Introduction to Robotics
CSE461

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BRAC University

Course Outcome

Sl.	CO Description	Weightage (%)
CO1	Understand basic robotics that includes the law of robotics, uses of a robot, mechanical aspect of robot, type of primitive architecture, perceiving the environment, motor action, and different types of processing.	25
CO2	Implement different algorithms to 4DOF arm control, including forward and reverse kinematics. Examine Robot Control system and Navigation	20
CO3	Relate camera vision, sensors, machine learning, deep learning, and other AI algorithms with robot vision.	20
CO4	Categorize robot communication protocols (I2C, UART, USB, SPI, RS 485, Canbus, Modbus, LoRa, Bluetooth, RF, Zigbee, Wifi)	15
CO5	Investigating different types of robots, their characteristics, features, and applications, Design and Develop a Robot to solve a real-life problem.	20

Lesson Plan

- Introduce basic robotics that include the law of robotics, uses of robot, mechanical aspect of robot, type of primitive architecture, perceiving the environment, motor action, mechanical design, different types of processing and recent robotic trends.
- Review on Linear algebra and trigonometry, Robot Arm Forward Kinematics, Robot Arm Inverse Kinematics
- Robot Vision and Perception including vision sensors, visual servoing, physical sensors and LIDAR.
- Control Theory: Classic Feedback Diagram, First-Order and Second-Order Systems, PID Controller
- Navigation: Basics of Navigation, Localization techniques and Mapping
- Applications of AI and Machine Learning in Computer
- Introduce robot communication protocols including I2C, UART, USB, SPI, RS 485, Canbus, Modbus, LoRa, Bluetooth, RF, Zigbee, Wifi and other modern protocols.
- Case Study and Presentation.

Reference Books

- Introduction to AI robotics by Murphy, Robin
- Intelligent systems and robotics by George W. Zobrist and C.Y. Ho.
- Springer Handbook of Robotics by Bruno Siciliano, Oussama Khatib
- Robotics, Vision and Control: Fundamental Algorithms In MATLAB, Second Edition by Peter Corke
- Modern Robotics: Mechanics, Planning, and Control by Kevin M. Lynch
- Probabilistic Robotics by Sebastian Thrun, Wolfram Burgard, Dieter Fox
- Introduction to Robotics by S K Saha
- Robotics: Control, Sensing, Vision, and Intelligence by K S Fu, Rafael C. Gonzalez, C S G Lee

Marks Distribution

- **Quizzes/Class Tests: 15%**
- **Assignments: 10%**
- **Mid Term Examination: 20%**
- **Final Examination: 30%**
- **Lab: 25%**
- **Total: 100%**

Objective of Robotics

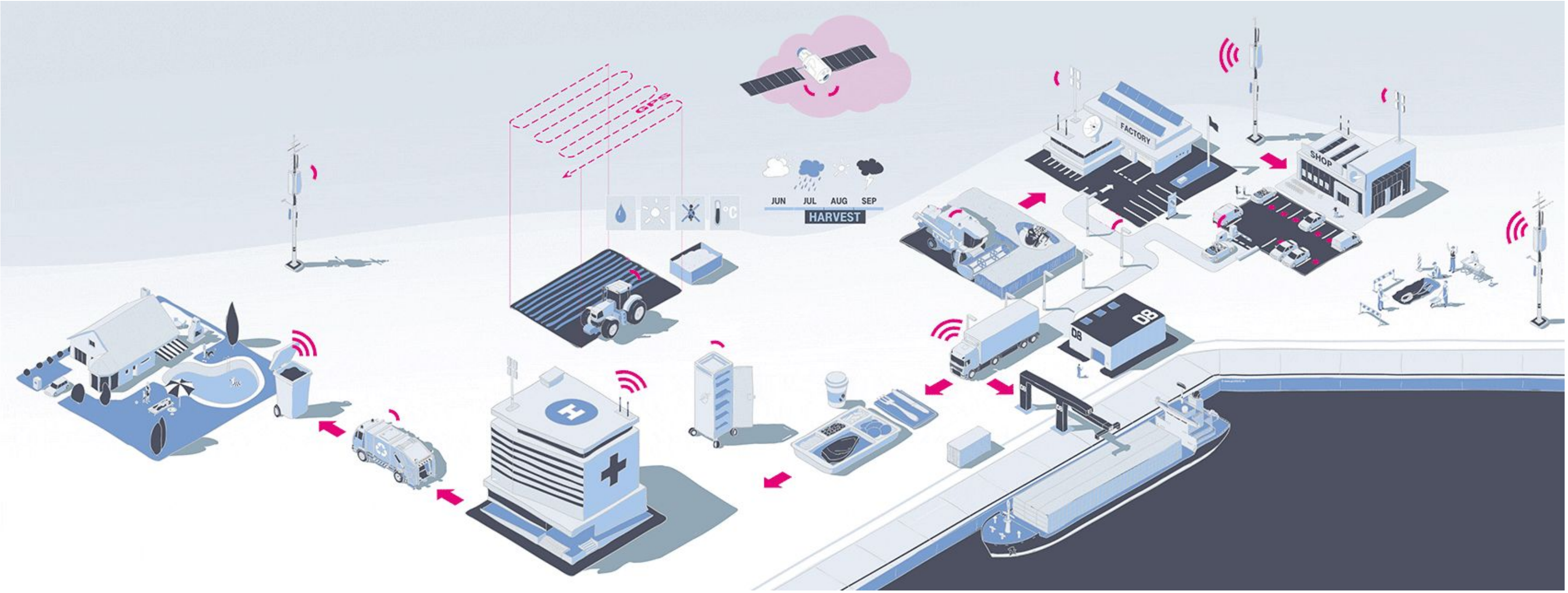
- Industry Automation
- Smart, IoT and Embedded Systems
- Efficient task specific Robot

4th Industrial Revolution

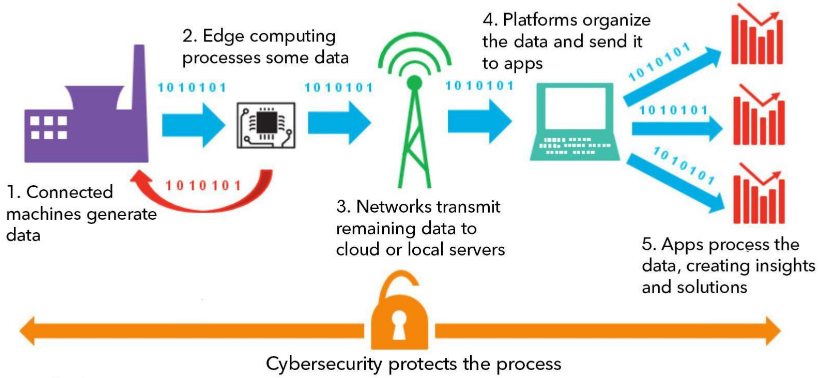
Industry Automation

https://www.youtube.com/watch?v=HX6M4QunVmA

Connects Everything that has the ability to communicate automatically and Smart way



IoT+Cloud+ Blockchain



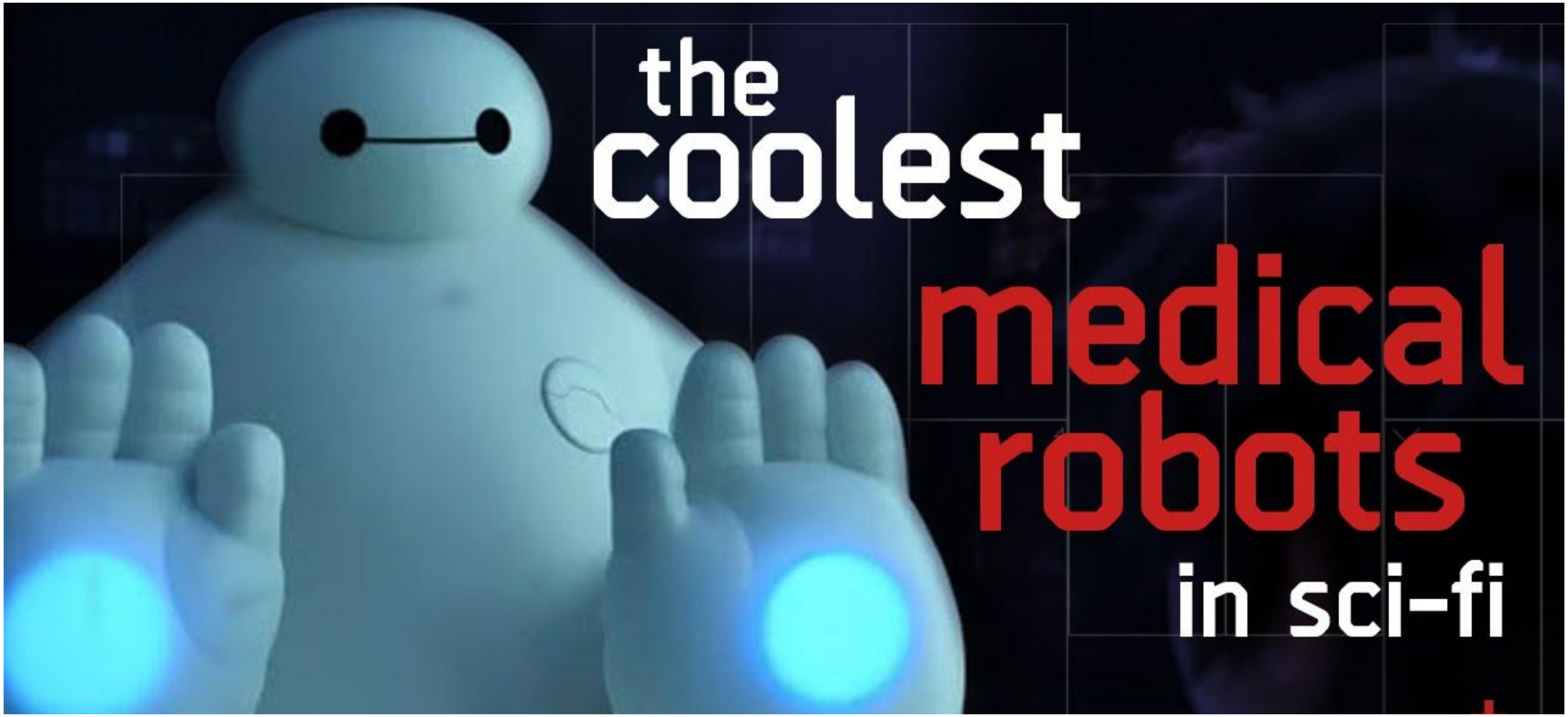
By Fusion of technologies…

Application specific Robot

Application specific Robot

Application specific Robot

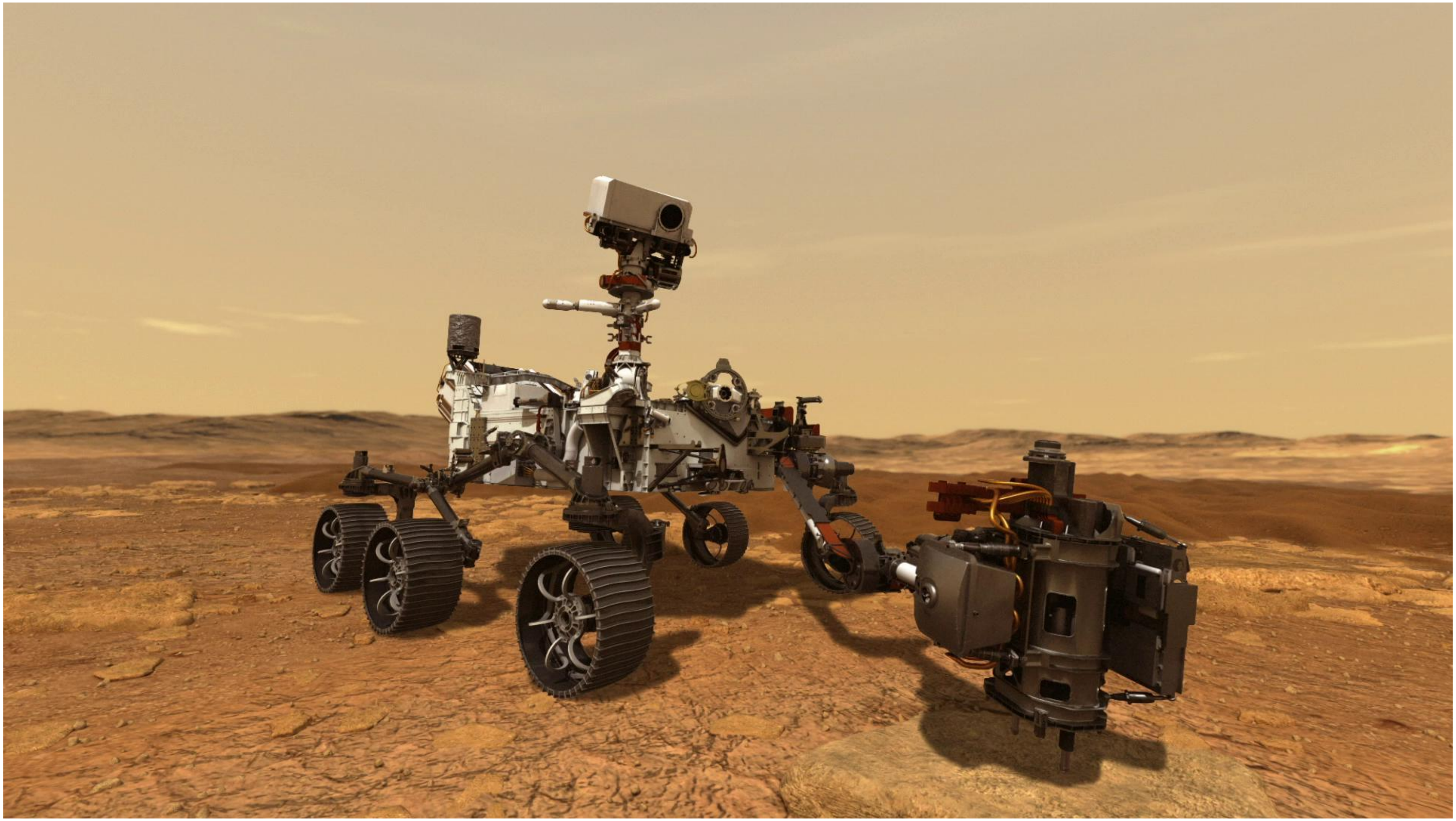
Application specific Robot



Application specific Robot

Application specific Robot

Application specific Robot



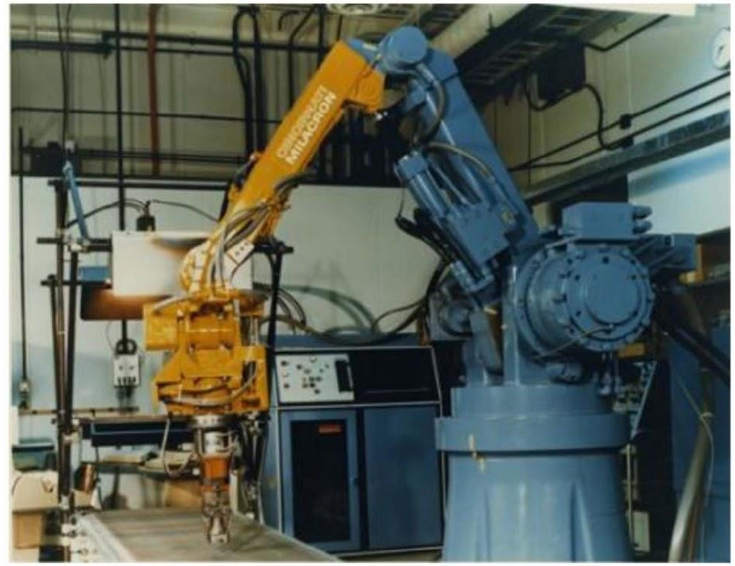
What is our ultimate goal?

- Robotics
- Embedded System
- Super Human (Ironman)
- Intelligent Machine



Why Intelligent Machines?

