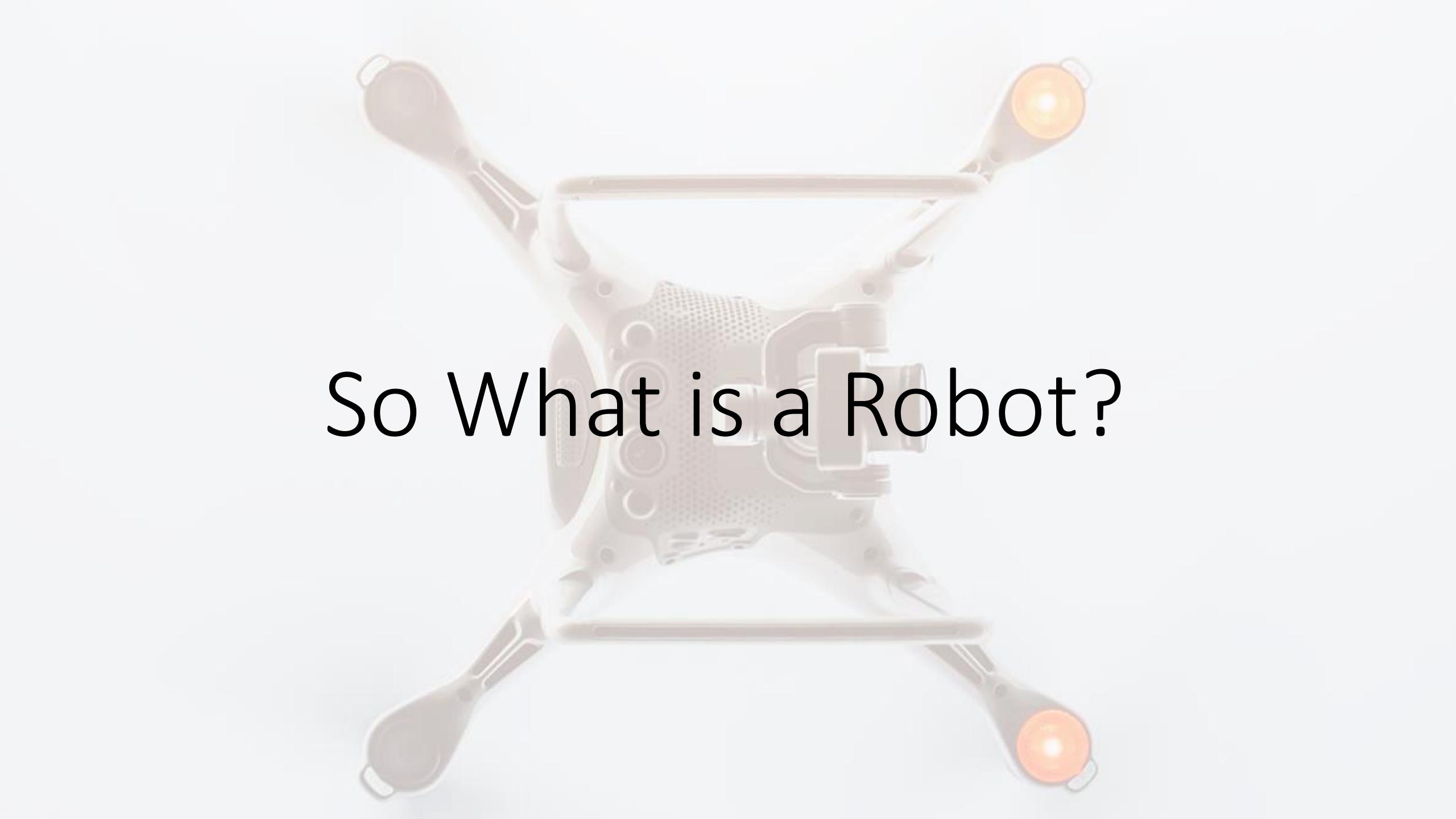


# Introduction to Robotics

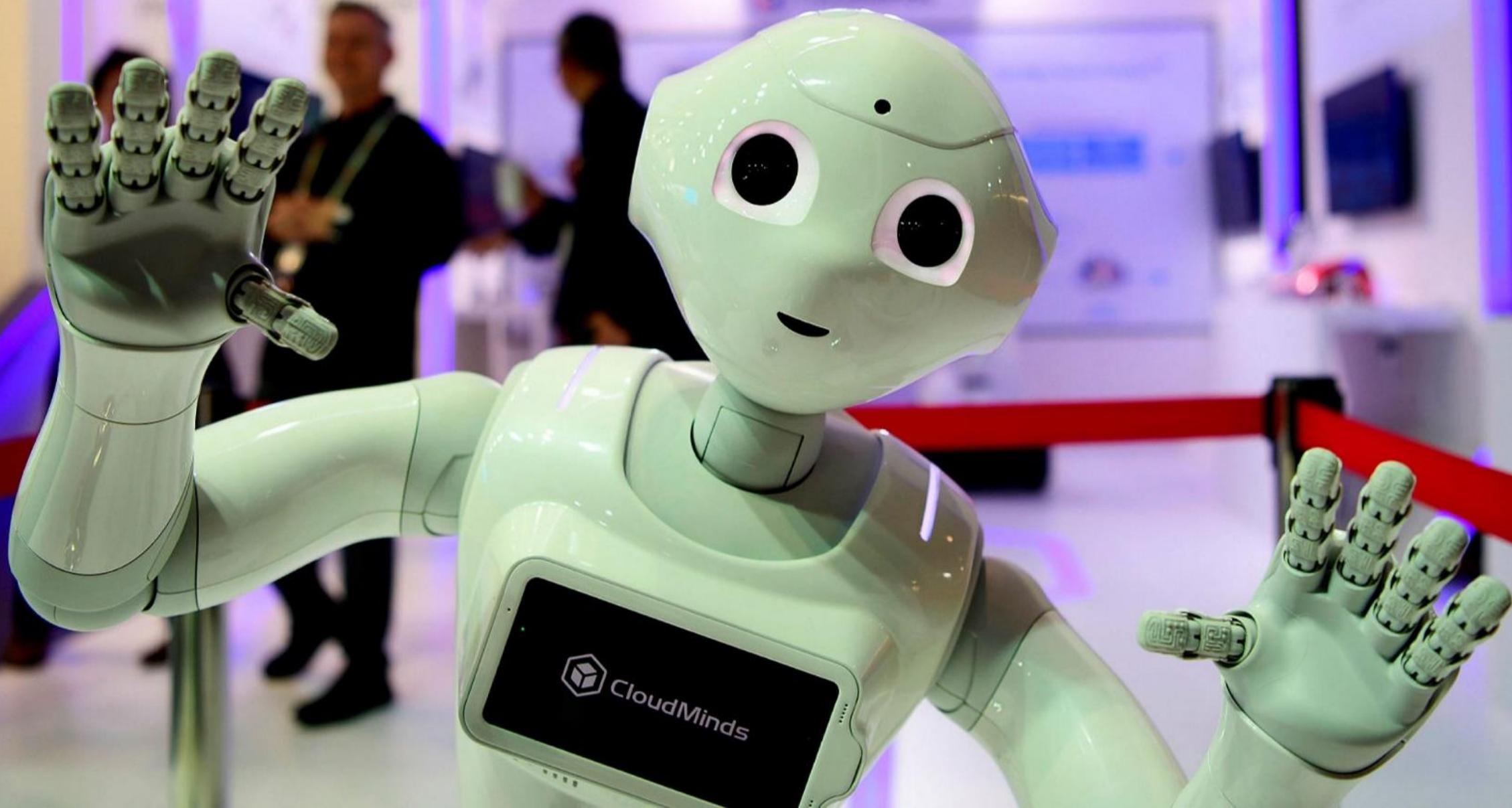




Overview



# So What is a Robot?







J.A.R.V.I.S





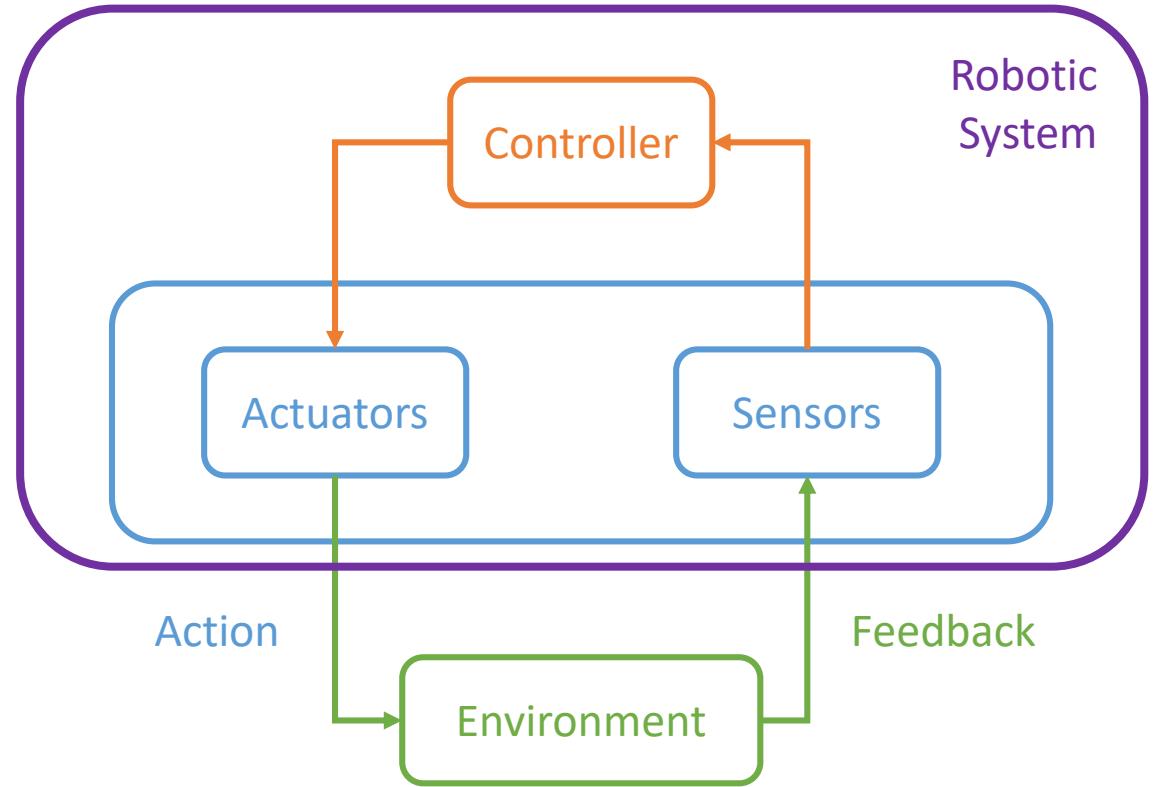
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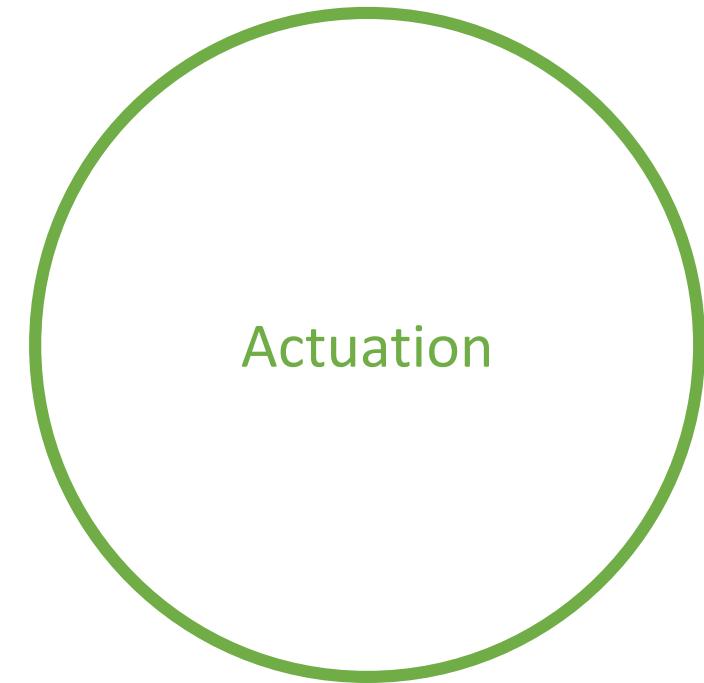
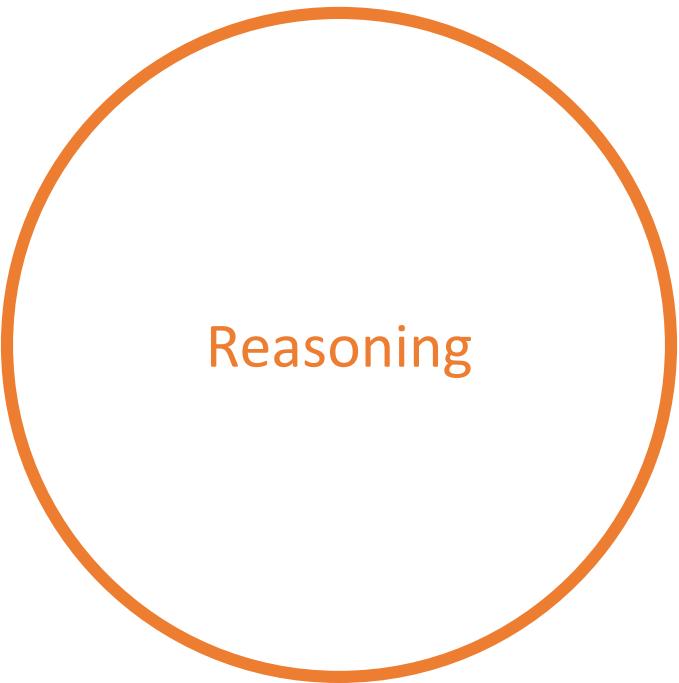
