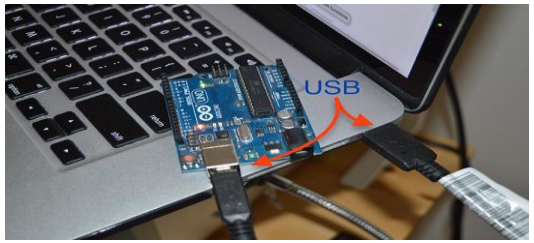
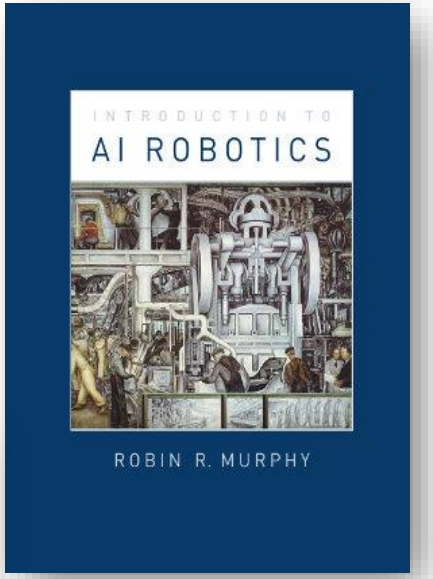
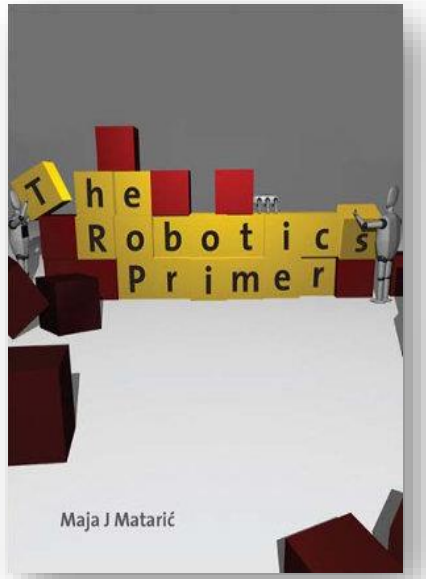
Introduction to Robotics

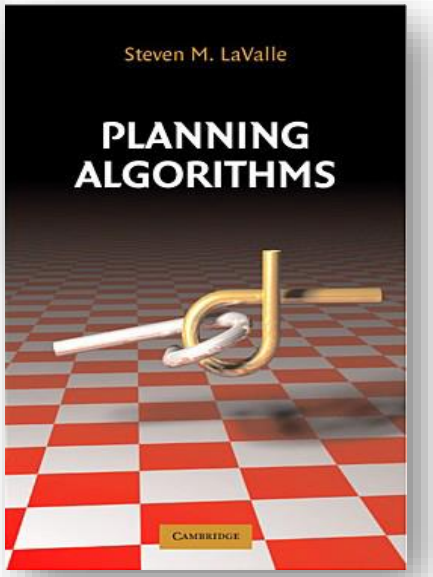


Textbooks

- Introduction to AI Robotics, Robin R. Murphy
  MIT Press, 2000
- The Robotics Primer, Maja J. Mataric,
  MIT Press, 2007
- Planning Algorithms, Steven M. LaValle,
  Cambridge University Press, 2006



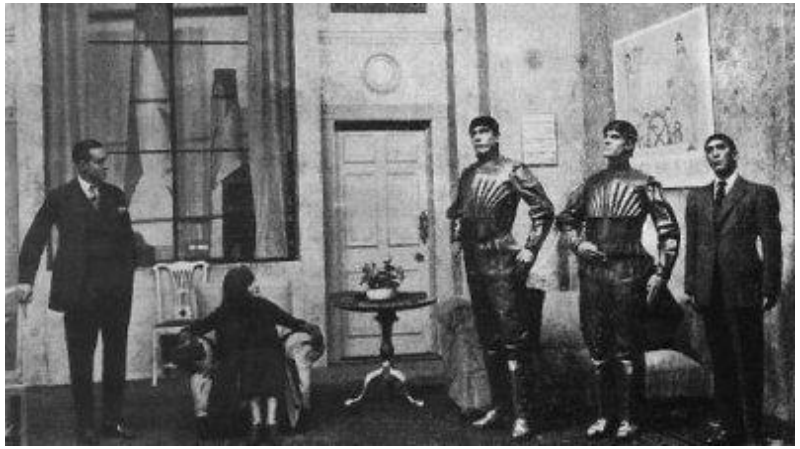




Overview of the Lectures

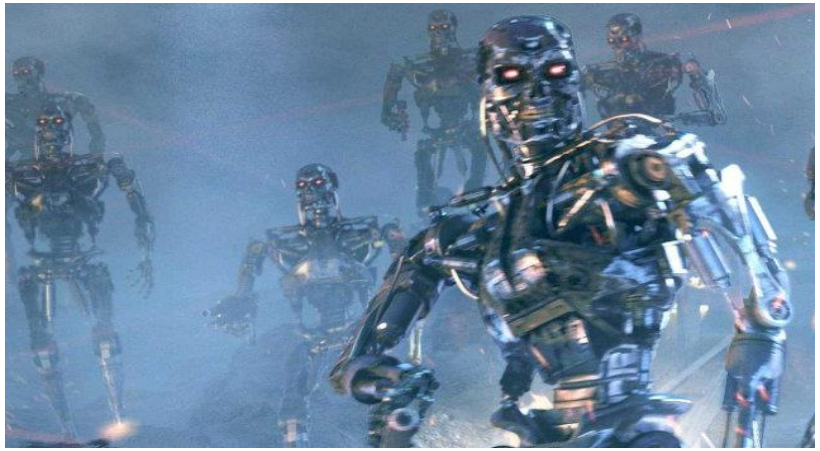
1. Introduction to (AI) robotics
2. Robotic paradigms and control architectures
3. Path and motion planning
4. Grid and graph based methods
5. Robotic Information Garthering - exploration of unknown environment
6. Randomized sampling-based motion planning Methods
7. Multi-Goal Planning - robotic variants of the TSP
8. Data collection planning - TSP(N), PC-TSP(N), and OP(N)
9. Data collection planning with curvature-constrained vehicles
10. Multi-robot data collection planning
11. Game theory in robotics
12. Game theory in robotics
13. Game theory in robotics

What is Understood as Robot?