- Energy Saving
- Accuracy
- Convenience
- Efficiency
- Adaptability in Dynamic Environment
- Perform Dull, Dirty, difficult and Dangerous Job

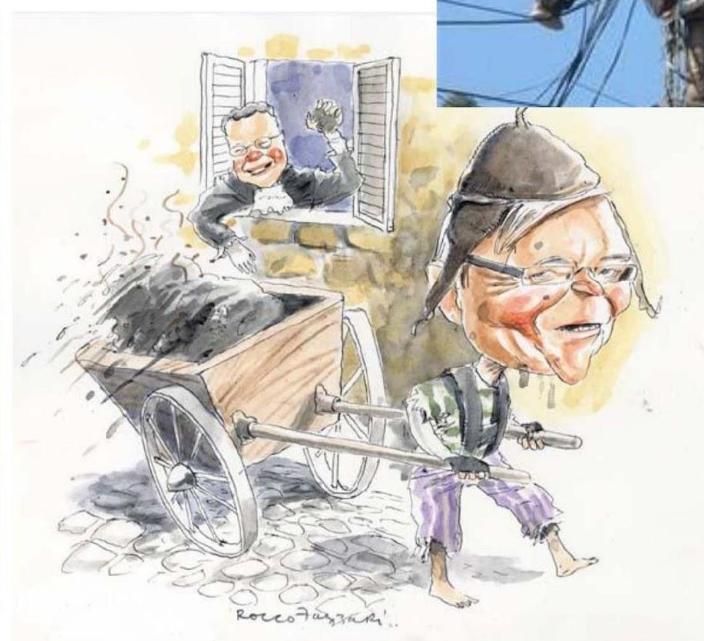


Do Things that Living Things Can't

- **Fukushima**
- **World Trade center**
- **RANA Complex**
- **Tajrin fashion**

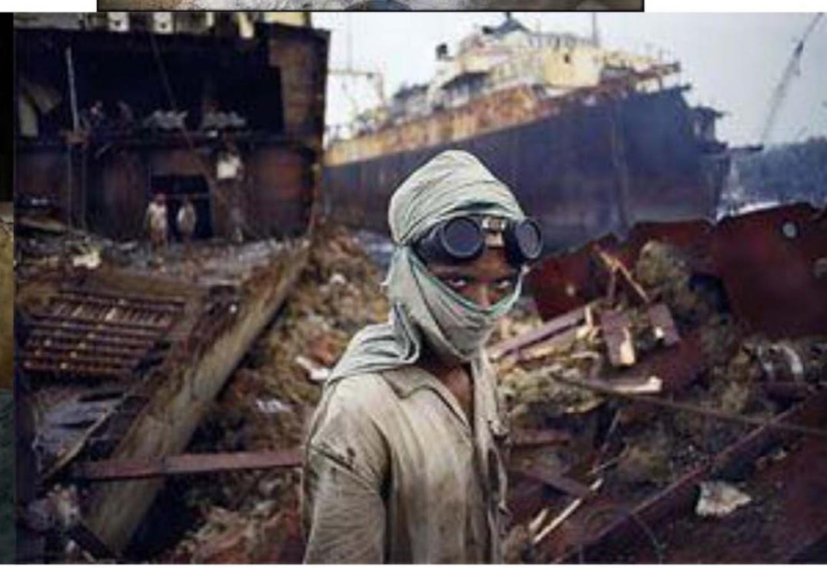
Dull, Dirty, difficult and Dangerous

Dull, Dirty, difficult and Dangerous



Dull, Dirty, difficult and Dangerous

Dull, Dirty, difficult and Dangerous

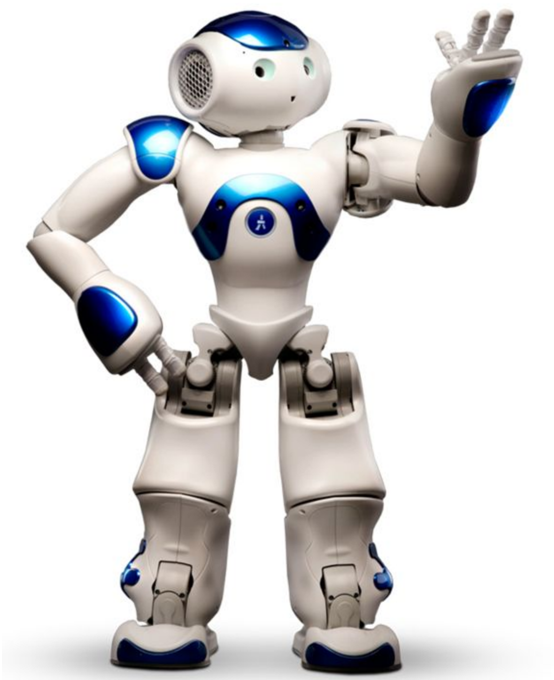


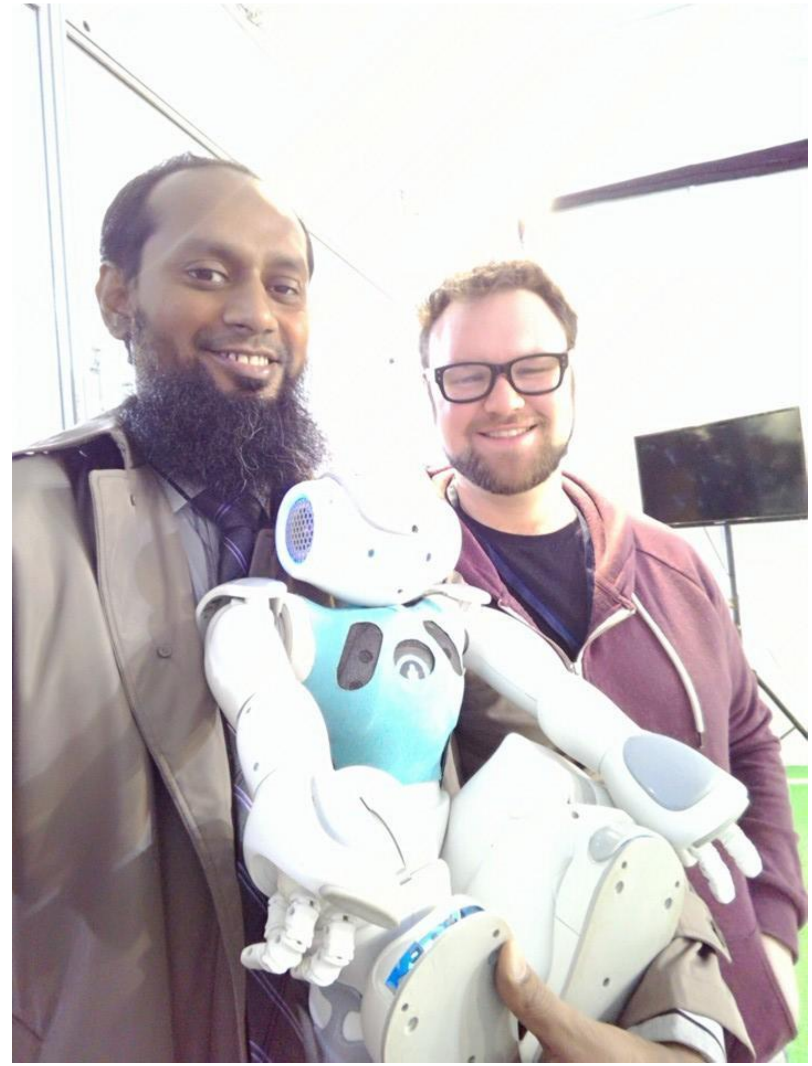
Dull, Dirty, difficult and Dangerous

Why Superhuman?

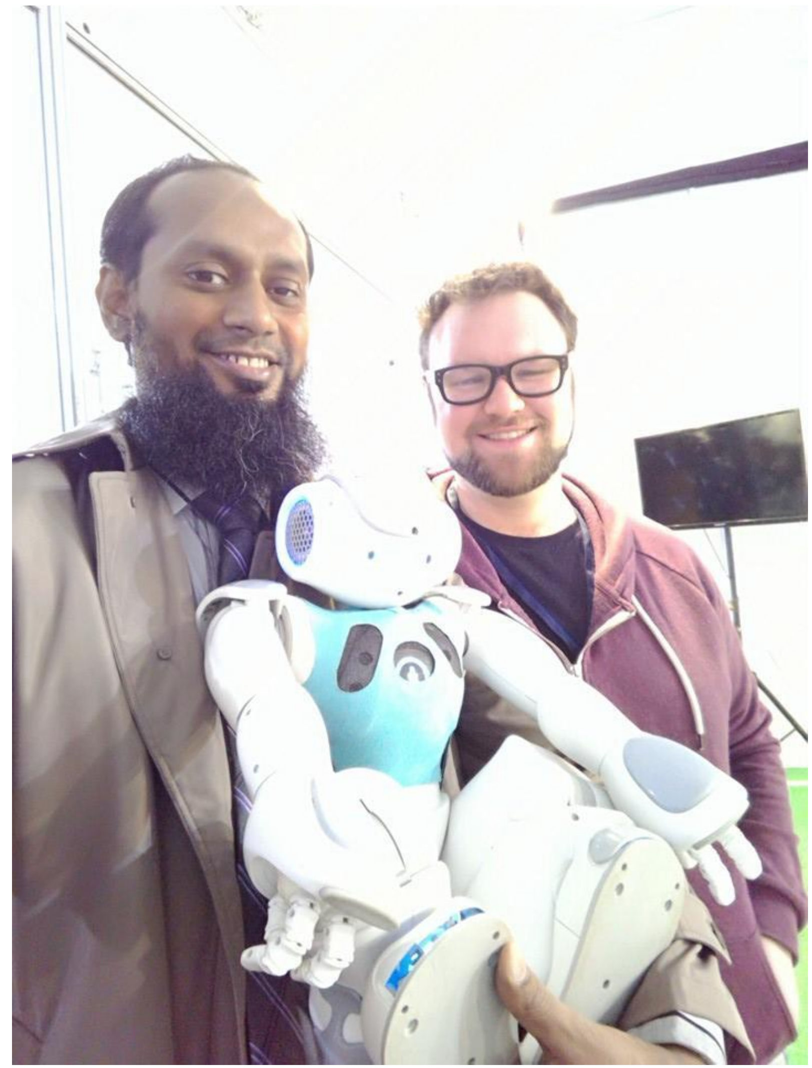
- Limitation of:
  - Perfect Sensing
  - Numerical Processing
  - Muscle Power
  - Communication
  - Path planning
  - Localization
- Overcome by:
  - Sensor fusion
  - Computer
  - Motor, Actuator, Engine and Engineering
  - Communication Technologies and NLP
  - Algorithms
  - GPS

Popular Humanoid Robot

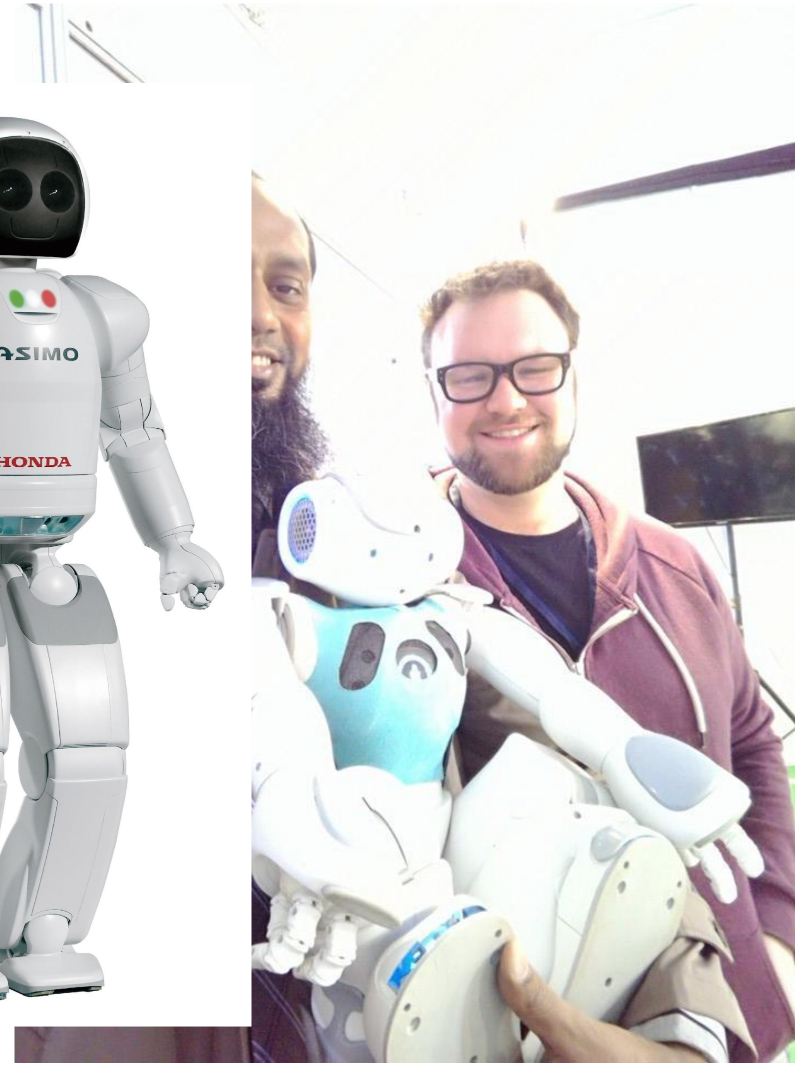




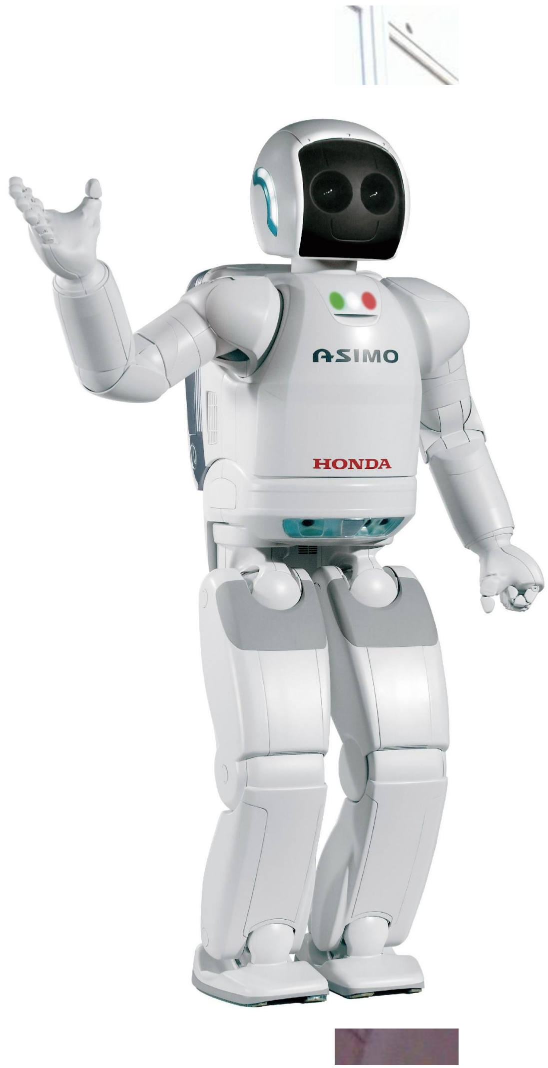
Popular Humanoid Robot



Popular Humanoid Robot



Popular Humanoid Robot



Popular Humanoid Robot

Popular Humanoid Robot

Pop obot

Law of AI Robot

1. A robot must not harm human being, nor through in action allow one to come to harm.
2. A robot must always obey human beings, unless that is in conflict with the first law.
3. A robot must protect from harm, unless that is in conflict with the first two laws.
4. A robot always should have a kill switch.

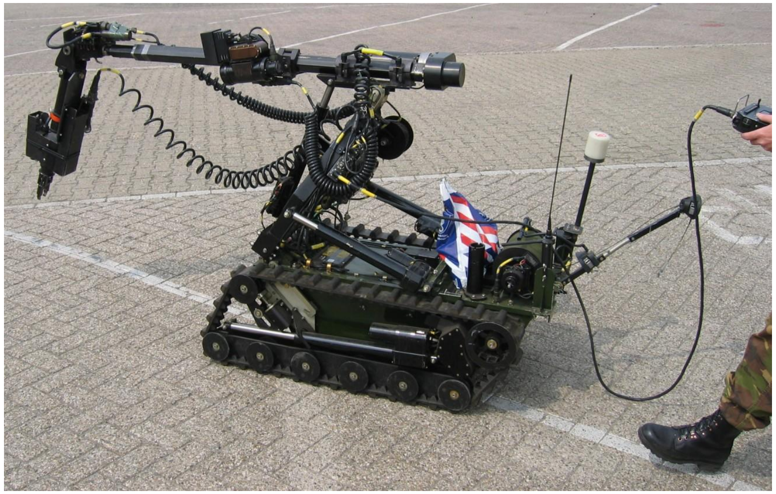
Thumb Rules on the decision of a Robot Uses

- The first rule to consider, what is known as the Four D of Robotics, i.e. is the task dirty, dull, dangerous, or difficult? If so, a human will probably not be able to do the job efficiently. Therefore, the job is appropriate for automation or for robotic labor.
- The second rule is that a robot may not leave a human jobless. Robotics and automation must serve to make our lives more enjoyable, not miserable.
- A third rule involves asking whether you can find people who are willing to do the job. If not, the job is a candidate for automation and Robotics.
- A four rule of thumb is that the use of robots or automation must make short-term and long-term economic sense.