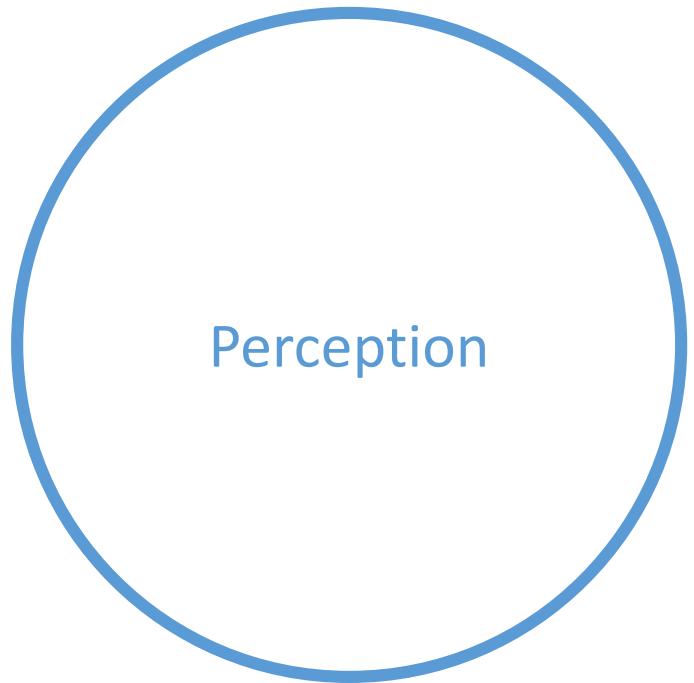
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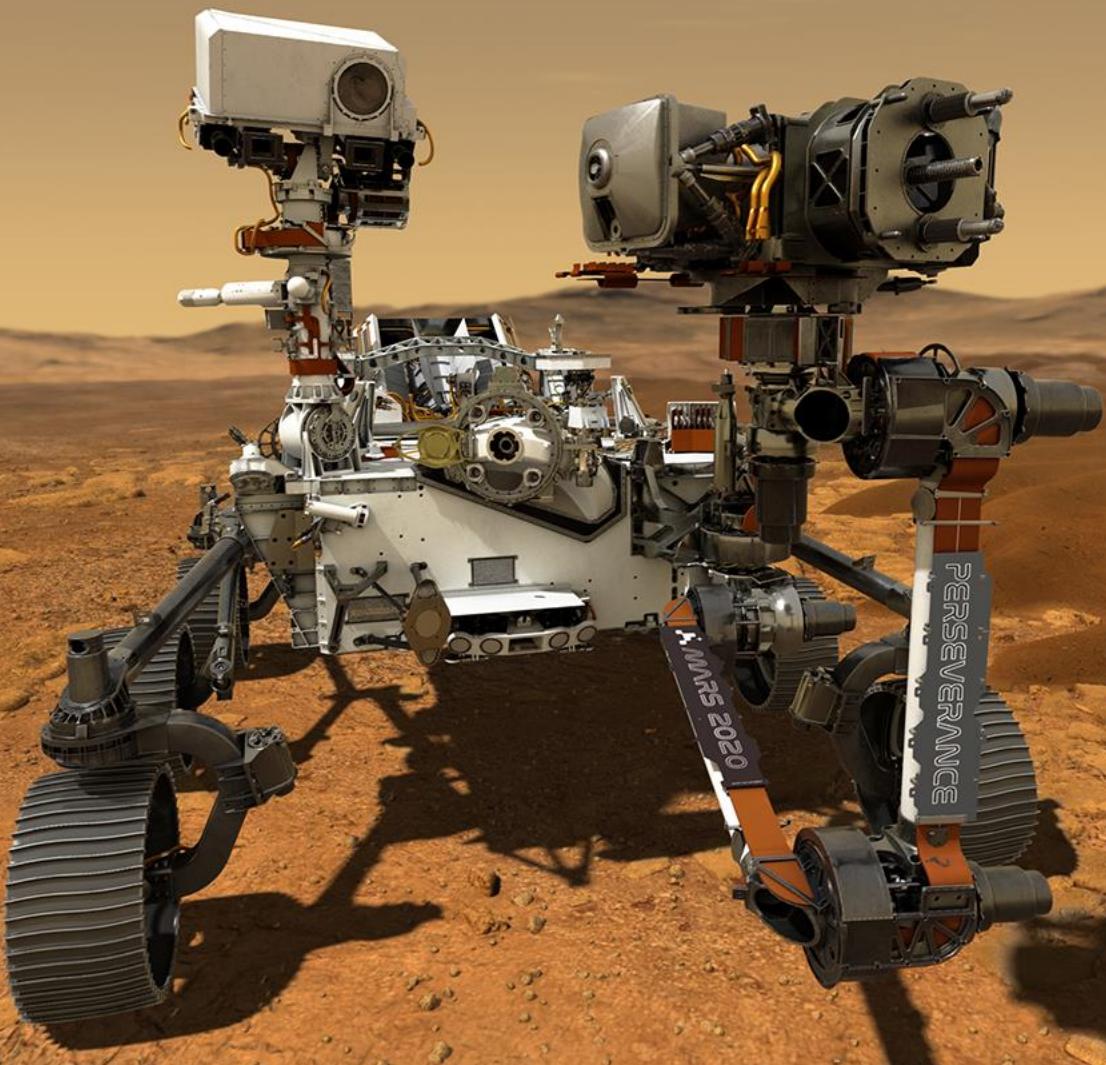
07

# Robotics: The Essential Components

- Perception
  - The robot senses the environment
- Planning/Reasoning
  - It uses prior knowledge to reason in a rational manner
- Actuation
  - Ability to move objects or itself in the Environment







