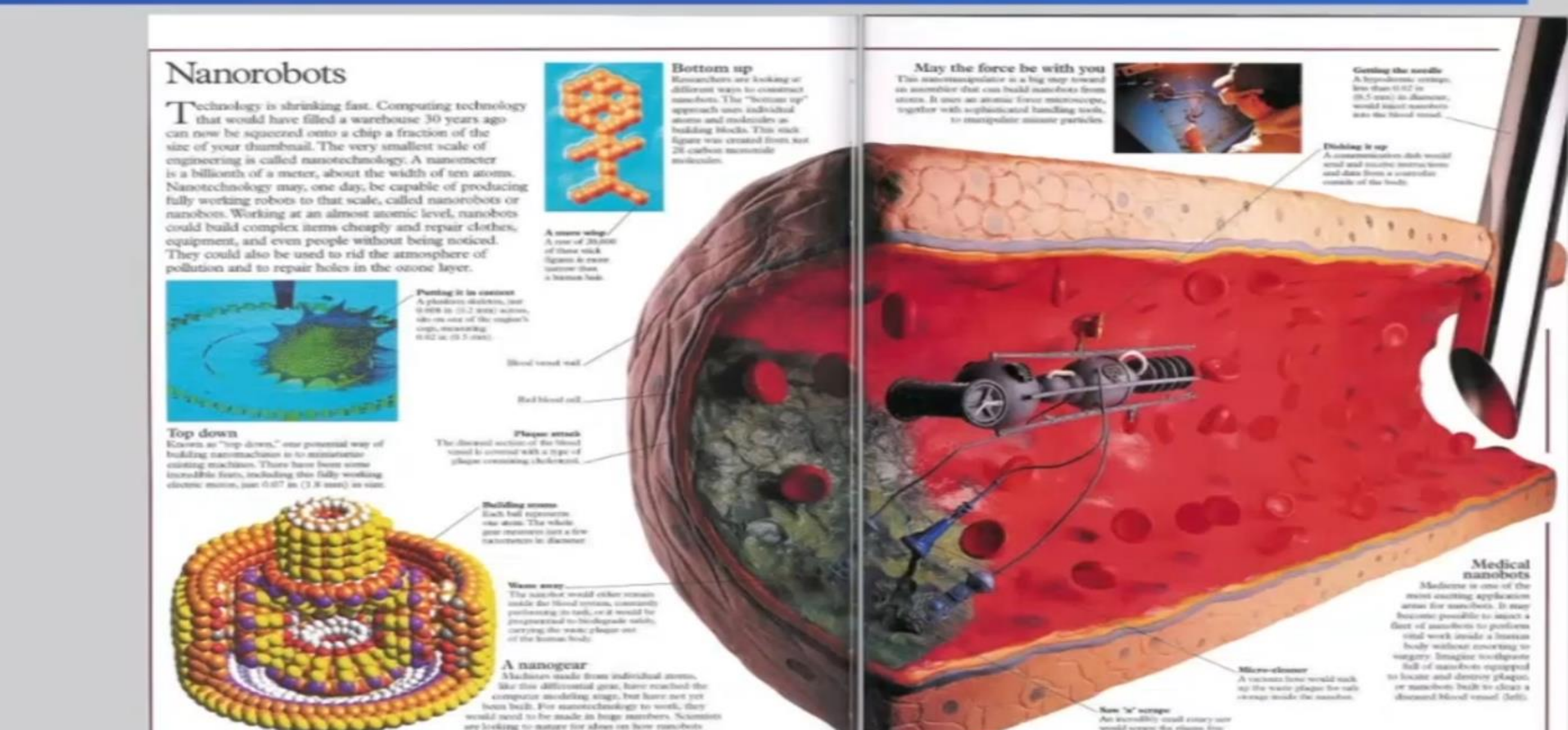


Fig. Killing viruses or bacteria

Introduction

Future Robots----???????

Micro – Robot Surgeon for bypass surgery!



Nanorobots

Technology is shrinking fast. Computing technology that would have filled a warehouse 30 years ago can now be squeezed onto a chip a fraction of the size of your thumbnail. The very smallest scale of engineering is called nanotechnology. A nanometer is a billionth of a meter, about the width of ten atoms. Nanotechnology may, one day, be capable of producing fully working robots to that scale, called nanorobots or nanobots. Working at an almost atomic level, nanobots could build complex items cheaply and repair clothes, equipment, and even people without being noticed. They could also be used to rid the atmosphere of pollution and to repair holes in the ozone layer.

