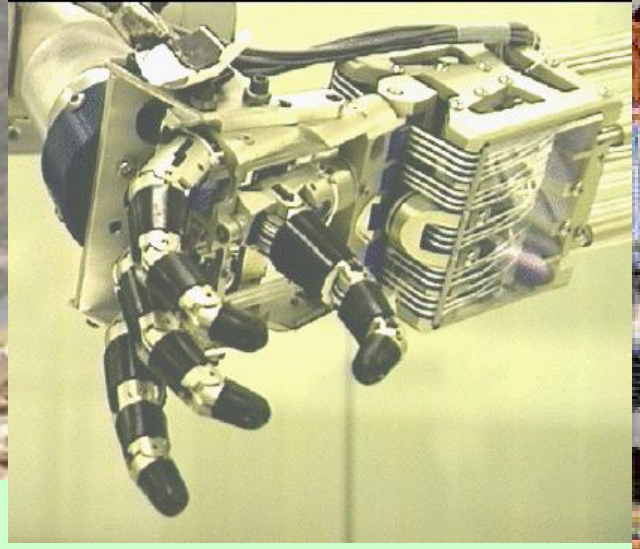
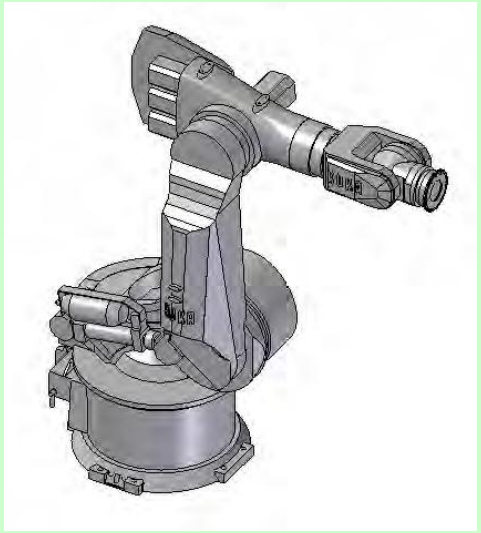
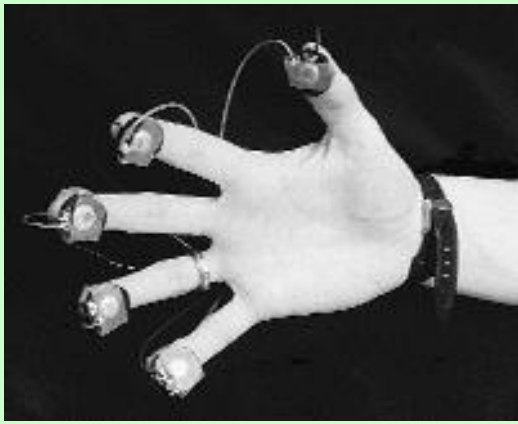


UOW
MALAYSIA
KDU PENANG
UNIVERSITY COLLEGE

PART OF THE UNIVERSITY
OF WOLLONGONG AUSTRALIA
GLOBAL NETWORK

CAI3034N
Autonomous Mobile Robotics





Learning Objectives

At the end of the course, students will be able to:

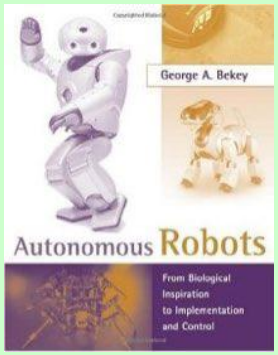
- **LO1**: Critically assess the theoretical capabilities of autonomous mobile robots.
- **LO2**: Understand and critically evaluate the range of possible applications for mobile robotic systems.
- **LO3**: Implement and empirically evaluate intelligent control strategies, by programming autonomous mobile robots to perform complex tasks in dynamic environments.

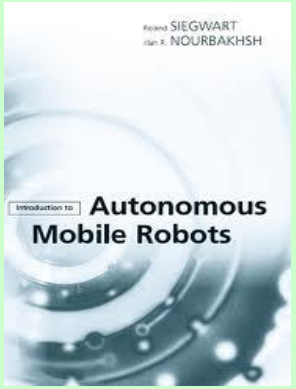
Outline Syllabus

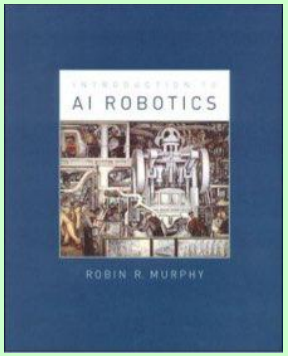
- Introduction to autonomous mobile robotics
- Robotic systems
- Robot programming
- Navigation
- Control architectures
- Motion and control
- Robot behaviours
- Obstacle avoidance
- Robotic mapping and self-localisation
- Robot vision and sensing

Reading material

- Bekey, G.A.: *Autonomous robots*. MIT Press,2005
- Siegwart, R. and Nourbakhsh, I.R.: *Introduction to autonomous mobile robots*. MIT Press,2004
- Murphy, R.R.: *An Introduction to AI Robotics*.MIT Press, 2000





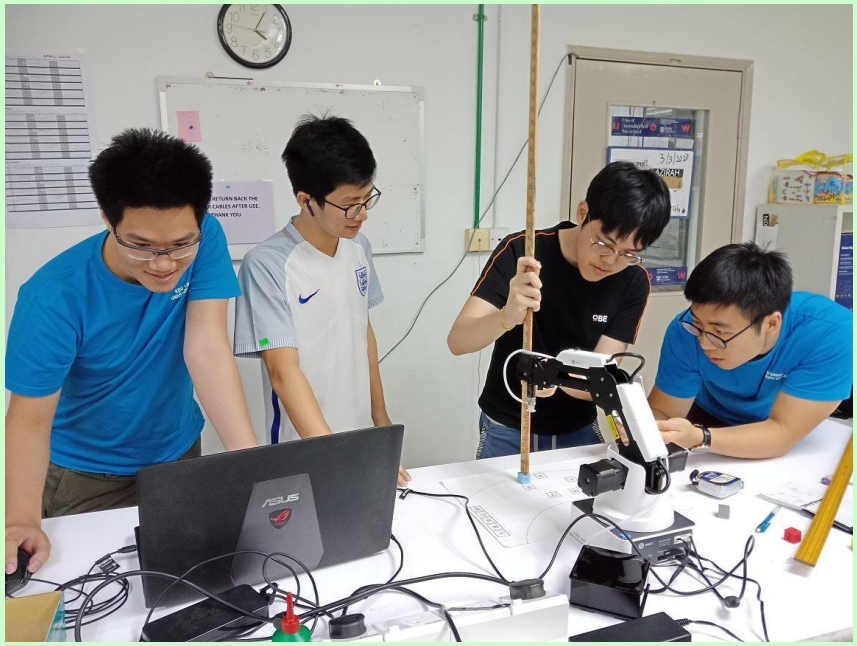


Assessment

- **Assignment 1 – 30%**
  - Task: **Programming with ROS**
    - Robot Chase and Prediction.
- **Assignment 2 – 30%**
  - Metal-Detecting Robot with Obstacle Avoidance and Feedback.
- **Final Exam – 40%**
  - 4 questions

Assignments

- https://www.youtube.com/watch?v=ucKvLq9tw5M



UOW KDU

https://www.youtube.com/watch?time_continue=2&v=H1v4tdcqTzs&feature=emb_logo

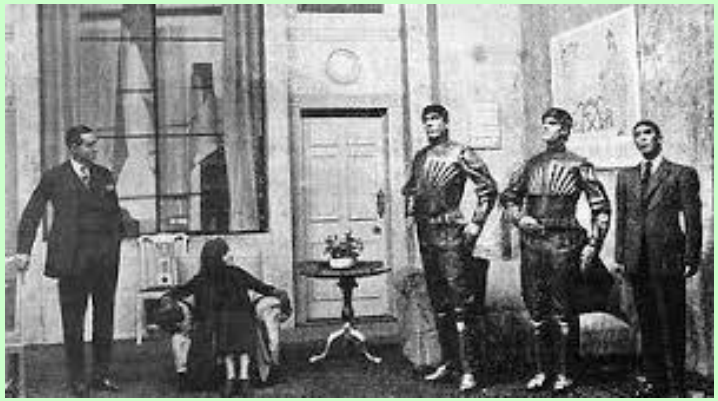
What is Robot?

" **A robot is a reprogrammable, multi-functional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."**

(Robotics Institute of America, 1979)

- **The word "robot" was coined by a Czech novelist Karel Capek in a play titled** *Rossumovi Univerzální Roboti* (RUR) in **1920. English phrase is Rossum's Universal Robots.**
- **Rossum = wisdom, Universal = multidisplinary, Robot = forced labour or servant**

What is Robot?



A scene from the play, showing three robots

- Capek had initially thought of naming the robot characters in his play labori, which is Latin for labor, or work, but didn't like the way the word sounded. He consulted with his brother Joseph, his close friend and confidante, and together they decided on the term roboti, or robots in English. Robot comes from the Czech word robota, which quite literally translates to "menial labour" or "forced labour".

A Robot is:

An electromechanical device that is:

- **Reprogrammable**
- **Multifunctional**
- **Sensible for environment**

Why do we need robots?

Robot uses

Decontaminating Robot

Cleaning the main circulating pump housing in the nuclear power plant

Jobs that are dangerous for humans

Robot uses

Welding Robot

Repetitive jobs that are boring, stressful, or labor-intensive for humans

Robot uses

Menial tasks that human don't want to do

The SCRUBMATE Robot

Scrubmate is an autonomous cleaning robot. It is capable of tasks such as washing floors and cleaning restrooms.

Robots in Hospital

Beijing-based robotics company CloudMinds sent 14 robots to Wuhan to deal with Coronavirus patients. The robot has an autonomous navigation and obstacle avoidance system. It can be used to deliver food, drinks and medicine to patients without direct person-to-person contact.