Uncrewed Vehicle

- Remote control vehicle (RC)
- Unmanned ground vehicle (UGV)
- Unmanned aerial vehicle (UAV)
  - Unmanned combat aerial vehicle (UCAV)
  - Miniature UAV (SUAV)
  - Delivery drone
  - Micro air vehicle (MAV)
  - Target drone
- Autonomous spaceport drone ship
- Unmanned surface vehicle (USV)
- Unmanned underwater vehicle (UUV)
  - Remotely operated underwater vehicle (ROUV)
  - Autonomous underwater vehicle (AUV)
- Uncrewed spacecraft: robotic spacecraft or space probe

Remote control vehicle (RC)



Unmanned ground vehicle (UGV)

Unmanned aerial vehicle (UAV)


Unmanned combat aerial vehicle (UCAV)
Miniature UAV (SUAV)
Delivery drone
Micro air vehicle (MAV)
Target drone

Unmanned aerial vehicle (UAV)

Unmanned combat aerial vehicle (UCAV)
Miniature UAV (SUAV)
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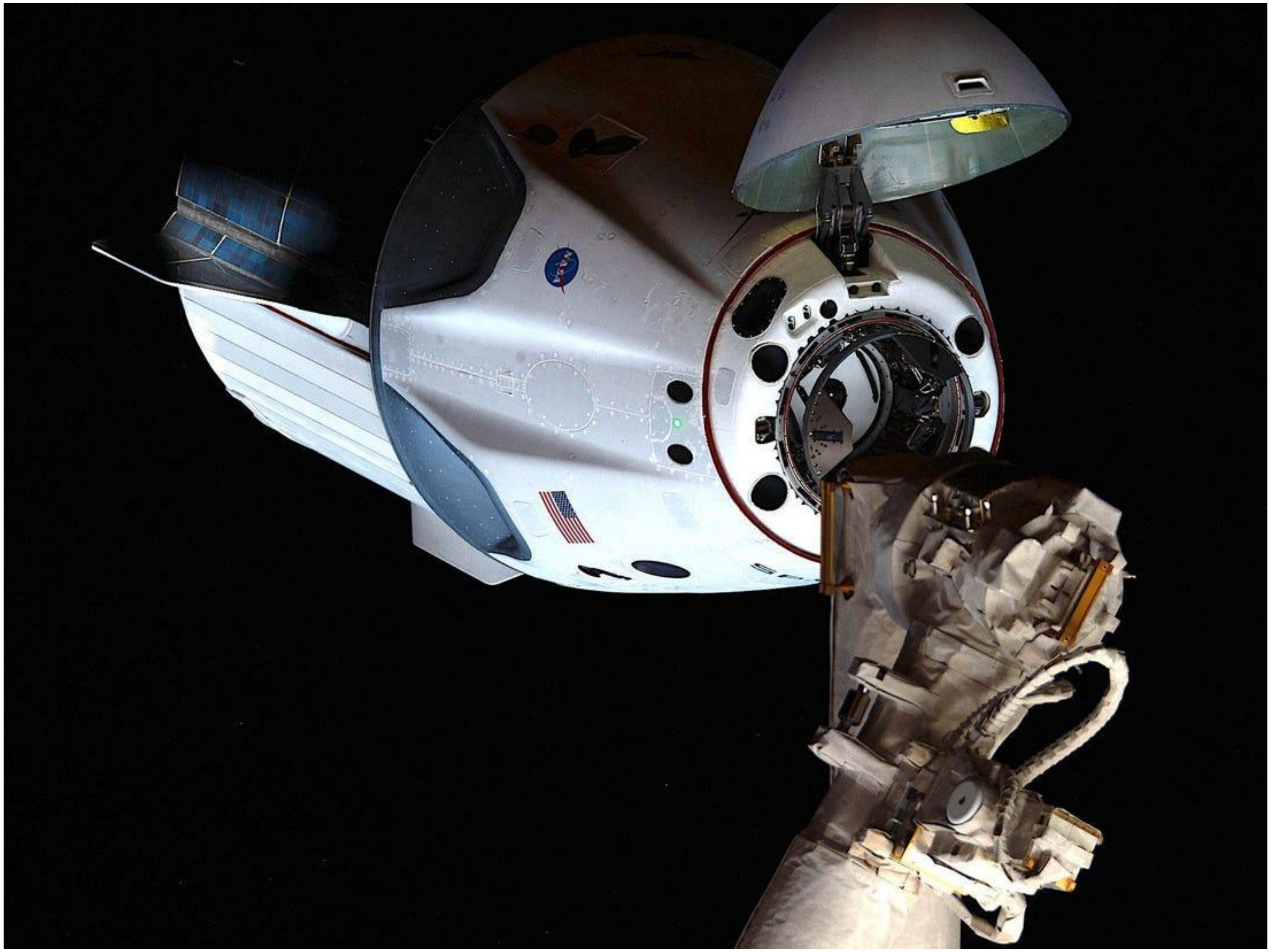
Target drone

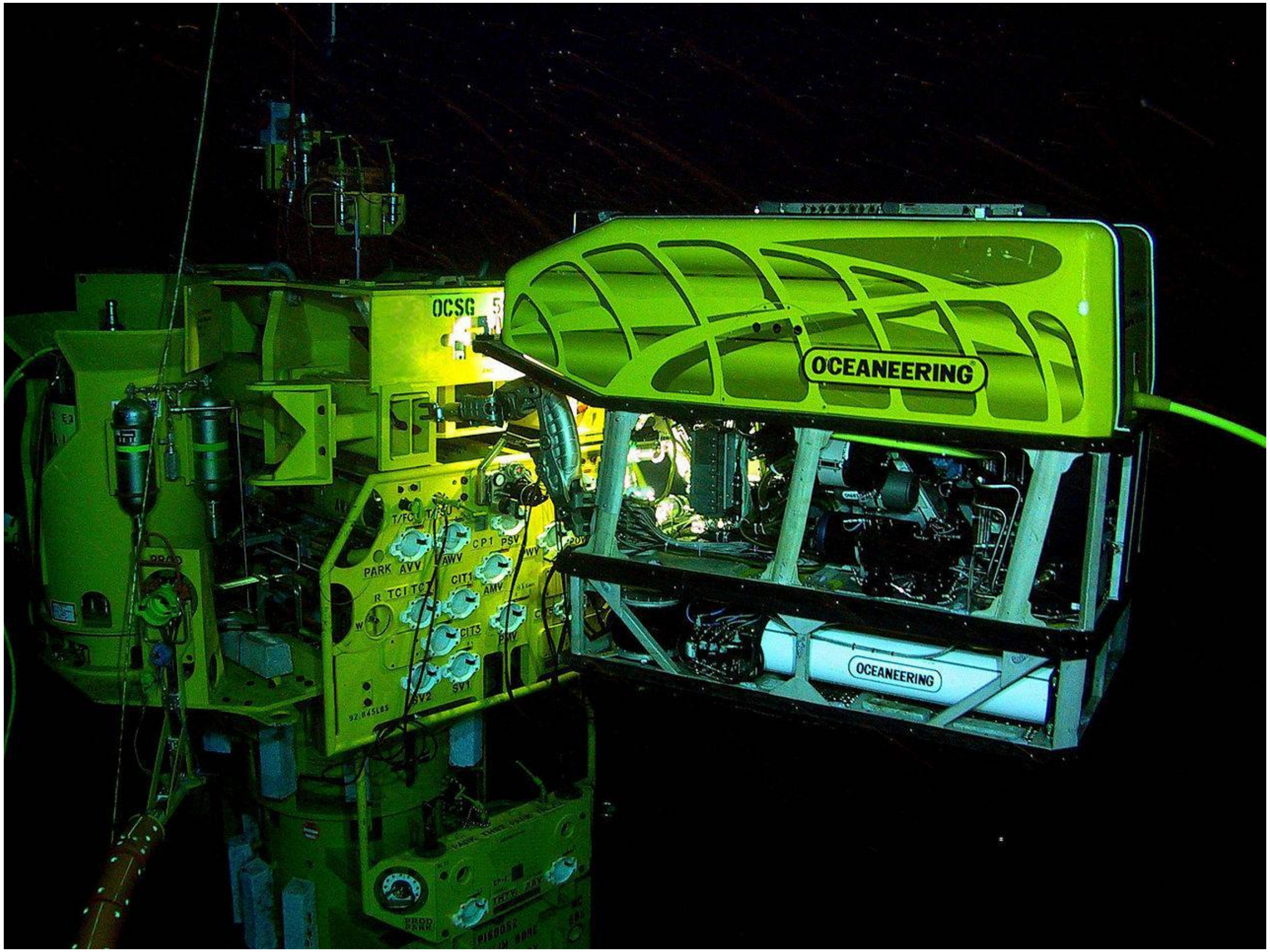
Uncrewed spacecraft



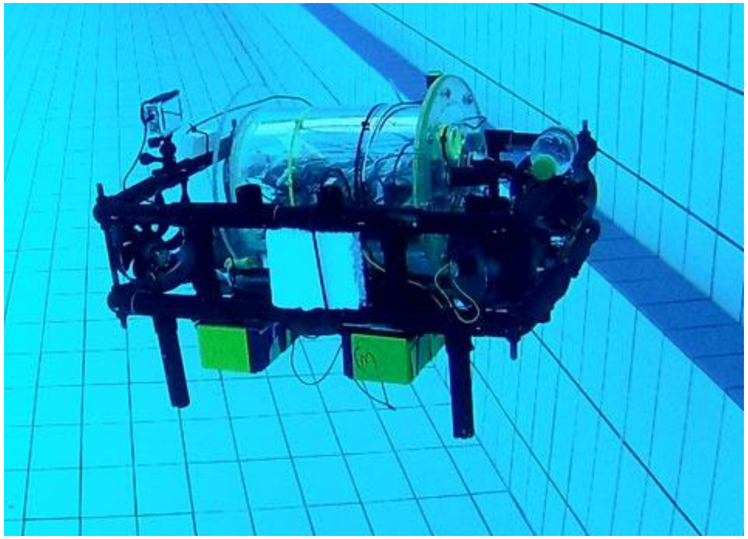
Autonomous spaceport drone ship

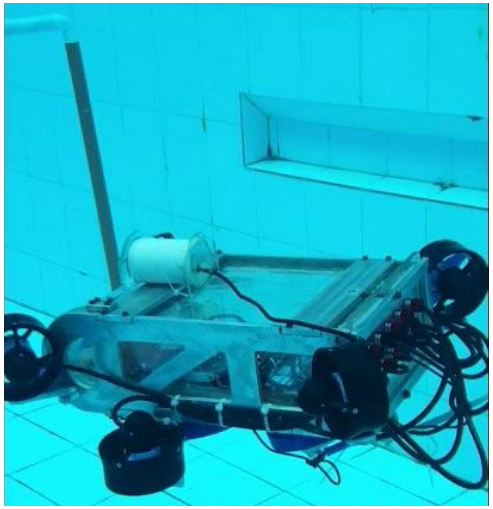
Unmanned surface vehicle (USV)

Remotely operated underwater vehicle (ROUV)



Autonomous underwater vehicle (AUV)