Bottom up

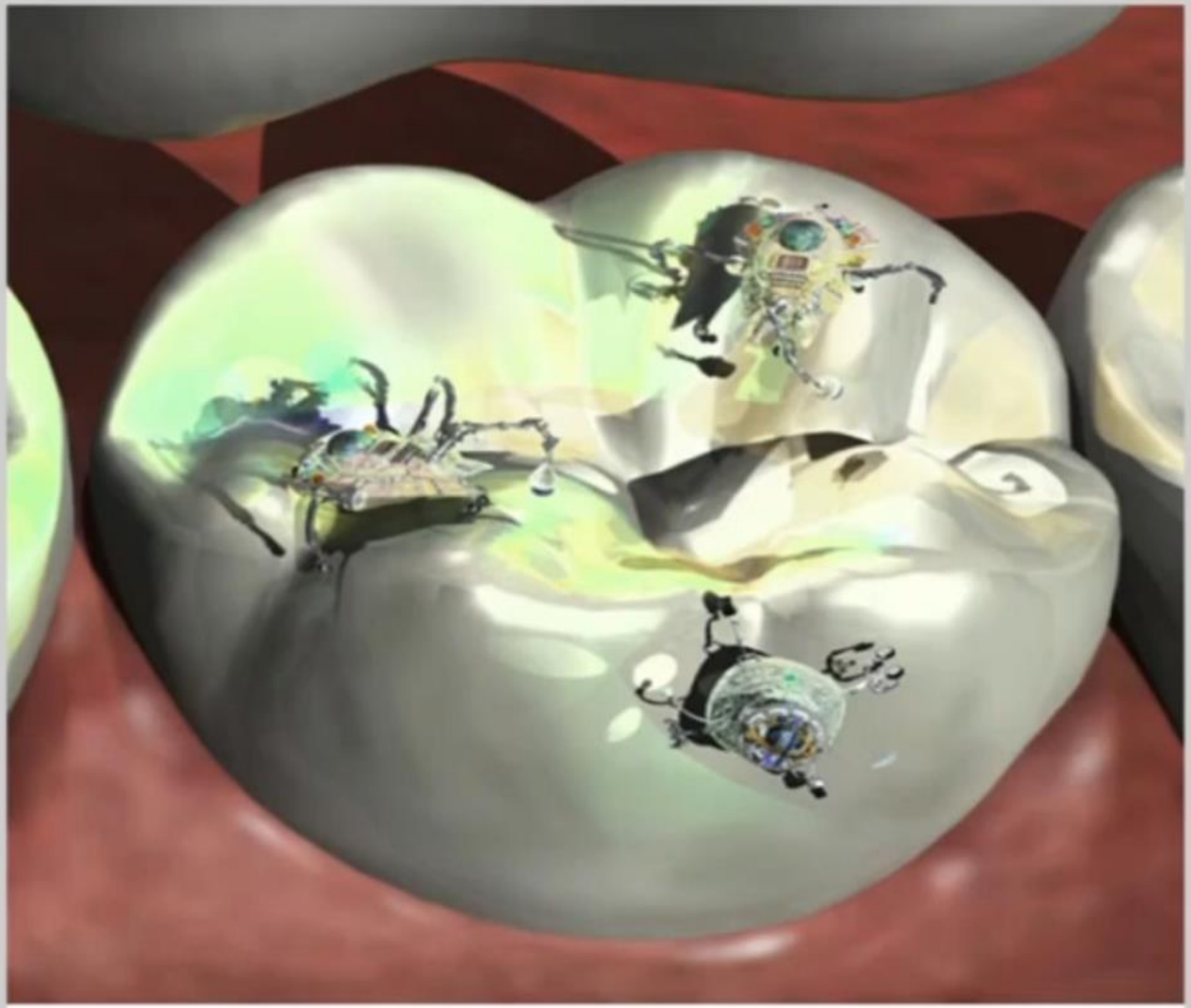
Top down

A nanogear

May the force be with you

Medical nanobots

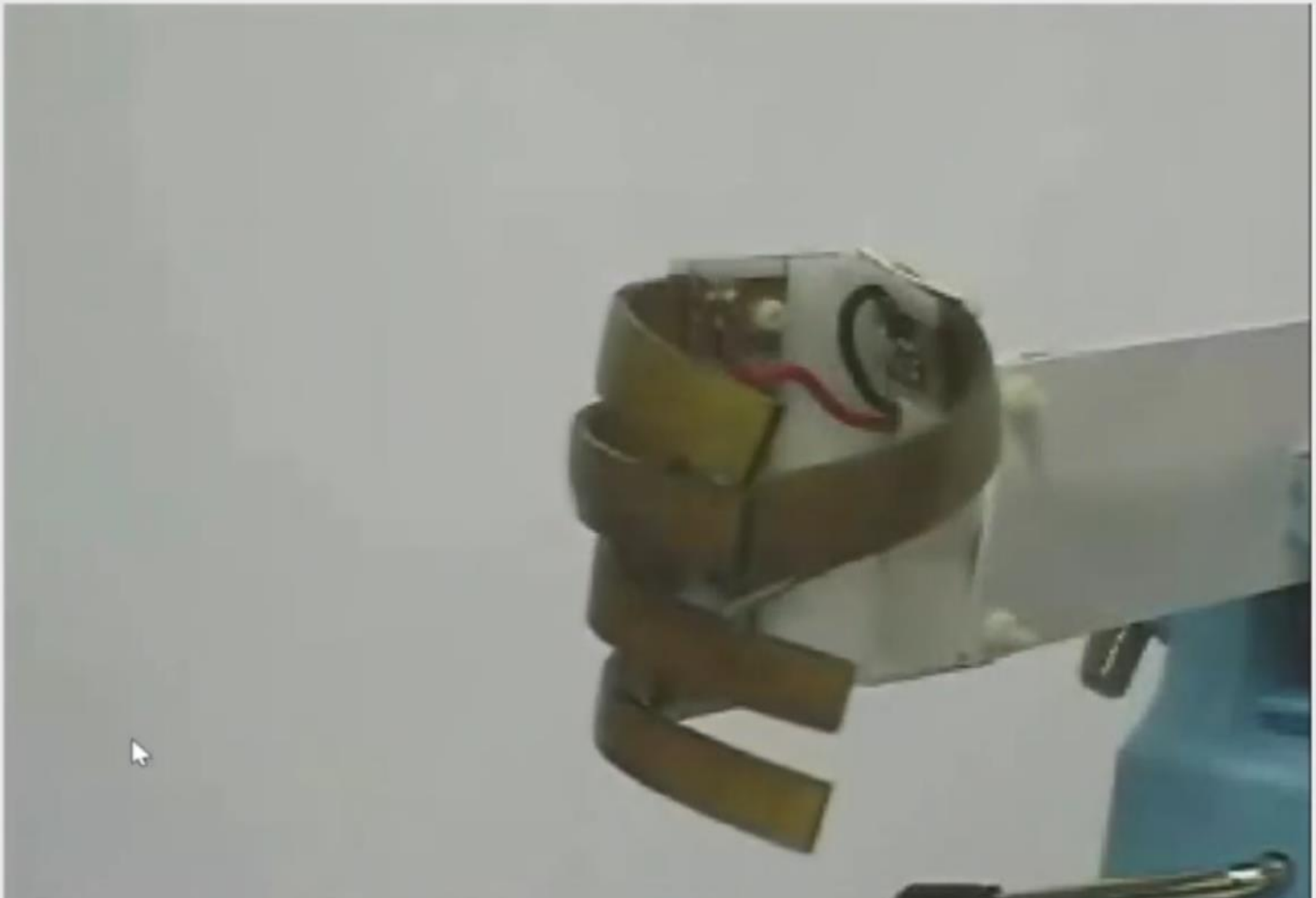
Micro-robot Dentist !



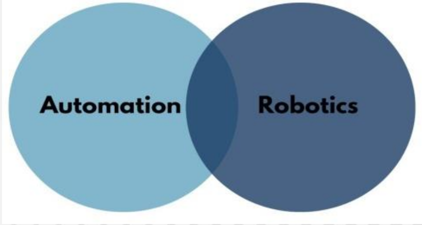
Micro Robotic Hair Cut !

Hand with no joints : Artificial muscles

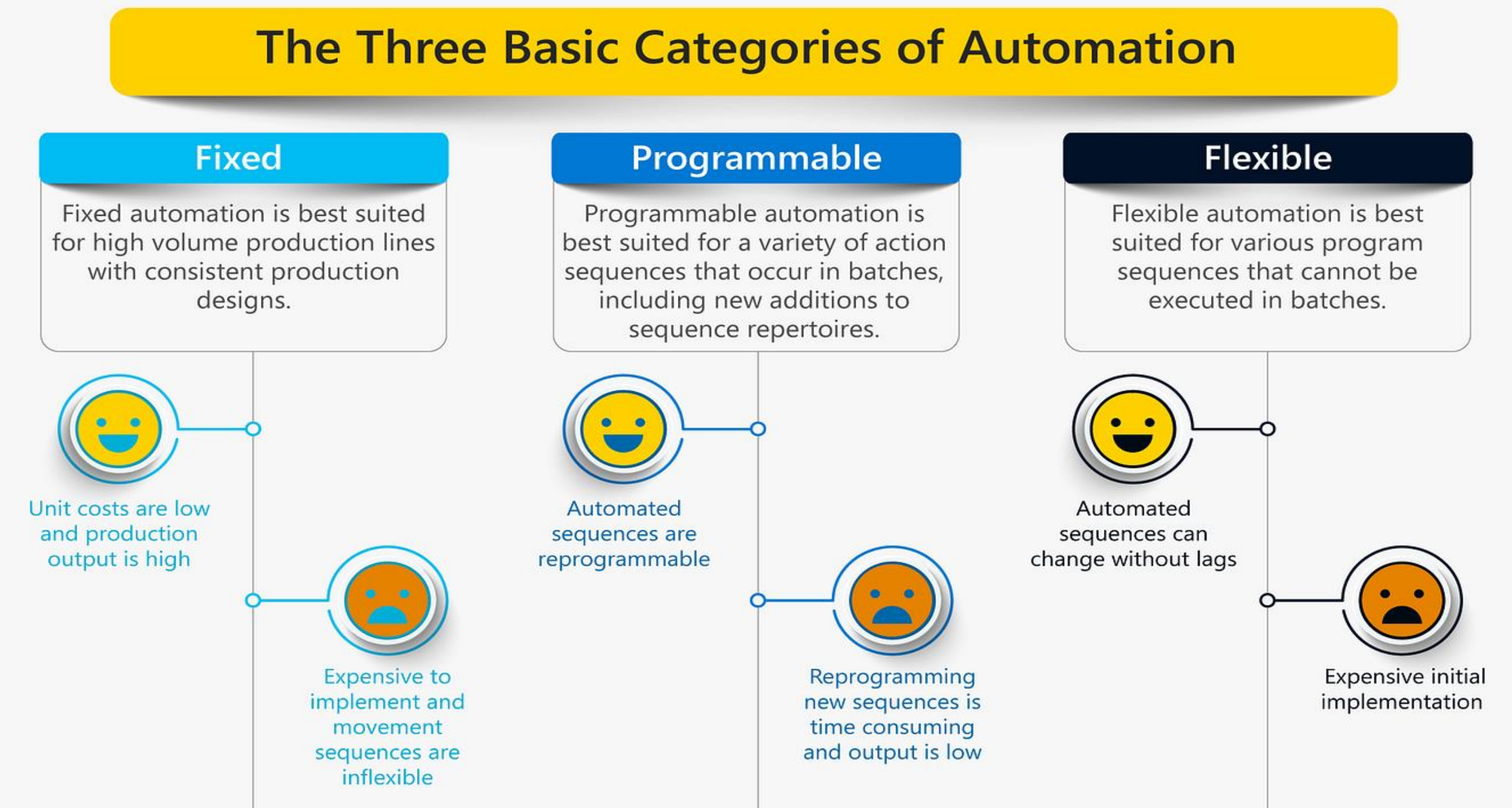
- Five finger hand with artificial muscles (EAP)



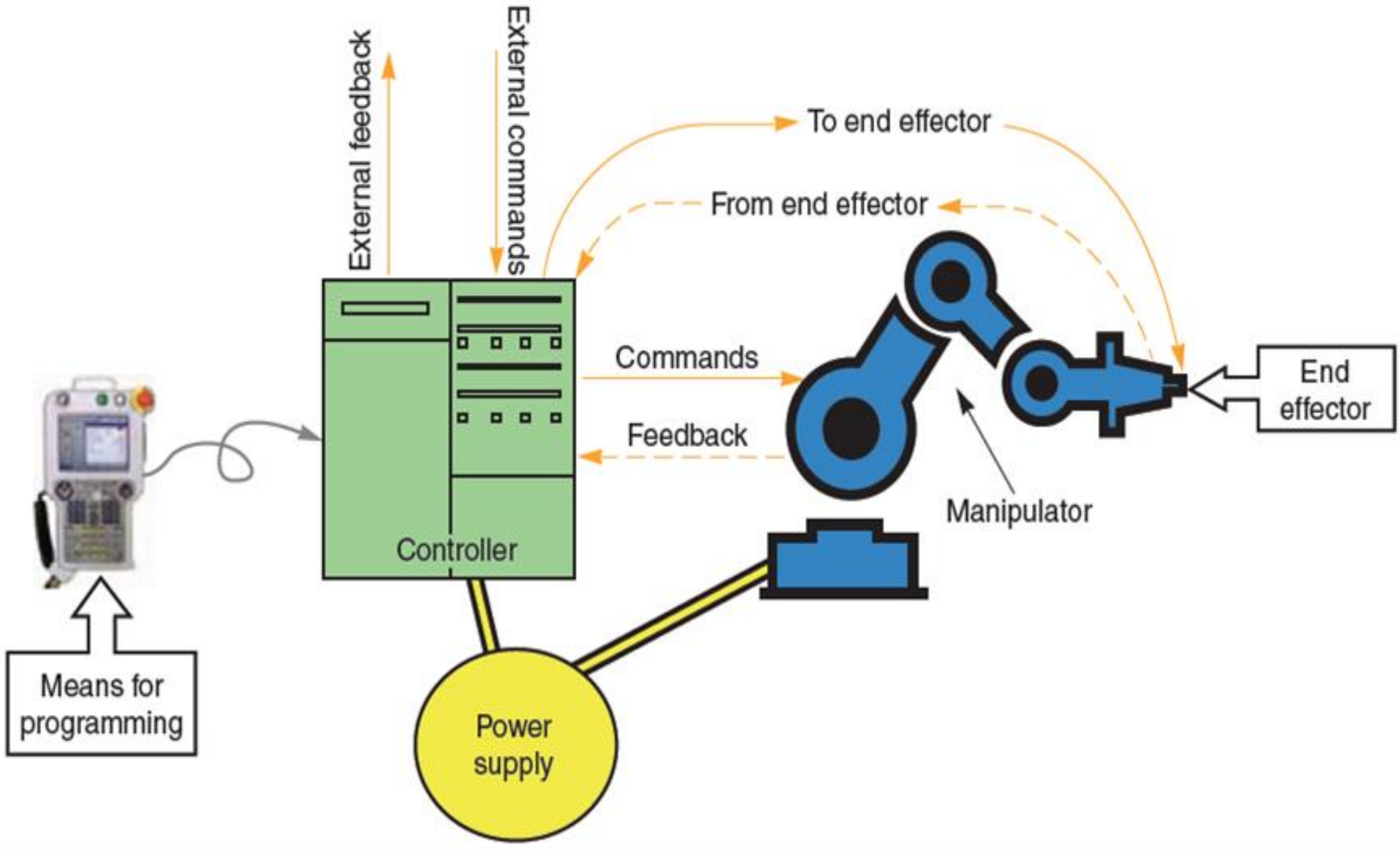
Automation



- Automation involves a mechanical device that can imitate the actions of people or animals. Robotics involves the design, construction, and operation of a robot.
- A robot is a machine that performs complicated tasks and is guided by automatic controls.