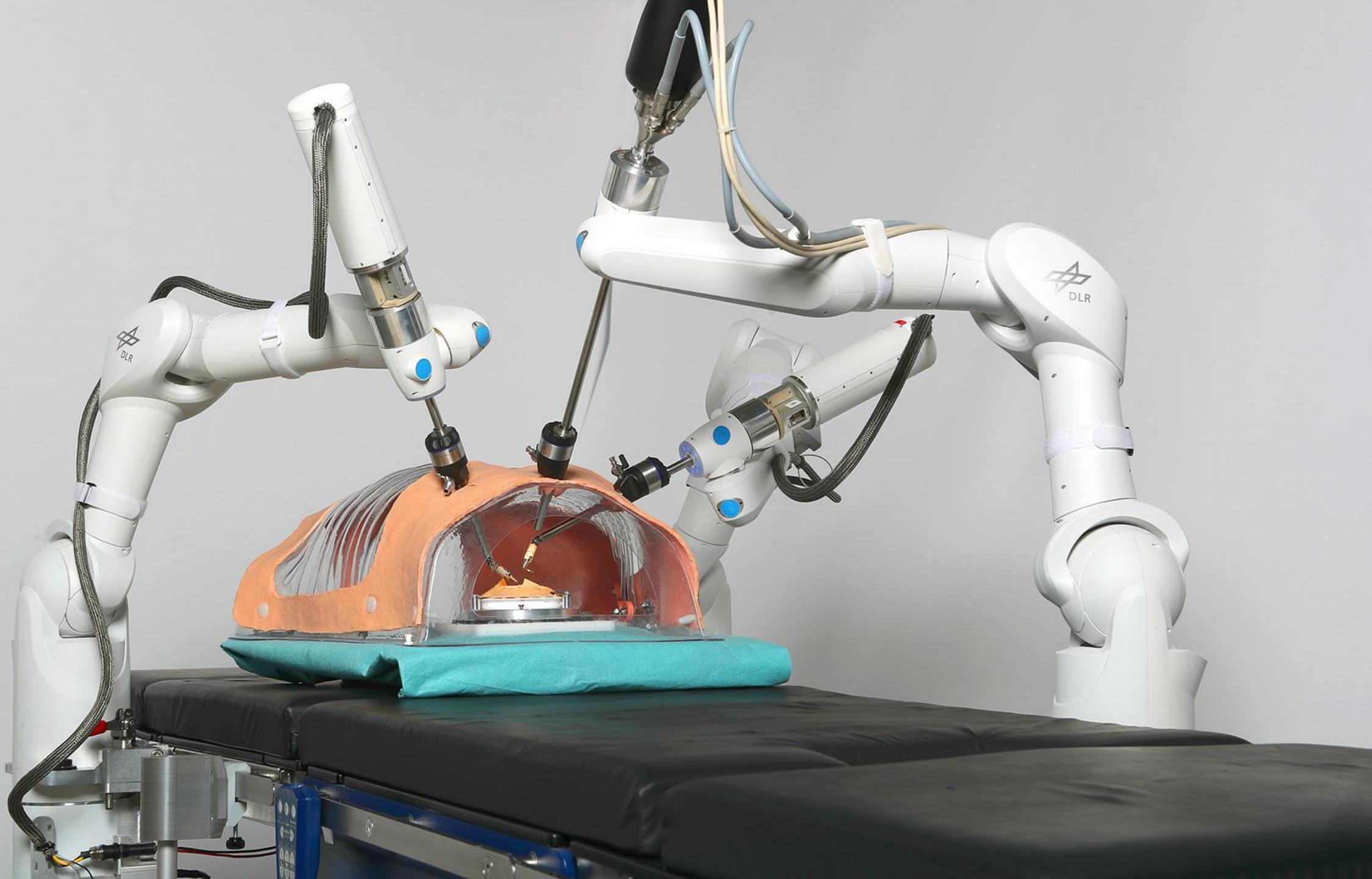










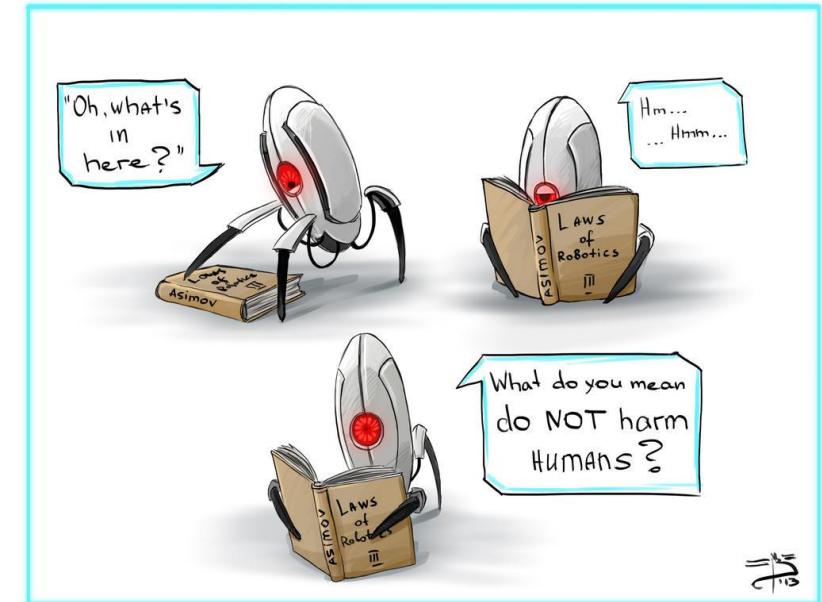


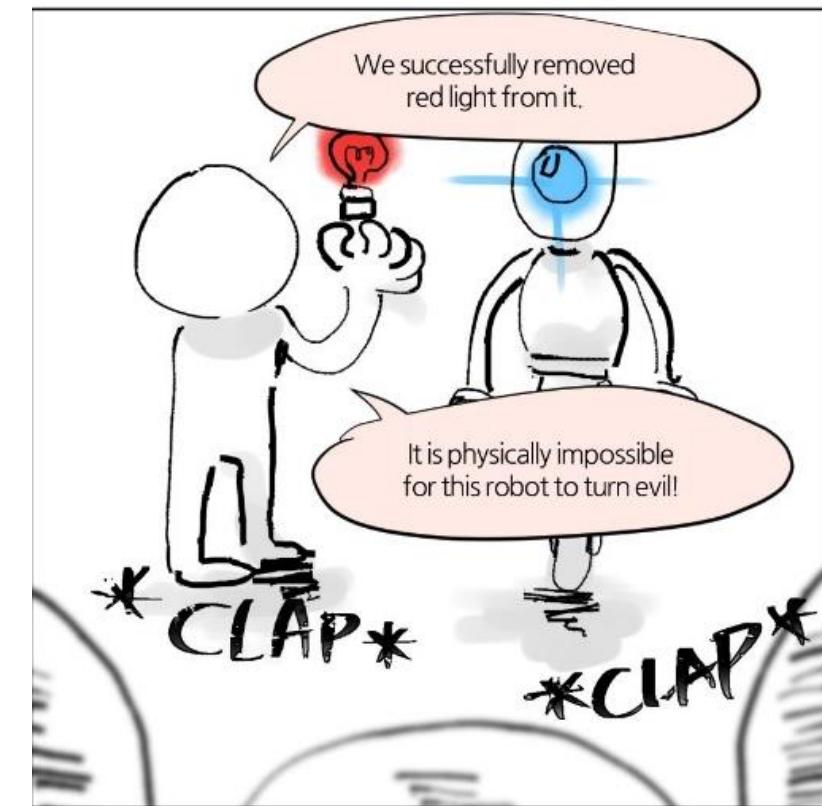
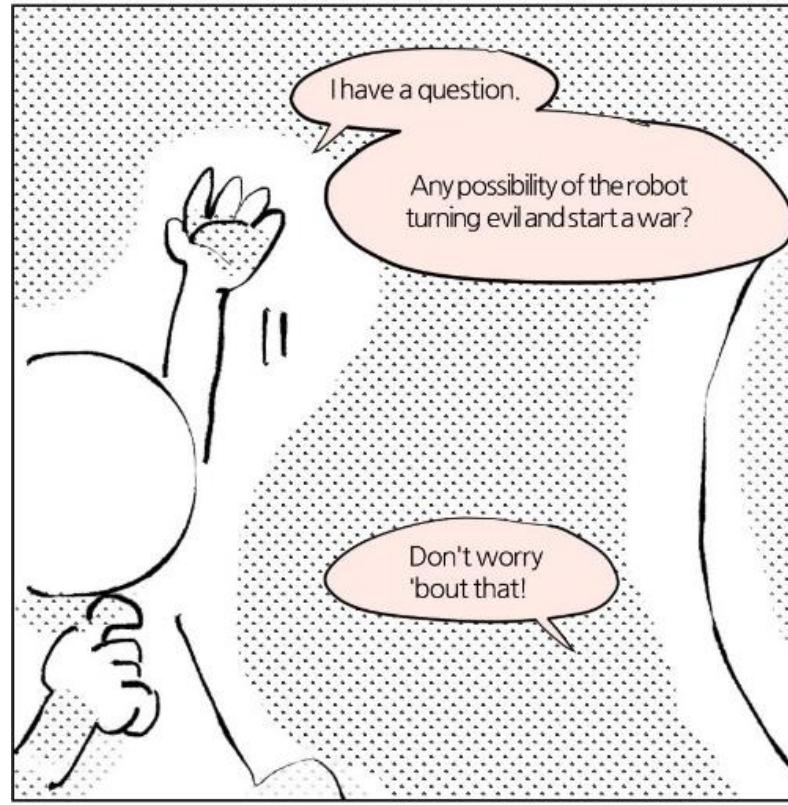
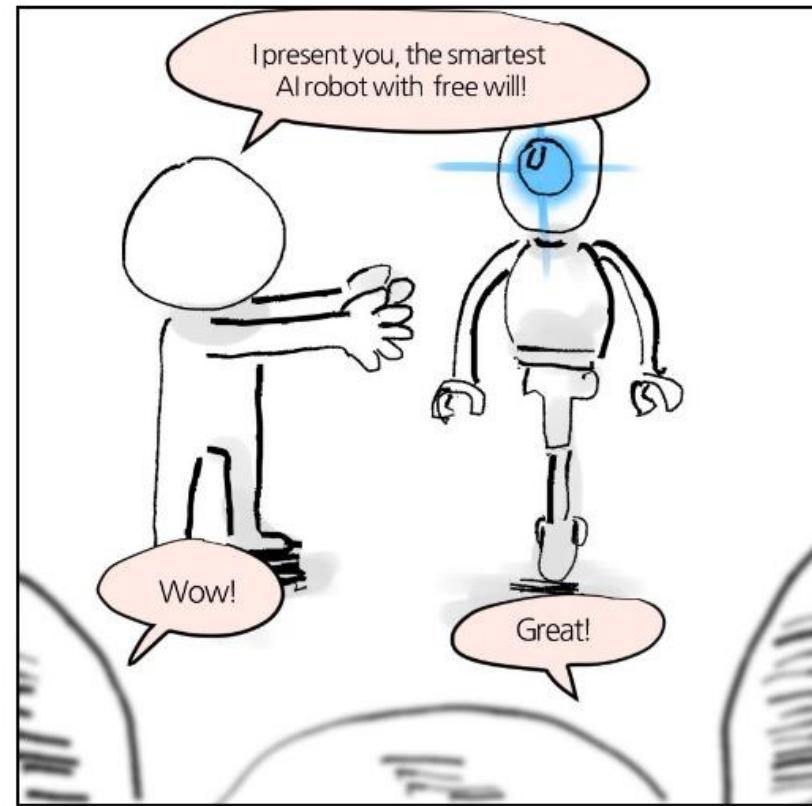


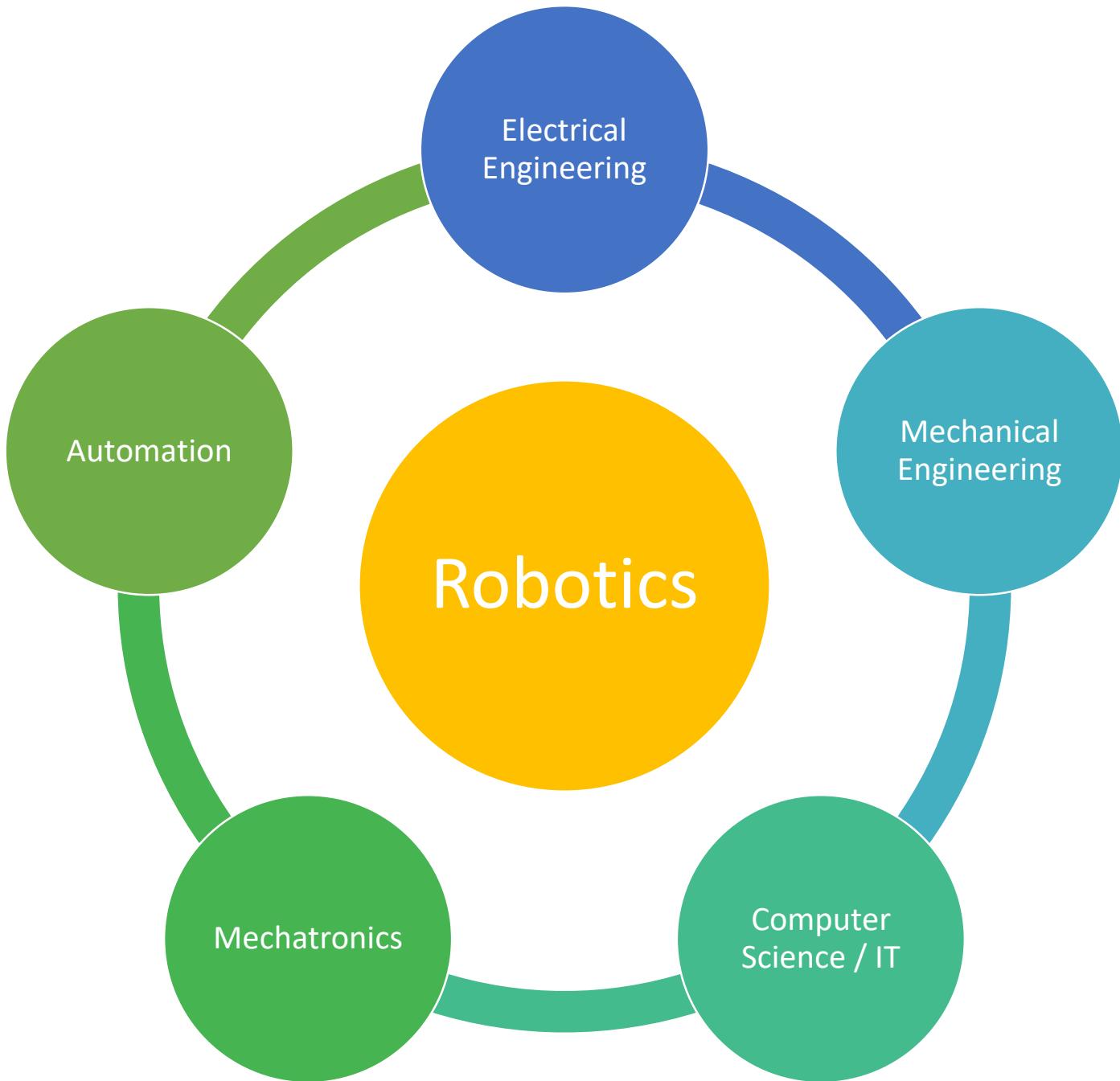


# Asimov's Three Laws of Robotics

- ❖ **Zeroth Law:** A robot may not harm humanity, or, by inaction, allow humanity to come to harm.
- ❖ **First Law:** A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- ❖ **Second Law:** A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- ❖ **Third Law:** A robot must protect its own existence as long as such protection does not conflict with the First or Second Law