Robot dog enforces social distancing in Singapore

https://www.youtube.com/watch?v=l6PRsE-UF0o&t=71s&ab_channel=StevenBonesEverything

Unmanned combat aerial vehicle (UCAV)

Also known as a **combat drone** or simply a **drone**, is an unmanned aerial vehicle (UAV) that usually carries missiles, anti-tank guided missile (ATGM), and/or bombs and is used for drone strikes

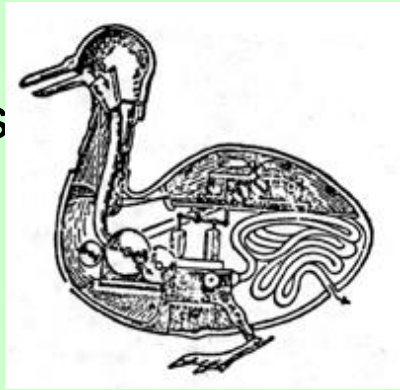
https://www.youtube.com/watch?v=rnLaSzTzj0A&ab_channel=USMilitaryNews

Other uses

- **Exploration**
- **Security**
- **Agriculture**
- **Automobile**
- **Construction**
- **Entertainment**
- **Health care: hospitals, patient-care, surgery, etc.**
- **Laboratories: science, engineering , etc.**
- **Law enforcement: surveillance, patrol, etc.**
- **Manufacturing**
- **Military: demining, surveillance, attack, etc.**
- **Mining, excavation, and exploration**
- **Transportation: air, ground, rail, space, etc.**
- **Utilities: gas, water, and electric**
- **Warehouses**

History

1738 - Jacques de Vaucanson builds a mechanical duck made of more that 4,000 parts The duck could quack, bathe, drink water, eat grain, digest it and void it. Whereabouts of the duck are unknown today.



https://www.youtube.com/watch?v=-wR6jAYgVPM

1805 - Doll, made by Maillardet, that wrote in either French or English and could draw landscapes.

https://www.youtube.com/watch?v=7ZiH7oF3OMM

History

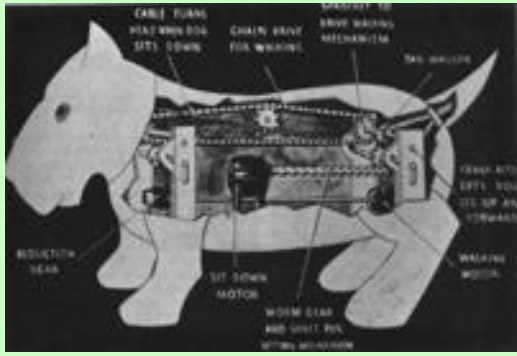
- **The first industrial robot: UNIMATE**
- 1954: The first programmable robot is designed by George Devol, who coins the term Universal Automation. He later shortens this to Unimation, which becomes the name of the first robot company (1962).

UNIMATE originally automated the manufacture of TV picture tubes

History

1940 - The smoking robot and his dog Sparko, used both mechanical and electrical components.

https://www.youtube.com/watch?v=4LYyWd_YNiA



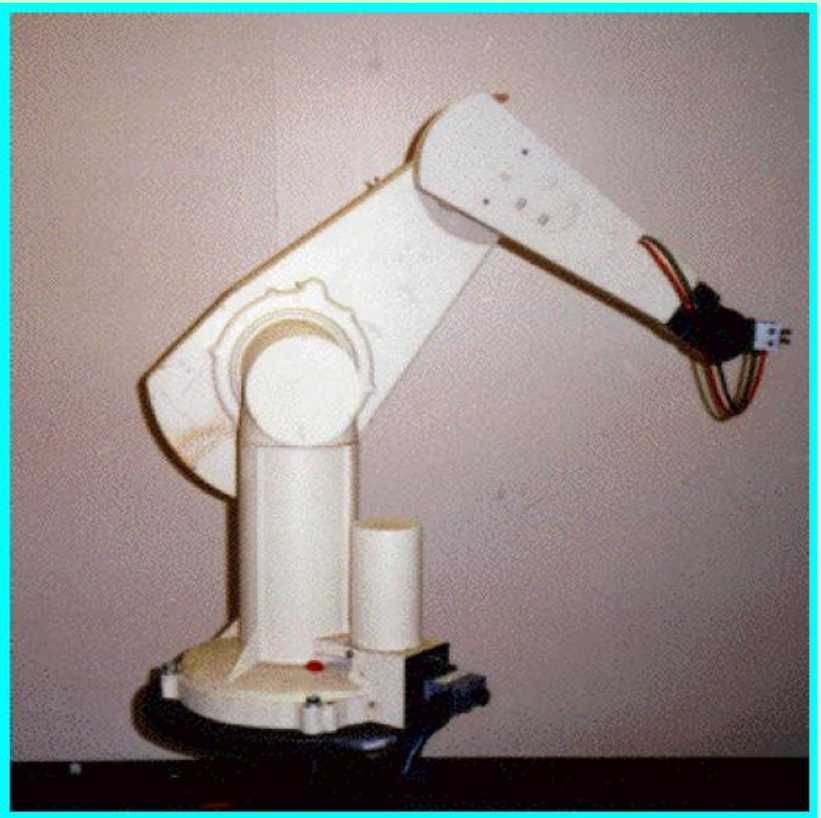
1940 - **Cybernetics** is a discipline that was created in the late 1940's by Norbert Wiener, combining feedback control theory, information sciences and biology to try to explain the common principles of control and communications in both animals and machines.

1948 - William Grey Walter builds Elmer and Elsie, two of the earliest autonomous robots with the appearance of turtles. The robots used simple rules to produce complex behaviors.

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

History

1978: The Puma (Programmable Universal Machine for Assembly) robot is developed by Unimation with a General Motors design support



PUMA 560 Manipulator

History

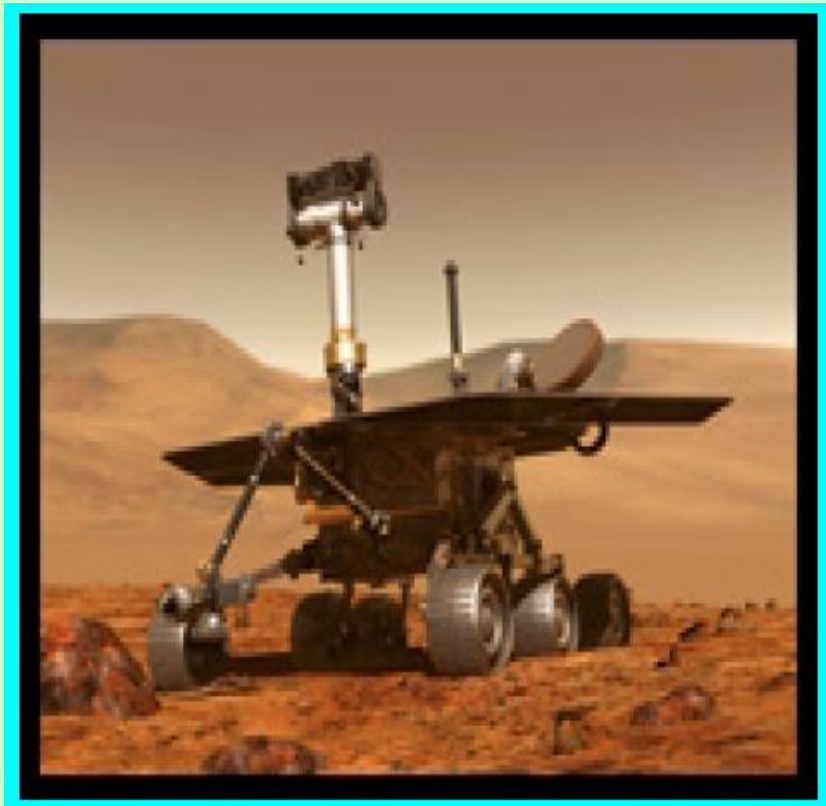
1980s: The robot industry enters a phase of rapid growth. Many institutions introduce programs and courses in robotics. Robotics courses are spread across mechanical engineering, electrical engineering, and computer science departments.

Adept's SCARA robots

Cognex In-Sight Robot

Barrett Technology Manipulator

History



1995-present: Emerging applications in small robotics and mobile robots drive a second growth of start-up companies and research

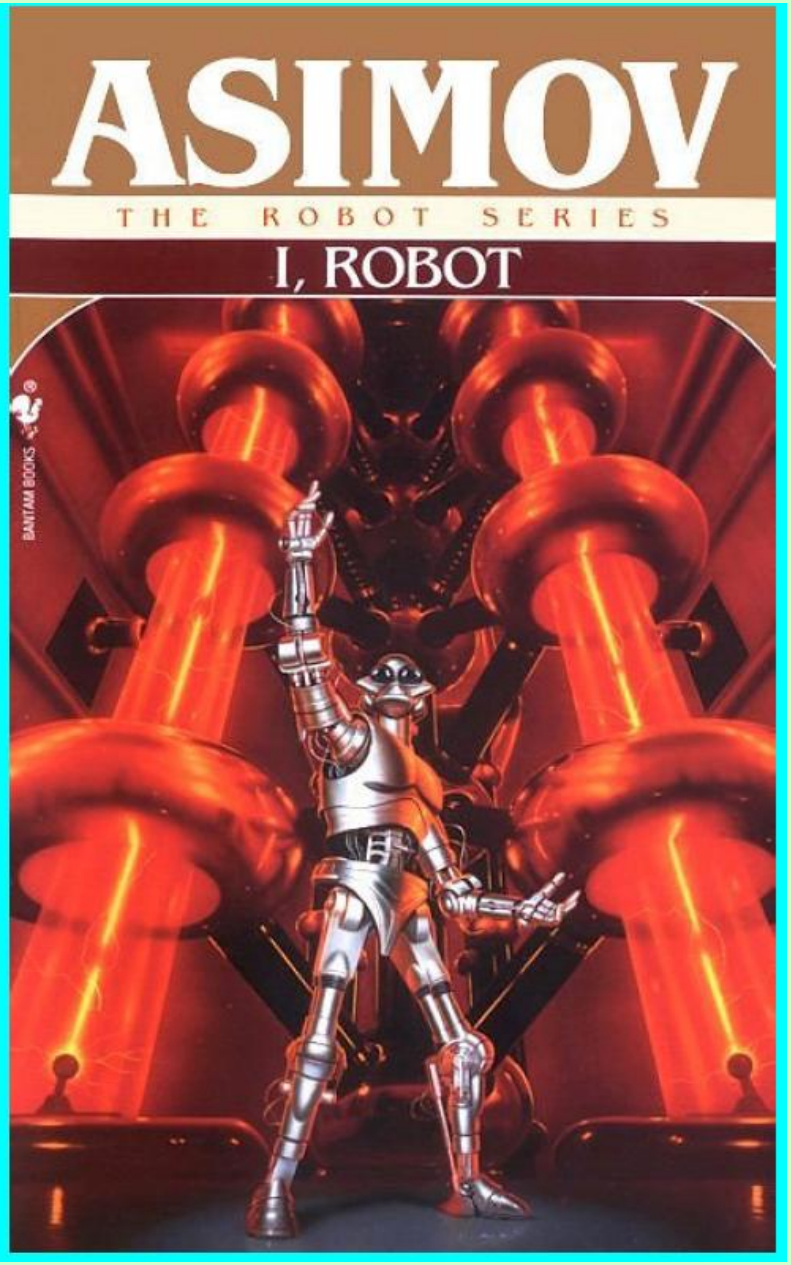
2003: NASA's Mars Exploration Rovers will launch toward Mars in search of answers about the history of water on Mars

History

- **2002** - iRobot introduces Roomba, a personal robotic vacuum cleaner.
- **2003** - Osaka University unveils their first 'Actroid', the term given for a humanoid robot with strong visual human characteristics.
- **2004** - The first DARPA Grand challenge is help. Sponsored by the US department of defence, the challenge is designed to create autonomous vehicles for warfare.
- **2004** - The Mars rovers Spirit and Opportunity land on Mars. As of November 25th 2009 The rover Spirit has completed 2150 days of its 92 day (90 sol) mission.
- **2010** - NASA and General Motors join forces to develop Robonaut-2, the new version of NASA's humanoid robot astronaut.