Components of Robots



Components of Robots

Actuators

- Inside the body of a robot small motor is present known as actuators. Robot moves in reaction to feedback from sensors with the help of actuators.

Controller

- The controller is the brain of a robot. Both the hardware and software are the controllers of the robot. The controller controls the movement of the manipulator and end effector.

Power supply

- The main source of power supply for robots are batteries and photovoltaic cells. Lead acid and silver cadmium batteries are mostly preferred. Industrial and manufacturing robots are consuming an average of 21000 kWh annually. In future it may be designed such as a robot may charge by itself when the power is low.

Manipulator

- The arm of the robot is called as manipulator. It resemble the human hand. It has several joints and links.

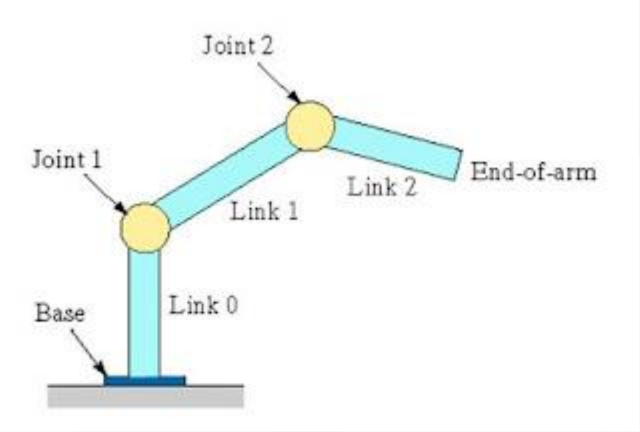
End effectors

- End effectors are used by robots to interact with the environment. They vary according to the task given to the robot. It performs the tasks that are performed by palm and fingers of human hand

Sensors

- Sensors are used to gather information from the surroundings. If camera is present Visual representation of the surroundings can be seen. Microphones allows to detect the surrounding sounds. If the robot is equipped with thermometer and barometer temperature and pressure can be found out. These informations are used to guide the robotics behaviour.

Robot Anatomy/ Structure



·***Manipulator*:** The manipulators in a robot are developed by the integration of links and joints. In the body and arm, it is applied for moving the tools in the work volume. It is also used in the wrist to adjust the tools.

·***End Effectors*:** A hand of a robot is considered as [end effectors.] ***The*** grippers and tools are the two significant types of end effectors. The grippers are used to pick and place an object, while the tools are used to carry out operations like spray painting, spot welding, etc. on a work piece.

·***Robot Joints*:** The joints in an industrial robot are helpful to perform sliding and rotating movements of a component.

·***Kinematics*:** It concerns with the assembling of robot links and joints. It is also used to illustrate the robot motions.

Manipulator Joints

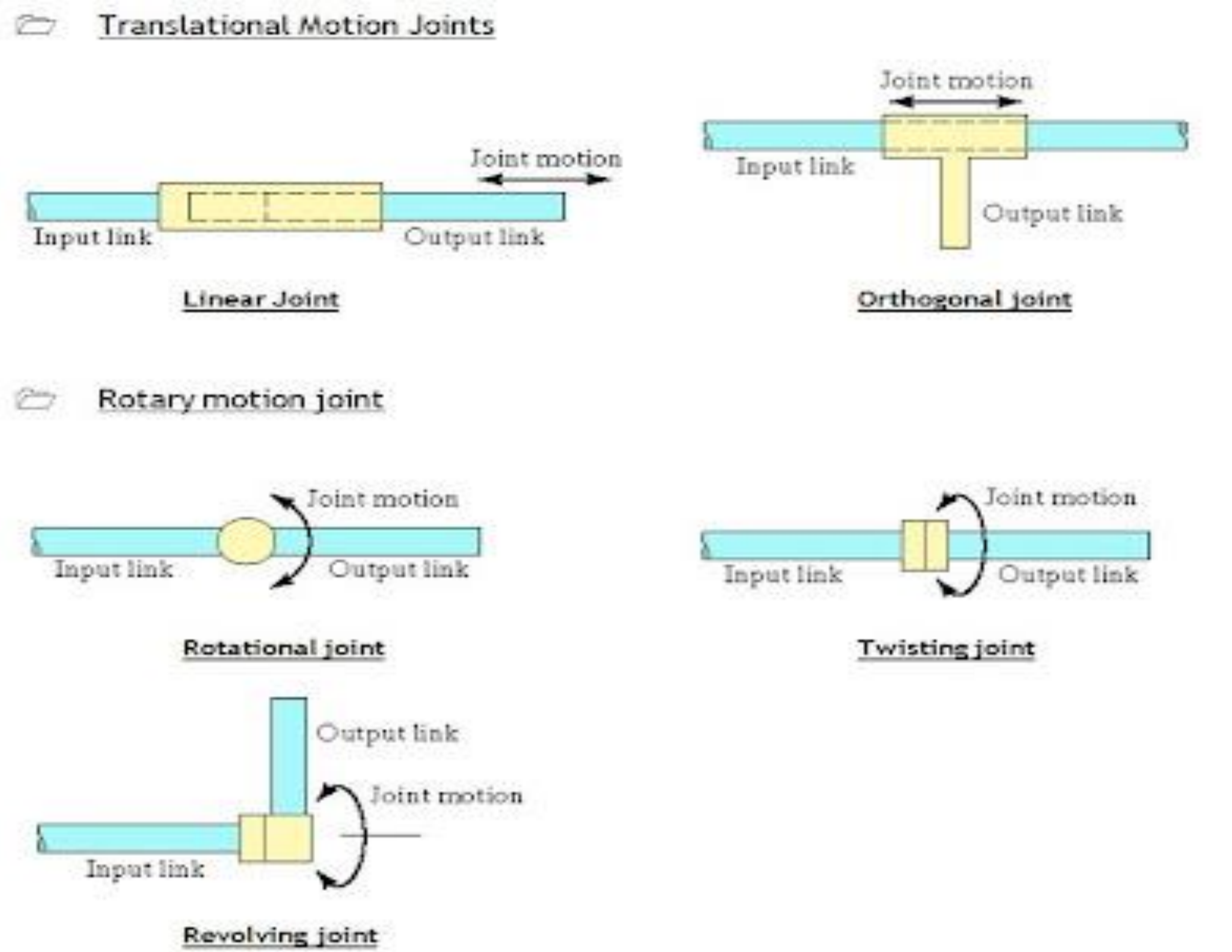
Types of Manipulator Joints:

Translational motion

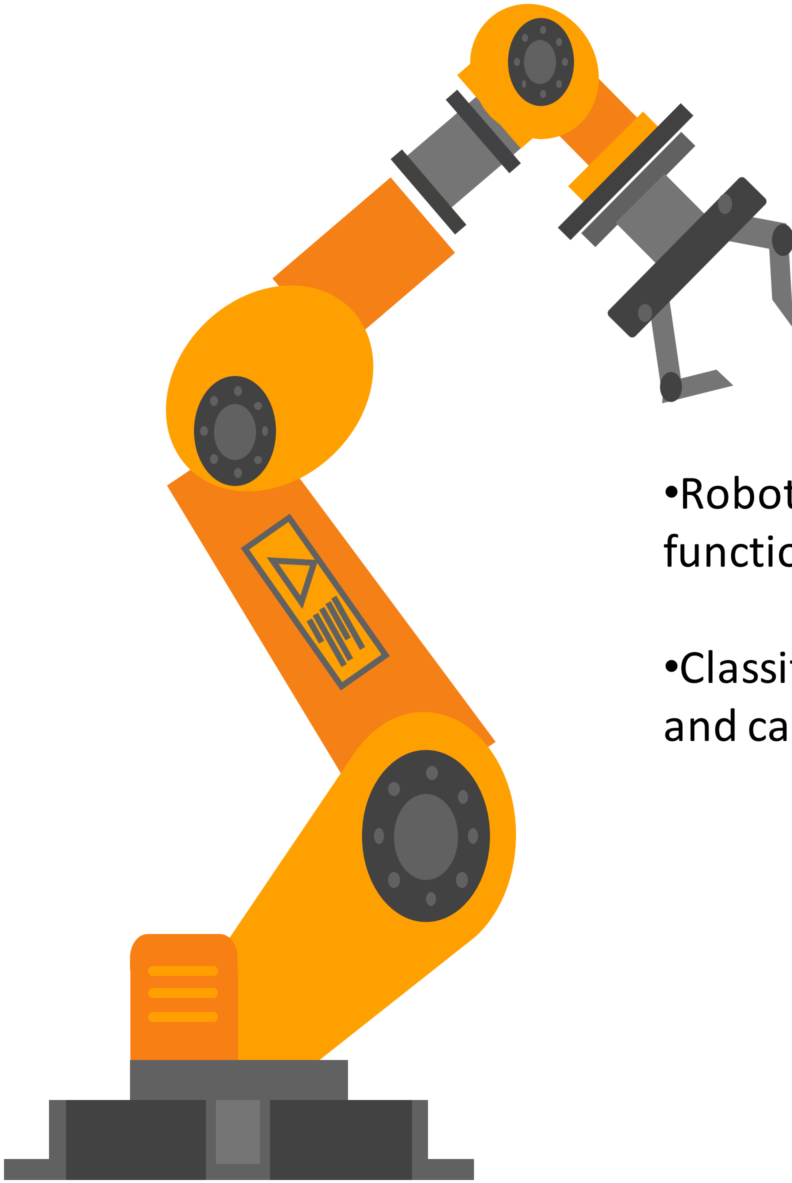
Linear joint
(type L)
Orthogonal joint
(type O)