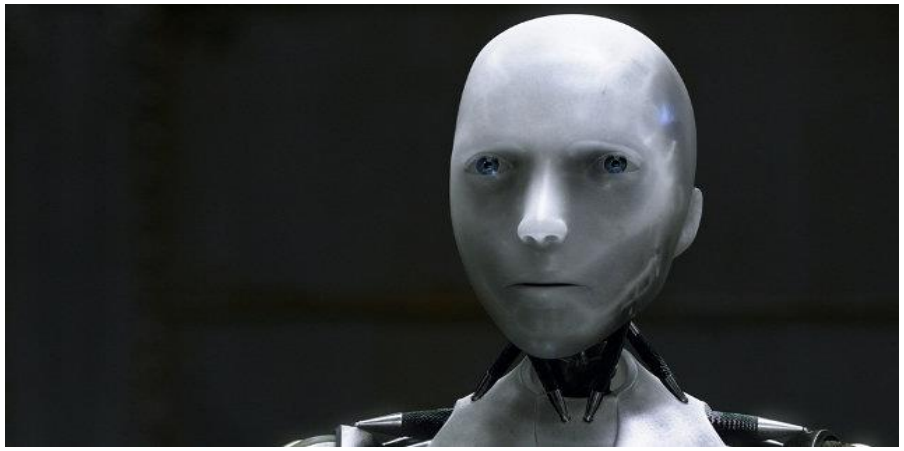


Rossum's Universal Robots (R.U.R)

Industrial robots



Cyberdyne T-800



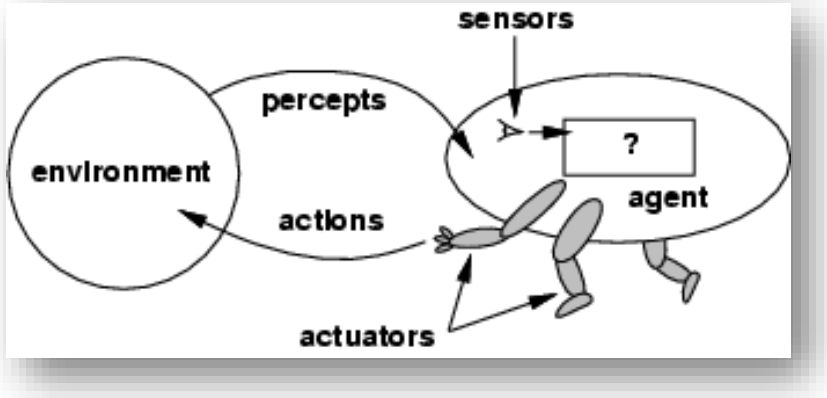
NS-5 (Sonny)

- Artificial Intelligence (AI) is probably most typically understand as **an intelligent robot**

Artificial Intelligence - Robotics

Agents

- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators



- The agent function maps from percept histories to actions:

$$[f: \mathcal{P}^{\star} \rightarrow \mathcal{A}]$$

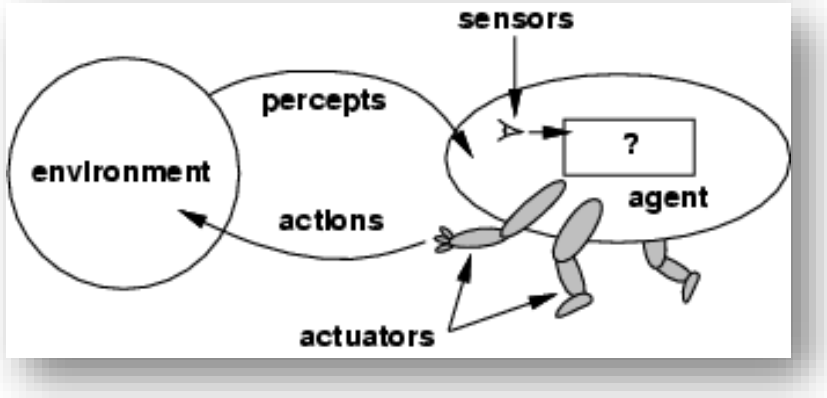
- The agent program runs on the physical architecture to produce *f*

Agent = Architecture + Program

Artificial Intelligence - Robotics

Agents

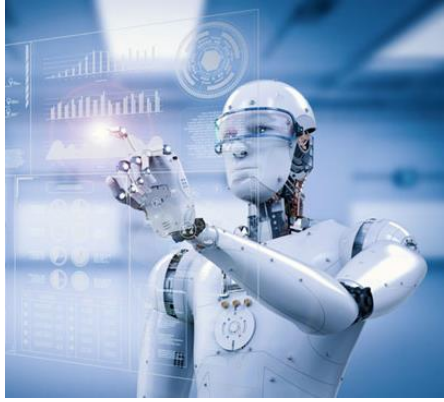
- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators