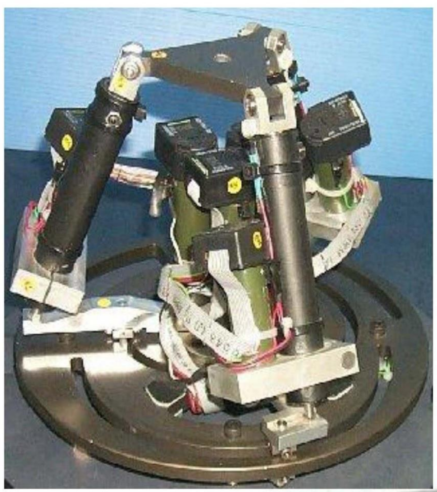


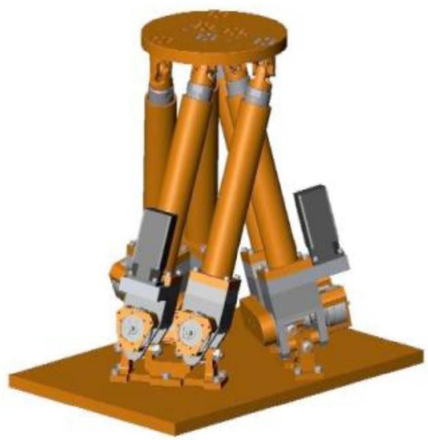


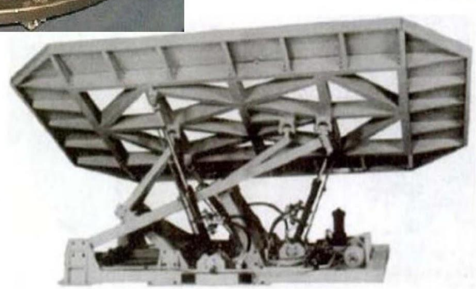
Uncrewed spacecraft

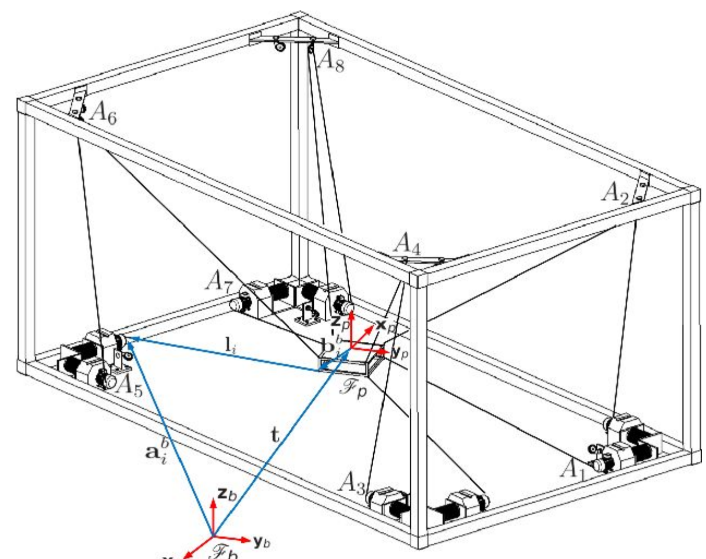
Parallel Robot

- Flight Simulator
- Milling Machine
- Cable Driven Parallel Robot







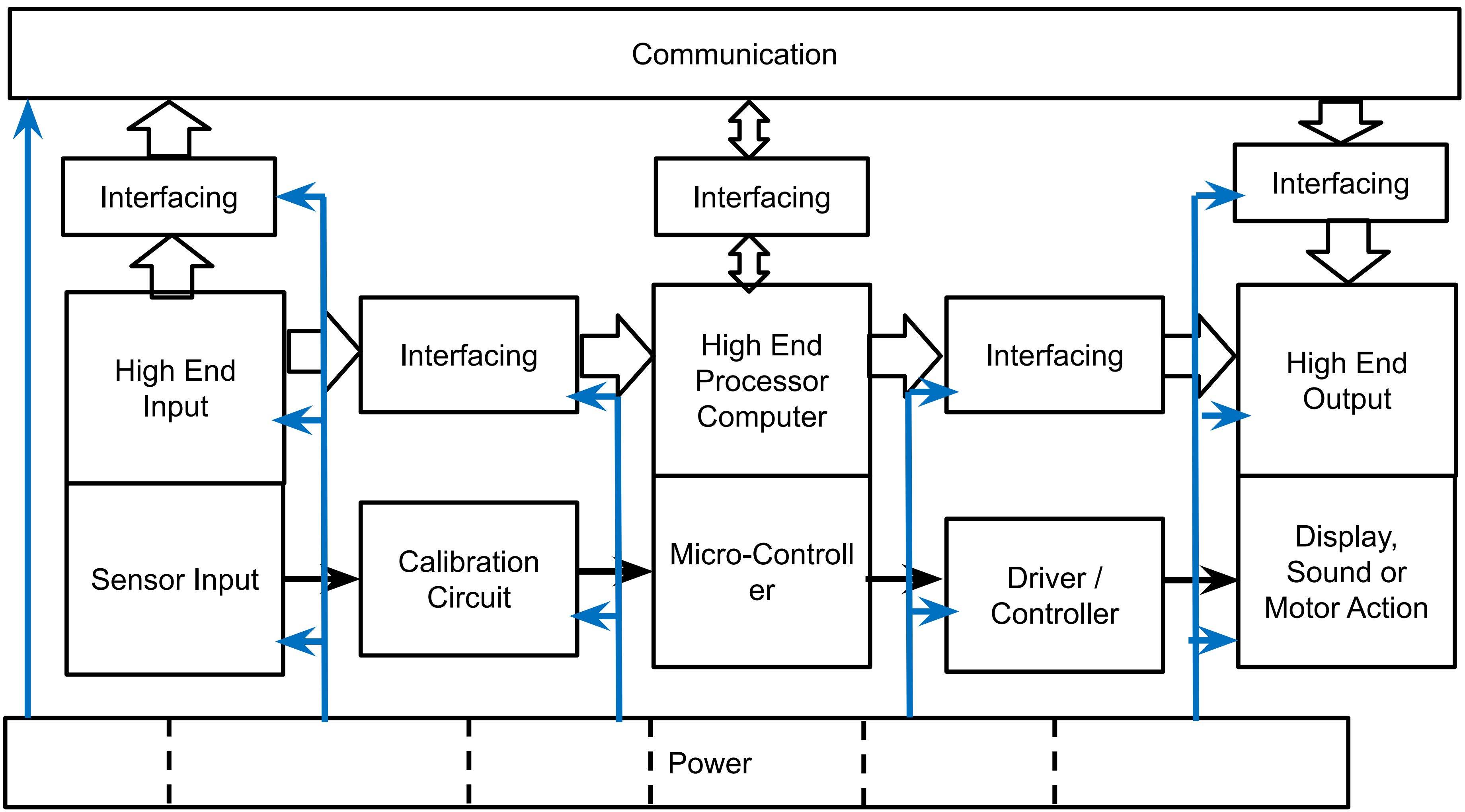


3D Printer

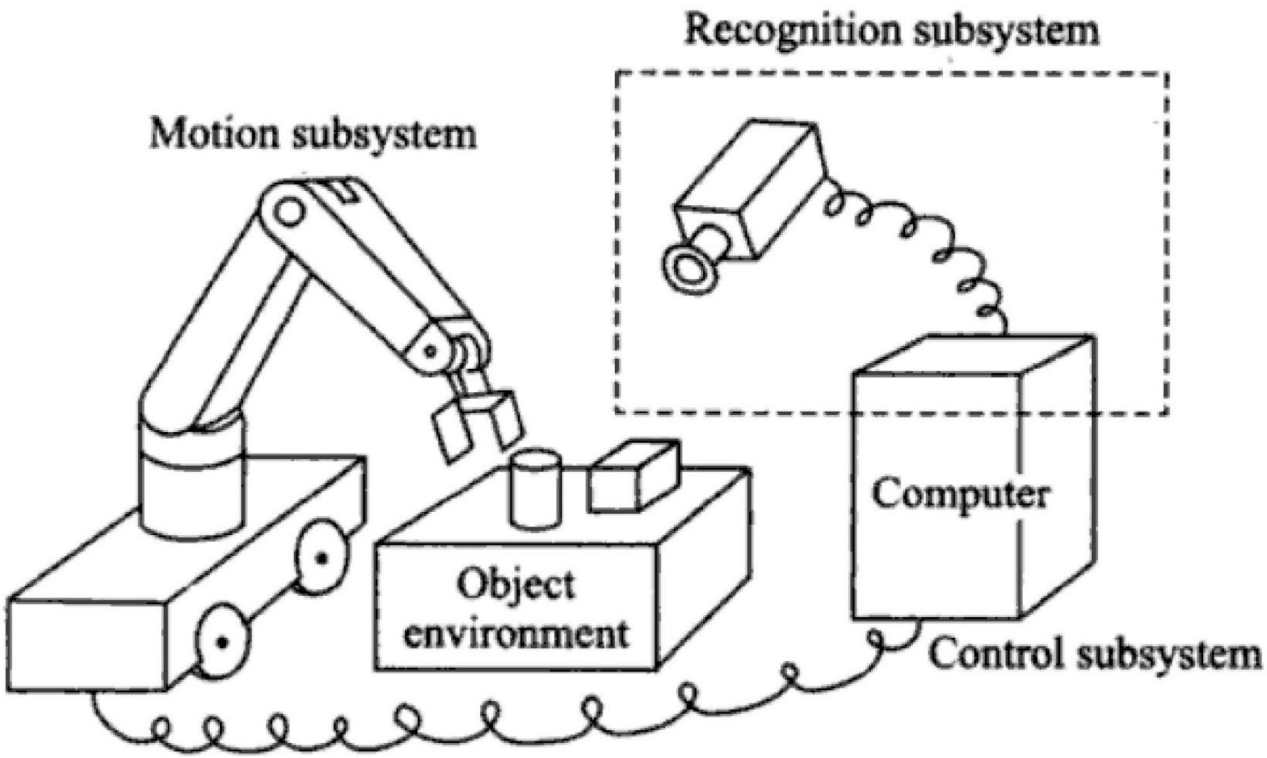
Sub-Systems

- Sense/Perception
- Plan/Control
- Act/Motor Action
- Power
- Communication

Hardware Architecture



Three primitives of robotics



- Sense
- Plan
- Act

AI Primitives within an Agent

SENSE

PLAN

ACT

LEARN

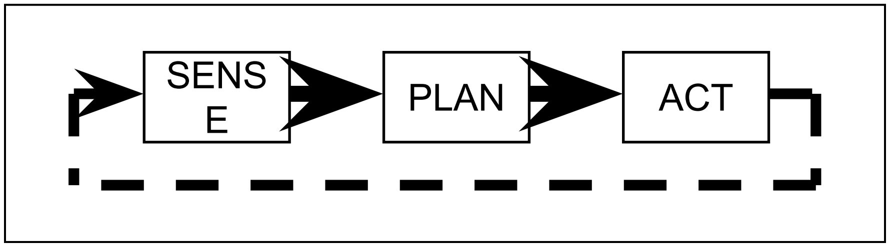
ROBOTIC PARADIGMS

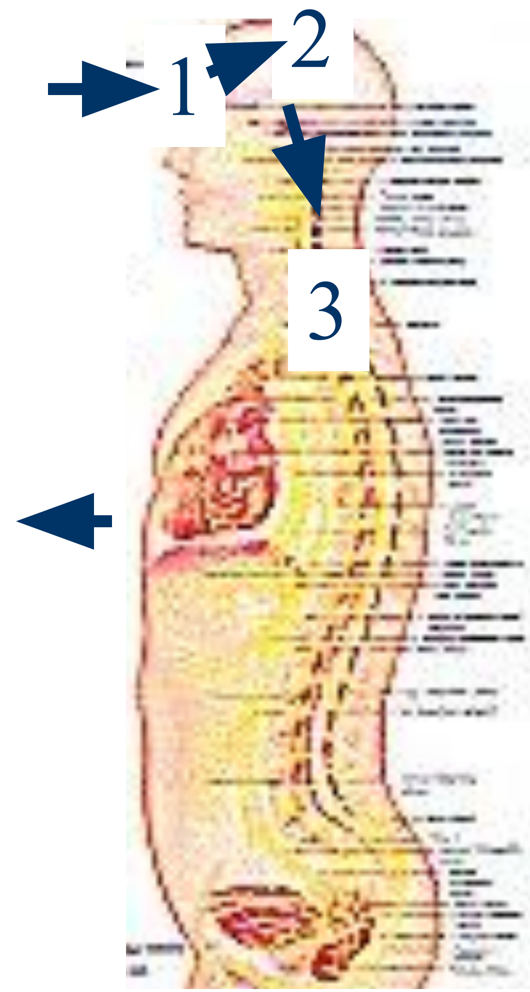
- Hierarchical/deliberative paradigm
- The reactive paradigm
- Hybrid deliberate/reactive paradigm

- A fourth category, not always listed, is "Behavior-Based Control"

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

Hierarchical/deliberative paradigm





Hierarchical/deliberative paradigm

Control people hated because didn't "close the loop"

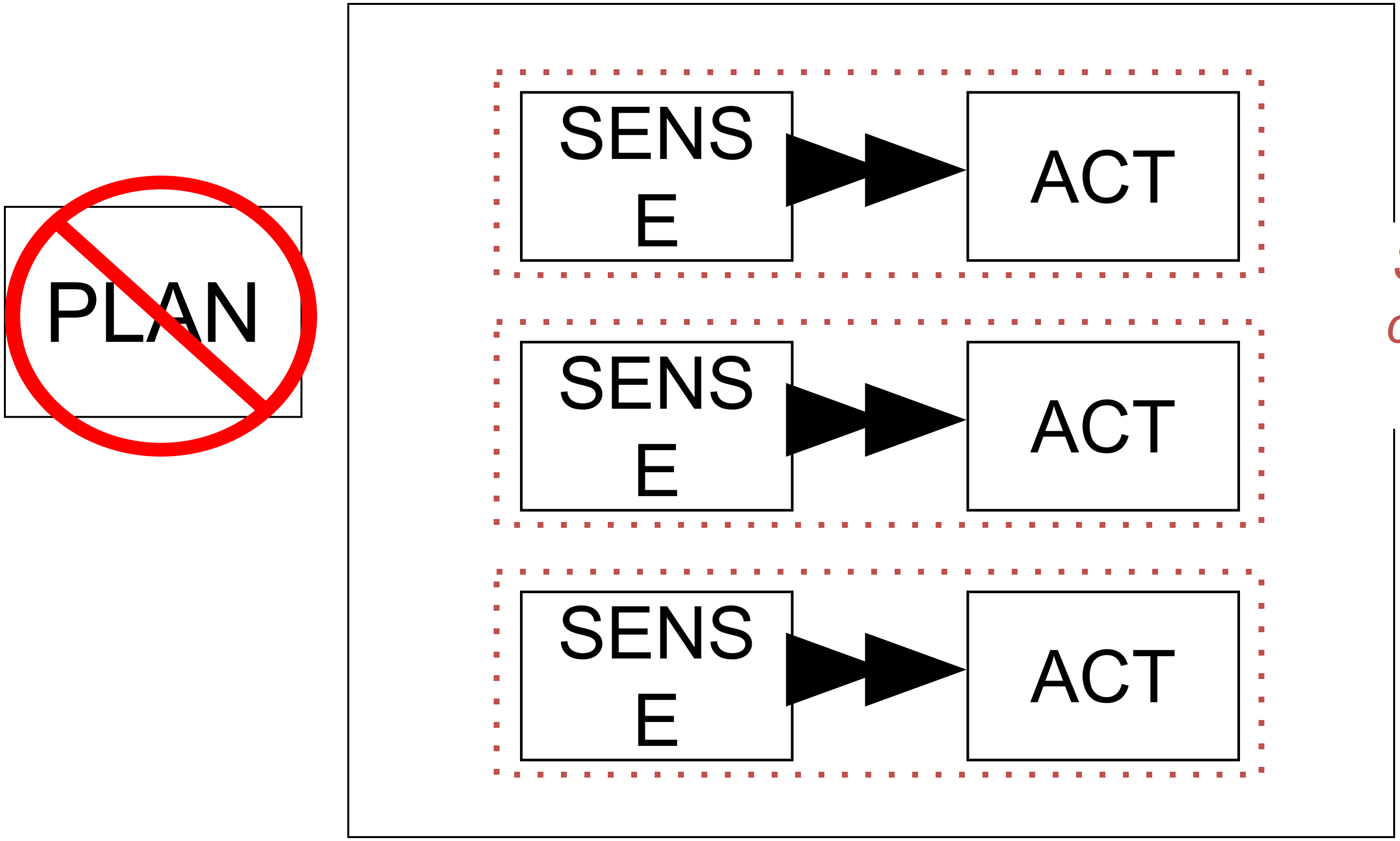
AI people hated because monolithic

Users hated because very slow

Hierarchical/deliberative paradigm

- The robot operates in a top-down fashion, heavy on planning.
- The robot senses the world, plans the next action, acts; at each step the robot explicitly plans the next move.
- All the sensing data tends to be gathered into one global world model.

The reactive paradigm



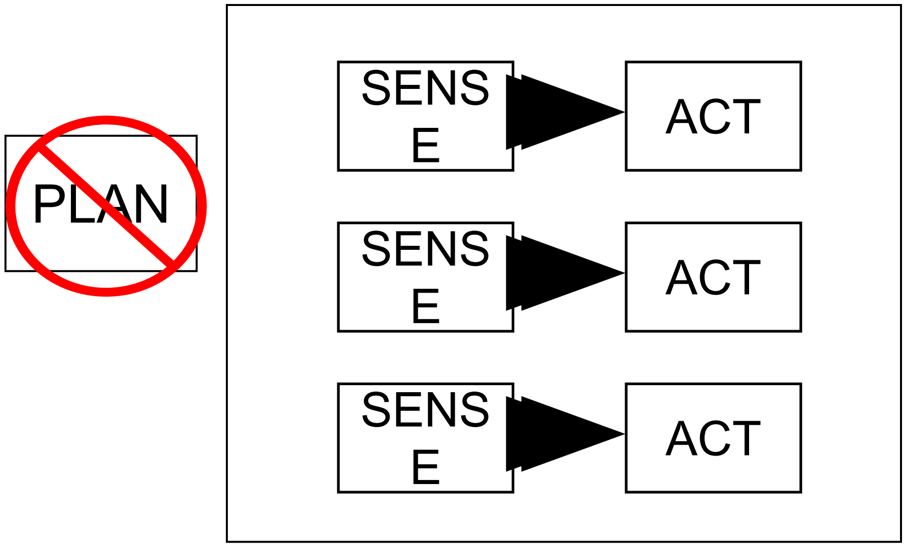
SENSE-ACT couplings are "behaviors"

Behaviors are independent, run in parallel

The reactive paradigm

- Sense-act type of organization.
- The robot has multiple instances of Sense-Act couplings.
- Robot take the local sensing data and compute the best action to take independently of what the other processes are doing.
- The robot will do a combination of behaviours.

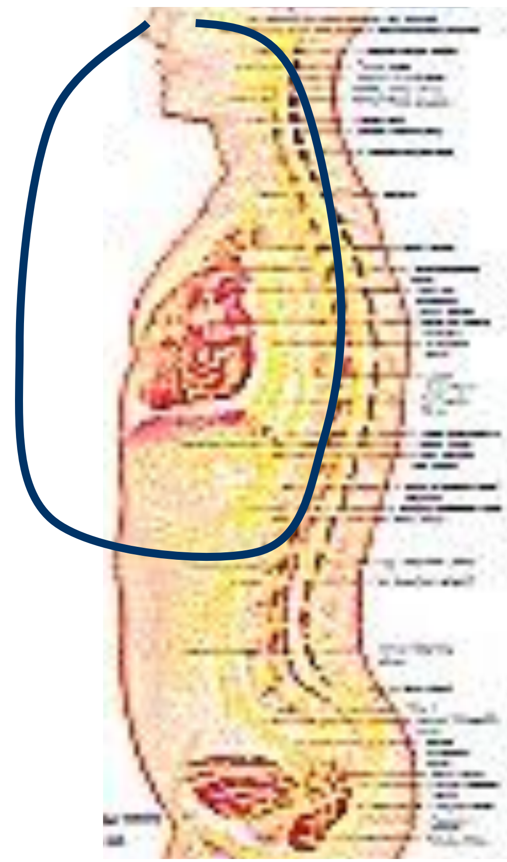
Reactive



Users loved it because it worked

AI people loved it, but wanted to put PLAN back in

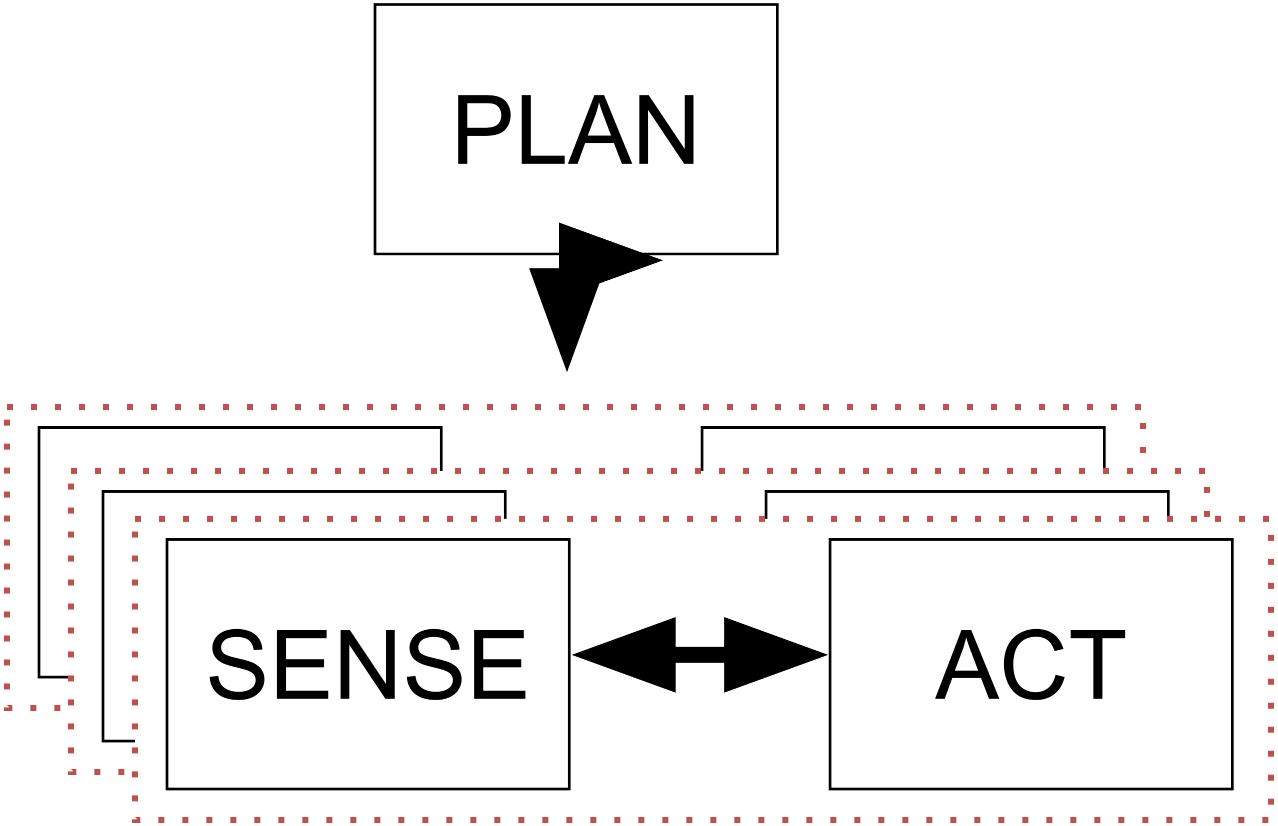
Control people hated it because couldn't rigorously prove it worked



Hybrid deliberate/reactive paradigm

- The robot first plans (deliberates) how to best decompose a task into subtasks (also called "mission planning") and then what are the suitable behaviours to accomplish each subtask.
- Then the behaviours starts executing as per the Reactive Paradigm.
- Sensing organization is also a mixture of Hierarchical and Reactive styles; sensor data gets routed to each behaviour that needs that sensor, but is also available to the planner for construction of a task-oriented global world model.