Rotary motion

Rotational joint
(type R)
Twisting joint
(type T)
Revolving joint
(type V)

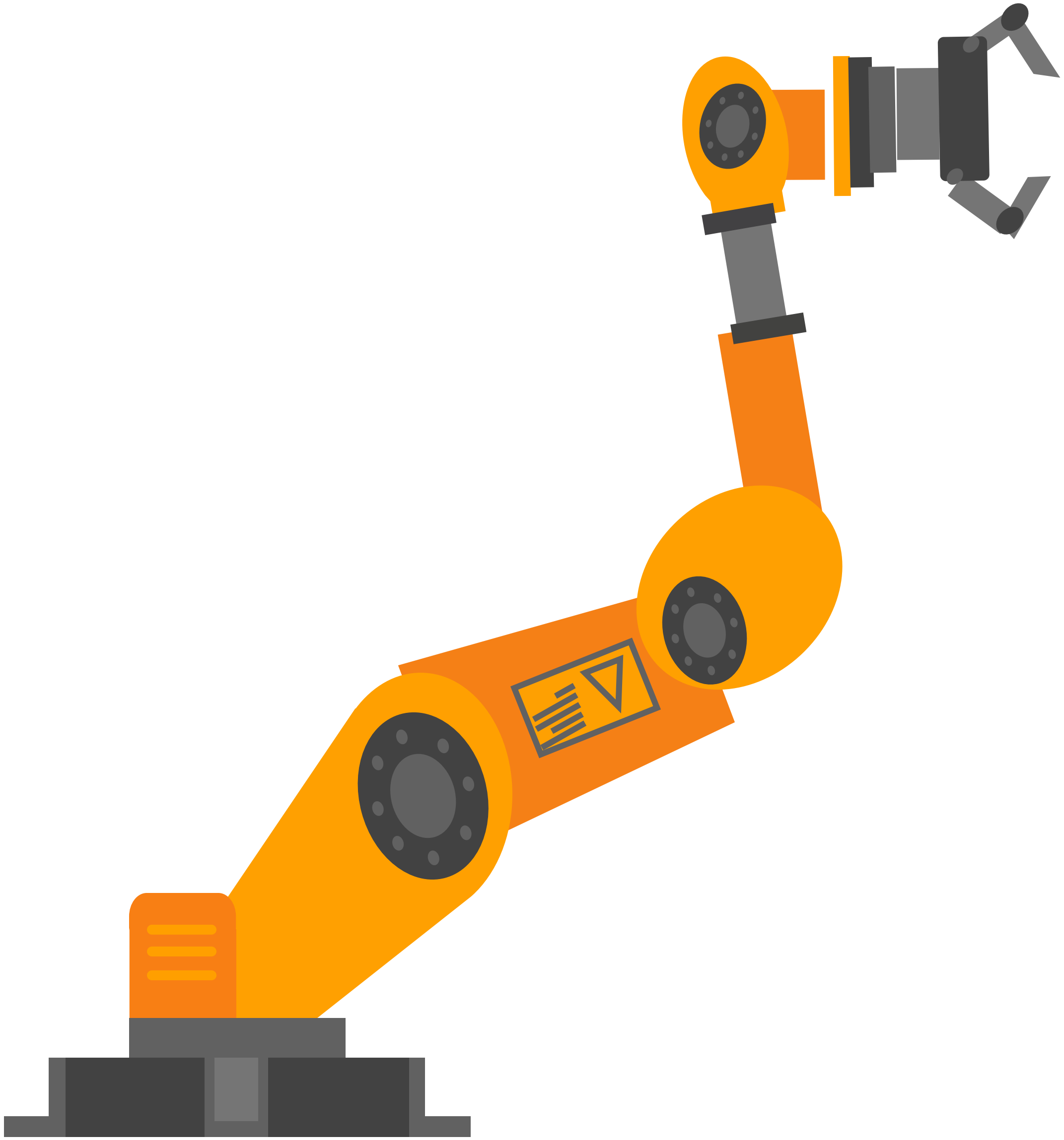


Robotics classification with respect to geometrical configuration (Anatomy)



- Robots are categorized based on their functionality, design, and application.
- Classification helps understand their diverse roles and capabilities.

Robotics classification with respect to geometrical configuration (Anatomy)



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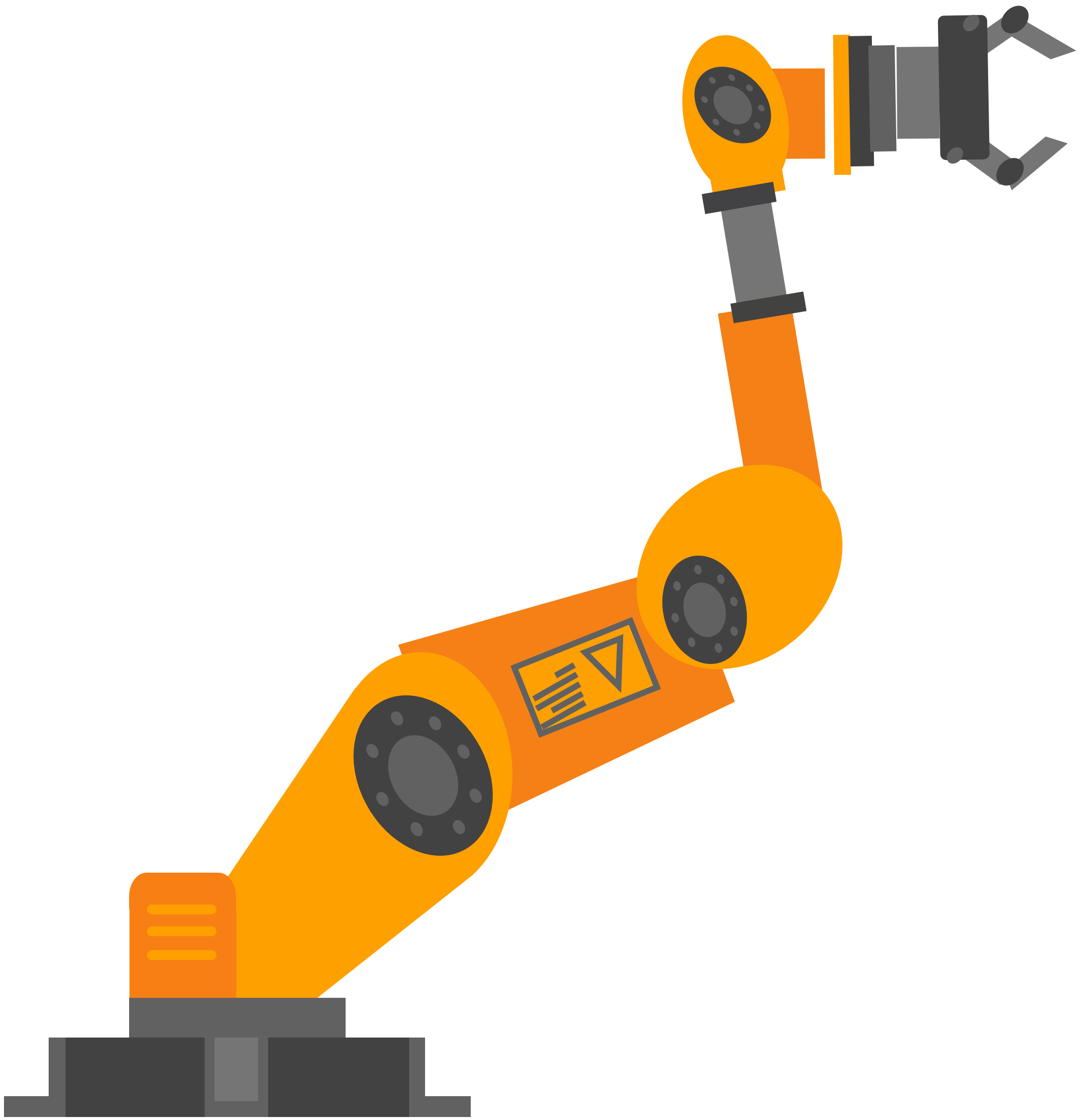