Intelligent agent

- is a system that perceives its environment and takes actions which maximize its chances of success. (Russell & Norvig 2003)

Robot - Robotics



Robotics:

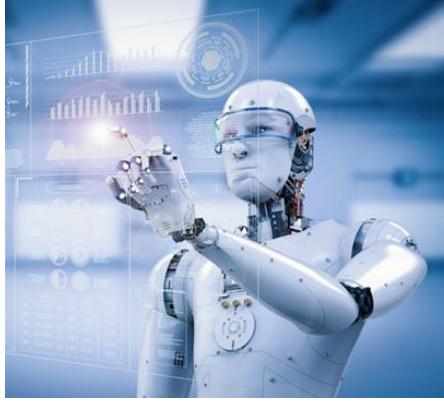
Robotics is an applied engineering science that has been referred to as a combination of machine tool technology and computer science.
It includes machine design, production theory, micro electronics, computer programming & artificial intelligence.

OR

"**Robotics**" is defined as the science of designing and building Robots which are suitable for real life application in automated manufacturing and other non-manufacturing environments.

The branch of technology that deals with the design, construction, operation, and application of robots, as well as computer systems for their control, sensory feedback, and information processing is **ROBOTICS**.

Robot - Robotics



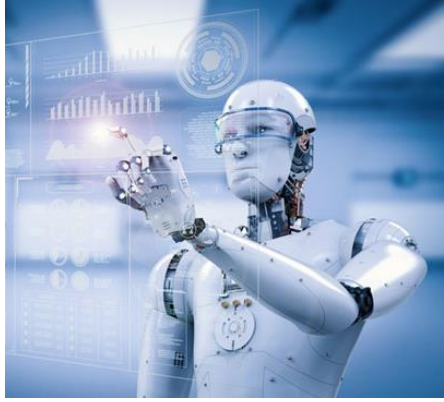
Robotics:

Robotics is a sub-domain of engineering and science that includes mechanical engineering, electrical engineering, computer science, and others.

Robotics deals with the design, construction, operation, and use of robots and computer systems for their control, sensory feedback, and information processing.

A robot is a unit that implements this interaction with the physical world based on sensors, actuators, and information processing.

Robot - Robotics



What is Robot?

Robots are the artificial agents acting in real world environment.

A robot is an autonomous system which exists in the physical world, can sense its environment, and can act on it to achieve some goals

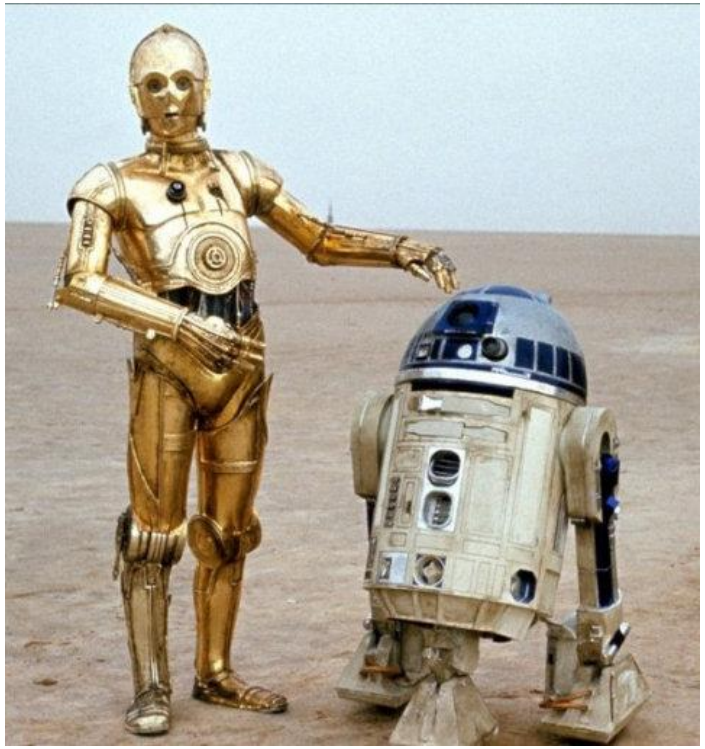
Objective

Robots are aimed at manipulating the objects by perceiving, picking, moving, modifying the physical properties of object, destroying it, or to have an effect thereby freeing manpower from doing repetitive functions without getting bored, distracted, or exhausted.

Intelligent Robots

- React to the environment – sensing
- Adapt to the current conditions
- Make decision and new goals

- Even though they are autonomous systems, the behavior is relatively well defined
- Adaptation and ability to solve complex problems are implemented as algorithms and techniques of Artificial Intelligence



Stationary vs Mobile Robots

A robot can be **static** (industrial robot or manipulator) or **mobile**.

Robots can be categorized into two main groups:

- **Stationary** robots – defined (limited) working space
- **Mobile** robots – it can move, and therefore, it is necessary to address the problem of navigation