Hybrid deliberate/reactive paradigm

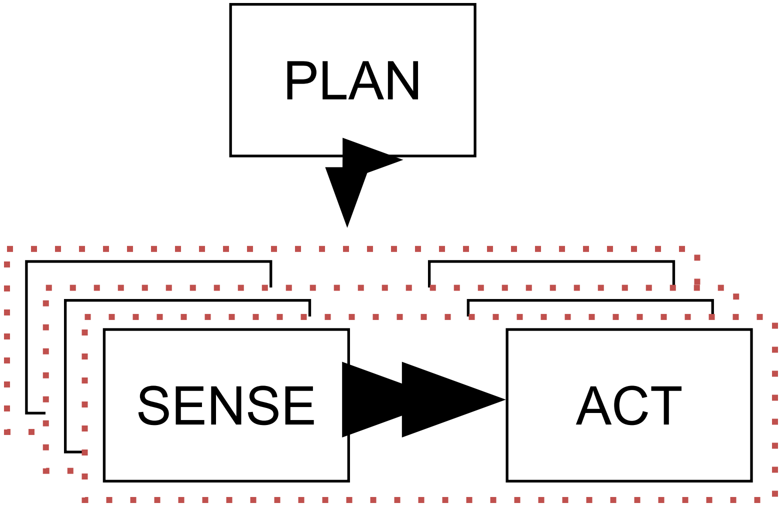


Plan, then sense-act until task is complete or need to change;
Note movement towards event-driven planning rather than continuous

Advantages

- Asynchronous processing technique allow to function Independently
- Planner can slowly computer next goal while robot can perform reactive task
- First reactive updates then global panner for planning
- Good software Modularity

Hybrid



Control people hated it because AI, but are getting over it

AI people loved it

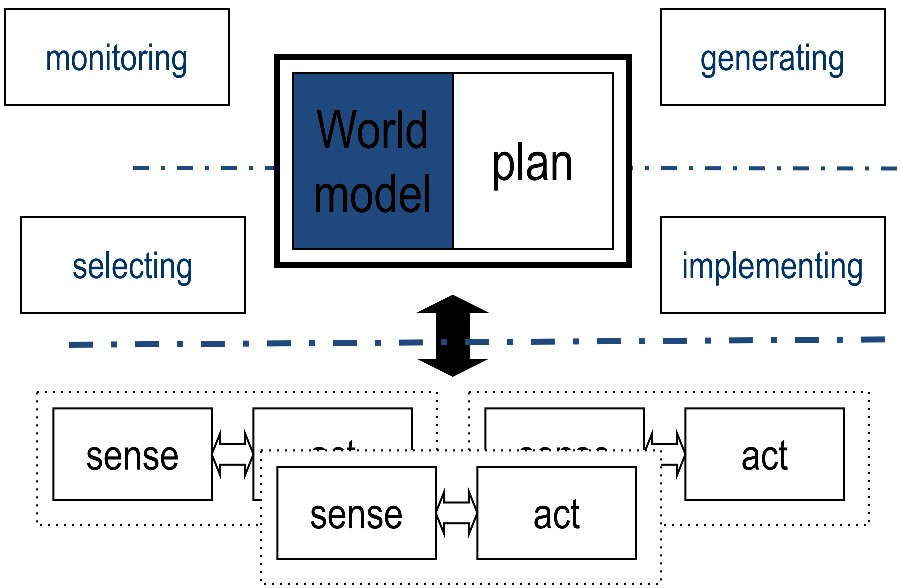
Users loved it

Local and Global Model

- Reactive for Local control
- Deliberative for Global control

- However; Robot behavioral management requires to know its current mission, state and environment beside path-planning, map-making, monitoring etc. So, both local and global models are required to be considered for a robot performance.

How AI Relates to Factory Automation



Deliberative:

- **Upper level is *mission generation* & *monitoring***
- **But World Modeling & Monitoring is hard (SA)**

- **Lower level is *selection* of behaviors to accomplish task (*implementation*) & local monitoring**

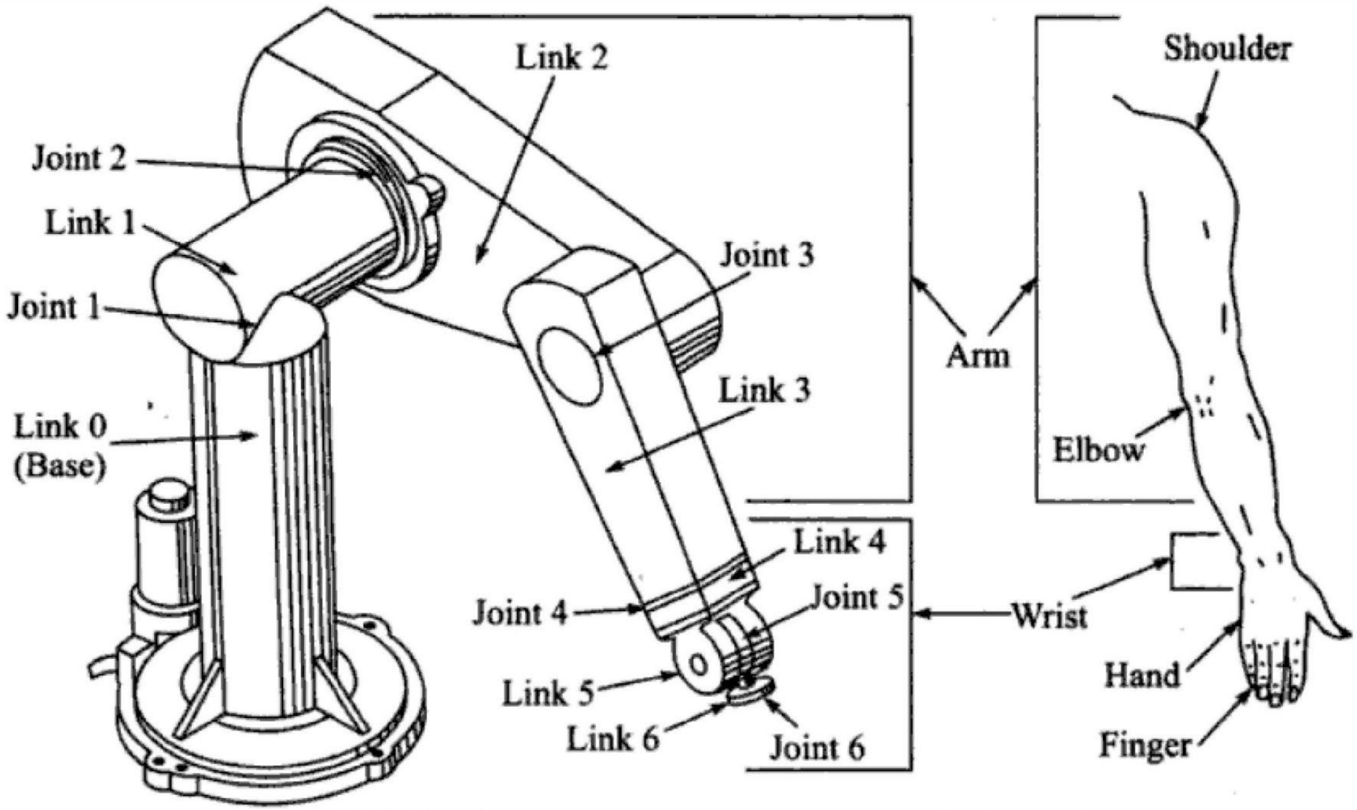
Reactive (fly by wire, inner loop control):

- **Many concurrent stimulus-response behaviors, strung together with simple scripting**
- **Action is generated by sensed or internal stimulus**
- **No awareness, no monitoring**
- **Models are of the vehicle, not the “larger” world**

Subsystems

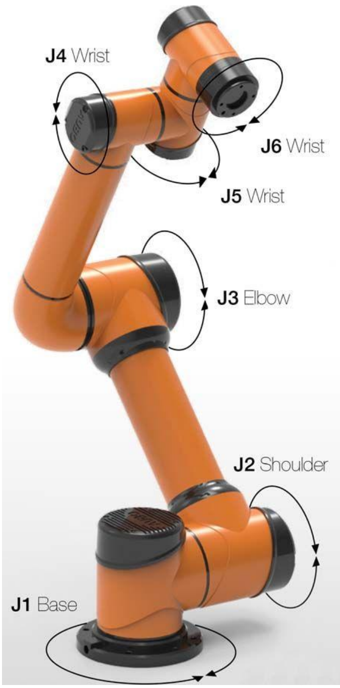
- **Motion**
  - Manipulator
  - End Effectors
  - Actuator
  - Transmission
    - Belt and Chain
    - Gears
    - Link Mechanism
- **Recognition**
  - Sensors
  - ADC
- **Control**
  - Digital Controller
  - DAC
  - Amplifier

Manipulator



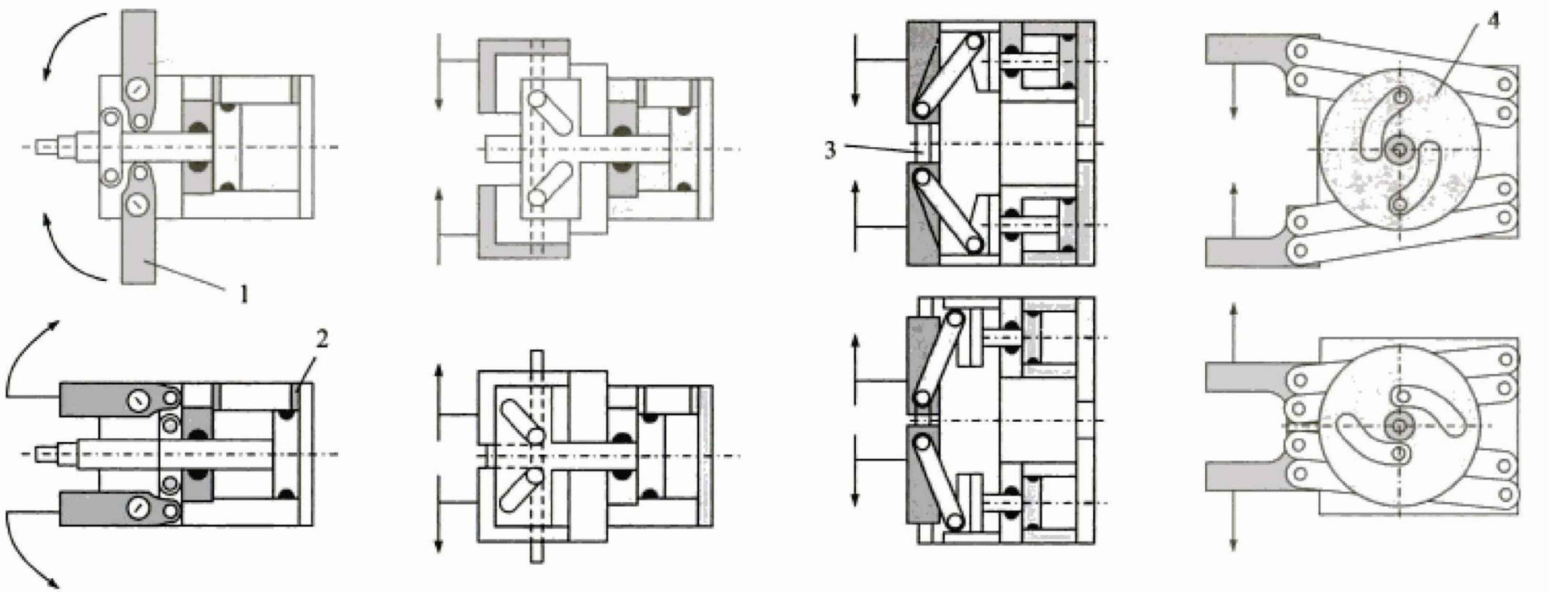
(a) PUMA robot (b) Equivalent human parts

Manipulator



Motion

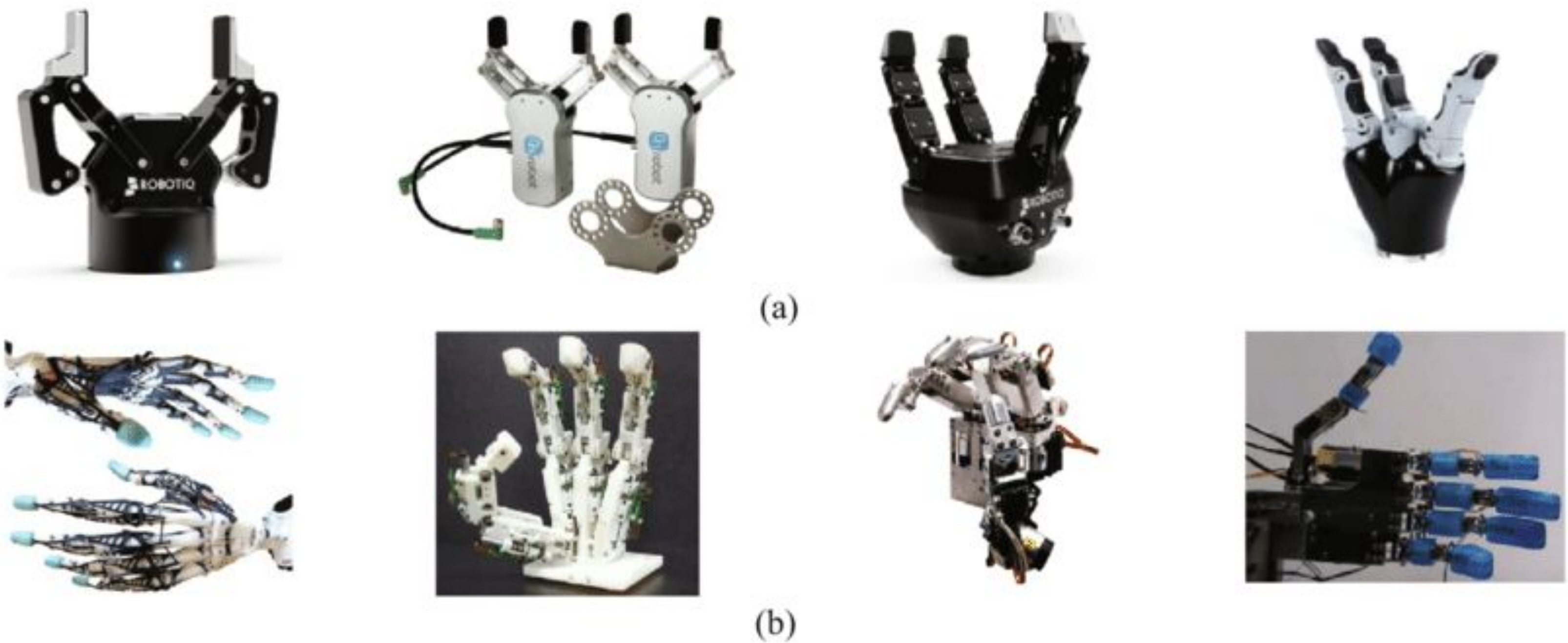
End-effector



(a) (b) (c) (d)