Laws of Robotics

- Asimov proposed three "Laws of Robotics" and later added the "zeroth law"
- Law 0: A robot may not injure humanity or through inaction, allow humanity to come to harm
- Law 1: A robot may not injure a human being or through inaction, allow a human being to come to harm, unless this would violate a higher order law
- Law 2: A robot must obey orders given to it by human beings, except where such orders would conflict with a higher order law
- Law 3: A robot must protect its own existence as long as such protection does not conflict with a higher order law



Humanity is the human race, which includes everyone on Earth. It's also a word for the qualities that make us human

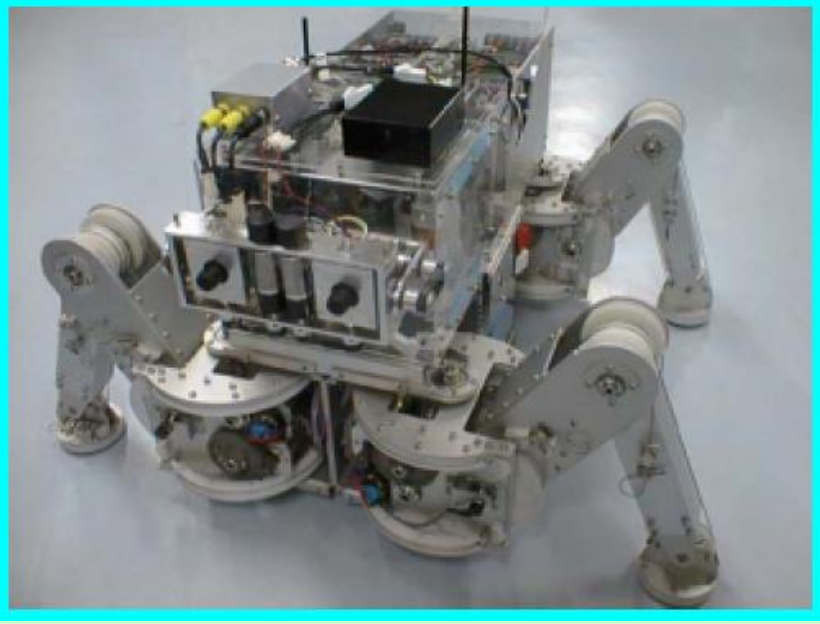
Type of Robots

Manipulator

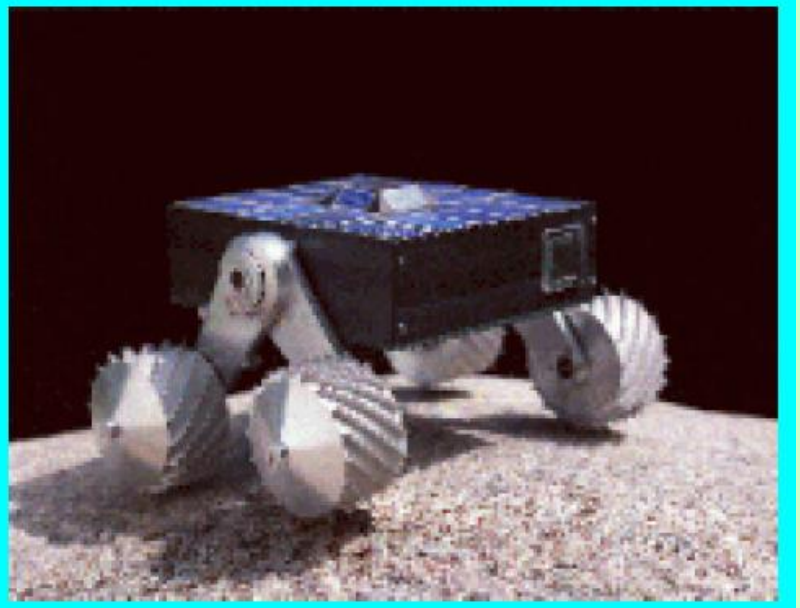
1. In robotics a manipulator is a device used to manipulate materials without direct contact.
2. It is an arm-like mechanism that consists of a series of segments, usually sliding or jointed called cross-slides, which grasp and move objects with a number of degrees of freedom.
3. The applications were originally for dealing with radioactive or biohazardous materials, using robotic arms, or used in inaccessible places.
4. In recent developments they are used in diverse range of applications including welding automation, robotically-assisted surgery and in space.

Type of Robots

Legged Robot



Wheeled Robot

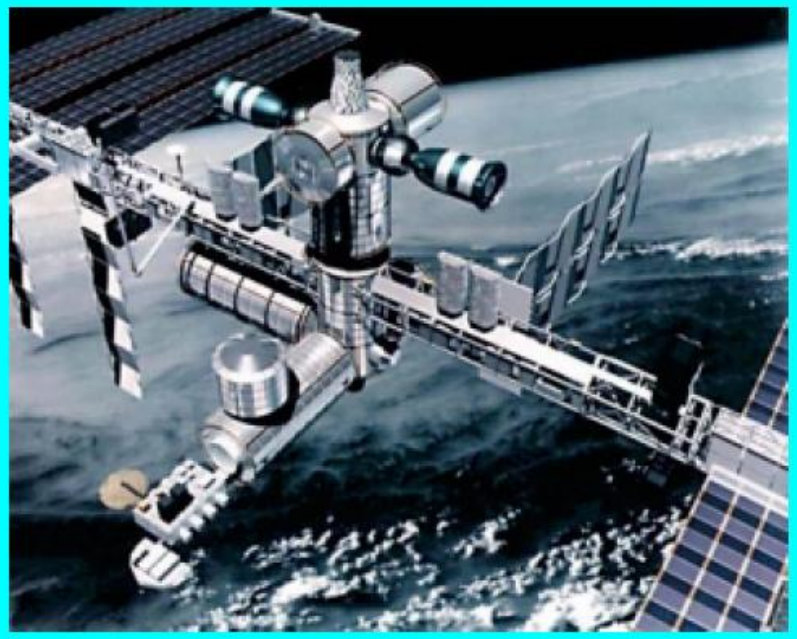


Type of Robots

Autonomous Underwater Vehicle

Unmanned Aerial Vehicle

Space Robots



NASA Space Station

Industrial Robots

“Big arms”

https://youtu.be/N5AYZxsnDuM

AGVs

https://youtu.be/FFBnXWNrsEM

Industrial Robots

- Industrial robots
  - used in factories to manufacture boxes and pack and wrap merchandise
- Car manufacturers own 50% of today's robots
- Robots used in hazardous situations
  - Nuclear power plants
  - Response to bomb threat
  - Outer space exploration

Robotic arm arranging chocolates

https://youtu.be/9mG1bgs_ND0

Industrial Robots

- Traditional industrial robot control uses robot arms and largely pre-computed motions
  - Programming using “teach box”
  - Repetitive tasks https://youtu.be/tywZsEGm1xc
  - High speed
  - Few sensing operations
  - High precision movements
  - Pre-planned trajectories and task policies
  - No interaction with humans

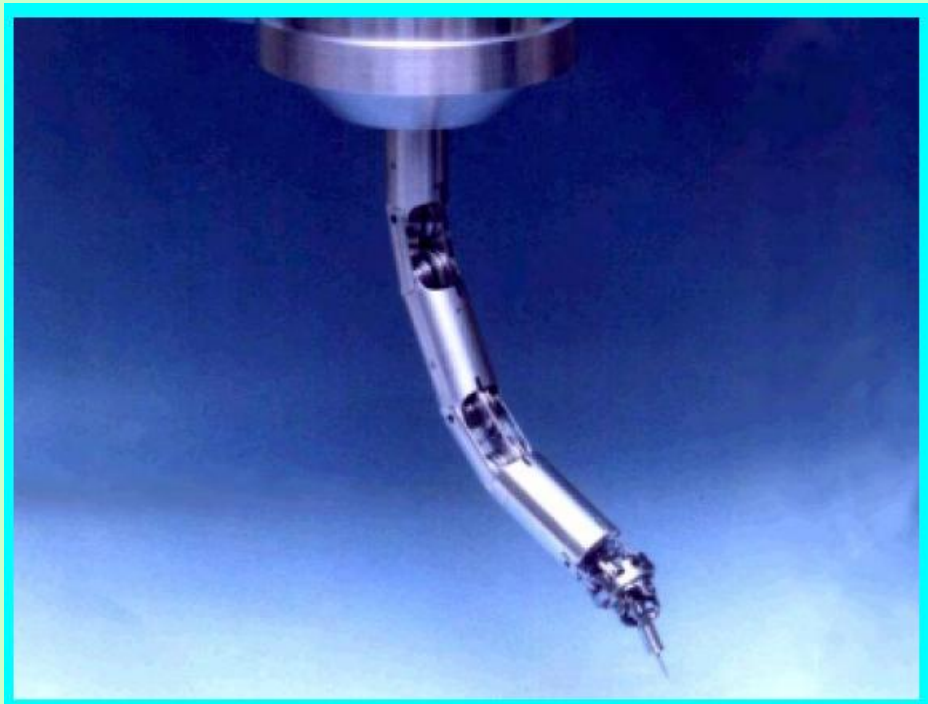
Problems of Traditional Industrial Robots