Figure 1 Robotic Manipulators

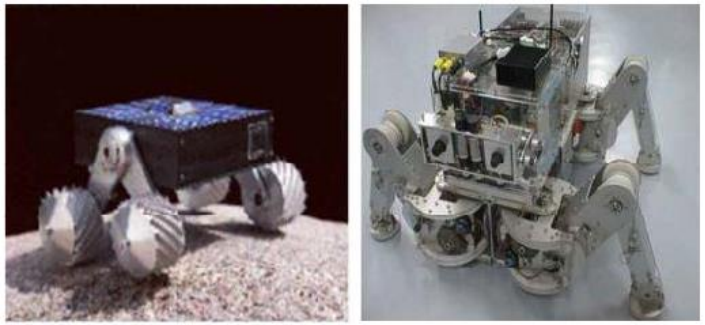


Figure 2 mobile robots

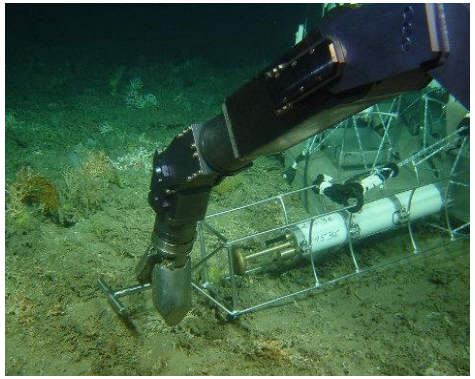
Stationary Robots (industrial robot or manipulator)

- Conventional robots needs separated and human inaccessible working space because of safety reasons
- Cooperating robots share the working space with humans

Mobile Robots:

- Regarding the **environment**: ground, underground, aerial, surface, and underwater vehicles
- Based on the **locomotion**: wheeled, tracked, legged, modular



انواع واستخدامات الروبوت:

1. روبوتات صناعية Industrial robots:

وهي عبارة عن روبوتات ذراعية يمكن تطوعيها وإعادة برمجتها لإنجاز أعمال صناعية كأعمال اللحام والطلاء والتجميع. يمكنها الحركة في ثلاث محاور وتستخدم في الشركات الصناعية الكبرى.

ABB robot

2. روبوتات إجتماعية أو منزلية household robots:

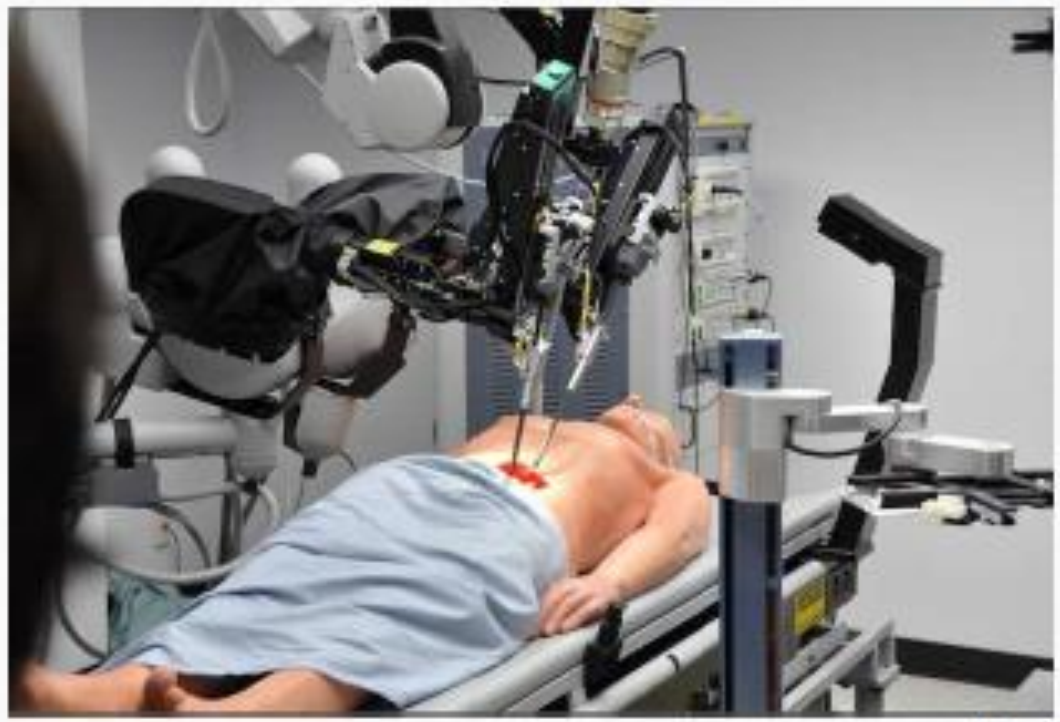
تقوم بالاعمال المنزلية ولها المقدره على تعليم الاطفال ولعب الشطرنج. تتميز بدرجة عالية من الاستقلالية Autonomous robots وهي الربوتات التي لديها برامج تمكنها من اتخاذ القرار المناسب لكيفية انجاز العمل حسب البيئة التي حولها.

Asimo root

3. روبوتات طبية Medical Robots:

تقوم بالأعمال الطبية كالعمليات الجراحية المعقدة ويتم التحكم فيها بنظام ال teleoperation system.

وهنالك بعض الانواع من الروبوتات الطبية التي تستخدم في تعويض الاعضاء البشرية للمعاقين.



Da Vinci robot

4. روبوتات خدمية service robots:

وهي الروبوتات التي تقوم بأعمال خدمية كالروبوتات التي تقوم بمرافقة وتوجيه الضيوف وجمع البينات والدوريات الامنية والروبوتات التي تستخدم في البحوث العلمية كالروبوتات الفضائية والروبوتات الدقيقة Nano robots

Enon robot

Components of AI Robot

A robot is an autonomous system which exists in the physical world, can sense its environment, and can act on it to achieve some goals

- The robot has a physical **body** in the physical world – embodiment
- The robot has sensors and it can sense/perceive its environment
- A robot has effectors and actuators – it can act in the environment
- A robot has controller which allows it to be autonomous

❑ The physical **body**– embodiment

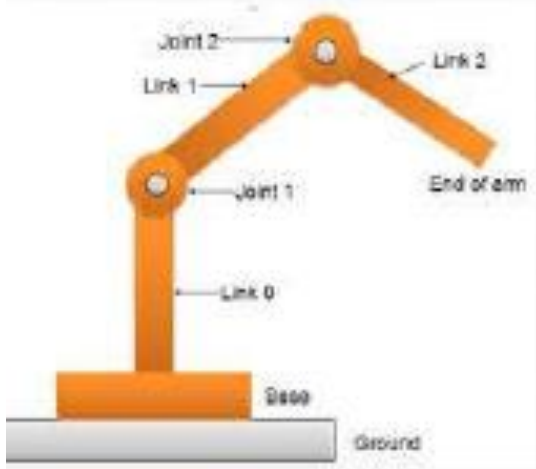
- The robot body allows the robot to act in the physical world.
  E.g., to go, to move objects, etc.