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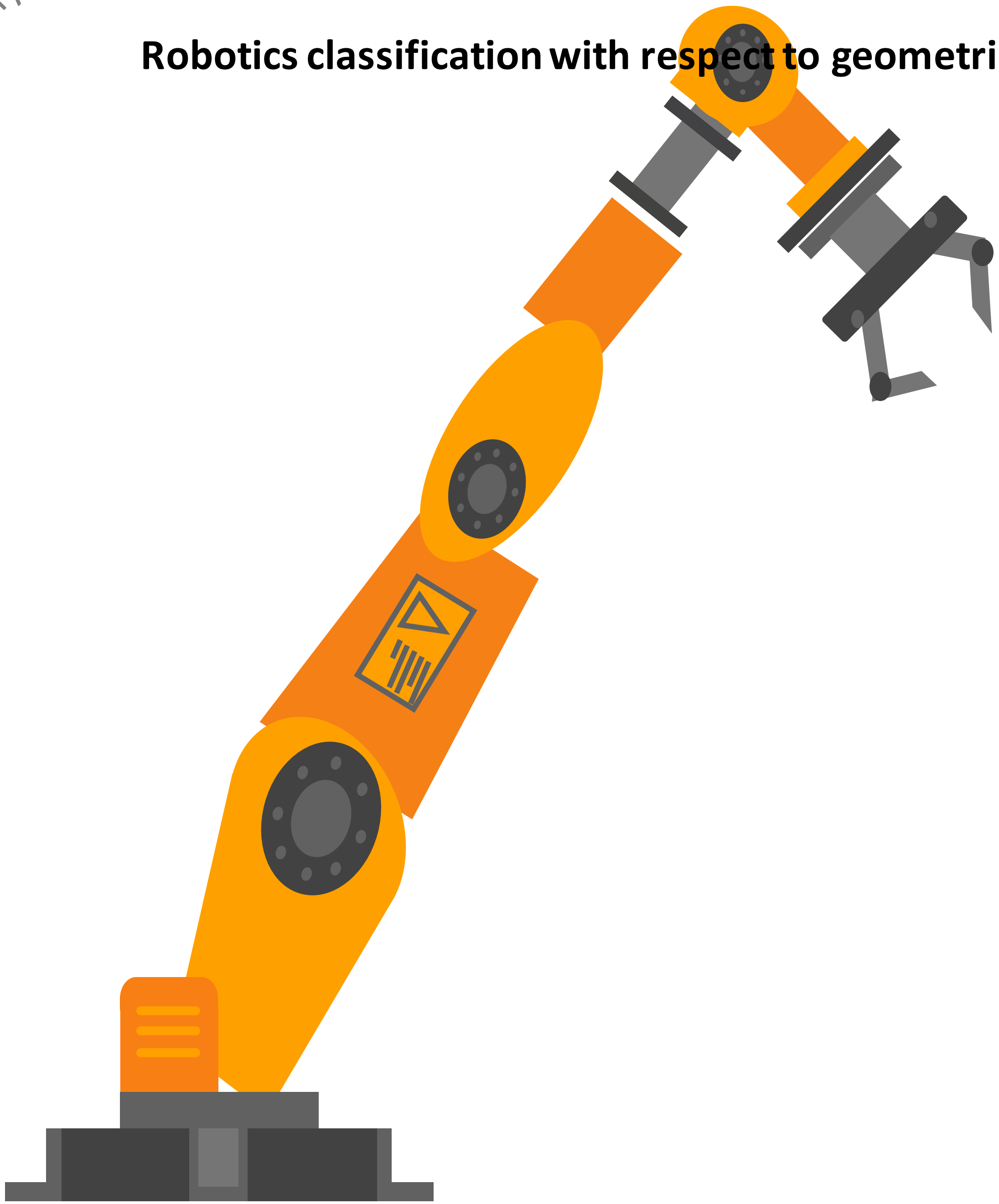

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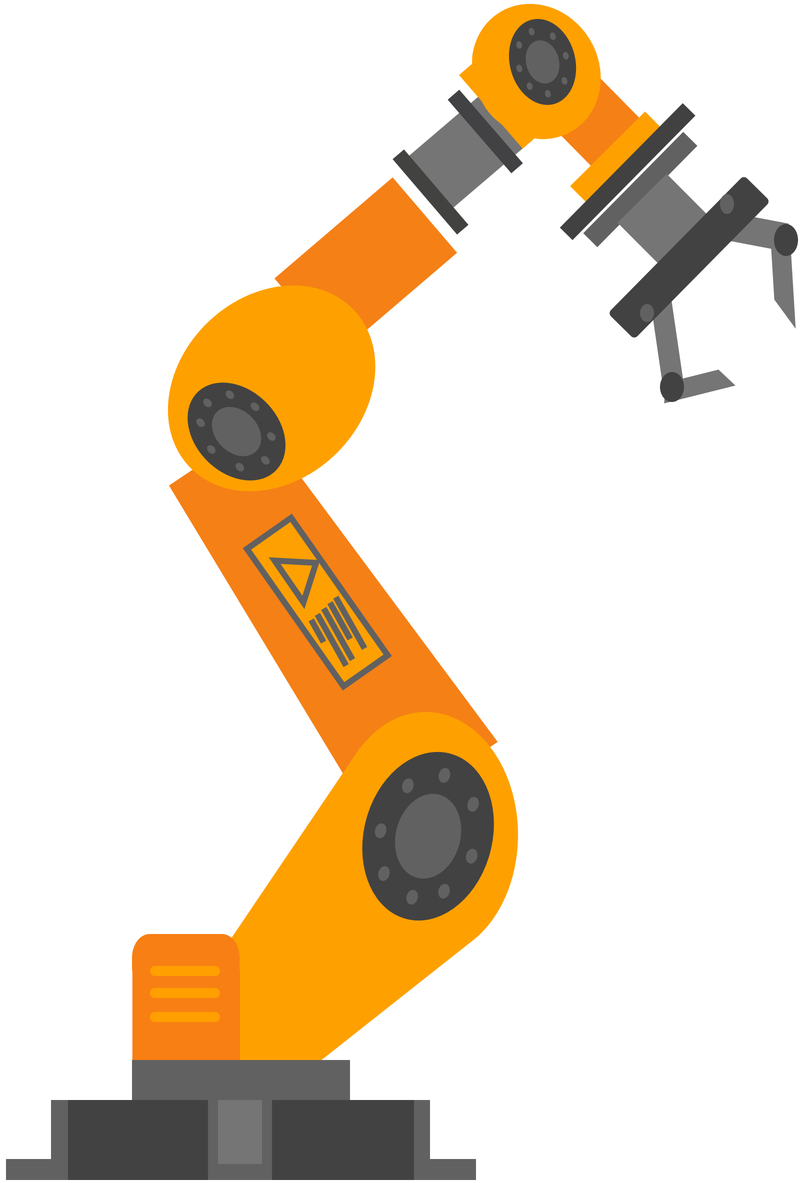
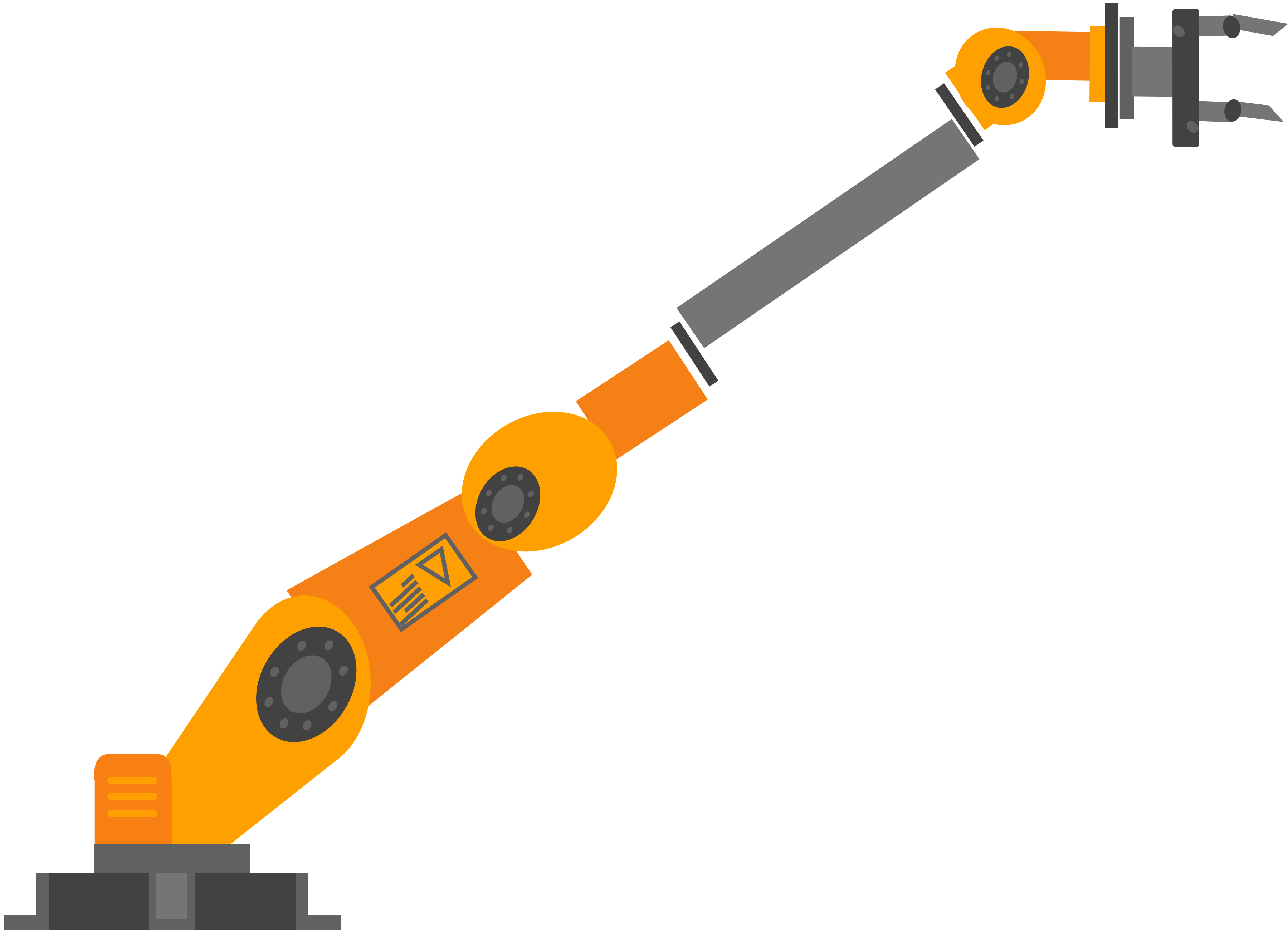
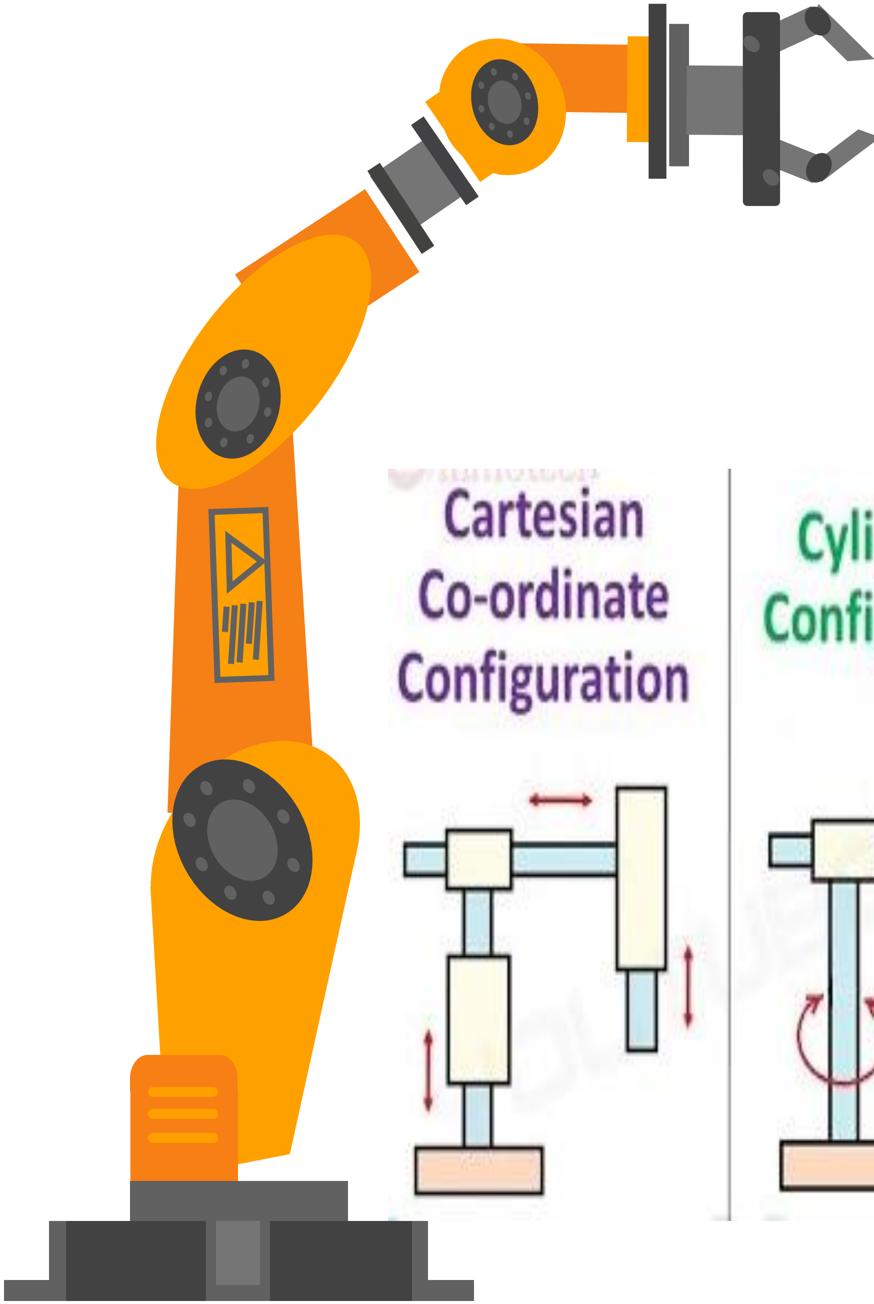
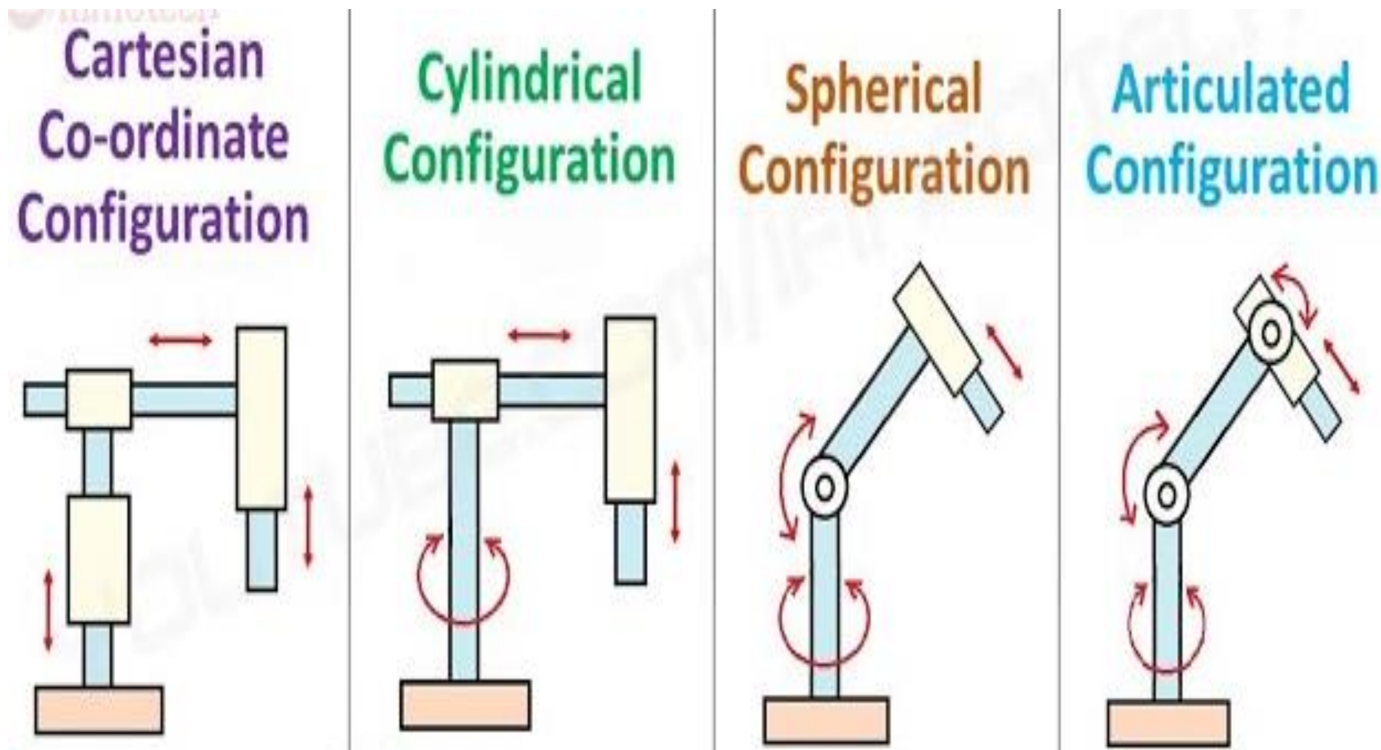