- Traditional programming techniques for industrial robots lack key capabilities necessary in intelligent environments:
  - Only limited on-line sensing
  - No incorporation of uncertainty
  - No interaction with humans
  - Reliance on perfect task information
  - Complete re-programming for new tasks

Requirements for Robots in Intelligent Environments

- **Autonomy** (the right of self-government)
  - Robots have to be capable of achieving task objectives without human input
  - Robots have to be able to make and execute their own decisions based on sensor information
- **Intuitive Human-Robot Interfaces**
  - Use of robots in smart homes cannot require extensive user training
  - Commands to robots should be natural for inhabitants
- **Adaptation**
  - Robots have to be able to adjust to changes in the environment

Medical Robots

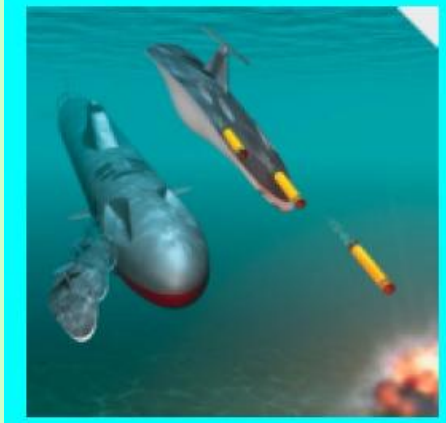


Robotic assistant for micro surgery

https://www.youtube.com/watch?v=vugOOuq256M

https://www.sunwaymedical.com/sunway-robotic-surgery-centre

Military Robots



SPLIT STRIKE: Deployed from a sub's hull, Manta could dispatch tiny mine-seeking AUVs or engage in more explosive combat.

PREDATOR

ISTAR

GLOBAL HAWK

GOLDENEYE

Robots at Home

Sony SDR-3X Entertainment Robot

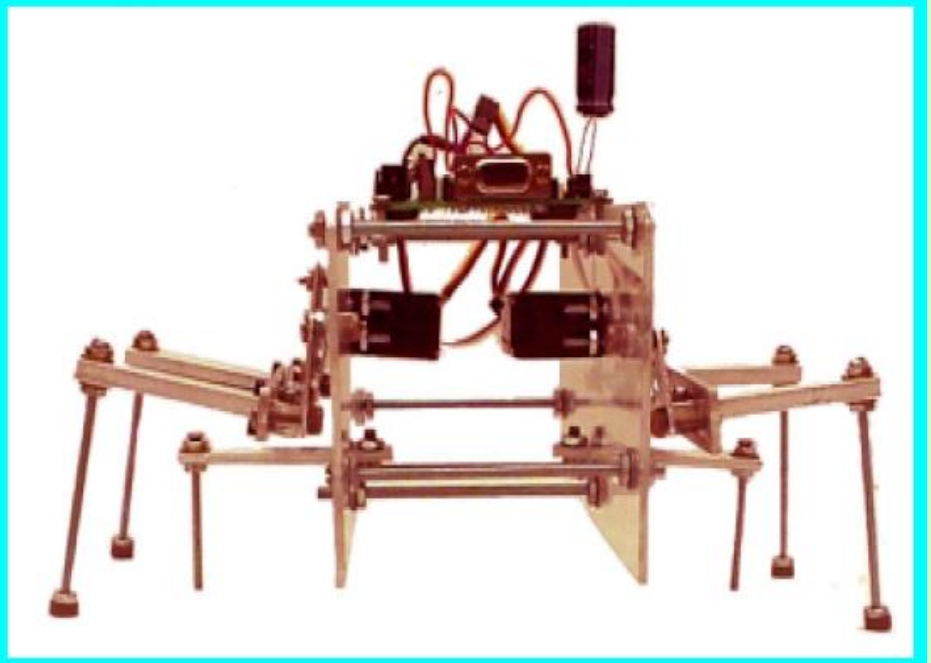
Sony Aido

Robot Base: Fixed vs Mobile

Robotic manipulators used in manufacturing are examples of fixed robots. They can not move their base away from the work being done.

A255 robot

Mobile bases are typically platforms with wheels or tracks attached. Instead of wheels or tracks, some robots employ legs in order to move about.



Quiz

1. Who first introduced the word “robot”?
   a. Isaac Asimov b. Karel Capek
   c. Isaac Newton d. R2-D2

2. What was the purpose of Asimov’s Laws of Robotics?
   a. To insure that robots always serve mankind
   b. To insure that robots become our friends
   c. To insure that robots become sentient
   d. To insure that the military never gains control of robots

3. Which of the following is NOT a fictional robot?
   a. R2-D2
   b. The Unimate
   c. The Cyberdyne Systems Model 101Terminator
   d. Lieutenant Commander Data

Quiz

4. Which of the following statements is true?
   a. All robots are intelligent machines
   b. All robots act like humans
   c. All robots are feedback mechanism which controlled remotely
   d. All robots are electromechanical machines using electronic programming

5. What do industrial robots usually look like?
   a. Humanoid with legs and arms
   b. A rigid mechanism with wheels
   c. A multi-jointed arm with a fixed base
   d. A small tractor and performs intricate tasks with its metal fingers

6. The czech word “Robota” meaning ___.
   a. forced labour
   b. robot
   c. humanoid
   d. manipulator

Quiz

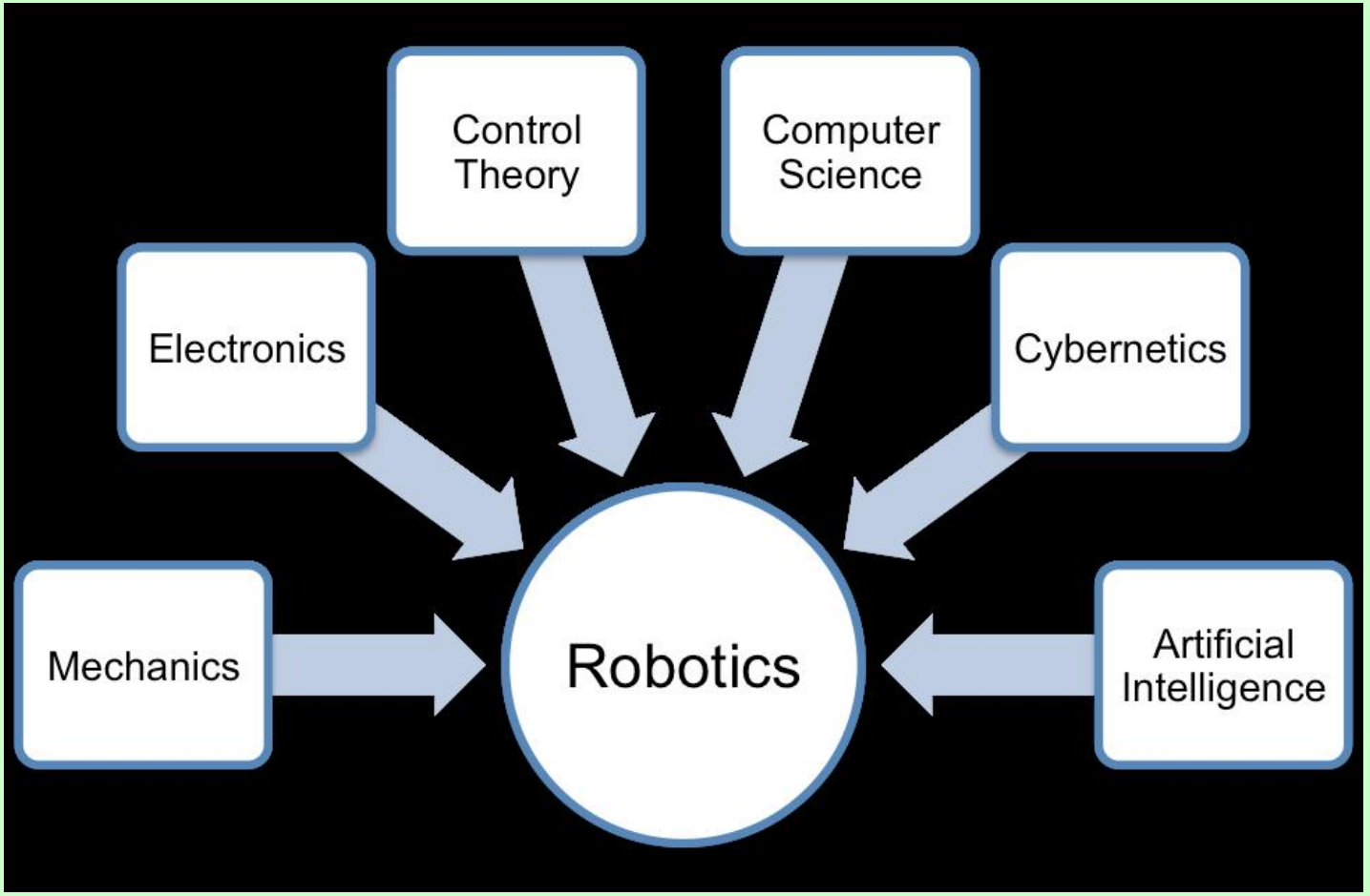
7. Where are AGV robots used most often?
   a. In an industrial plant
   b. In a student robot
   c. In military applications
   d. In automotive applications

8. List three common robotic applications.
   Jobs that are:

9. Describe three features of a robot.

10. List three benefits of robot use in industry.

Science and technology of robots



Cybernetics is the study of human control functions and of mechanical and electronic systems designed to replace them, involving the application of statistical mechanics to communication engineering.