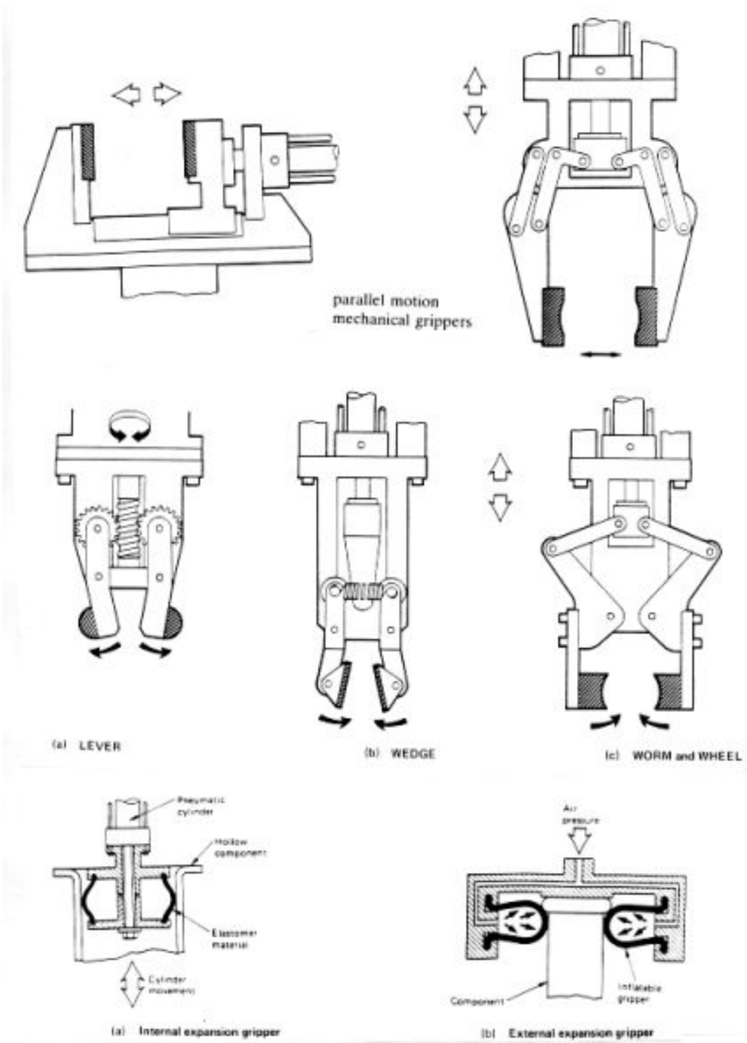
1: Big jaw or finger; 2: Pneumatic cylinder; 3: Straight guideway; 4: Cam disk

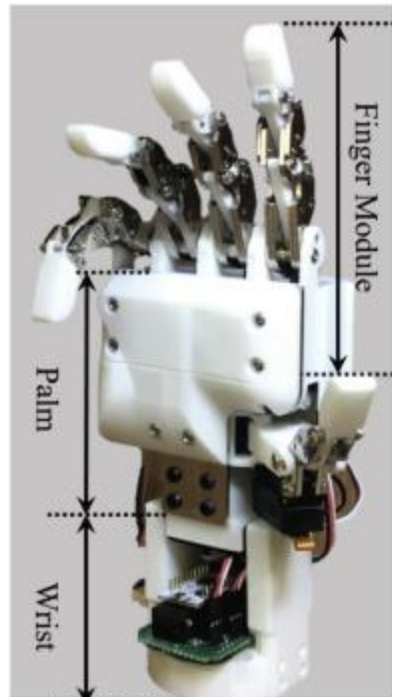
End Effector



Two types of fingered end-effectors: (a) gripper type, (b) anthropomorphic type

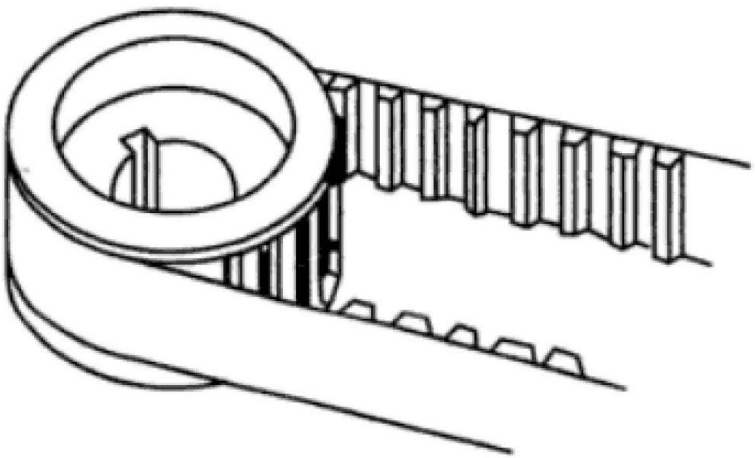
End Effector



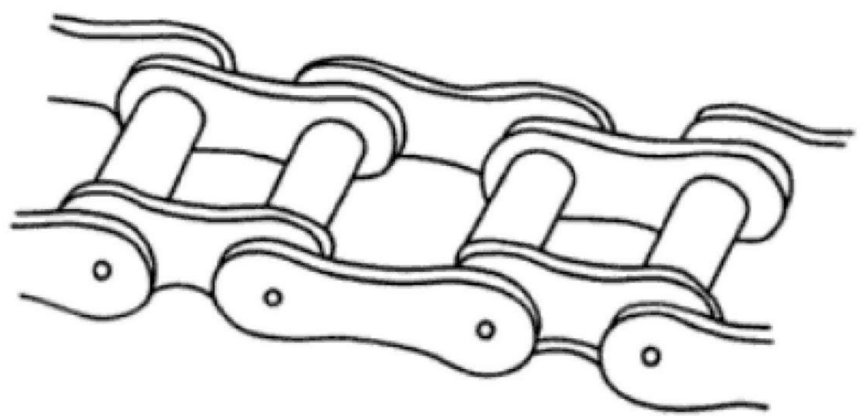


Transmission (Belt and chain)

Motion



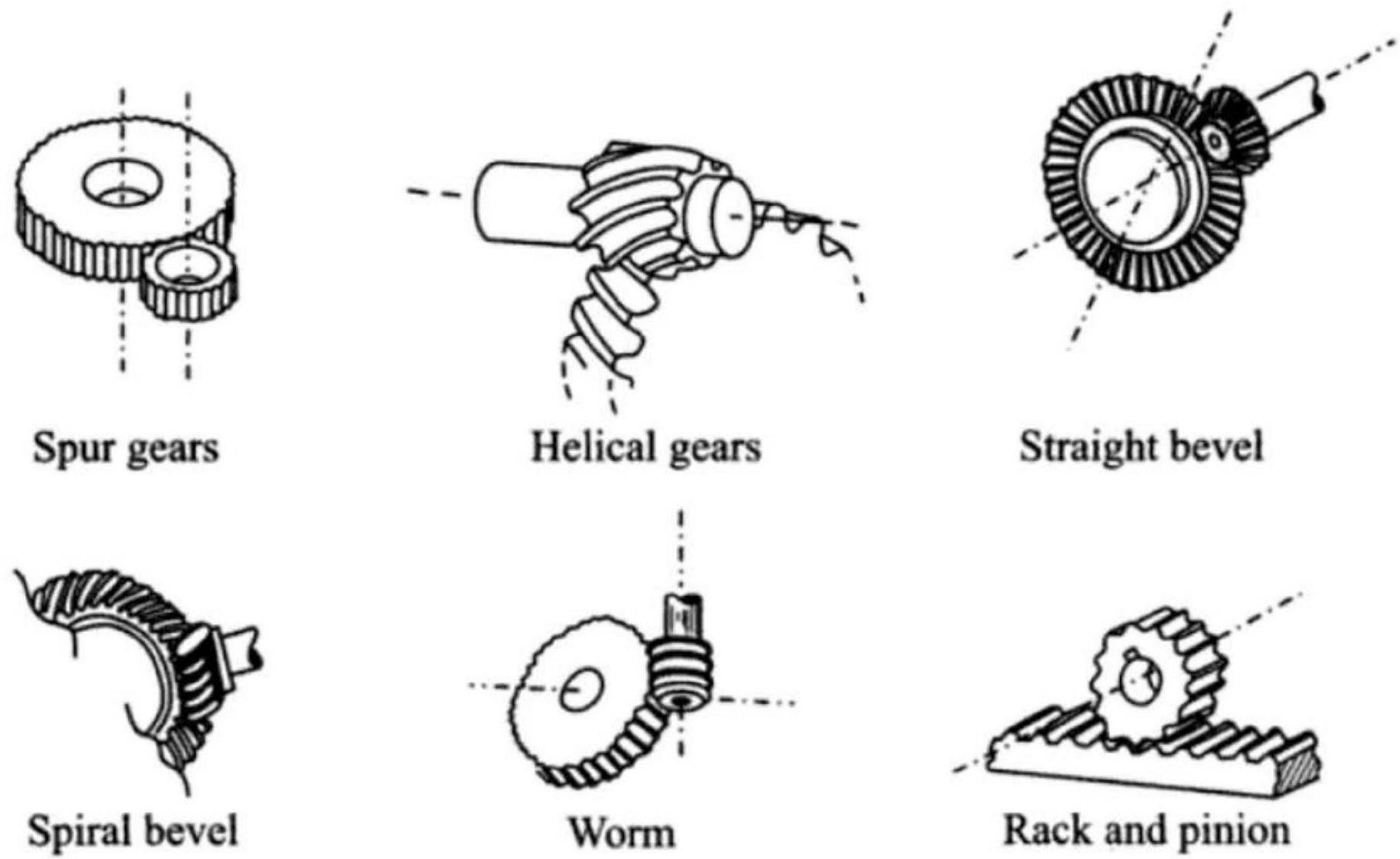
(a) Synchronous belt



(b) Roller chain

Motion

Transmission (Gears)



Transmission (Link Mechanism)

Motion

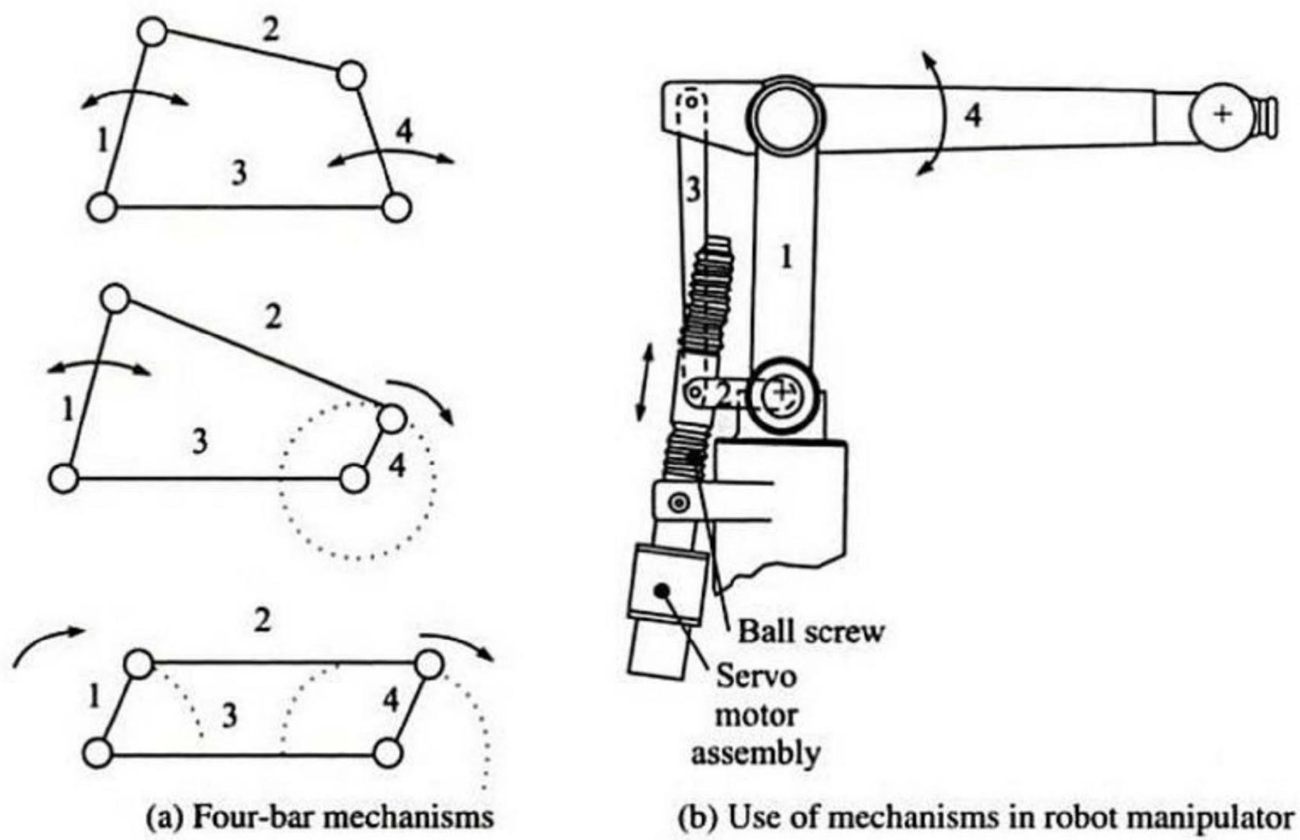
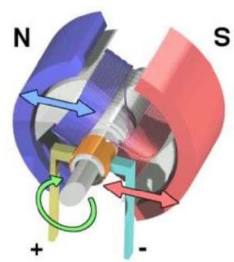
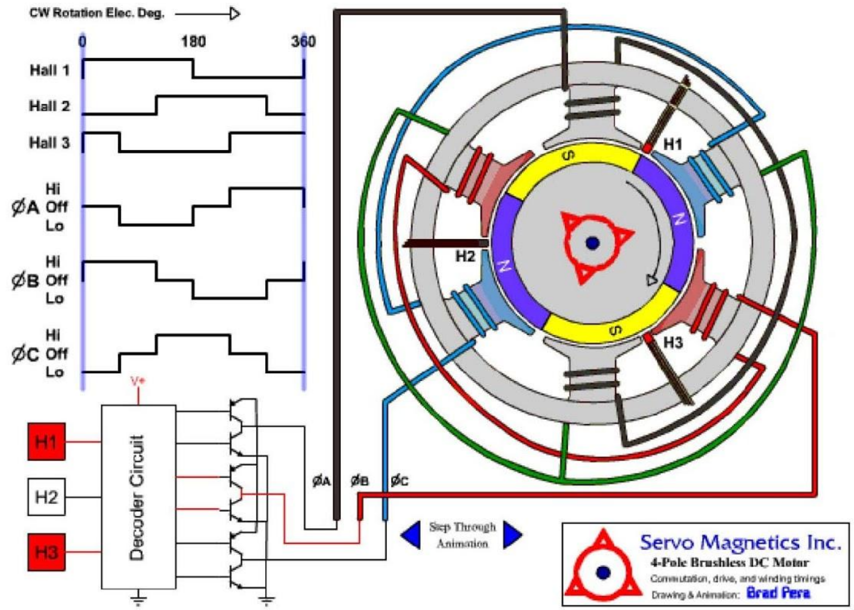


Fig. 2.7 Mechanisms and their use in robot manipulator

DC, Stepper, Servo, Induction Motor

Motion





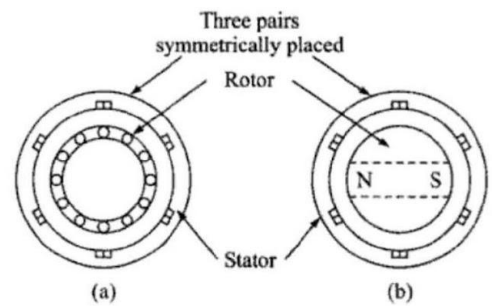
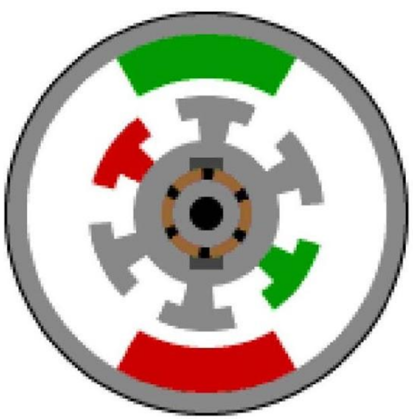


Fig. 3.13 AC three-phase motor



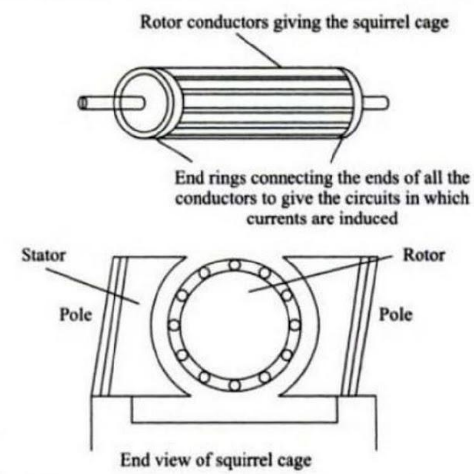


Fig. 3.12 Single-phase induction motor

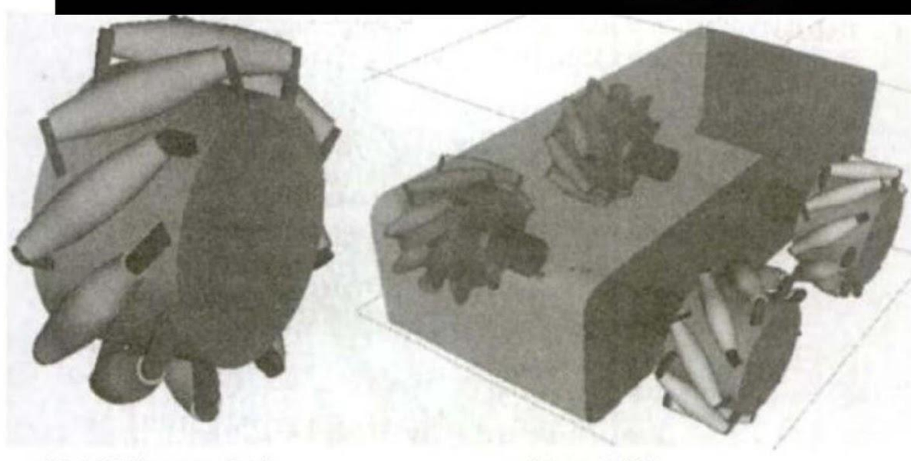
Actuators

Pneumatic Actuator

Hydraulic Actuator

Electric Actuator

AGV with Multi Directional Wheel



(a) A Mekanum wheel (b) An AGV

Fig. 1.5 An Automatic Guided Vehicle (AGV) with Mekanum wheels [Courtesy: Angeles (2003)]