✓ Software agent is not a robot

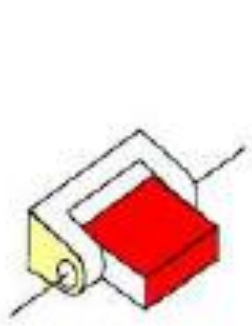
- Embodied robot is under the same physical laws as other objects
  - It must use actuators to move
  - It needs energy
  - It takes some time to speed up and slow down

- The physical **body**– embodiment

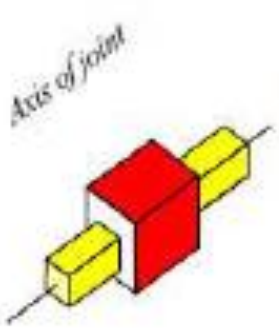
بنية جسم الروبوت معظمها ميكانيكية (kinematic chain) وتتكون من القضبان والمفصلات (links & joints) وتعتبر القضبان بمثابة العظام للروبوت والتي تتصل فيما بينها عن طريق مفصلات دورانية (Revolute joints) أو إنتقالية (Prismatic joints) أو كروي (Spherical joints) او شاملة (Universal joints) لتسهيل حركة الربوت.



(RR) robot

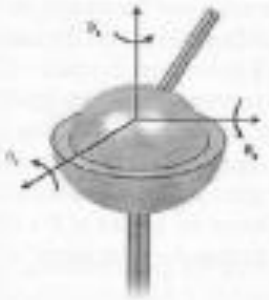


Revolute



Prismatic

Universal joint (RR)



spherical joint (RRR)

❑ Sensing / Perception

- **Sensors** are devices that enable a robot to perceive its physical environment to get information about itself and its surroundings

- Sensing allows the robot to know its state

  State can be fully observable, partially observable, or unobservable

  State can be discrete (e.g., on/off, up/down, colors) or continuous (velocity)

- State space consists of all possible states in which the system can be

  (space refers to all possible values)

  - External state – the state of the world as the robot can sense it
  - Internal state – the state of the robot as the robot can perceive it.

❑ Sensing / Perception

- **Sensors** are devices that enable a robot to perceive its physical environment to get information about itself and its surroundings

Temperature Sensor

Light Sensor

Force Sensor

Sound Sensor

Object Sensors

Effectors and Actuators - Action

- Effector – any device on a robot that has an effect on the environment.
- Effectors enable a robot to take an action. They use underlying mechanism such as muscles and motors called actuators

- Actuator – a mechanisms that allows the effector to execute an action or movement, e.g., motors, pneumatics, chemically reactive materials, etc.

- Effectors and actuators provide two main types of activities
- Locomotion – refers how the robot body moves from one location to another location

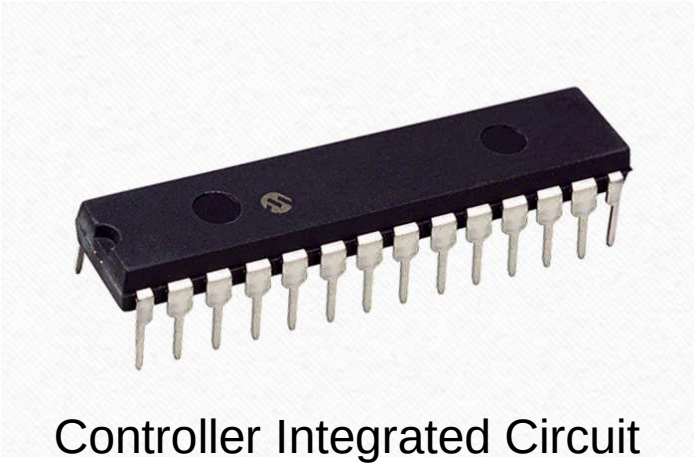
  Mobile robotics – robots that move around
- Locomotion mechanisms – wheels, legs, modular robots, but also propellers etc.