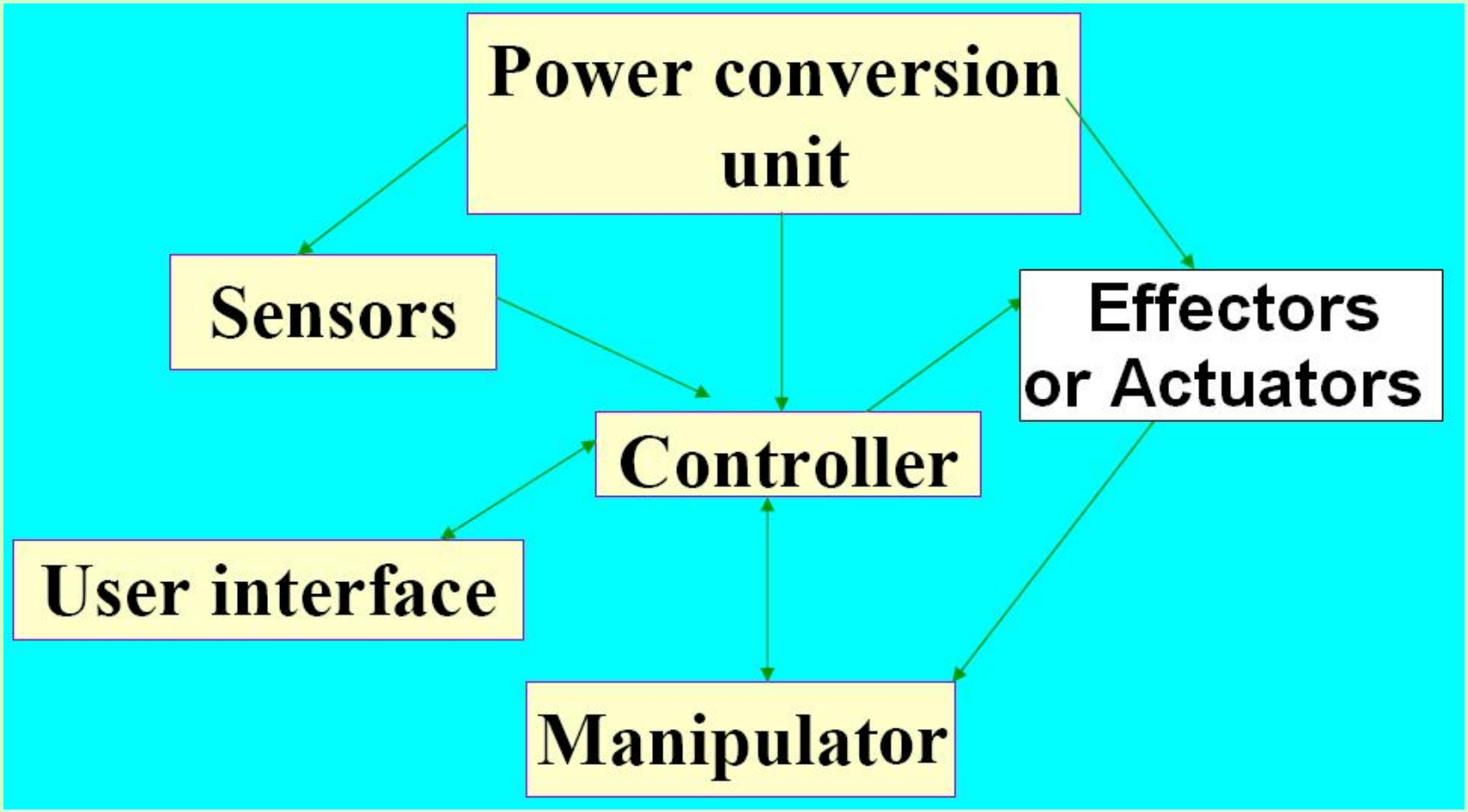
Knowledgebase for Robotics

•Typical knowledgebase for the design and operation of robotics systems

- –Dynamic system modeling and analysis
- –Feedback control
- –Sensors and signal conditioning
- –Actuators (muscles) and power electronics
- –Hardware/computer interfacing
- –Computer programming

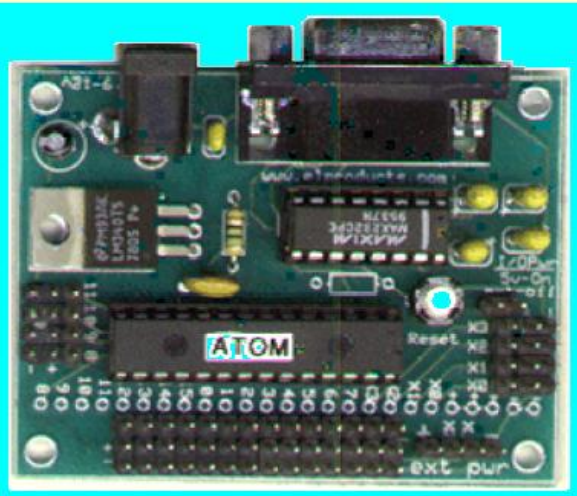
Disciplines: mathematics, physics, biology, mechanical engineering, electrical engineering, computer engineering, and computer science

Key Components of a Robot

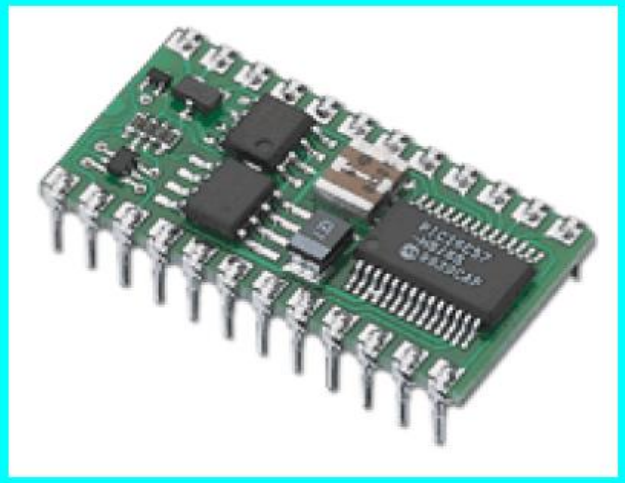


Controller

- Provide necessary intelligence to control the manipulator/mobile robot
- Process the sensory information and compute the control commands for the actuators to carry out specified tasks



RoboBoard Robotics Controller



BASIC Stamp 2 Module

Robot Senses

•Human senses: sight, sound, touch, taste, and smell provide us vital information to function and survive

•Robot sensors: measure robot configuration/condition and its environment and send such information to robot controller as electronic signals (e.g., arm position, presence of toxic gas)

•Robots often need information that is beyond 5 human senses (e.g., ability to: see in the dark, detect tiny amounts of invisible radiation, measure movement that is too small or fast for the human eye to see)

Robot sensors


Gyroscope


Lever Switch


Linear Encoder


GPS


Camera


Laser Rangefinder


Sonar Ranging


Accelerometer

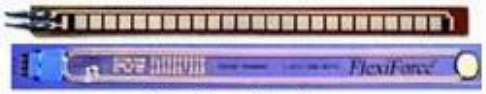

Piezo Bend


PIR


Rotary Encoder


Pyroelectric Detector


Pressure


Resistive Bend


Metal Detector


Pendulum Resistive Tilt


Gas


UV Detector


Radiation


Magnetometer


IR Modulator Receiver


Microphone


Infrared Ranging


CDS Cell


Compass


Magnetic Reed Switch

PIR = Passive Infrared sensor (motion sensor) Pyroelectric used for detecting electromagnetic radiation magnetometer is a device that measures magnetism

Vision Sensor

Vision Sensor: e.g., to pick bins, perform inspection, etc.

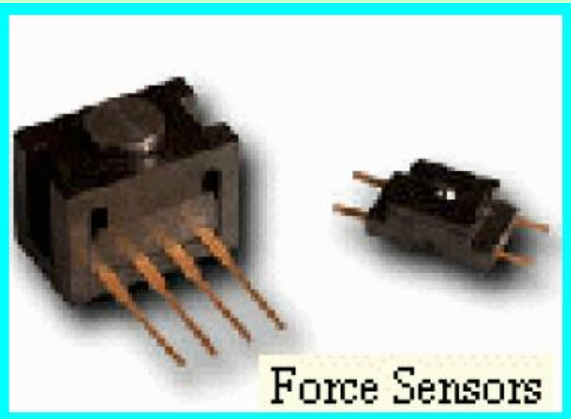
In-Sight Vision Sensors

Part-Picking: Robot can handle work pieces that are randomly piled by using 3-D vision sensor. Since alignment operation, a special parts feeder, and an alignment pallete are not required, an automatic system can be constructed at low cost.

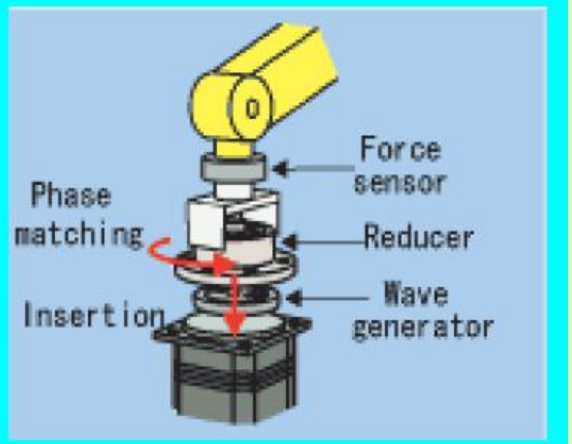
https://www.youtube.com/watch?v=7UpR8X4T_vE

Force Sensor

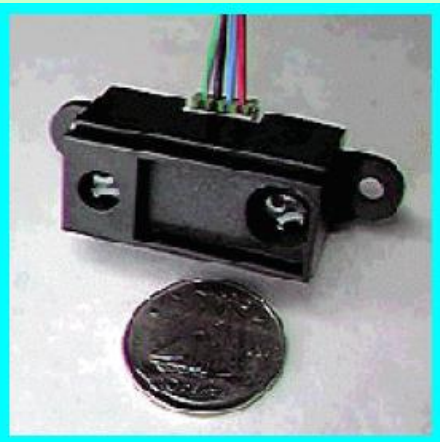
Force Sensor: e.g., parts fitting and insertion, force feedback in robotic surgery



Parts fitting and insertion: Robots can do precise fitting and insertion of machine parts by using force sensor. A robot can insert parts that have the phases after matching their phases in addition to simply inserting them. It can automate high-skill jobs.