# Sensors

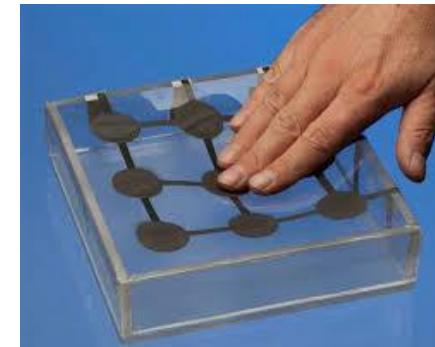
- A device that detects events or changes in environment and sends the information to other electronic components such as computer processors.
- It provides usable output in response to a specified measurand.
- The active element of a sensor is known as a transducer.



**Ultrasonic Sensor**



**Proximity Sensor**

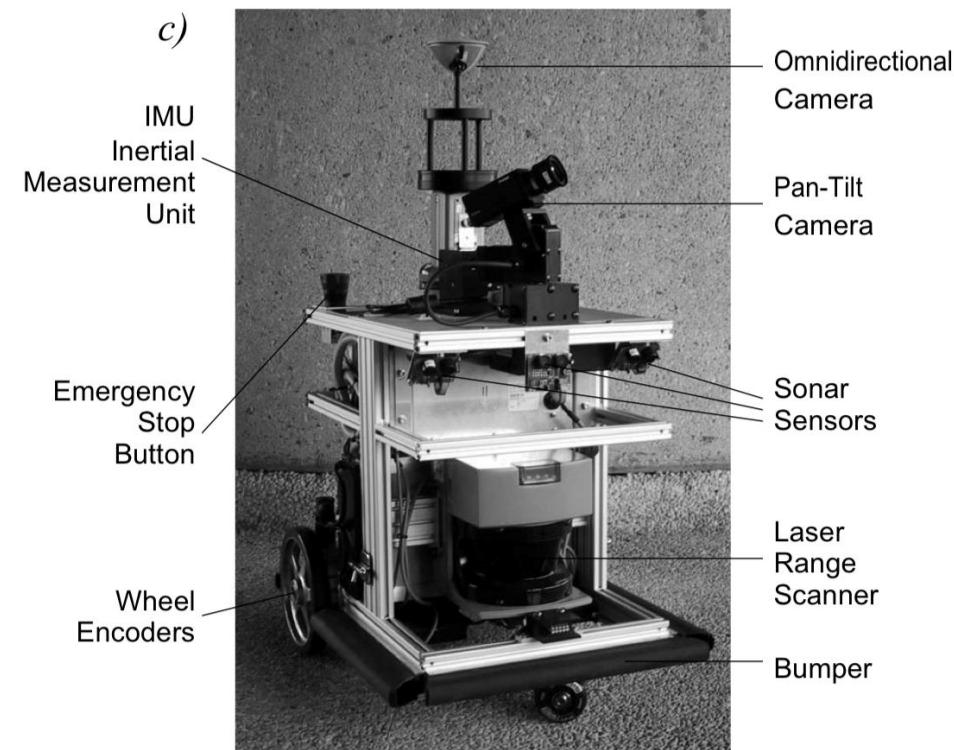
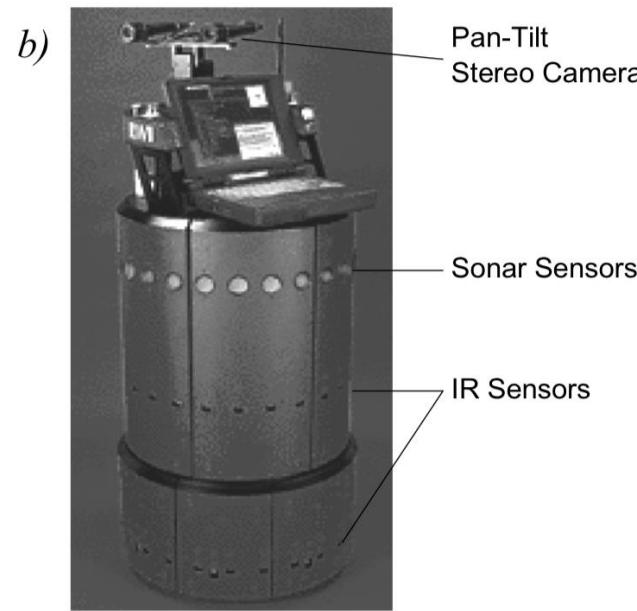
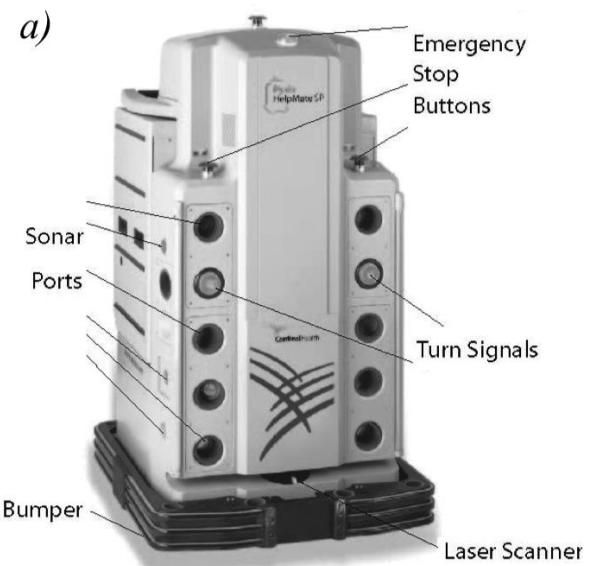


**Tactile Sensor**



What and How many  
Sensors does our phone  
have?



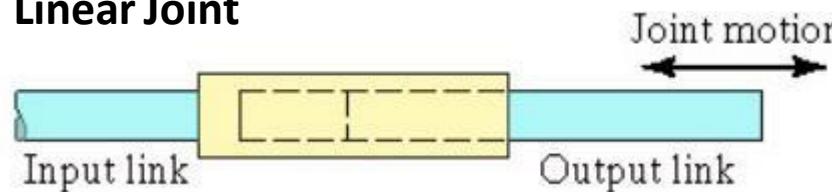


~~Overview~~  
~~Perception~~  
Hardware &  
Actuation

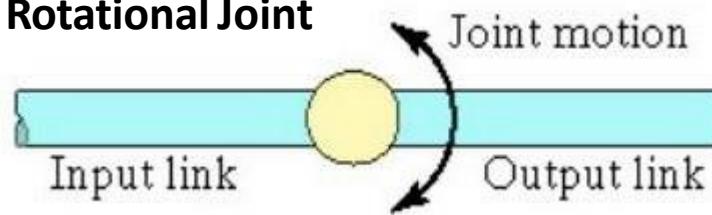


# Types of Joints

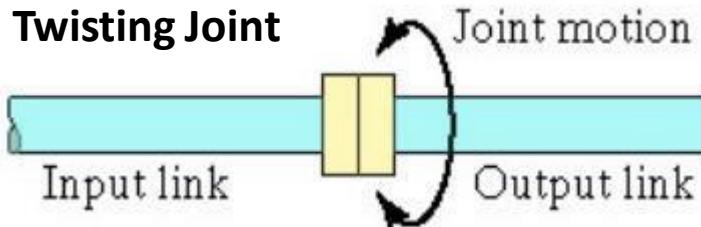
**Linear Joint**



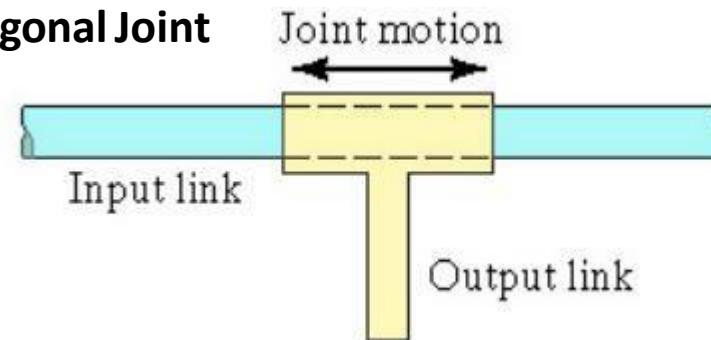
**Rotational Joint**



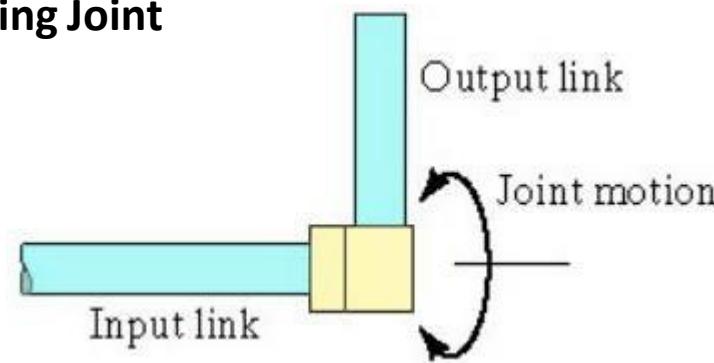
**Twisting Joint**



**Orthogonal Joint**



**Revolving Joint**



# Actuators

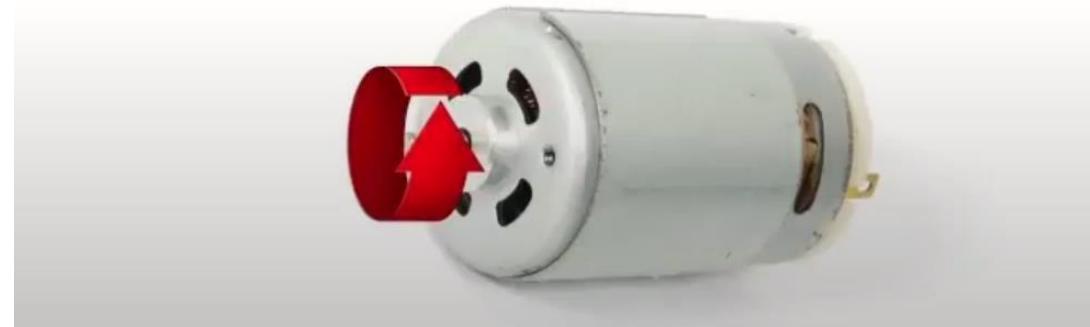
These are the components of a robot that actually cause the robot's joints to move.