- Manipulation – handling objects

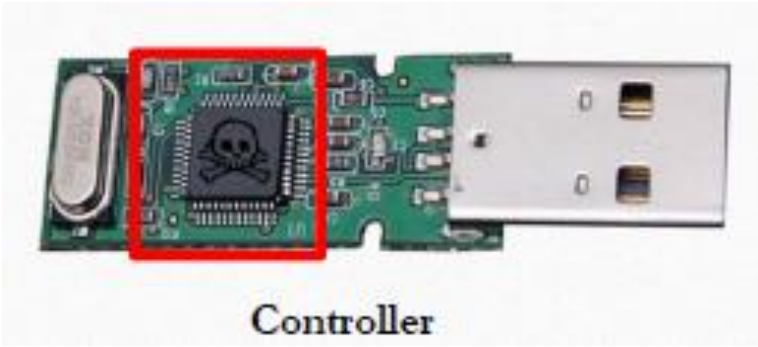
  Robotic arms

❑ Controller

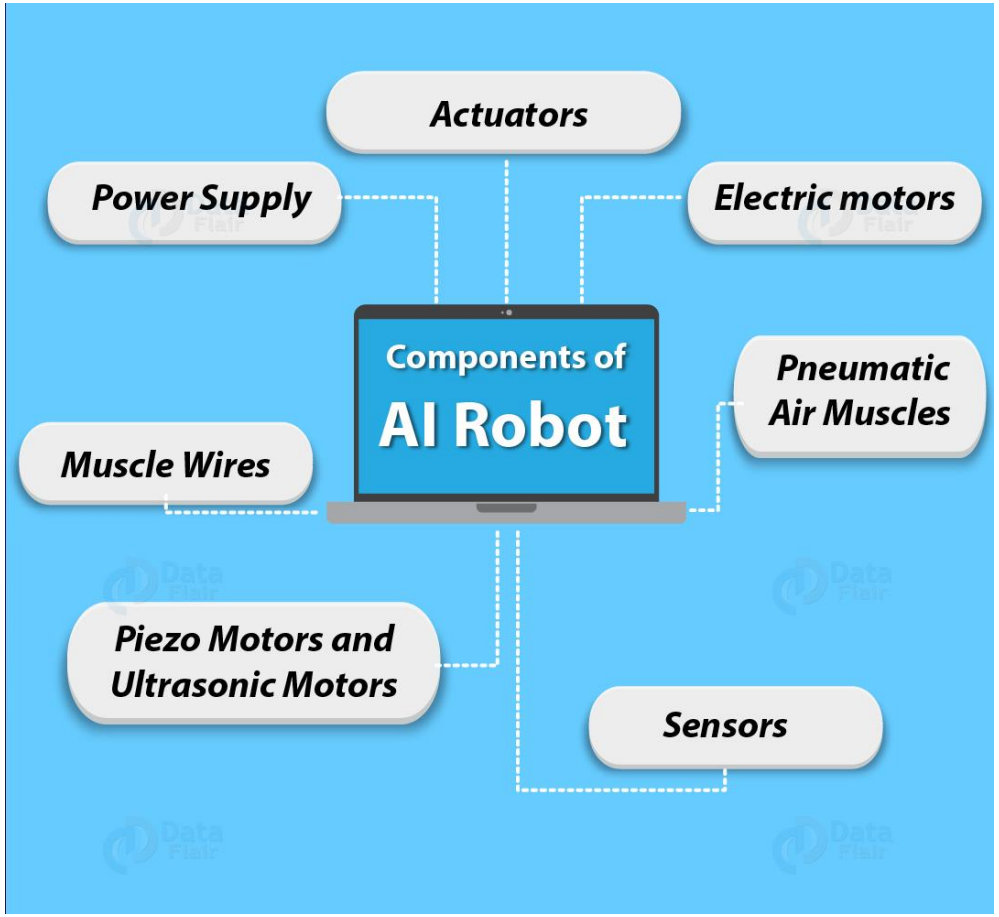
- **Controller : The controller receives data from the computer, controls the motions of the actuator and coordinates these motions with the sensory feedback information.**



Controller Integrated Circuit



Controller


Actuators
Power Supply
Electric motors
Components of
AI Robot
Pneumatic
Air Muscles
Muscle Wires
Piezo Motors and
Ultrasonic Motors
Sensors

Components of AI Robot

Robots are constructed with the following :

- Power Supply – The robots are powered by batteries, solar power, hydraulic, or pneumatic power sources.
- Actuators – They convert energy into movement.
- Electric motors (AC/DC) – They are required for rotational movement.
- Pneumatic Air Muscles – They contract almost 40% when air is sucked in them.
- Muscle Wires – They contract by 5% when electric current is passed through them.
- Piezo Motors and Ultrasonic Motors – Best for industrial robots.
- Sensors – They provide knowledge of real time information on the task environment. Robots are equipped with vision sensors to be to compute the depth in the environment. A tactile sensor imitates the mechanical properties of touch receptors of human fingertips.

Characteristics of Robots

A robot has these essential characteristics:

Sensing: First of all your robot would have to be able to sense its surroundings. It would do this in ways that are similar to the way we sense our surroundings. Some of the numerous robotic sensors include: light sensors (eyes), touch and pressure sensors (hands), chemical sensors (nose), hearing and sonar sensors (ears), and taste sensors (tongue) will give your robot awareness of its environment.

Movement: A robot needs to be able to move around its environment. Whether rolling on wheels, walking on legs or propelling by thrusters a robot needs to be able to move. To be counted as a robot, either the whole robot moves or like the Sojourner or just parts of the robot moves, like the Canada Arm. Energy: A robot needs to be able to power itself. A robot might be solar powered, electrically powered, battery powered. The way your robot gets its energy will depend on what your robot needs to do.