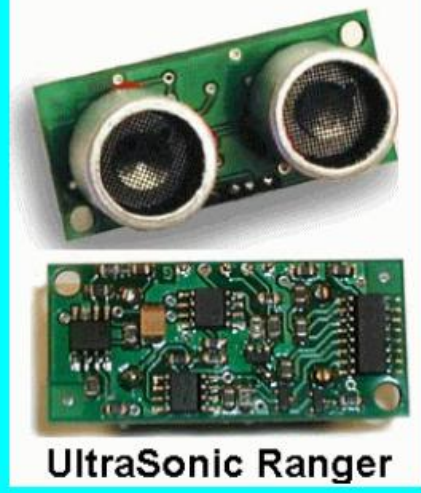


Proximity Sensor



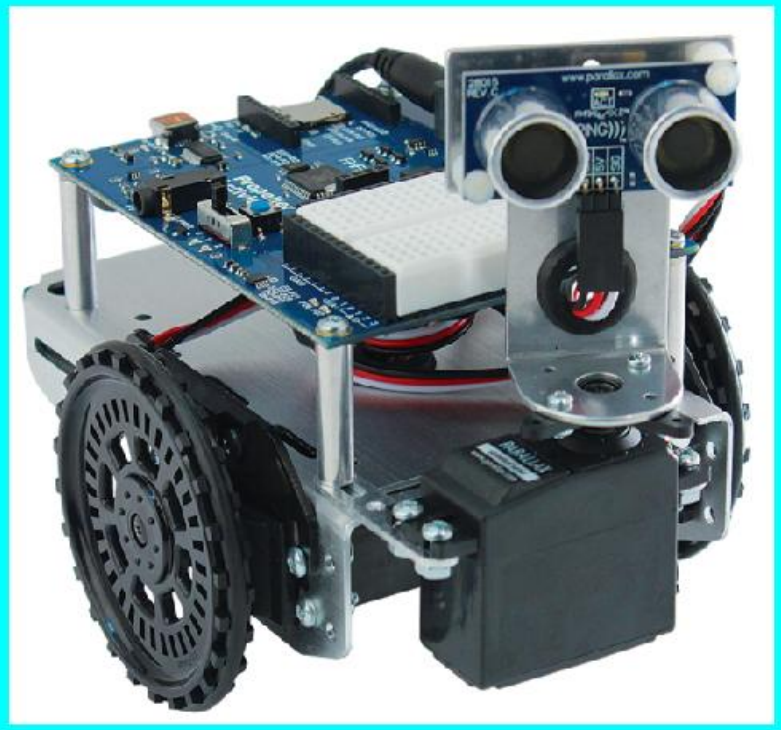
Infrared Ranging Sensor

Devantech SRF04



UltraSonic Ranger

Example



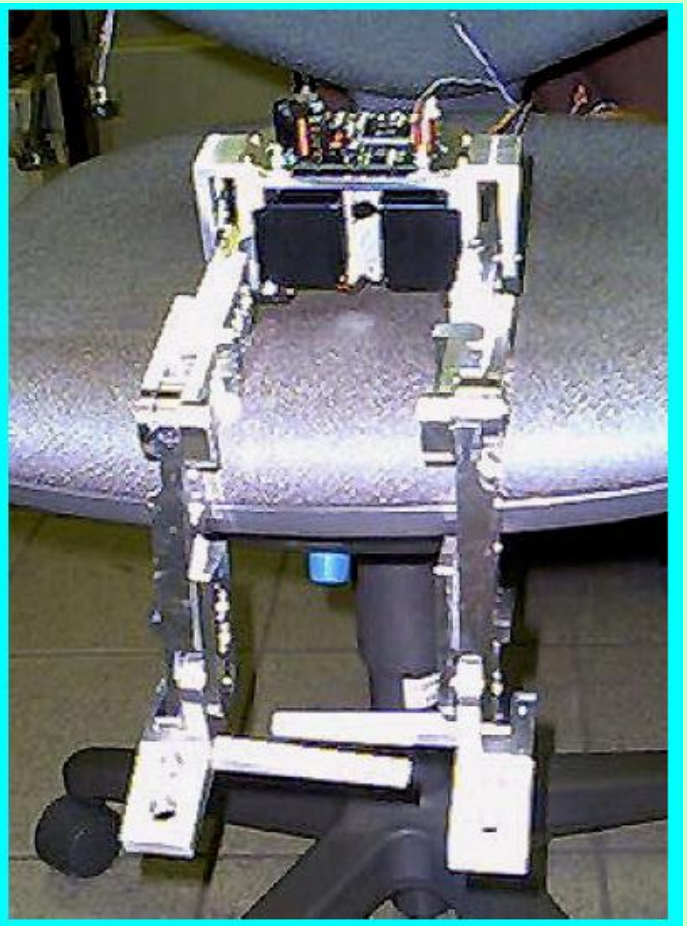
- 6 ultrasonic sonar transducers to explore wide, open areas
- Obstacle detection over a wide range from 15cm to 3m
- 16 built-in infrared proximity sensors (range 5-20cm)
- Infrared sensors act as a "virtual bumper" and allow for negotiating tight spaces

Tilt Sensor

Tilt sensors: e.g., to balance a robot

Tilt Sensor

Example



Planar Bipedal Robot

Effectors & Actuators

Effectors:

- hand, arm, gripper – manipulators

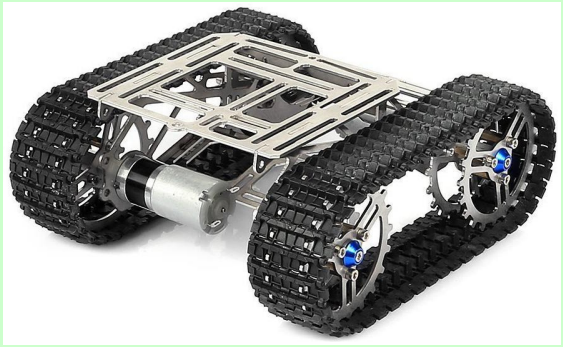
  https://youtu.be/uQ8N0AdRxrg

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

- wheels, legs, tracks, rotors – mobile robots

Actuators (muscles):

- electric motors, pneumatic and hydraulic systems



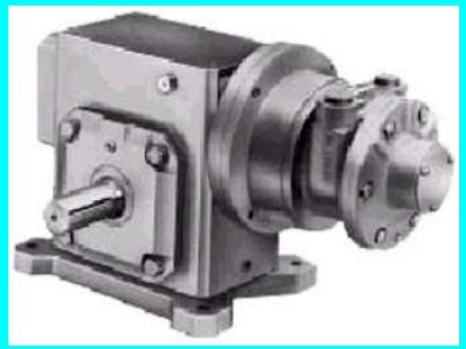
Actuators

Hydraulic Motor

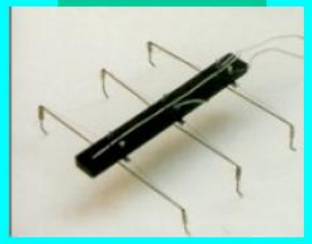
Pneumatic Cylinder

DC Motor

Stepper Motor



Pneumatic Motor



Muscle Wire

Servo Motor

Muscle wire: https://www.youtube.com/watch?v=wKoc7-APFsk

Videos

Hydraulic system

- https://www.youtube.com/watch?v=M1UddxRAjbc

Pneumatic system

- https://www.youtube.com/watch?v=moIG5pFxzfY

Interface Hardware

Interface units: Hardware to interface digital controller with the external world (sensors and actuators)