## Two Types Based on Motion:

- Linear
- Rotary



Linear Actuator



Rotary Actuator

# Actuators

## Basic Types

- Hydraulic
- Pneumatic
- Electric

### Hydraulic actuators

Used in heavy machineries.  
They generate very high forces.



Hydraulic Actuator

# Actuators

## Pneumatic actuators

Uses compressed air that acts on a piston that is present inside a cylinder to move a load along a linear path.

- They are safer compared to hydraulic actuators by the fact that they reduce the risk of fire.
- Lesser maintenance required.
- Uses air that is abundantly available and therefore reduce cost and is more efficient.



**Pneumatic Actuator**

# Actuators

## Electric Actuators

- They create a movement of load by generating a force by means of electric current interacting with magnetic fields.



**DC Motor**



**AC Motor**



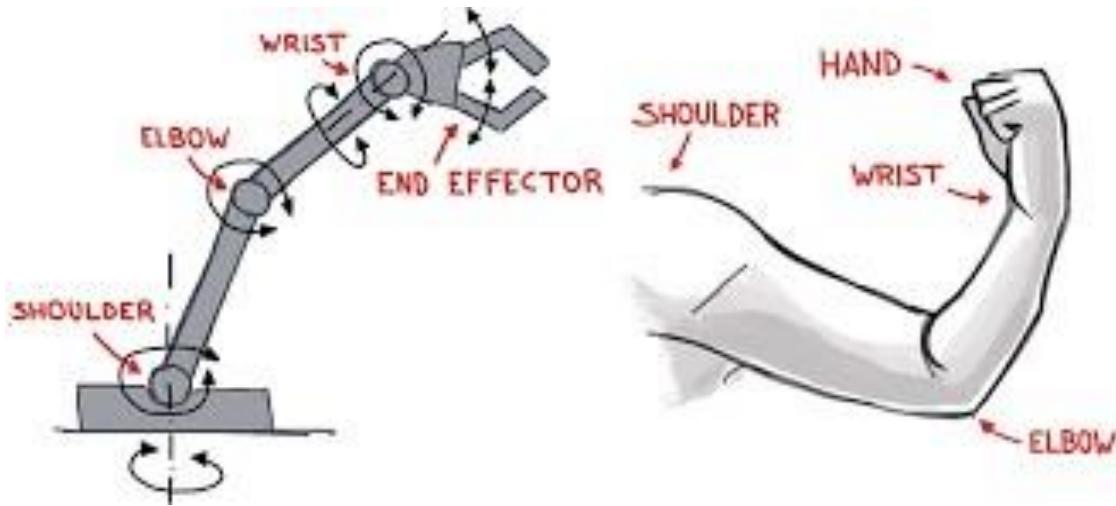
**Servo Motor**



**Stepper Motor**

# Robotic Arms

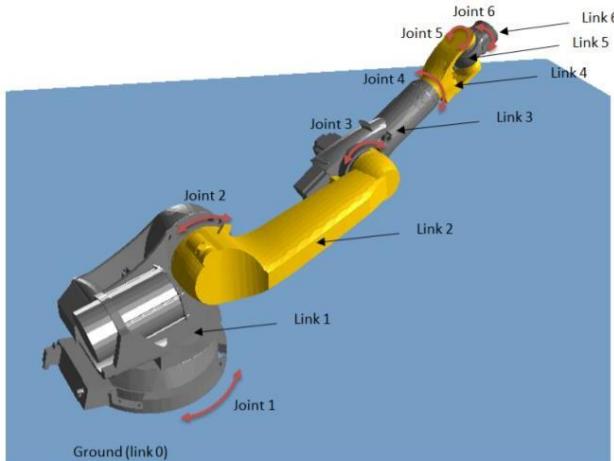
Some more parts of a robot (robotic arm)



Various Components of a Robotic Arm

# Robotic Arms

- **Manipulator**
  - The device or part of the robot that manipulates objects in environment without direct physical contact by the operator.
  - Made up of **links** and **joints**.
- **End Effector**
  - A specific device attached to the robot's manipulator that interacts directly with the object.



**Manipulator**



**End Effectors**

# Robotic Arms

## Types of End-Effectors

- **Grippers**

- It allows to pick up, manipulate and drop objects.
- Suitable for applications like pick and place, assembly, machine tending.



**Gripper**



**Process Tools**

- **Process Tools**

- Grippers can grasp the workpiece. But process tools can change the workpiece.
- Similar to a worker operating a power tool.
- Suitable for applications like welding, spray painting, 3D printing etc.

- **Sensors**

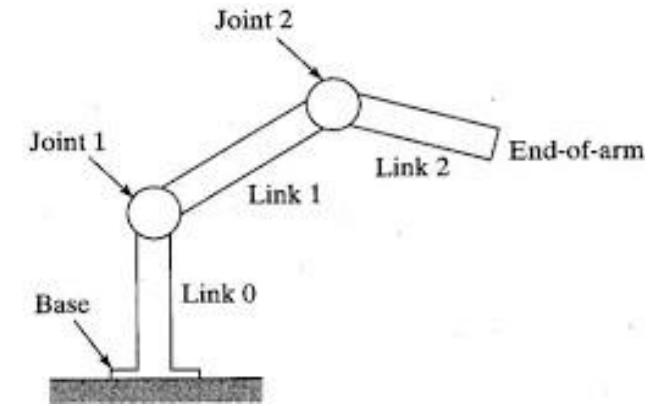
- Sensors can also be used as end effectors.
- Suitable mainly for inspection applications.
- Ultrasonic, laser scanners, 2D and 3D cameras, infrared sensors etc.



**Sensor**

# Robotic Arms

- **Links**
  - Rigid members that connect the joints.
- **Joints**
  - Movable components of the robot that cause the links attached to them to have a relative motion between the links.

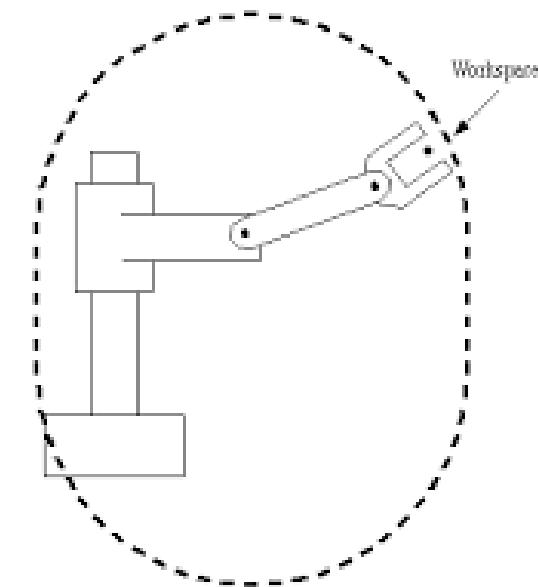


**Illustration of Links and Joints**

# Some More Basic Terms

## Degrees of Freedom (DOF)

- The minimum number of axes that are required to achieve any desirable position and orientation in the workspace or work envelope of the robot.
- **Reachable vs Dexterous Workspace**



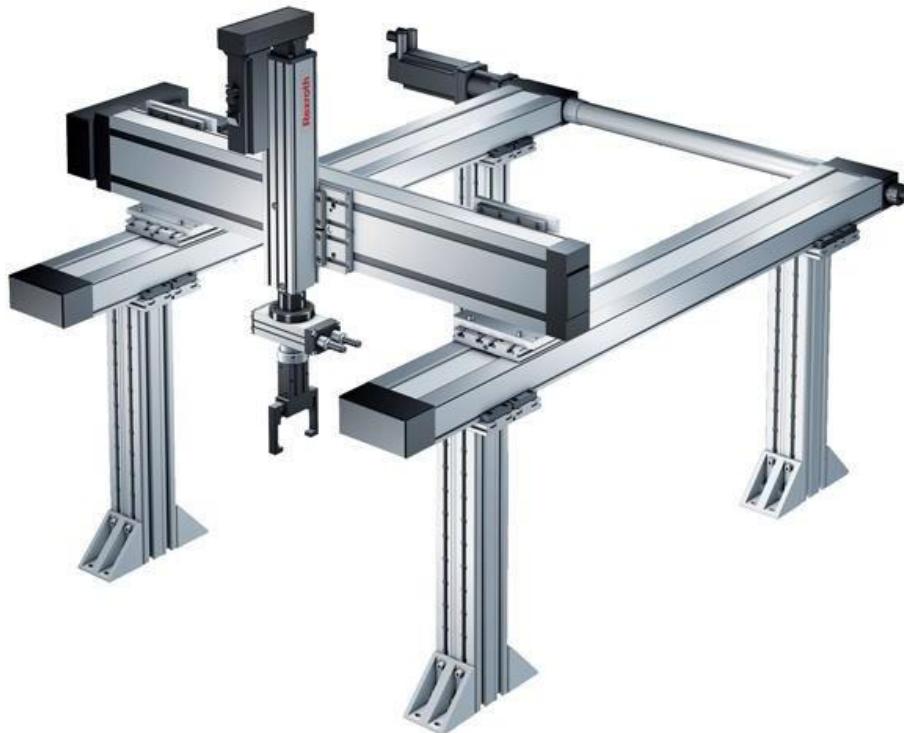
**Illustration of Robot's Workspace**

# Robot Configurations

## Robot Description

- The three joints are linear in nature.

Guess the workspace



Robot Image

# Robot Configurations

## Cartesian/ Rectangular Robot

- The three joints are linear in nature.

## Guess the workspace

- Cuboidal workspace

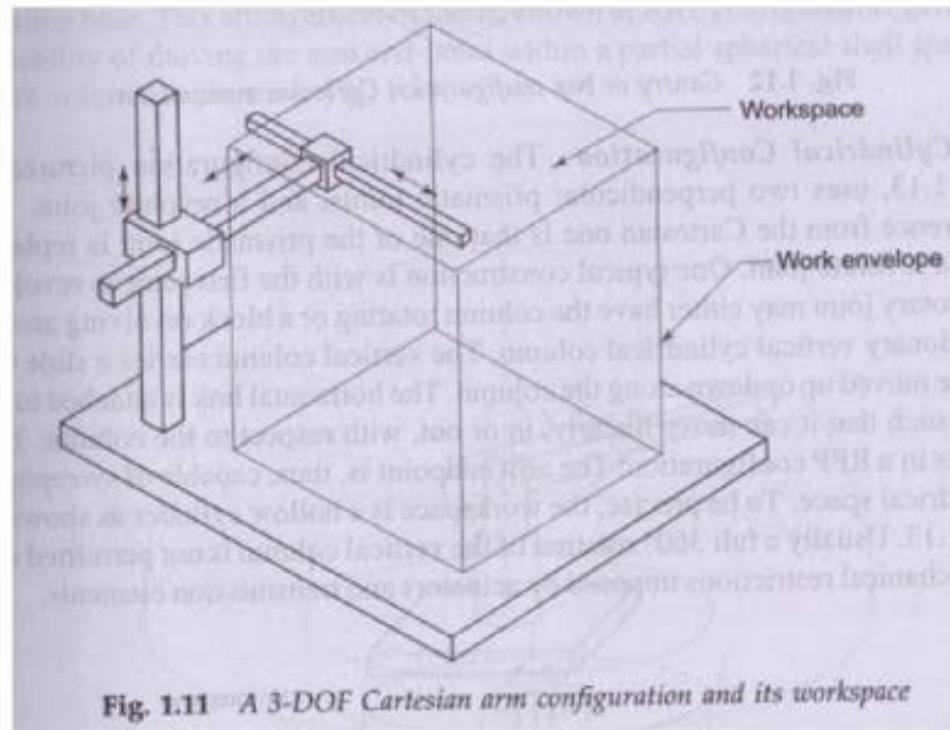


Fig. 1.11 A 3-DOF Cartesian arm configuration and its workspace

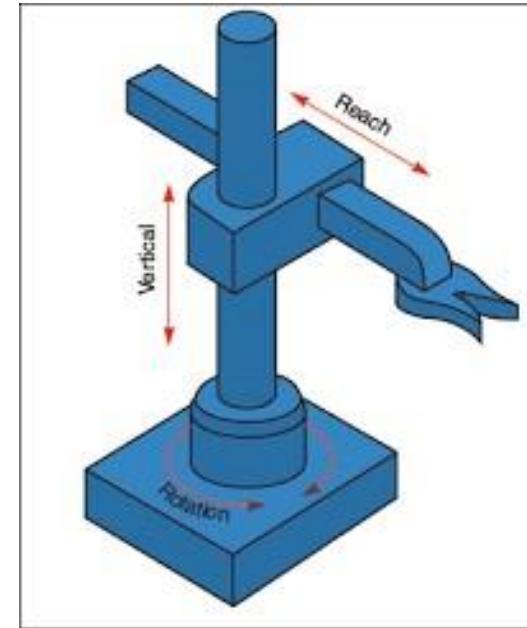
## Cartesian Robot

# Robot Configurations

## Robot Description

- Two linear joints and one revolute joint.