LEGO: MINDSTROM

Subsystems

- **Motion**
  - Manipulator
  - End Effectors
  - Actuator
  - Transmission
    - Belt and Chain
    - Gears
    - Link Mechanism
- **Recognition**
  - Sensors
  - ADC
- **Control**
  - Digital Controller
  - DAC
  - Amplifier

Recognition

Sensors

Sensor Examples

Recognition

Physical Property	Sensor
contact	switch
distance	ultrasound, radar, infrared
light level	photocells, cameras
sound level	microphone
rotation	encoders and potentiometers
acceleration	accelerometers gyroscopes

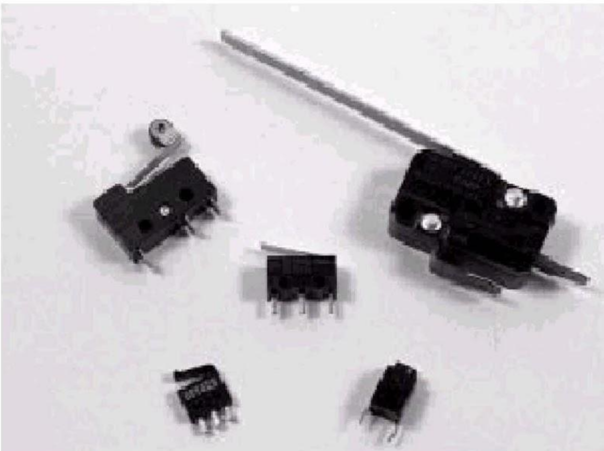
More Sensor Examples

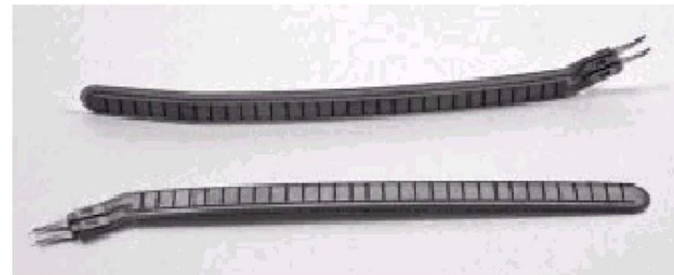
Recognition

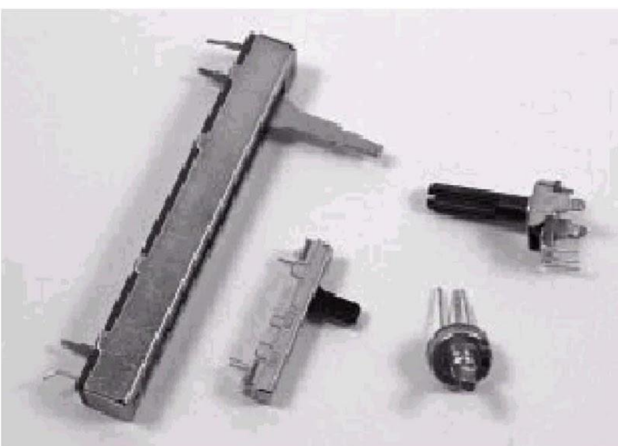
Physical Property	Sensor
magnetism	compass
smell	chemical
temperature	thermal, infra red
inclination	inclinometers, gyroscopes
pressure	pressure gauges
altitude	altimeters
strain	strain gauges

Recognition

Passive Sensor

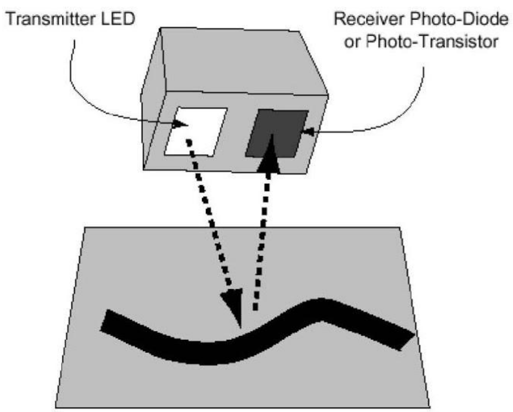


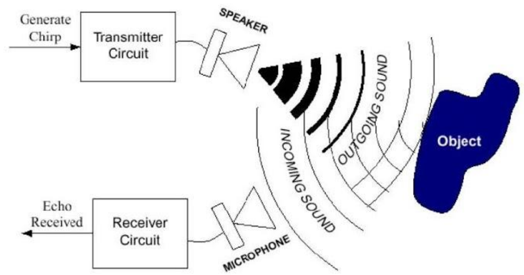


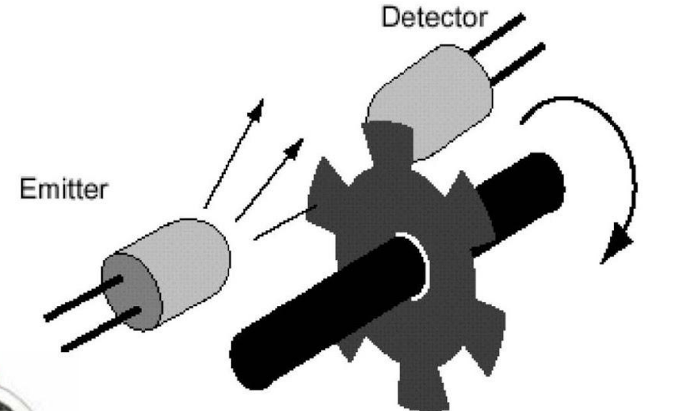


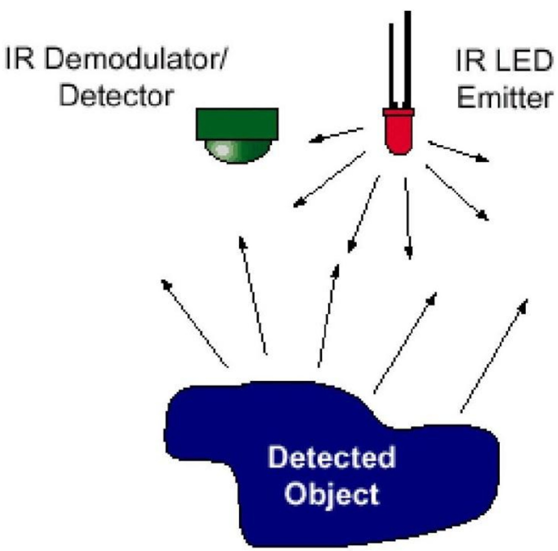
Recognition

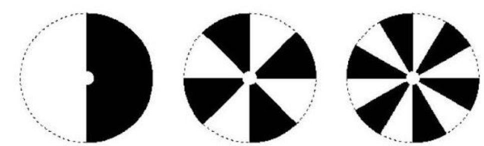
Active Sensors

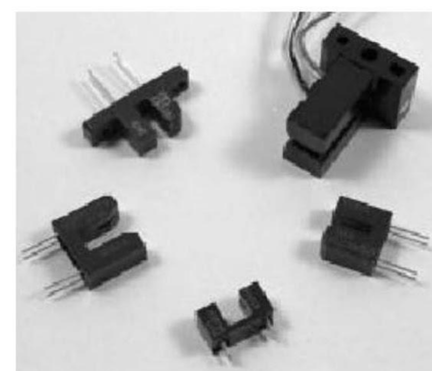






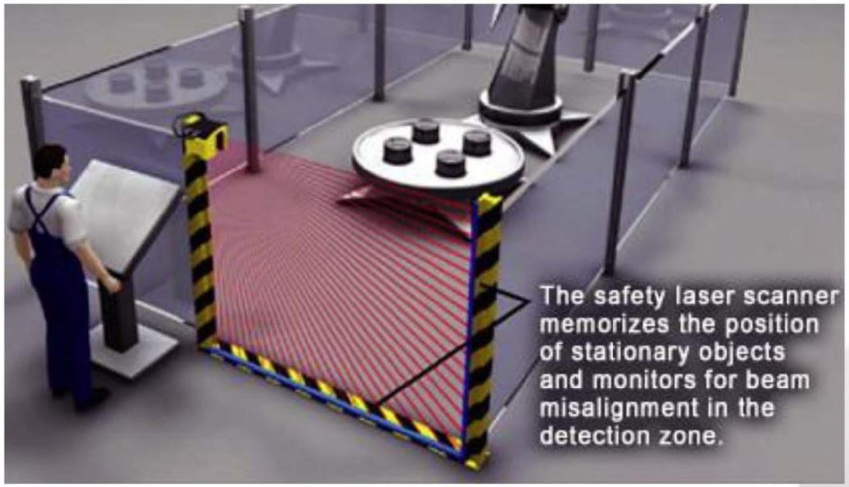


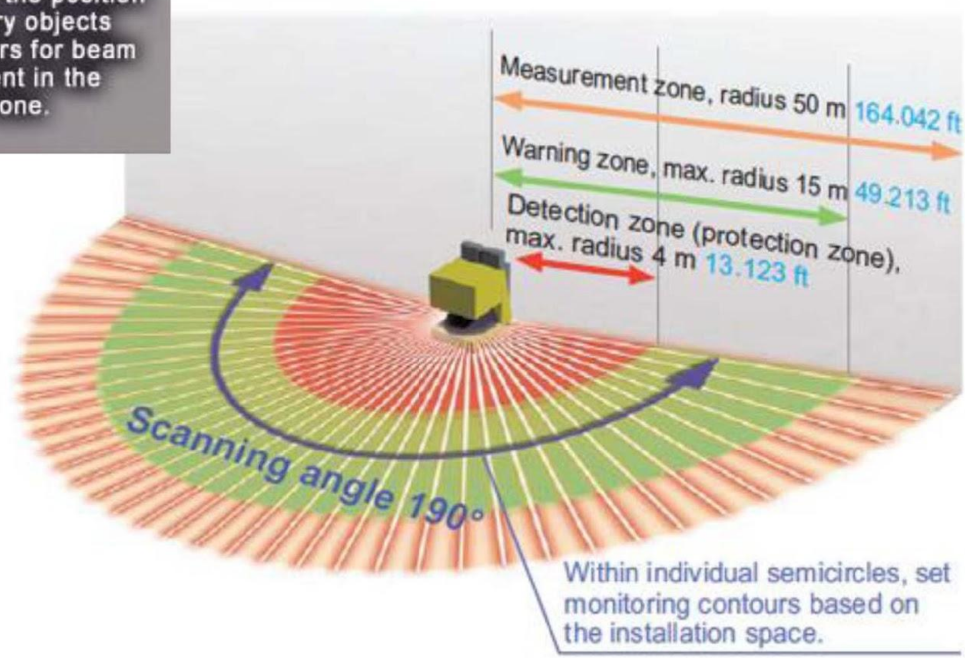




Recognition

Laser Scanner



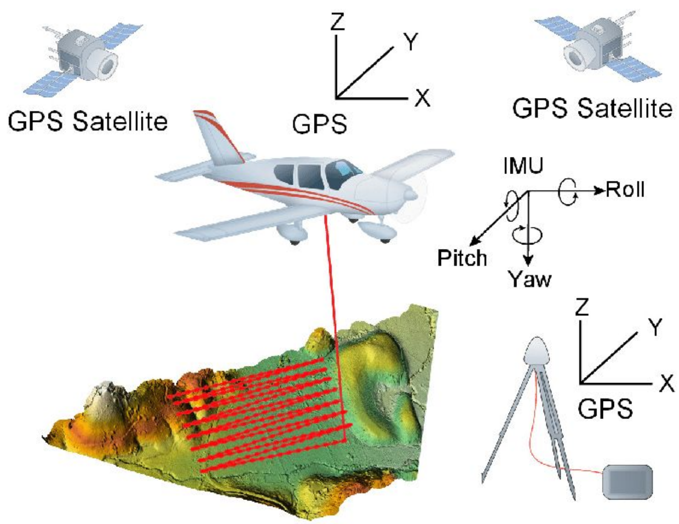


Detection zone: Instantly stops the machine upon intrusion (control output)

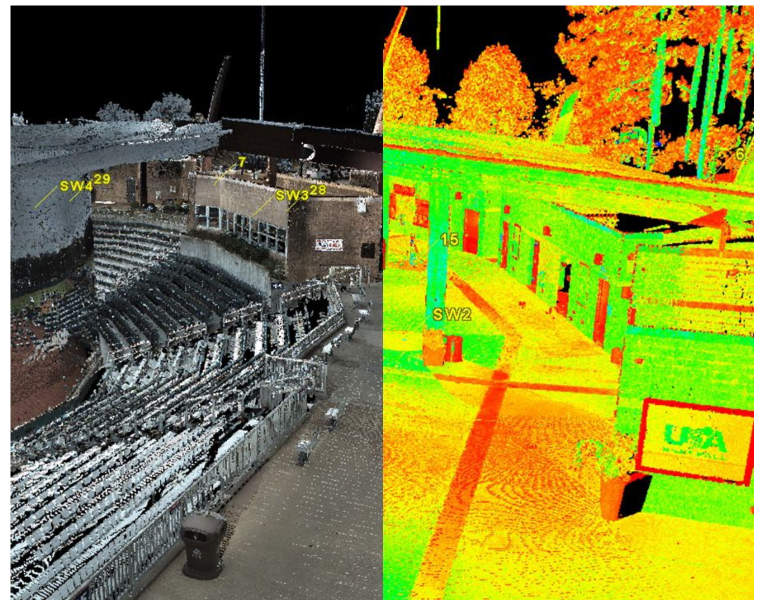
Warning zone: Releases warning upon intrusion (warning output)