Analog to Digital Converter

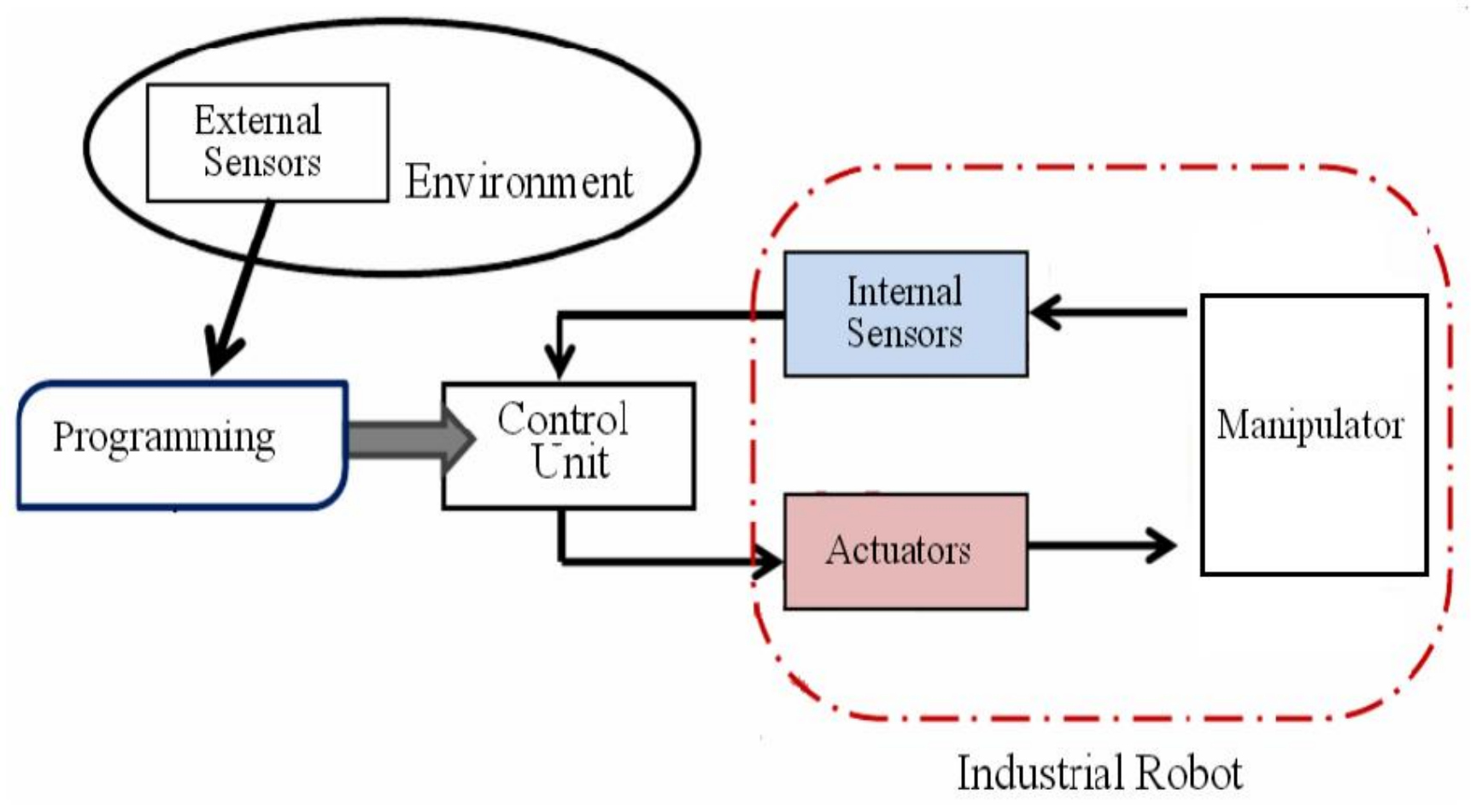
Operational Amplifiers

LM358

LM358

LM1458 dual operational amplifier

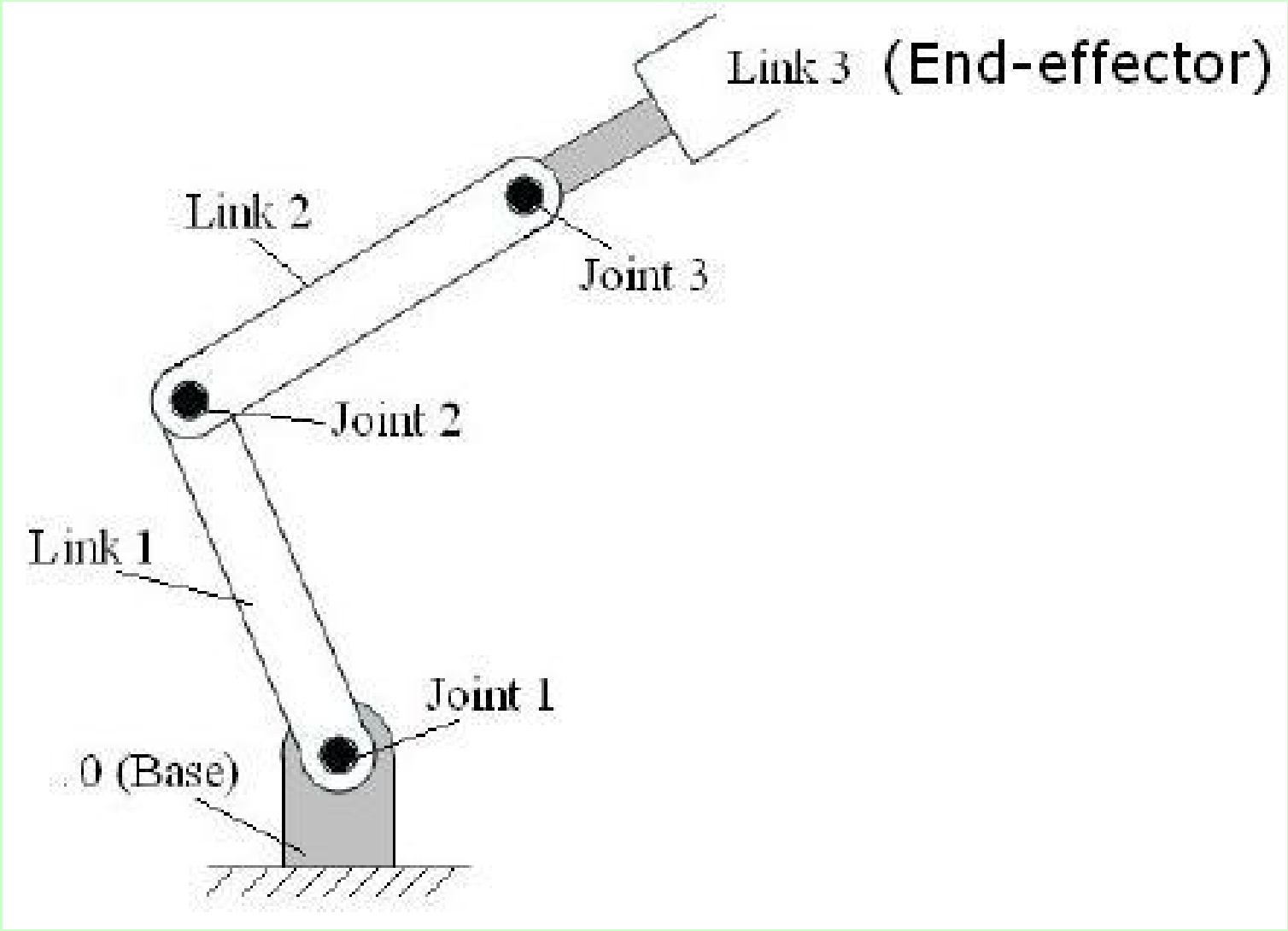
Block diagram of an industrial robotic system



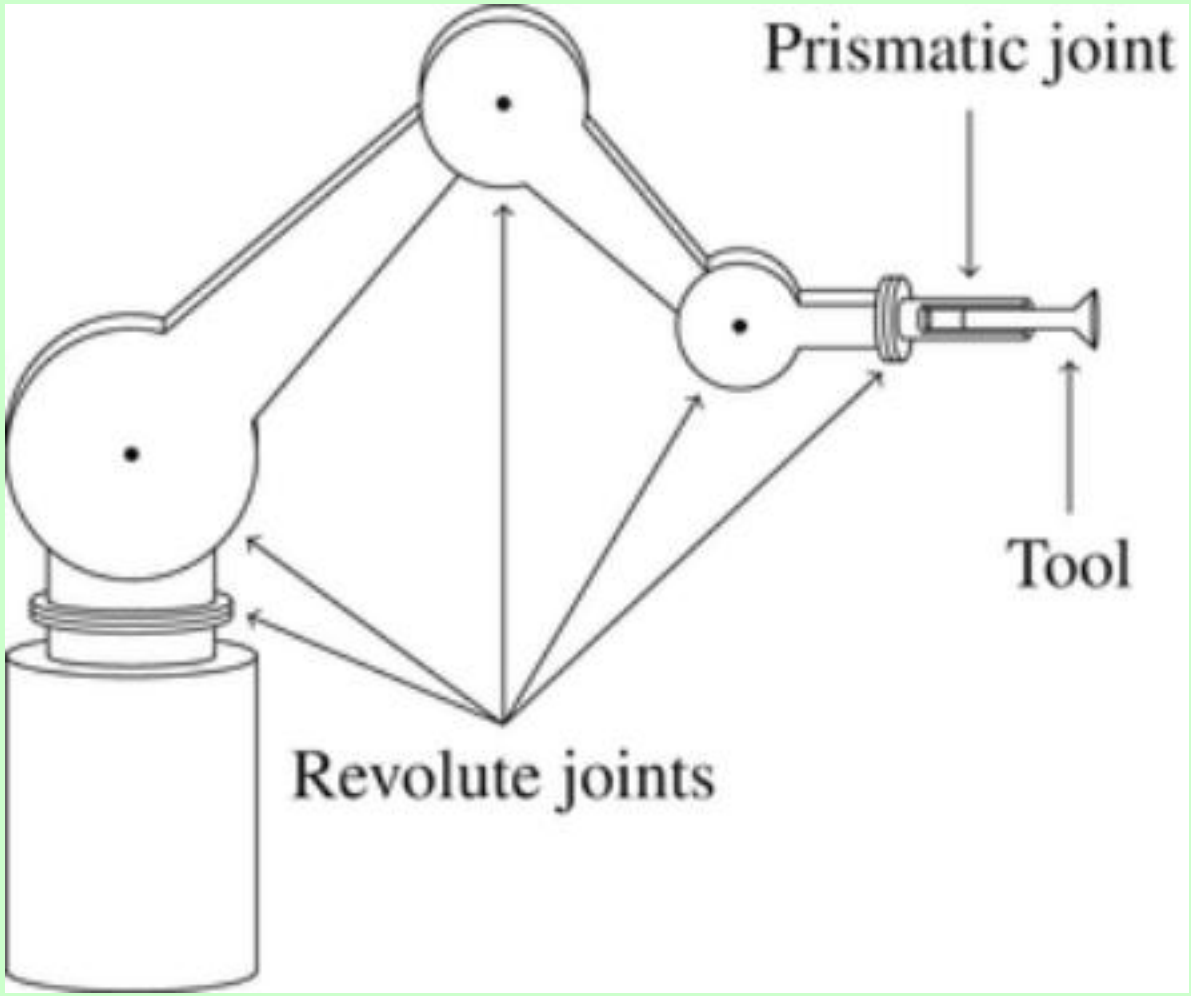
Block diagram of an industrial robotic system

- **Manipulator** = such as robotic arm allows robot to perform work
- **Actuator** = provide power to the manipulator
- **Internal sensor** = to collect and give the robot control unit information about the internal state of the robot
- **External sensor** = to collect and give the robot control unit information about its surroundings.
- **Control unit** = provides the intelligence to make the manipulator perform in a certain manner
- **Programming** = program the robot to perform specific tasks.

Robot Manipulator



Robot Manipulator



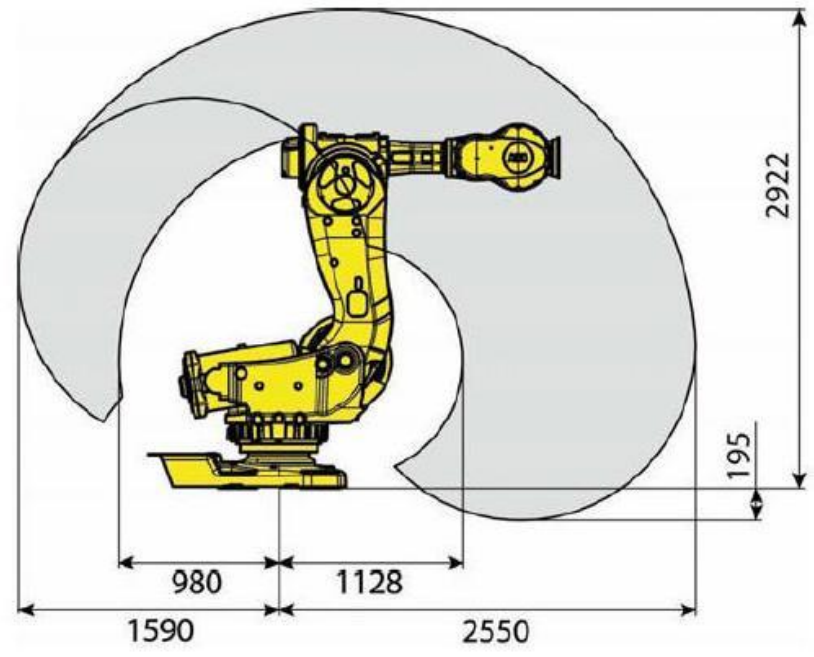
Major types of manipulators

Type 1: Cartesian (PPP)

https://www.youtube.com/watch?v=LUKKcHaBimc&ab_channel=JanomeIndustrialEquipment%E3%80%90Corporate%E3%80%91