**Guess the workspace**



**Robot Image**

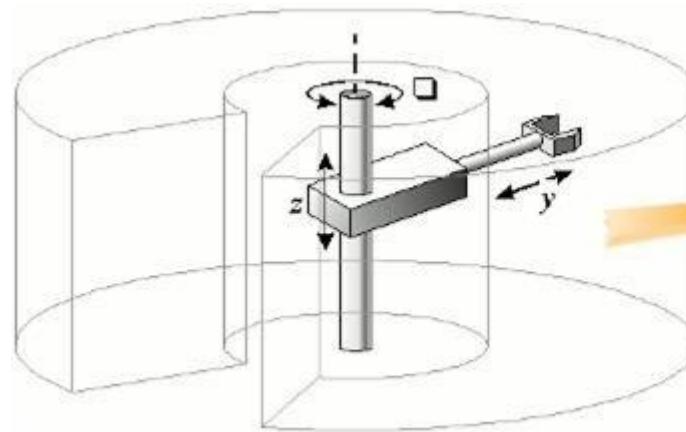
# Robot Configurations

## Cylindrical Robot

- Two linear joints and one revolute joint.

## Guess the workspace

- Cylindrical Workspace



Cylindrical work envelope.

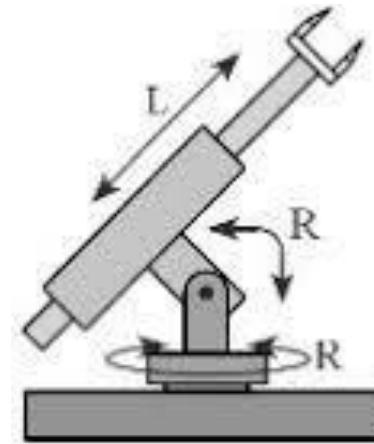
**Cylindrical Robot**

# Robot Configurations

## Robot Description

- Two revolute joints and one linear joint.

Guess the workspace



Robot Image

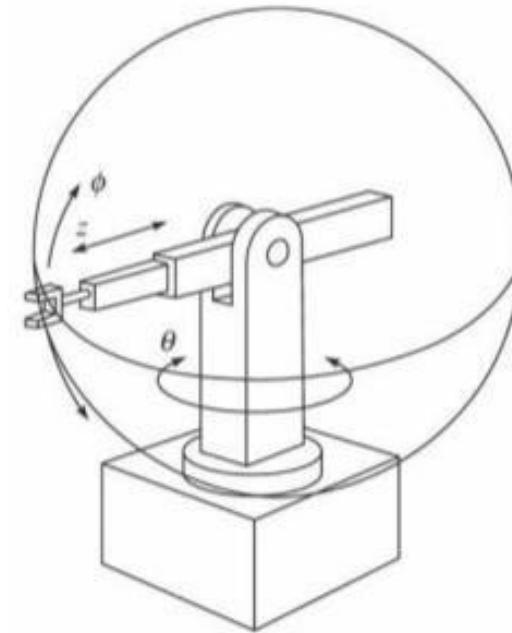
# Robot Configurations

## Spherical Robot

- Two revolute joints and one linear joint.

## Guess the workspace

- Spherical Workspace



**Spherical Robot**

# Robot Configurations

## Parallel Robots

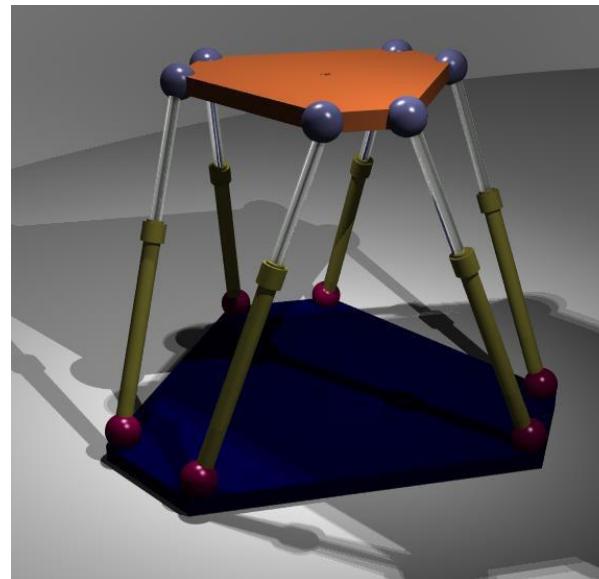
They consist of a fixed base and a moving platform, both of which are connected by a number of legs.

### Used in

- Flight simulators
- 3D printers
- Some pick and place robots

### Benefits

- High accuracy
- More stability



Parallel Manipulator



Parallel Robot

# Mobile Robotics

- Consists of a mobile platform that can freely move and so can have limitless operational area.
- These platforms themselves cannot manipulate objects.
- Typically used for applications such as cleaning, surveillance, monitoring and analysis.
- Mechanisms for motion: wheels, legs, wings, even jets.
- Safety is important.

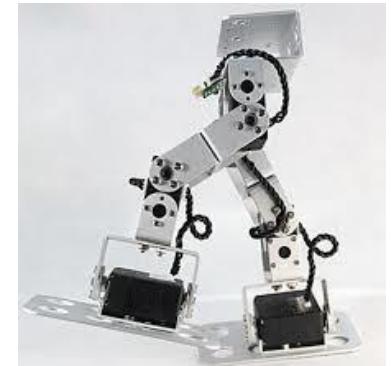
**Wheeled Mobile Robots**



**Drone**



**Biped Robot**

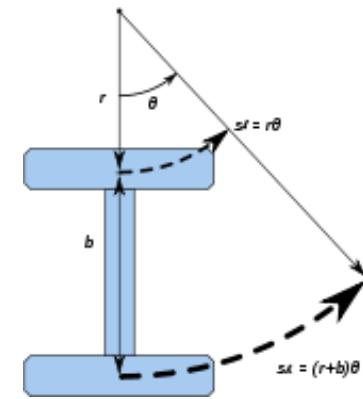


# Drive Concepts

## Differential Drive

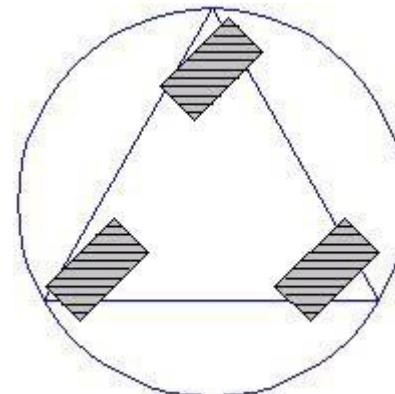
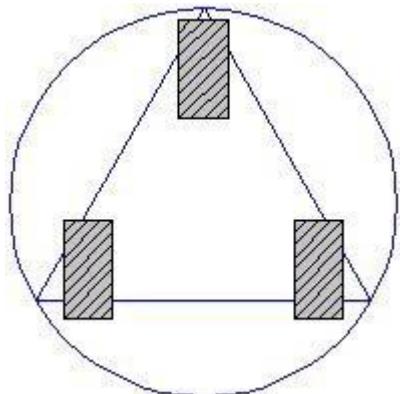
- Consists of two wheels which are powered.
- The third one is a free or passive wheel (castor).
- 2 Degrees of freedom.

Illustration of Differential Drive

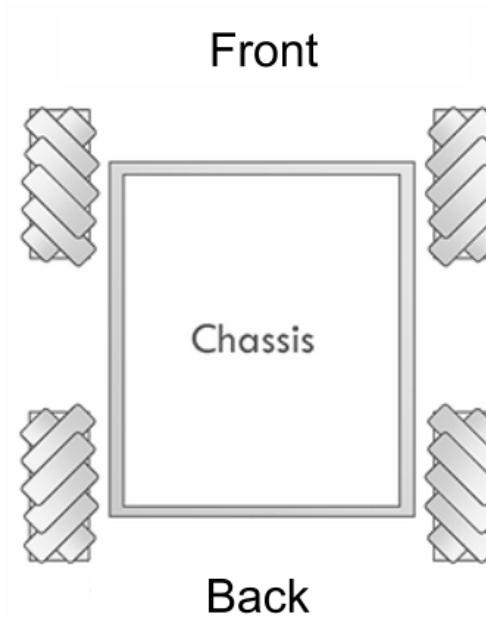


# Drive Concepts

**Omni Directional Drive**



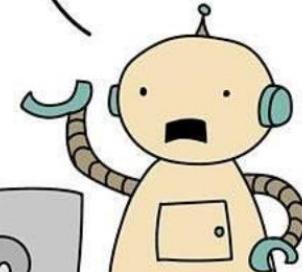
**Synchro Drive**



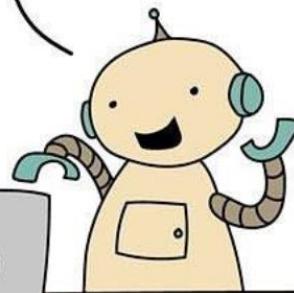
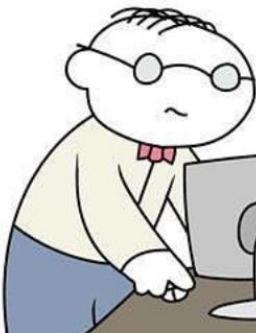
~~Overview~~  
~~Perception~~  
~~Hardware~~  
~~Actuation~~  
Reasoning



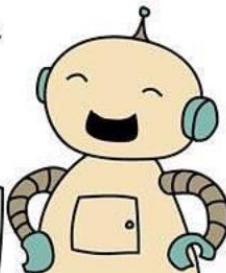
EXCUSE ME, COULD  
I GET AN ASSIST?