Robot Arm configuration





Robot Arm configuration

Cartesian coordinate or rectangular coordinate configuration is constructed by three perpendicular slides, giving only linear motions along the three principal axes.

It consists of three prismatic joints. The endpoints of the arm are capable of operating in a cuboidal space. Cartesian arm gives high precision and is easy to program.

Drawbacks: limited manipulatability o low dexterity (not able to move quickly and easily)
Applications: use to lift and move heavy loads.

https://www.youtube.com/watch?v=ci_mpRERMog
https://www.youtube.com/watch?v=2wG3aSqrGKc

The **cylindrical configuration** uses two perpendicular prismatic joints and a revolute joint. This configuration uses a vertical column and a slide that can be moved up or down along the column. The robot arm is attached to the slide, so that it can be moved radically with respect to column. By rotating the column, the robot is capable of achieving a workspace that approximates a cylinder. The cylindrical configuration offers good mechanical stiffness.

Drawback: Accuracy decreases as the horizontal stroke increases.

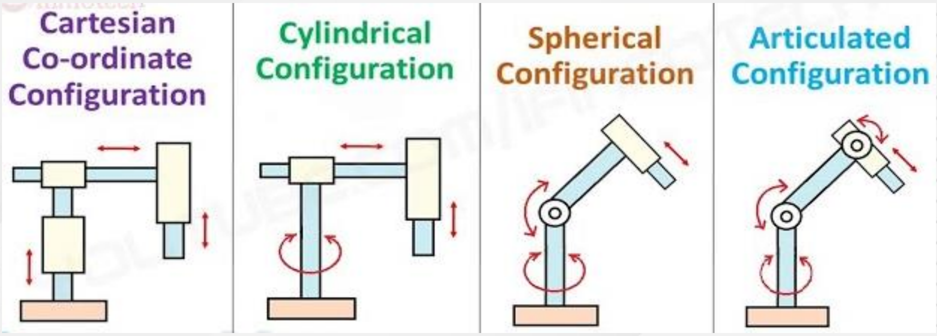
Applications: suitable to access narrow horizontal capabilities, hence used for machine loading operations.

Example: GMF model M-1A.

https://www.youtube.com/watch?v=Hj7PxjeH5y0

https://www.youtube.com/watch?v=Vt84DdK5kTg

Robot Arm configuration



Spherical/polar co-ordinate configuration : It consists of a prismatic joint that can be raised or lowered about a horizontal revolute joint. The two links are mounted on a rotating base. These various joints provide the capability of moving the arm endpoint within a partial spherical space. This configuration allows manipulation of objects on the floor.

Drawbacks: i. Low mechanical stiffness ii. Complex construction iii. Position accuracy decreases with the increasing radial stroke.

Applications: Machining, spray painting

Example: Unimate 2000 series, MAKER 110

https://www.youtube.com/watch?v=jrF5Dl6ntAc

Articulated/jointed arm configurations are similar to that of human arm. It consists of two straight links, corresponding to human fore arm and upper arm with two rotary joint corresponding to the elbow and shoulder joints. These two are mounted on a vertical rotary table corresponding to human waist joint. The work volume is spherical. This structure is the most dexterous one. This configuration is very widely used.

Applications: Arc welding, Spray coating.

Example: SCARA robot (Selective compliance Assembly Robot Arm) .

https://www.youtube.com/watch?v=OPKcfioww8E

Robot Arm configuration

SCARA (Selective Complaince Assembly Robot Arm) is a subclass used for rapid and smooth motions.