Major types of manipulators

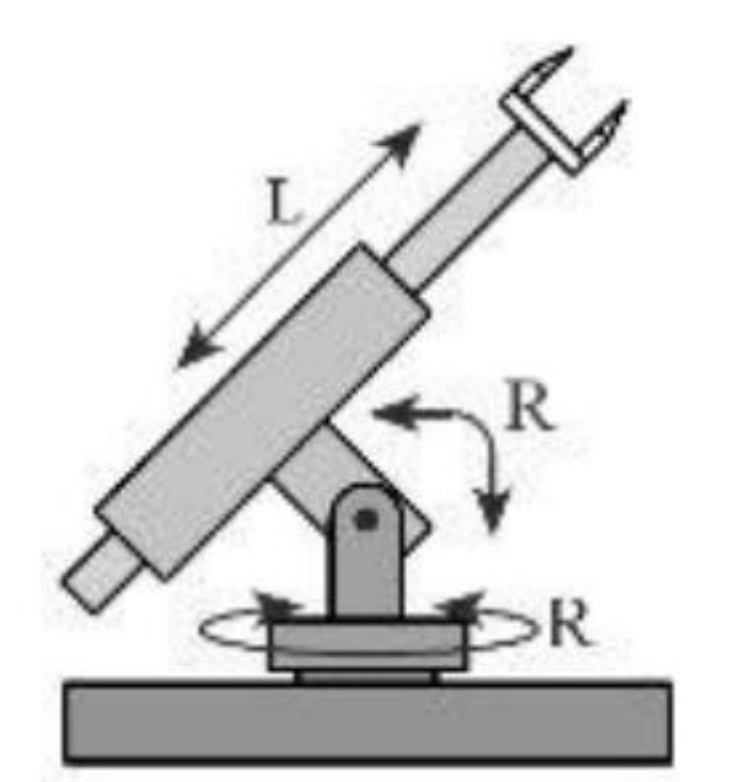
Type 2: Articulate (RRR)

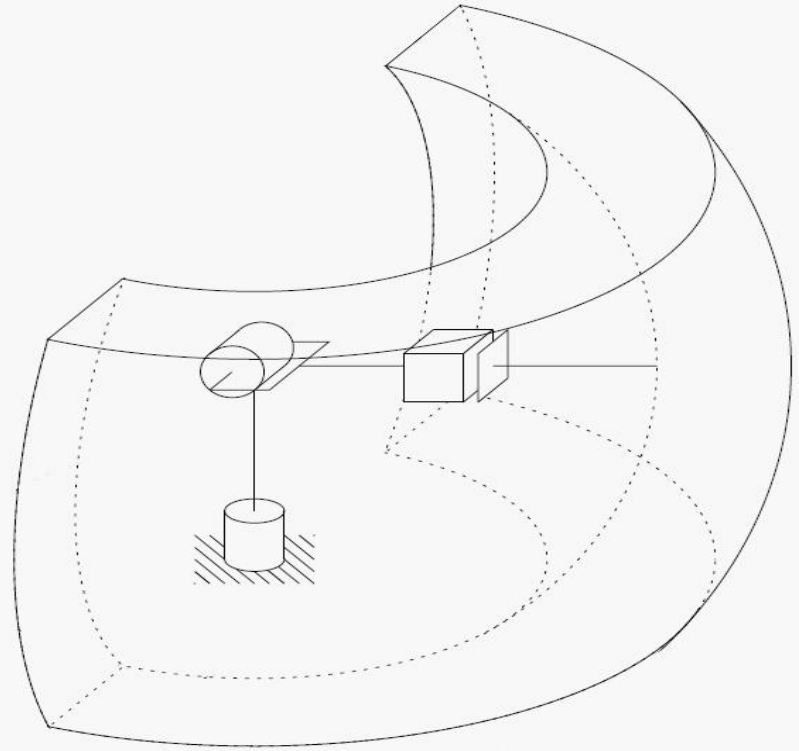


https://www.youtube.com/watch?v=HgDEqlhjhrE&ab_channel=DeltaIndustrialAutomation%E5%8F%B0%E9%81%94%E5%B7%A5%E6%A5%AD%E8%87%AA%E5%8B%95%E5%8C%96

Major types of manipulators

Type 3: Spherical (RRP)

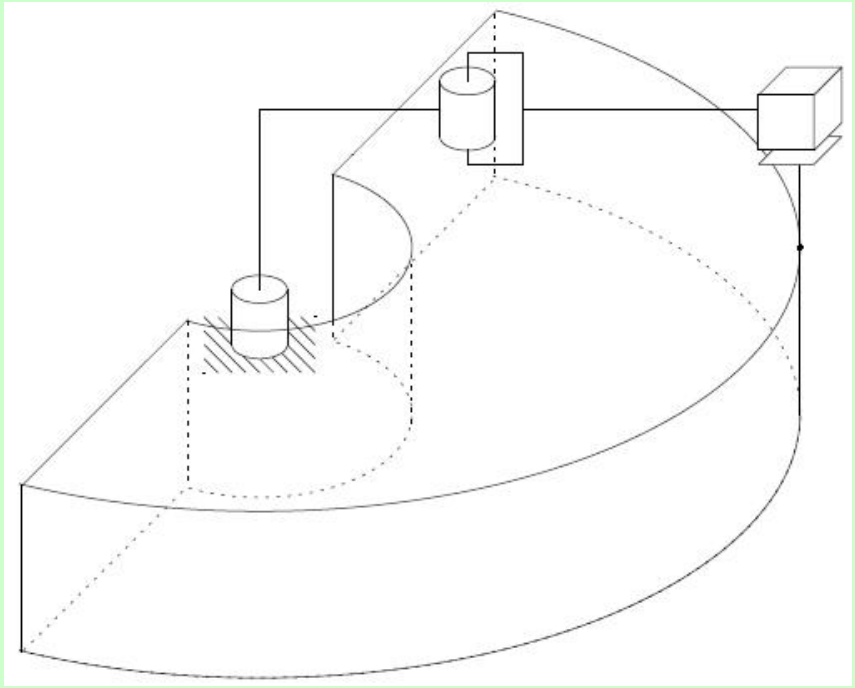




https://youtu.be/jBQFRG3-jbQ

Major types of manipulators

Type 4: SCARA (RRP)



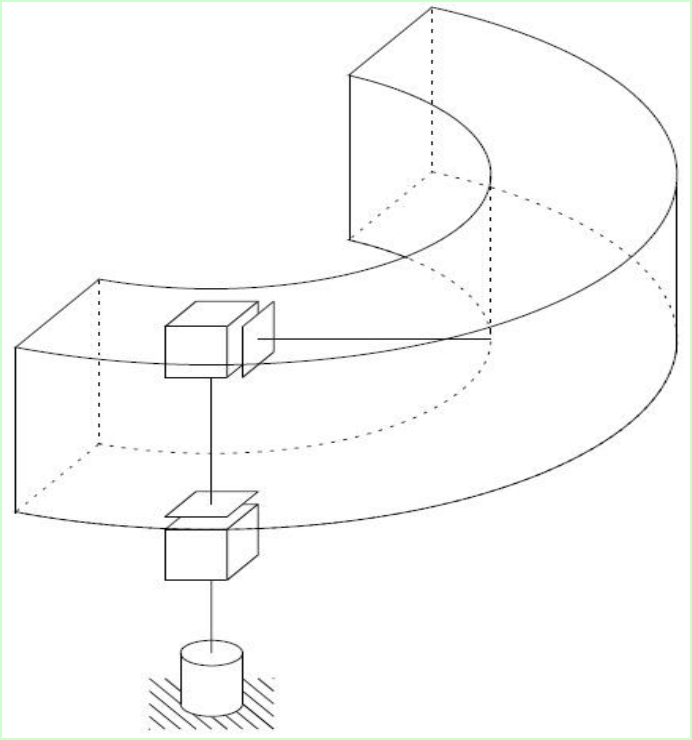
Selective Compliance Assembly Robot Arm

https://youtu.be/-m1oKuFkSTE

Major types of manipulators

Type 5: Cylindrical (RPP)

https://youtu.be/aRGKC3QEIQo



References

Major types of robotic manipulators:
https://www.youtube.com/watch?v=CHOmowqyTI0

Most advanced robots in the world:
https://www.youtube.com/watch?v=Jky9I1ihAkg
https://youtu.be/zhVDk8Y55pA

5 Most Advanced Humanoid Robots:
https://www.youtube.com/watch?v=9DaTZQxg21U&ab_channel=TechVision

5 Most Beautiful Robots In The World
https://www.youtube.com/watch?v=vvHWYsIydAQ

Fastest robots in the world
https://www.youtube.com/watch?v=RSv2v0EXRL8&t=53s&ab_channel=RavanaTech

Quiz

11. Which of the following terms is not one of the basic parts of a robot?

    a. peripheral tools b. end effector

    c. controller d. drive

12. The number of moveable joints in the base, the arm, and the end effectors of the robot determines

    a. operational limts

    b. workspace

    c. degrees of freedom

    d. flexibility

13. Which of the basic parts of a robot unit would include the computer circuitry that could be programmed to determin what the robot would do?

    a. sensor b. controller

    c. arm d. end effector

Quiz

14. For a robot unit to be considered a functional industrial robot, typically how many degrees of freedom would the robot have?
    a. three b. four
    c. six d. eight

15. Which engineering field would specialize in an understanding of robotic control systems?
    a. Electrical Engineering b. Mechanical Engineering
    c. Industrial Engineering d. Civil Engineering

16. Which engineering field would specialize in an understanding of robotic motion?
    a. Electrical Engineering b .Mechanical Engineering
    c. Industrial Engineering d. Civil Engineering

Quiz

17. Which of the name for information sent from robot sensors to robot controllers?

    a. electromagnetic wave b. pressure

    c. signal d. feedback

18. _____ is correct for proximity sensors?

    a. Inductive type b. capacitive type

    c. ultrasonic wave type d. all of the mentioned

19. What is an autonomous robot?

20. Describe two characteristics of an intelligent robot

CAI3034N