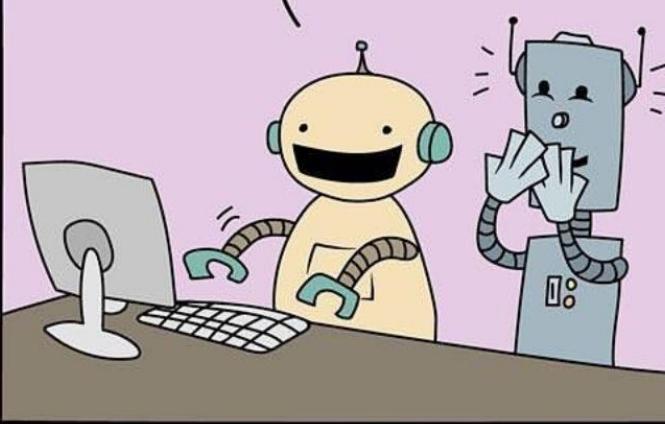
WOULD YOU MIND  
CLICKING ALL THE PHOTOS  
WITH BICYCLES?



THANKS, FRIEND.

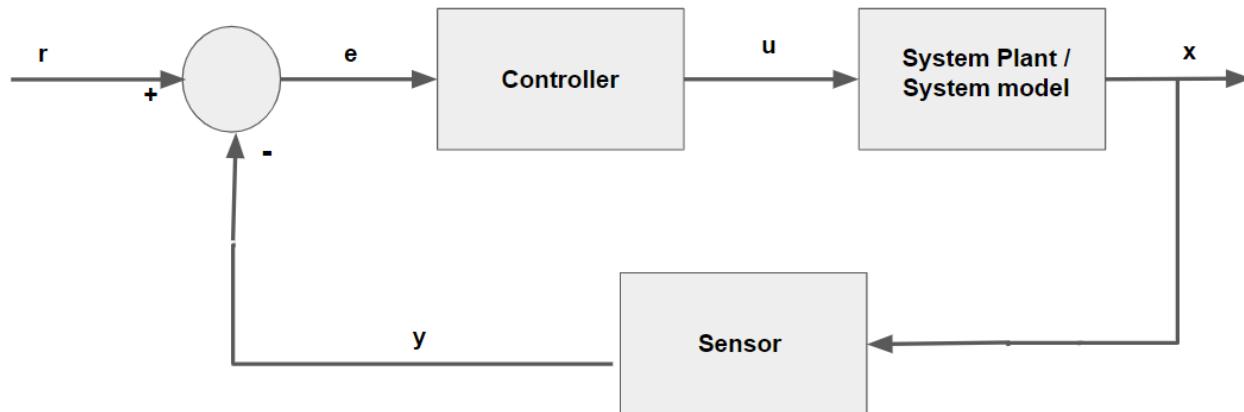


WE'RE IN!



# Control System

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



**Control System**

# Controllers



# Mobile Robot Localization

## **Problem**

- Localization is the problem of determining the pose of the robot relative to a given map of the environment.

## **Sensors**

- **Odometry, GPS, Laser-scanner, Camera**

## **World Representations**

- Topological graphs, grid-based maps

## **Filters**

- Kalman filter, Particle filters

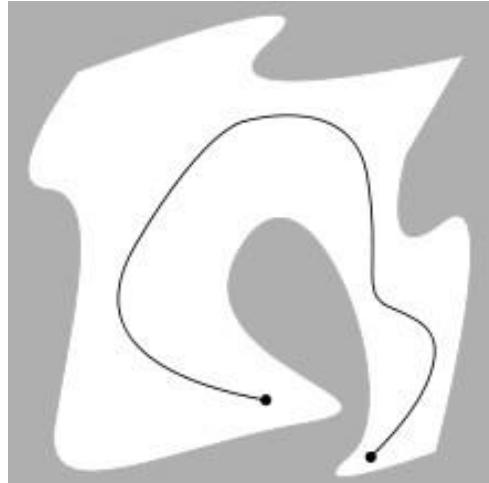
# Path Planning

## Problem

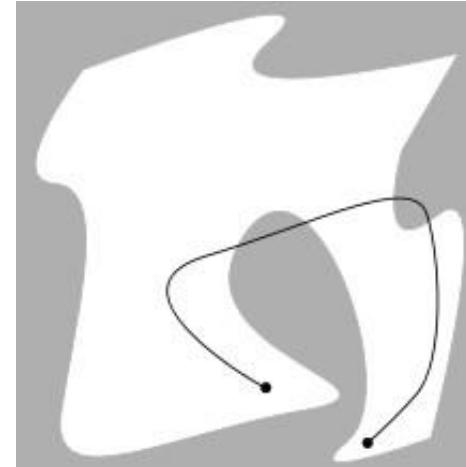
To find a sequence of valid robot configurations that moves the robot from a given location to the destination.

## Other Considerations

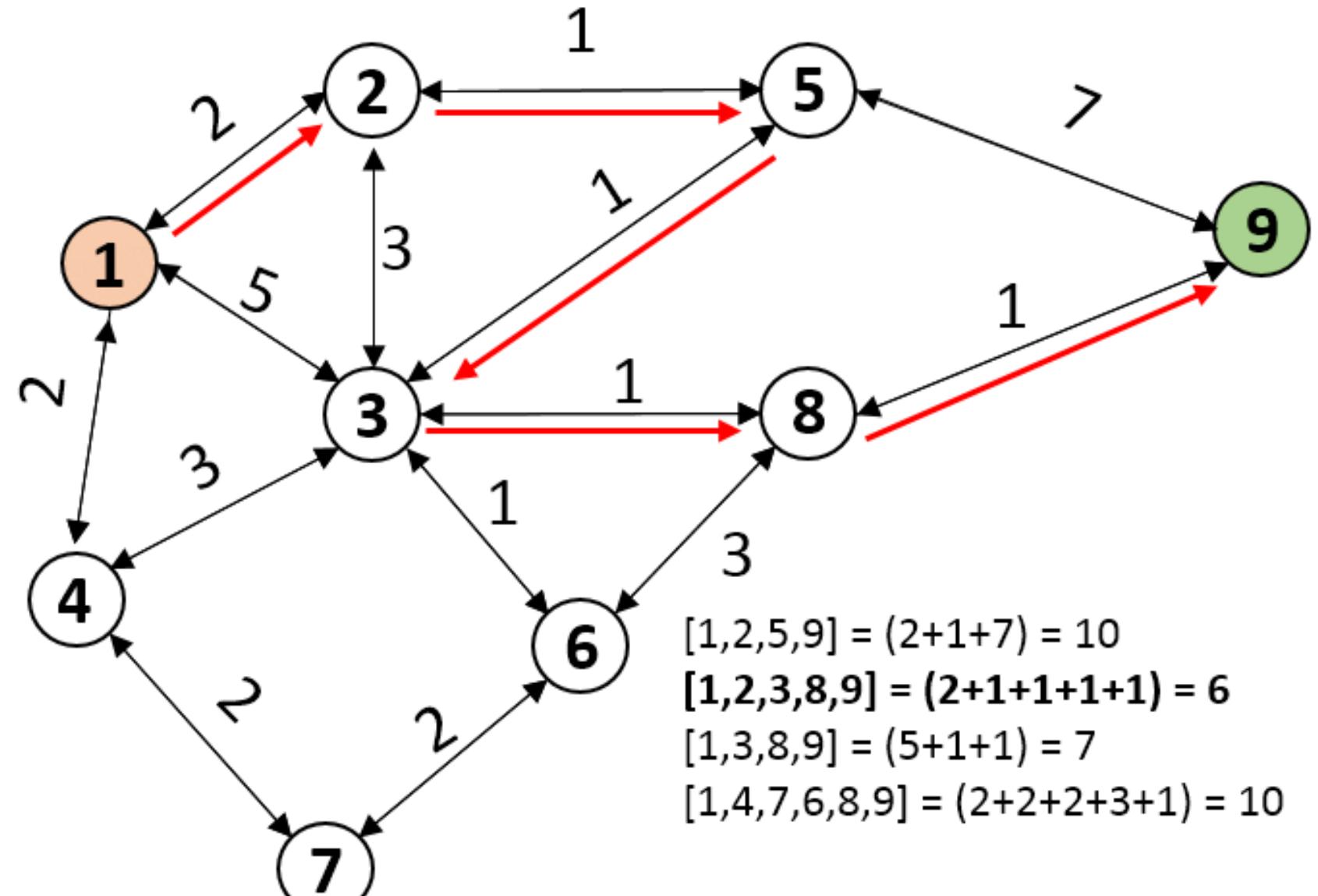
The task must be executed avoiding walls, or any other obstacles and falling down the stairs.



Example of a Valid Path



Example of an Invalid Path



Dijkstra's Algorithm

# Motion Planning

## Problem

Take the description of these tasks as inputs and generate speed and turning commands for the robot.

Basically generate commands that can be sent to robot's wheels to enable it to navigate along the planned path.