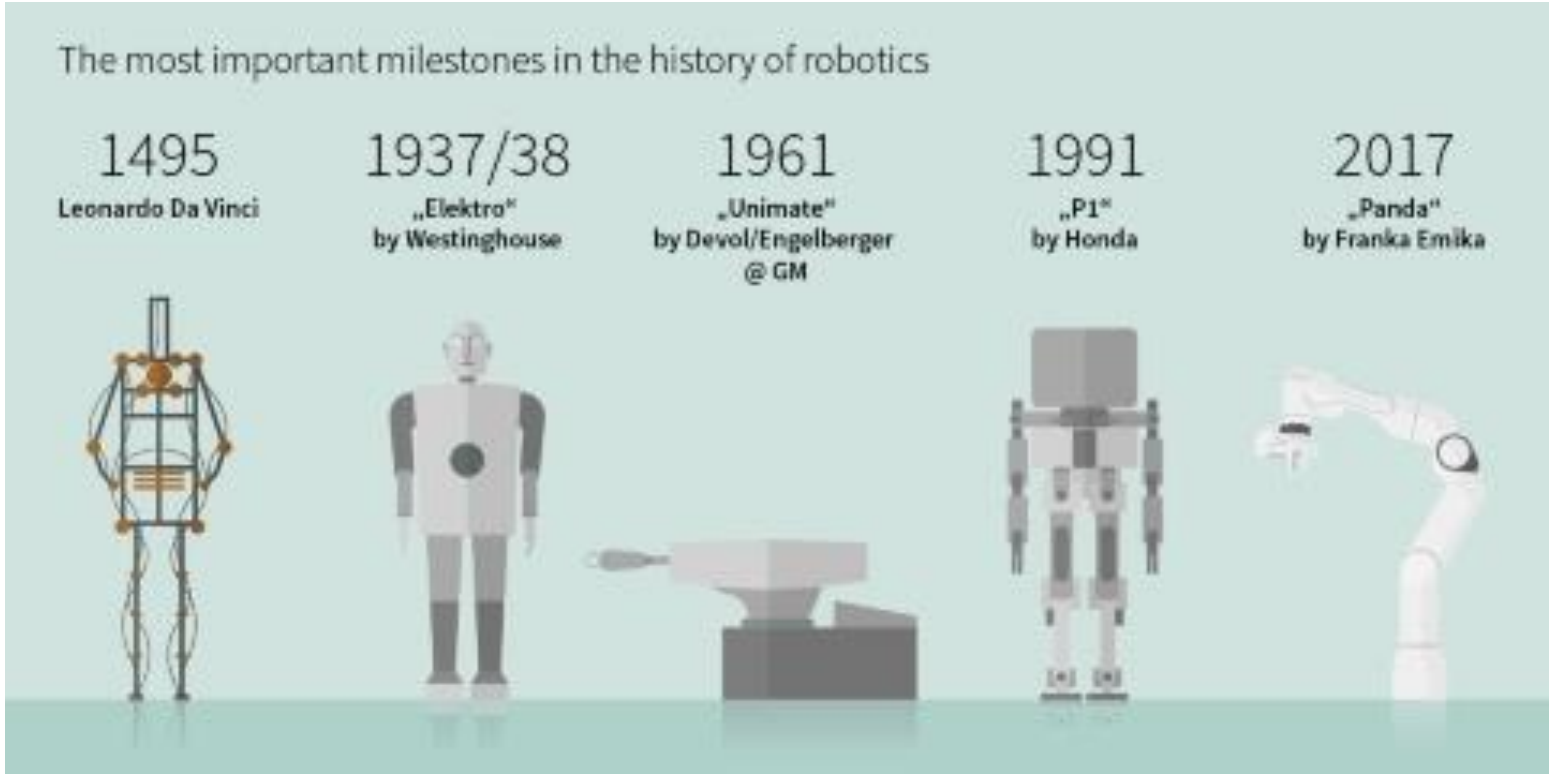
Intelligence: A robot needs some kind of "smarts." This is where programming enters the pictures. A programmer is the person who gives the robot its 'smarts.' The robot needs to have some way to receive the program so that it knows what it is to do. Why learn the basics of programming using robots instead of more traditional method? For the last 50 years, mainstream computer science has centered on the manipulation of abstract digital information.

General Applications Of Robots

Robots Are Applicable In The Following Areas:

- Machine loading
- Pick and place operations
- Welding Painting
- Sampling: Assembly operation
- Multi-Manufacturing
- Surveillance
- Medical arena: (helping the elderly and Disables, hospital delivery, surgical robots)
- Hazardous environments
- Exploration (planetary, undersea, polar)
- Search and rescue (earthquake rescue; demining)
- Mining and heavy transport; container handling
- Military (unmanned aircraft and submarines, insect robots)
- Domestic (Vacuum cleaning, lawn mowing, laundry, clearing the table, etc.).
- Transport (Autonomous cars).
- Entertainment (Sony AIBO, QRIO, Lego Mindstorms, Robocup competition, many others)

HISTORY OF ROBOTICS



Robotics Timeline

- **1922 Czech author Karel Capek wrote a story called Rossum's Universal Robots and introduced the word "Rabota"(meaning worker)**
- **1954 George Devol developed the first programmable Robot.**
- **1955 Denavit and Hartenberg developed the homogenous transformation matrices**
- **1962 Unimation was formed, first industrial Robots appeared.**
- **1973 Cincinnati Milacron introduced the T3 model robot, which became very popular in industry.**
- **1990 Cincinnati Milacron was acquired by ABB**