It is similar in construction to the jointer-arm robot, except the shoulder and elbow rotational axes are vertical. It means that the arm is very rigid in the vertical direction, but complaint in the horizontal direction.

https://www.youtube.com/watch?v=1QHJksTrk8s

Benefits:

Good Vertical Stiffness

Fewer joints/components

Small foot print

High Speed Operation

Excellent repeatability

Drawbacks:

Restricted motions

Less flexibility

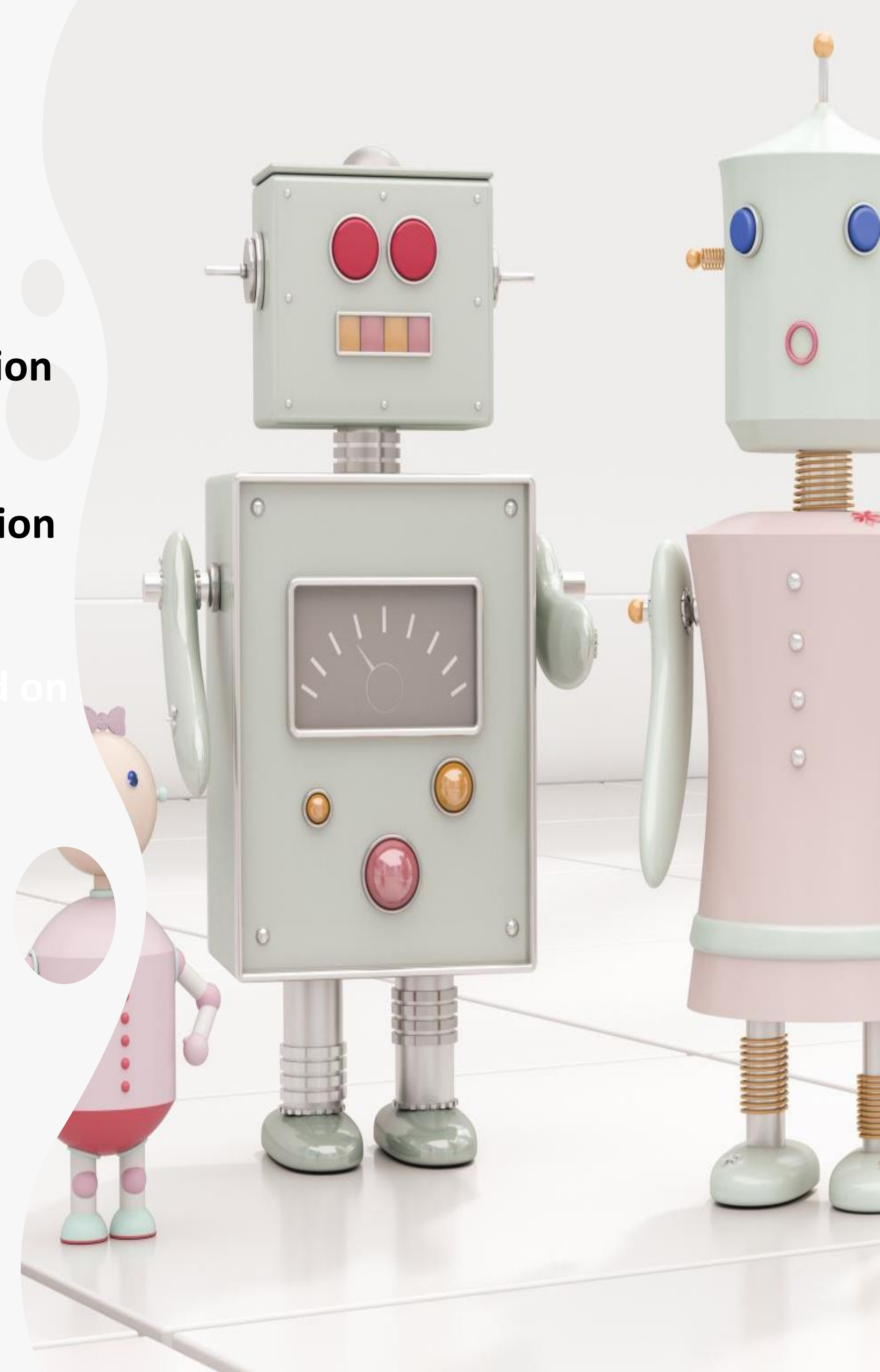
Horizontal compliance

Classification Based on Design and Application

Classification Based on Design and Locomotion

- Wheeled Robots
- Move on wheels, suitable for flat surfaces
- Examples: Robotic vacuum cleaners, warehouse robots
- Legged Robots
- Mimic human or animal locomotion, adaptable to varied terrains
- Examples: Humanoid robots, quadruped robots

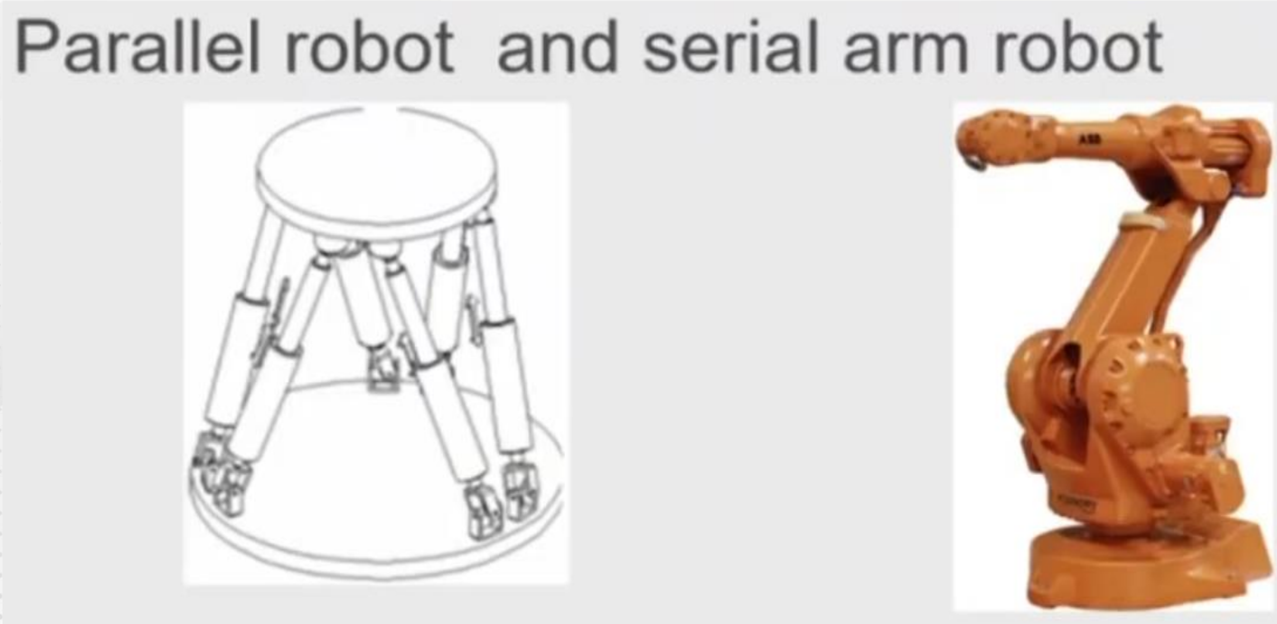
Classification Based on



Classification Based on Task Complexity

- Simple Reactive Robots
- Respond to immediate environmental stimuli
- Examples: Line-following robots, obstacle-avoidance robots
- Advanced Cognitive Robots
- Employ AI and decision-making for complex tasks
- Examples: AI-powered robots, autonomous vehicles

Other ways of Classifying Robots



https://www.youtube.com/watch?v=3fbmguBgVPA https://www.youtube.com/watch?v=jU7MZywxspU

Parallel/Delta

It looks less like a conventional robot and more like a three- or four-legged spider, with a fourth moving element extending from the centre to manipulate the end effectors, with in a hemispherical work envelope.

Benefits:

Very high speeds

Low installation profile

Drawbacks:

Smaller payloads

Less Flexibility

Parallel/Delta

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Benefits:

Very high speeds

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Drawbacks:

Smaller payloads

Less Flexibility

Controlled system

To perform as per the program instructions, the joint movements an industrial robot must accurately be controlled. Micro-processor-based controllers are used to control the robots. Different types of control that are being used in robotics are given as follows.

a. Limited Sequence Control

It is an elementary control type. It is used for simple motion cycles, such as pick-and-place operations. It is implemented by fixing limits or mechanical stops for each joint and sequencing the movement of joints to accomplish operation. Feedback loops may be used to inform the controller that the action has been performed, so that the program can move to the next step. Precision of such control system is less. It is generally used in pneumatically driven robots.

Controlled system

b. Playback with Point-to-Point Control

Playback control uses a controller with memory to record motion sequences in a work cycle, as well as associated locations and other parameters, and then plays back the work cycle during program execution. Point-to-point control means individual robot positions are recorded in the memory. These positions include both mechanical stops for each joint, and the set of values that represent locations in the range of each joint. Feedback control is used to confirm that the individual joints achieve the specified locations in the program.

c. Playback with Continuous Path Control

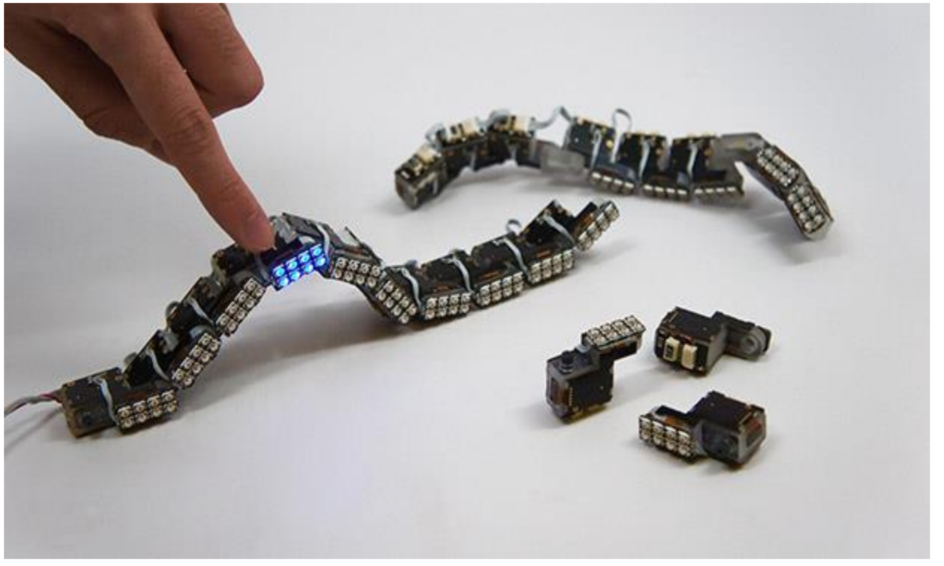
Continuous path control refers to a control system capable of continuous simultaneous control of two or more axes. The following advantages are noted with this type of playback control: greater storage capacity—the number of locations that can be stored is greater than in point-to-point; and interpolation calculations may be used, especially linear and circular interpolations.