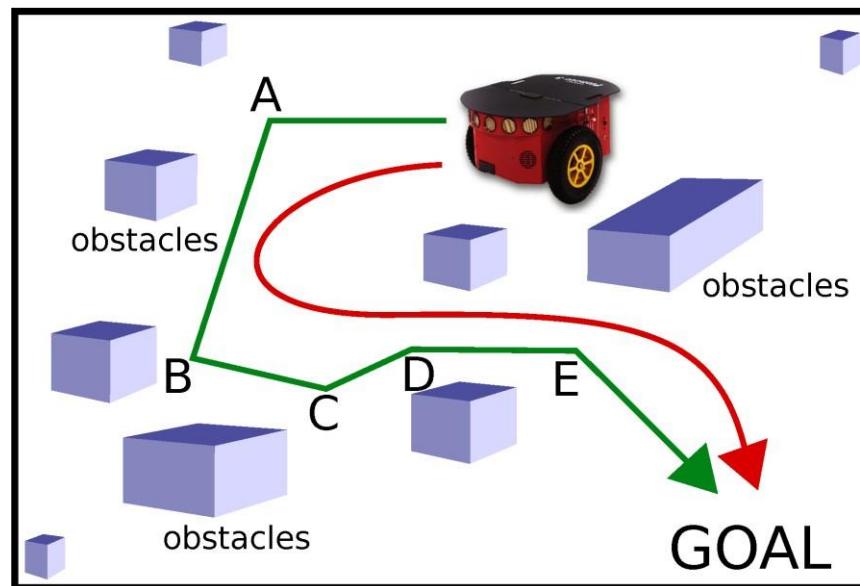
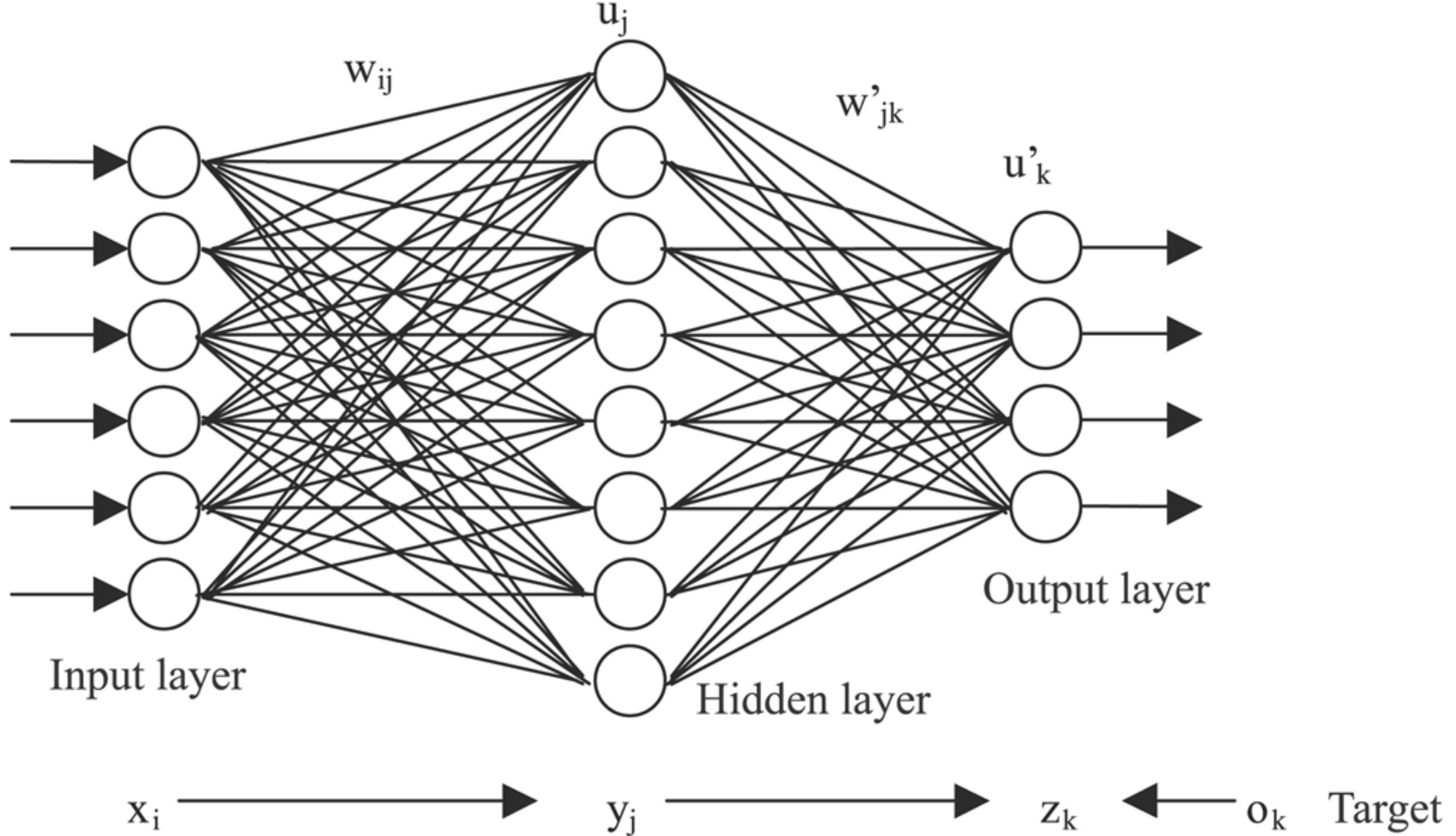
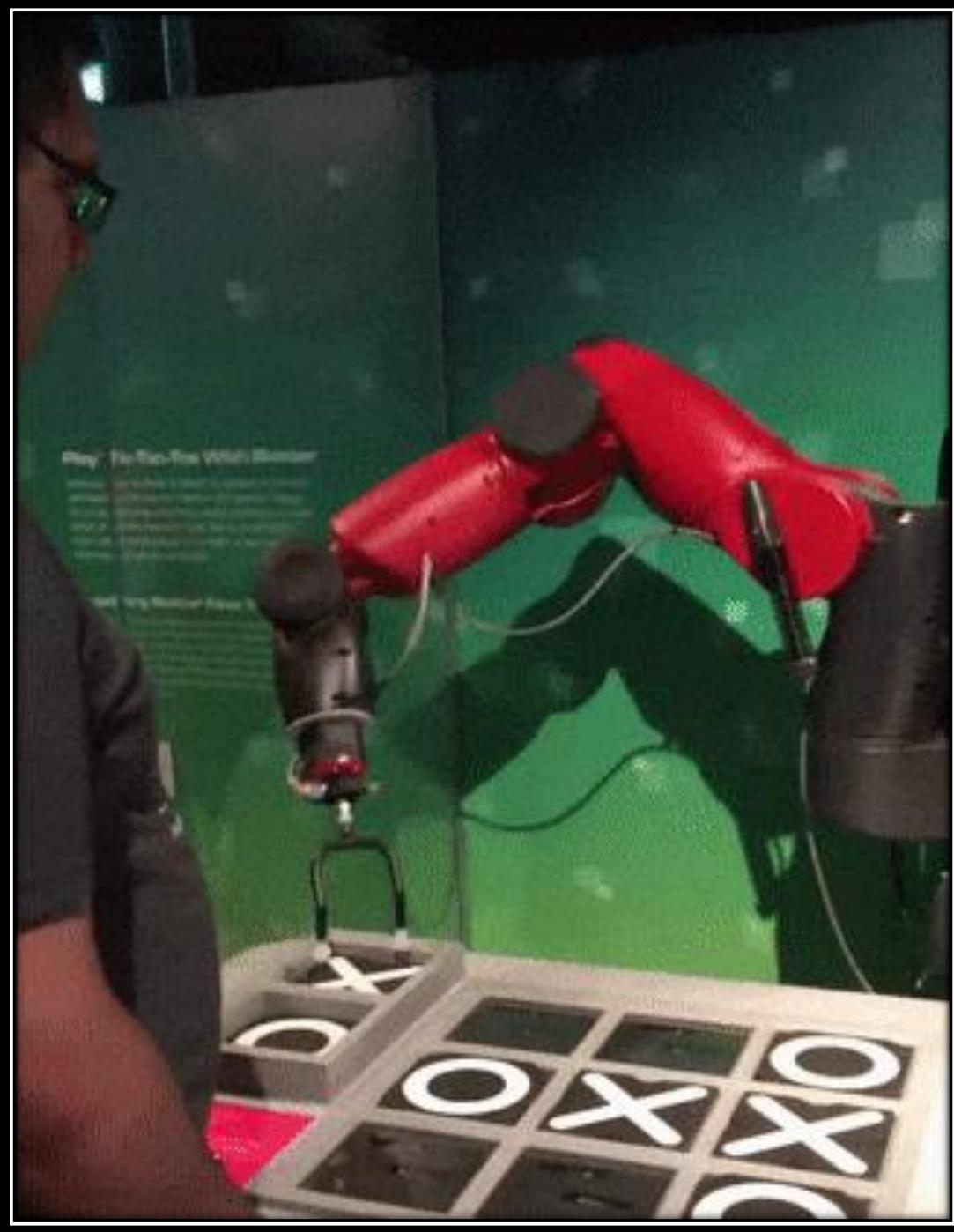


Illustration of Motion Planning





# Software

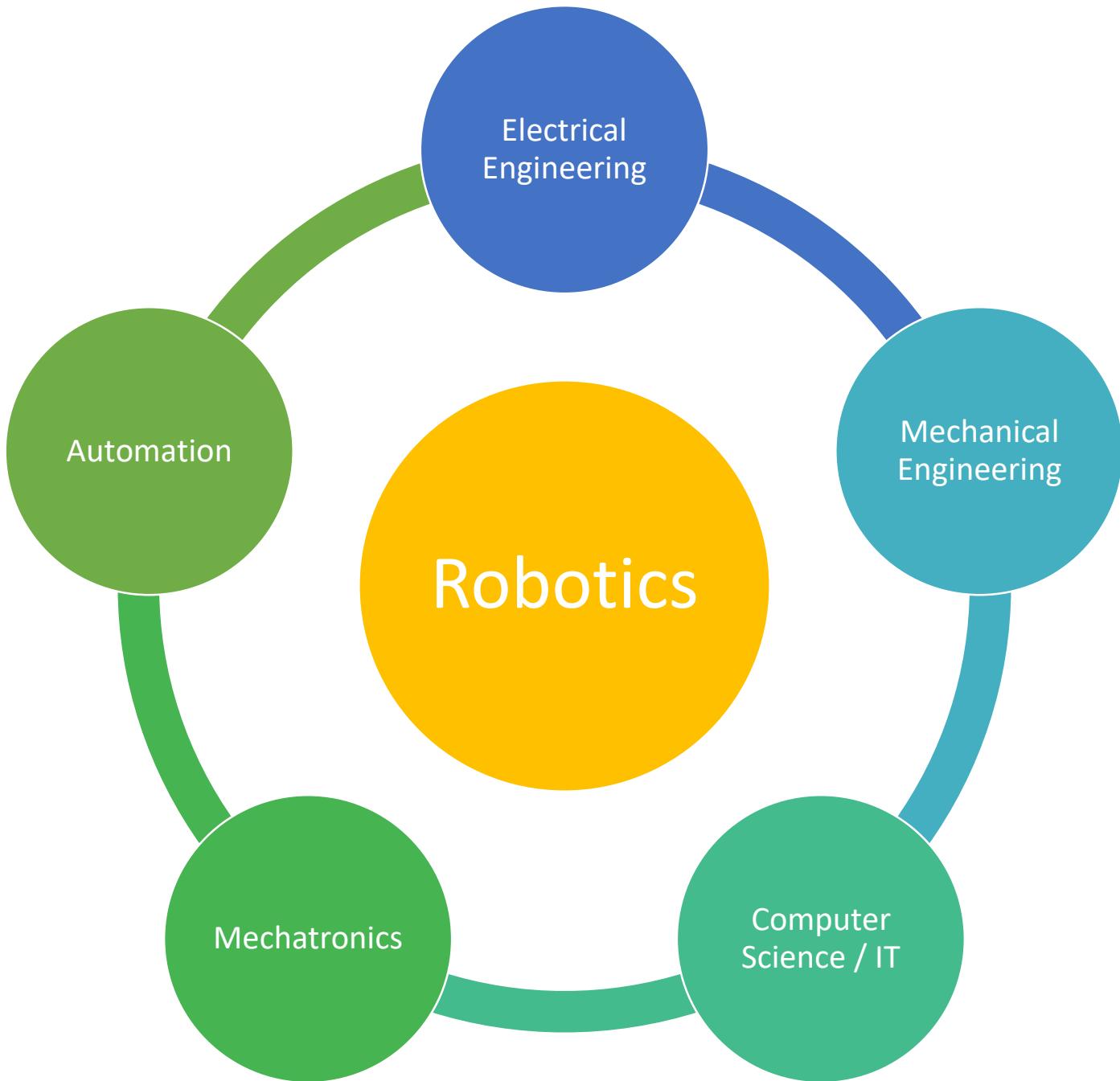
- Languages: C++, Python, Java
- Frameworks: ROS, Orocosp, Fawkes
- Simulators: Gazebo, Stage, V-Rep, OpenRAVE
- Useful libraries: KDL1, OpenCV, PCL, ZeroMQ, etc.

~~Overview~~  
~~Perception~~  
~~Hardware~~  
~~Actuation~~  
~~Reasoning~~  
Conclusion



# Open Topics

- Navigation
- Sensing
- Manipulation
- Task Planning
- Natural language processing
- Fault detection and error recovery
- Learning
- Sensor fusion
- Probabilistic reasoning
- Active perception
- Multi-robot systems
- Logging and databases
- Communication
- Human-robot interaction
- User interfaces
- Learning by demonstration



# Robotics: The Essential Components

- Perception
  - The robot senses the environment
- Planning/Reasoning
  - It uses prior knowledge to reason in a rational manner
- Actuation
  - Ability to move objects or itself in the Environment