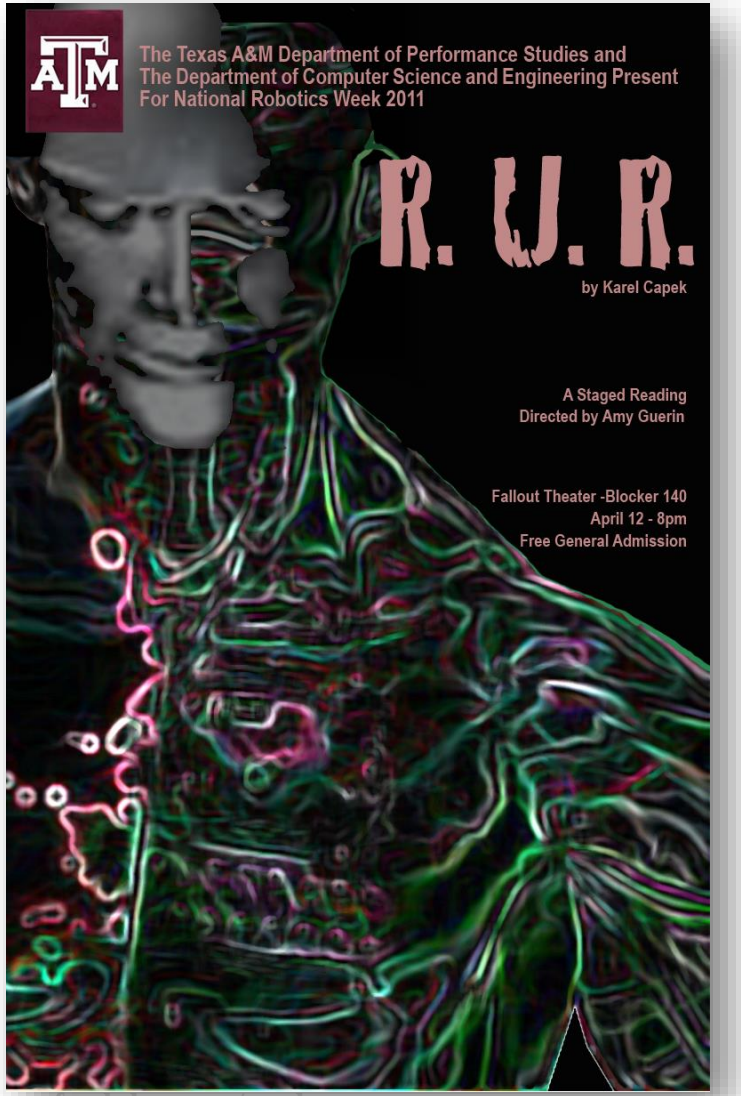
In 1495, the multiple genius and polymath Leonardo da Vinci designed what was probably the first human-like machine. His Mechanical Knight was able to sit and stand Other functions: lifting the visor and full movement of the arms. The movements were carried out with a complex system of pulleys and cables.

في عام 1495، صمم ليوناردو دافنشي العبقري متعدد الثقافات ما كان على الأرجح أول آلة تشبه الإنسان .كان فارسه الميكانيكي قادرًا على الجلوس والوقوف وظائف أخرى :رفع الحاجب والحركة الكاملة للذراعين .تم تنفيذ الحركات بنظام معقد من البكرات والكابلات .

- Čapek 1921: R.U.R.

The word robot was first used in the English language in the 1920 science fiction play R.U.R. by Czech author Karel Čapek. It was first performed on January 25, 1921. In the internationally successful play, autonomously thinking machines are the spitting image of humans. When they develop a consciousness, the robots rebel against their role as slaves which leads to the extinction of the human race. A touch of Terminator on the stage.

تم استخدام كلمة روبوت لأول مرة في اللغة الإنجليزية في مسرحية الخيال العلمي عام 1920 R.U.R. الكاتب التشيكي Karel Čapek. تم عرضه لأول مرة في 25 يناير 1921. في المسرحية الناجحة دوليًا ، تمثل آلات التفكير المستقل صورة البصق للبشر .عندما يطورون وعيًا ، تتمرد الروبوتات على دورهم كعبيد مما يؤدي إلى انقراض الجنس البشري .



www.fradulent.org/rur.htm

In November 2017, the Munich-based start up Franka Emika received the 2017 German Future Prize from the German President for its development of inexpensive, flexible, intuitively operated robots. The lightweight robots can be used in industrial applications and in healthcare. This is possible due to the torque sensors installed in the joints that respond to human touch. Another special feature of this robot is the price, which is well below the market average and, consequently, makes highly efficient, ultramodern robots appealing and affordable even for small and medium-sized companies.

في نوفمبر 2017، حصلت الشركة الناشئة Franka Emikaومقرها ميونيخ على جائزة المستقبل الألمانية لعام 2017من الرئيس الألماني لتطويرها للروبوتات الرخيصة والمرنة والتي تعمل بشكل حدسي .يمكن استخدام الروبوتات خفيفة الوزن في التطبيقات الصناعية والرعاية الصحية .هذا ممكن بسبب مستشعرات عزم الدوران المثبتة في المفاصل التي تستجيب للمسة البشرية .ميزة أخرى خاصة لهذا الروبوت هي السعر ، وهو أقل بكثير من متوسط السوق ، وبالتالي يجعل الروبوتات عالية الكفاءة والحديثة جذابة وبأسعار معقولة حتى بالنسبة للشركات الصغيرة والمتوسطة الحجم.

Advantages

1. Robots increase productivity, safety, efficiency, quality, and consistency of products.
2. Robots can work in hazardous environments.
3. Robots need no environmental comfort.
4. Robots work continuously without experiencing fatigue of problem.
5. Robots have repeatable precision at all times.
6. Robots can be much more accurate than human.
7. Robots can process multiple stimuli or tasks simultaneously.

Disadvantages

1. Robots replace human workers creating economic problems.
2. Robots lack capability to respond in emergencies
3. Robots, although superior in certain senses, have limited capabilities in Degree of freedom, Dexterity, Sensors, Vision system real time response system, real time response.
4. Robots are costly, due to Initial cost of equipment, Installation costs, Need for Peripherals, Need for training, Need for programming.

Difference in Robot System and Other AI Program

AI Programs	Robots
They usually operate in computer-stimulated worlds.	They operate in real physical world
The input to an AI program is in symbols and rules.	Inputs to robots is analog signal in the form of speech waveform or images
They need general purpose computers to operate on.	They need special hardware with sensors and effectors.