Controlled system

d. Intelligent Control

An intelligent robot exhibits behavior that makes it seems to be intelligent. For example, it may have capacity to interact with its ambient surroundings; decision-making capability; ability to communicate with humans; ability to carry out computational analysis during the work cycle; and responsiveness to advanced sensor inputs. They may also possess the playback facilities. However it requires a high level of computer control, and an advanced programming language to input the decision-making logic and other ‘intelligence' into the memory.

chain type



- As sensors, computers, actuators, and batteries decrease in size and increase in efficiency, it becomes possible to make robots much smaller without sacrificing a whole lot of capability.

- There's a lower limit on usefulness, however, if you're making a robot that needs to interact with humans or human-scale objects.

- You can continue to leverage shrinking components if you make robots that are modular: in other words, big robots that are made up of lots of little robots.

Serial manipulator & Parallel Manipulator.

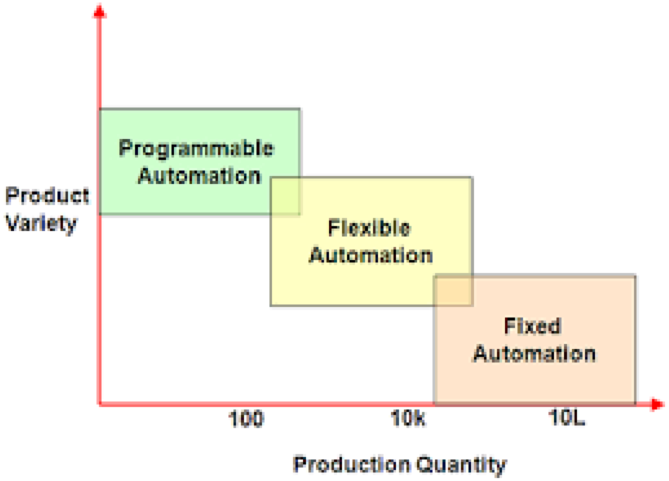
	Parallel manipulator	Serial manipulator
Type of manipulators	Closed loop	Open loop
End effectors	Platform	Gripper
Natural description	In Cartesian space	In joint space
Location of actuators	Near the immobile base	On the links
Inertia forces & stiffness	Less and high respectively	High and less respectively
Design considerations	Structure, workspace considerations, singularities, link interference	Strength and stiffness considerations, vibration characteristics.
Preferred property	Stiffness	Dexterity
Use of direct kinematics	Difficult and complex	Straightforward and unique
Use of inverse kinematics	Straightforward and unique	Complicated
Singularity	Static	Kinematic
Direct force transformation	Well defined and unique	Not well defined; may be non-existent, unique or infinite
Preferred application	Precise positioning	Gross motion

https://www.youtube.com/watch?v=3fbmguBgVPA

In Class Exercise

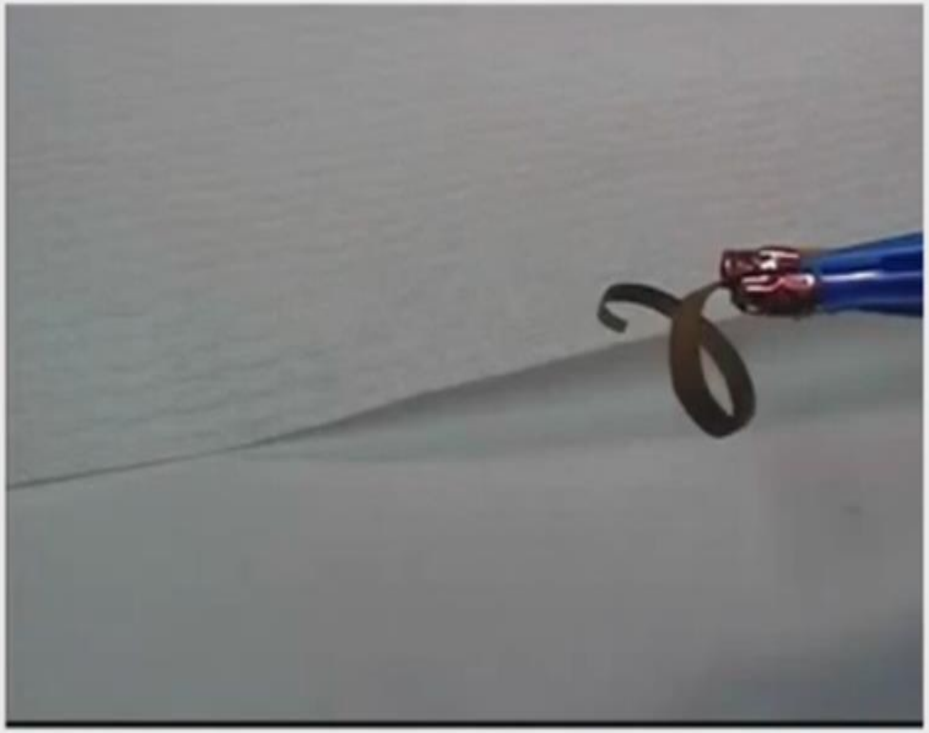
1. As a group, discuss an activity that you think could be automated by using a robot for Dept of CS / UoK.
2. Define the tasks that the robot will perform.
3. What kind of special tooling is required? Sketch if you will use any.
4. Can the activity be justified economically? Show your development – do not simply say yes or no.

Automation


Programmable Automation
Flexible Automation
Fixed Automation
Product Variety
100
10k
10L
Production Quantity

Snake, bird made of artificial muscles

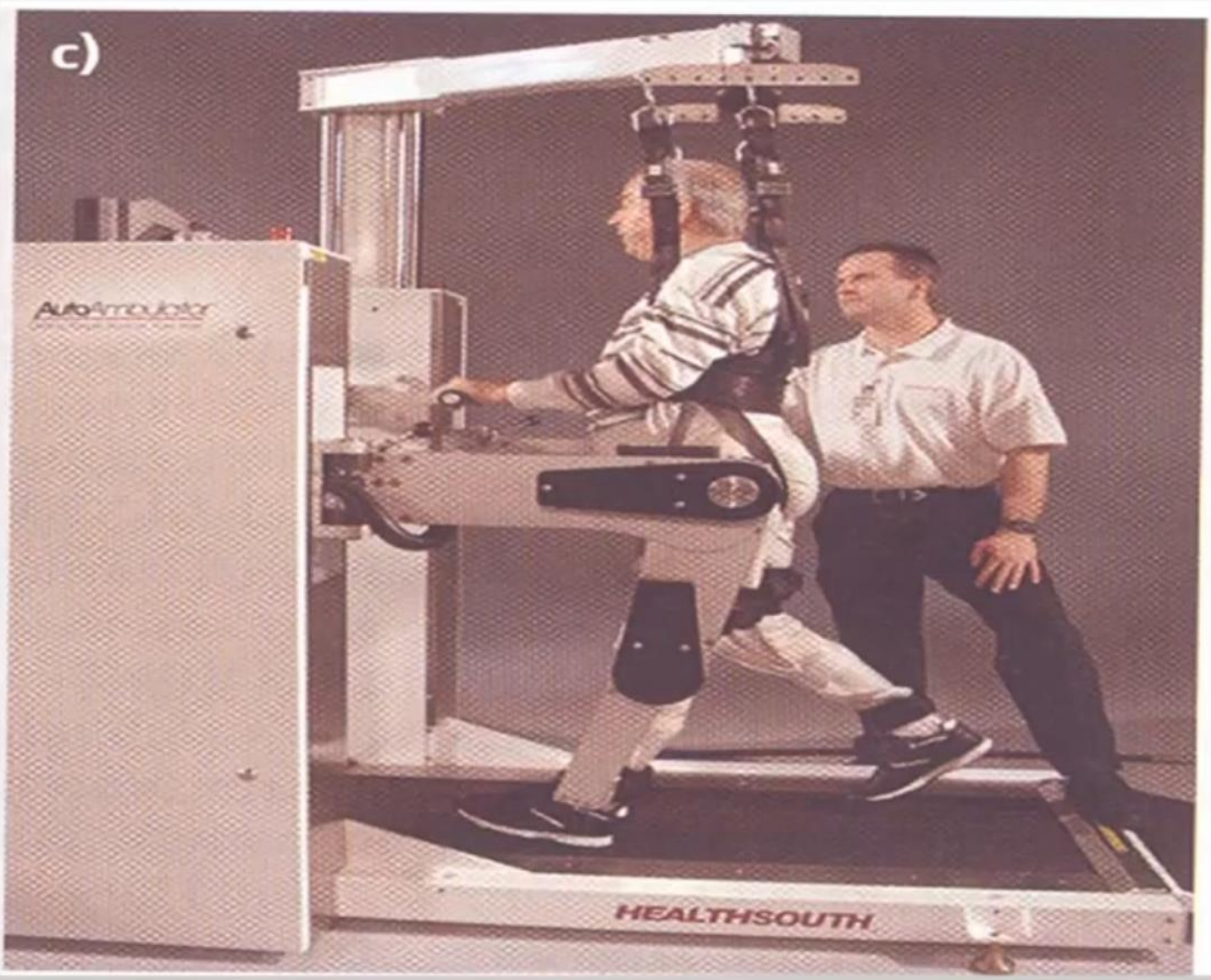
- Emulating biology



Robots for rehabilitation

Fig. HAL (Human assistive locomotion) Univ. of Tsukuba, Japan

Recover after surgery or stroke



Autonomous transport