LIDAR

Airborne LiDAR



Terrestrial LiDAR



Emotiv Electroencephalography (EEG) Headset

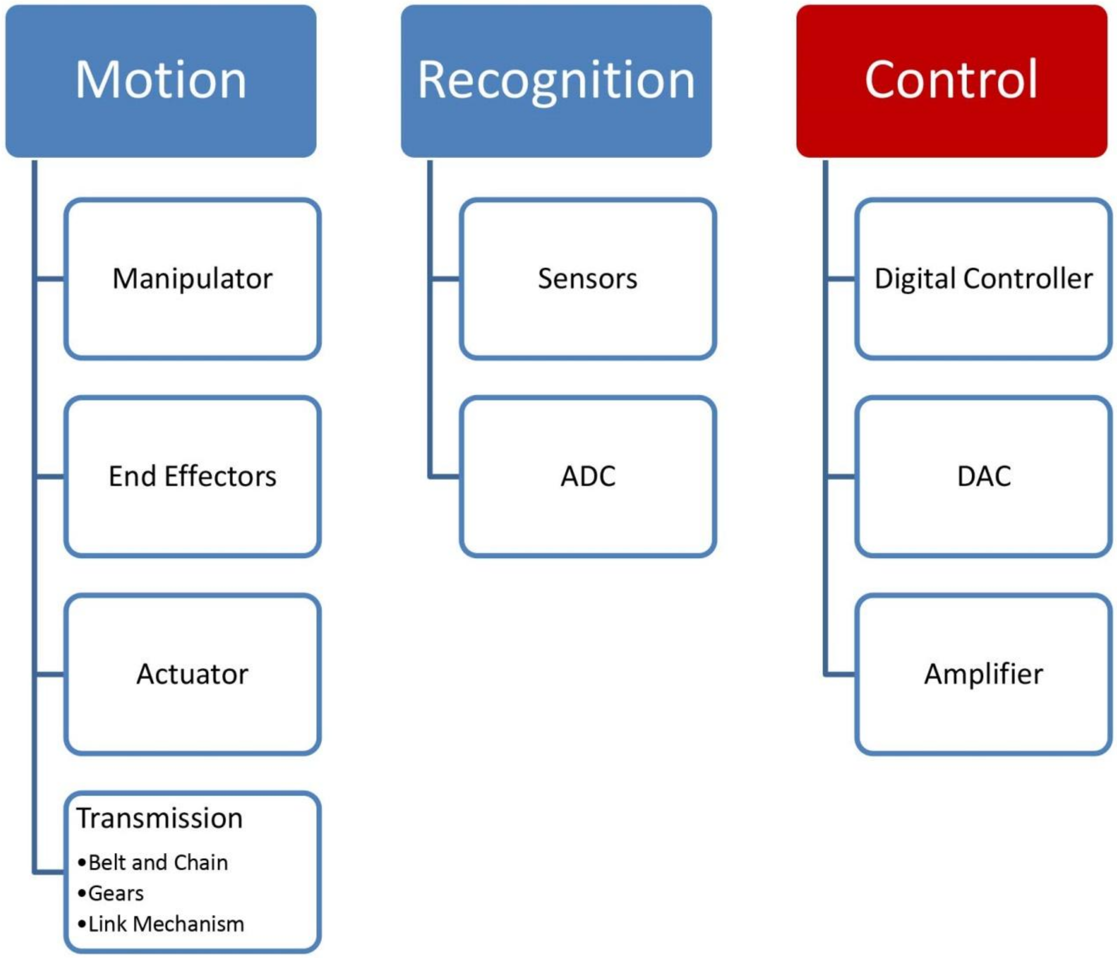
emotiv
you think, therefore, you can

LEAP Motion Sensor

MYO

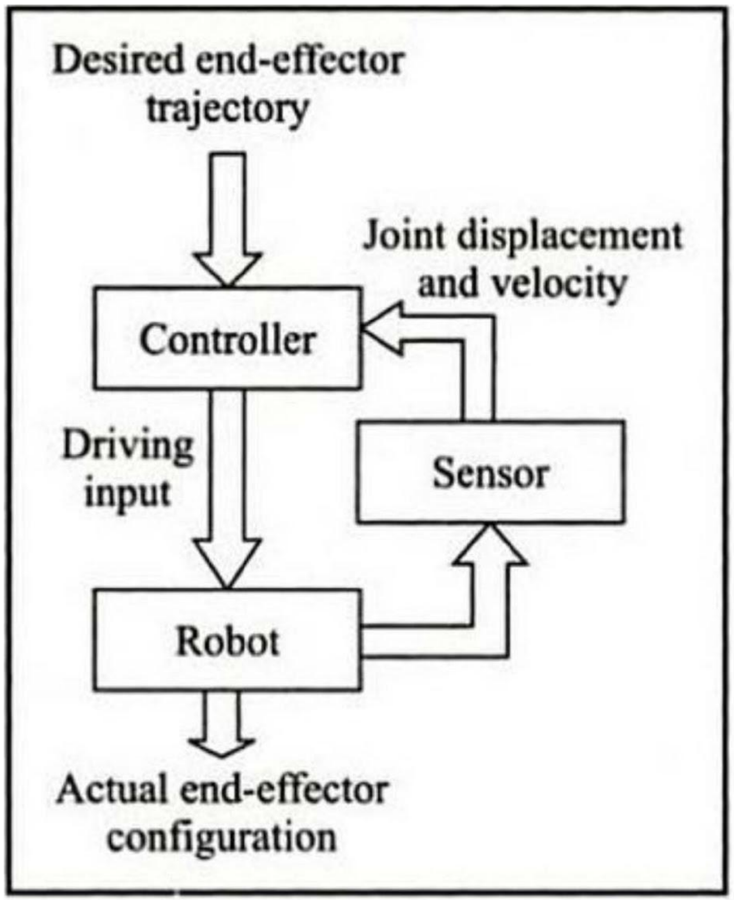

MYO
Unleash your inner Jedi
Image hosted by WittySparks.com

Subsystems



Motion
Manipulator
End Effectors
Actuator
Transmission
•Belt and Chain
•Gears
•Link Mechanism
Recognition
Sensors
ADC
Control
Digital Controller
DAC
Amplifier

Control Software



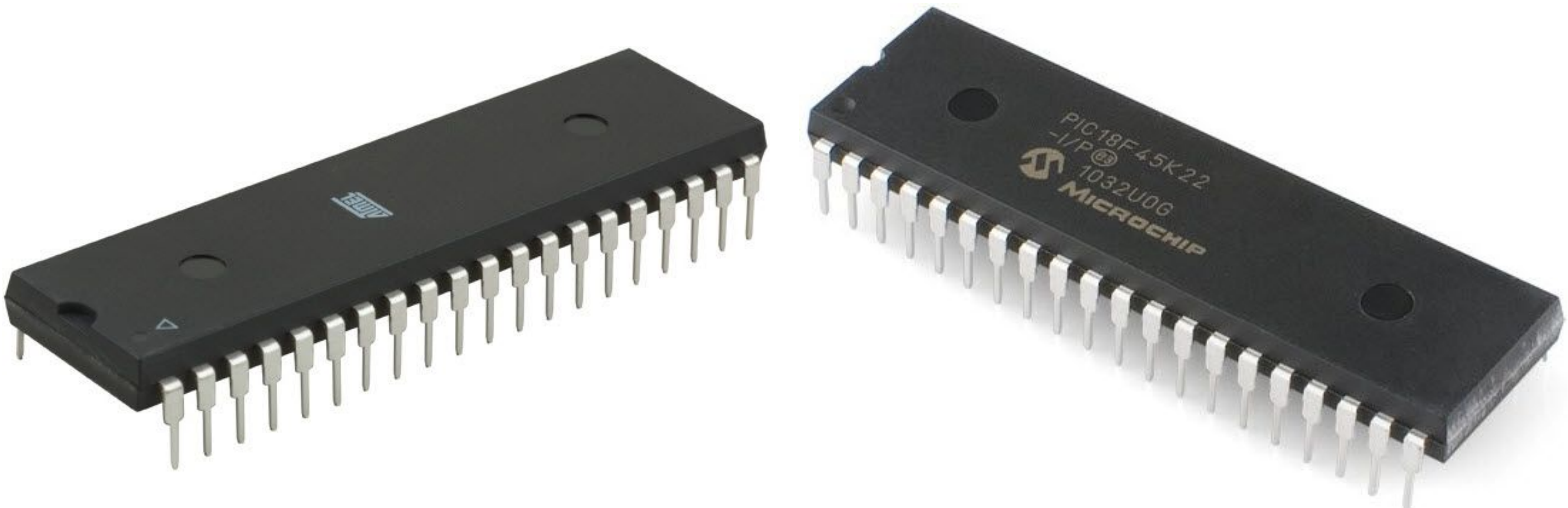
(a) Control scheme of a robot

- Robot Vision
- PID control
- Trajectory/Motion Planning
- Localization
- Manipulator Control
- UAV Navigation
- Sensors calibration and sensor fusion
- Kinematics and dynamics
- Interfacing
- Communication

Control Hardware

- Microcontrollers
- Arduino
- PLC
- FPGA
- Single Board Computer
- Portable PCs
- Cloud Computing System

Microcontrollers



Arduino

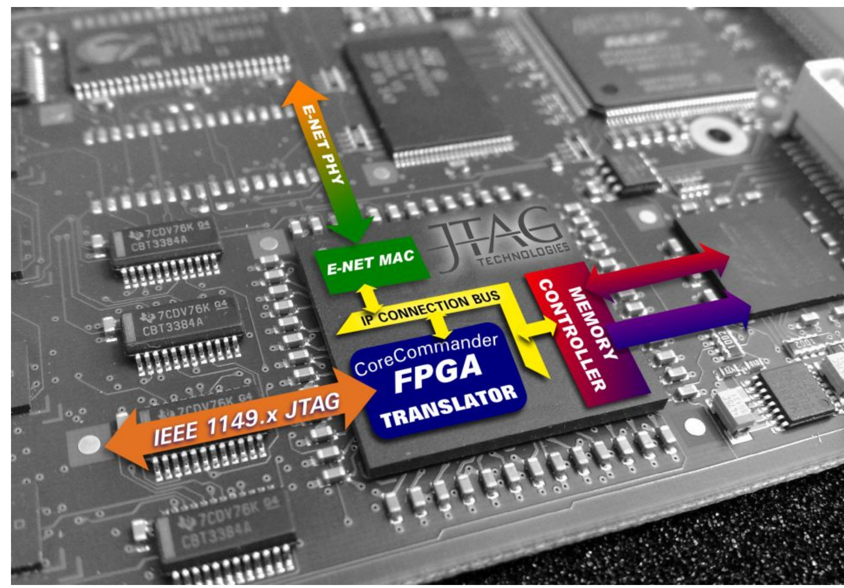

ARDUINO.CC
COMMUNICATION
MEGA
ARDUINO
2560
POWER
ANALOG IN
DIGITAL

Arduino

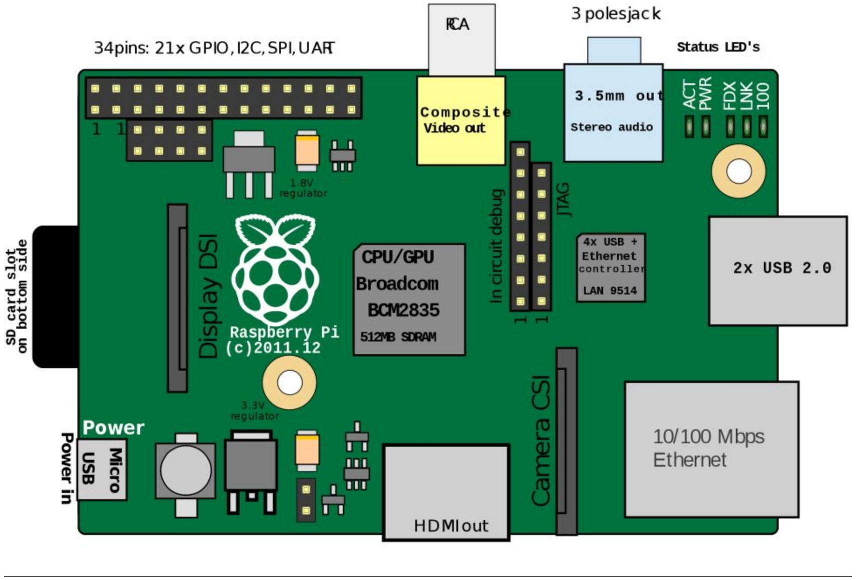

Arduino Uno
Arduino Leonardo
Arduino Mega 2560
Arduino LilyPad
Arduino Mega ADK
Arduino Fio
Arduino Ethernet
Arduino Pro
Arduino BT
Arduino Nano
Arduino Mini
Arduino Pro Mini

Programmable Logic Controller (PLC)

Field-Programmable Gate Array (FPGA)

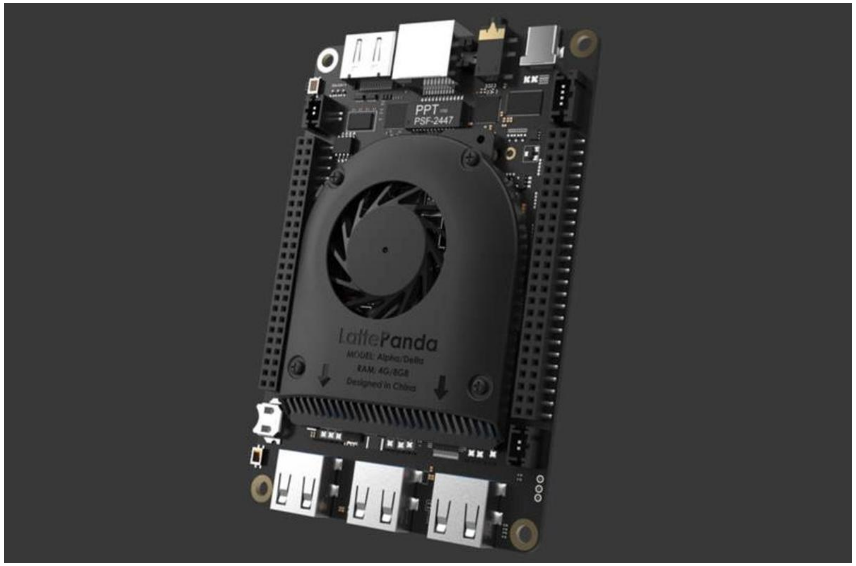


Single board Computer



Raspberry PI 4, Tinkerboard

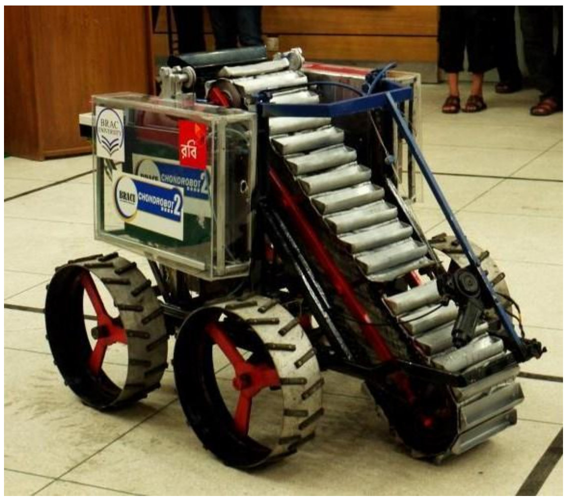
Little Panda and Jetson nano

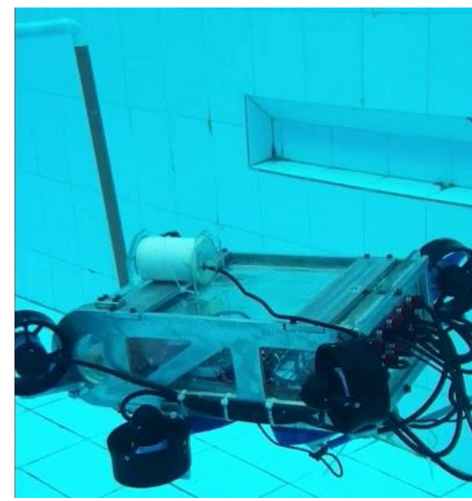


Intel Nuc and BRIX

Cloud Computing Infrastructure

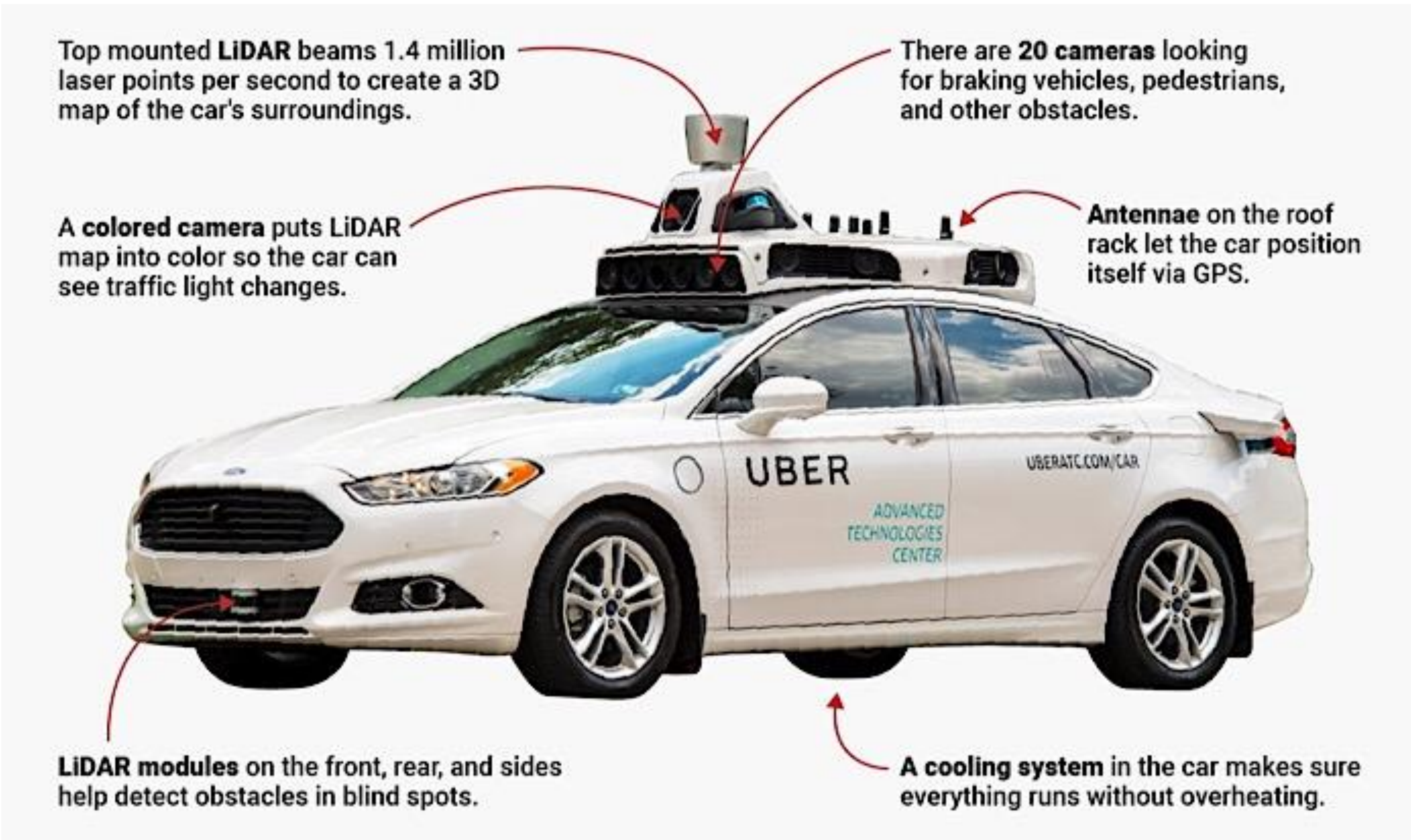
Projects we can proud of



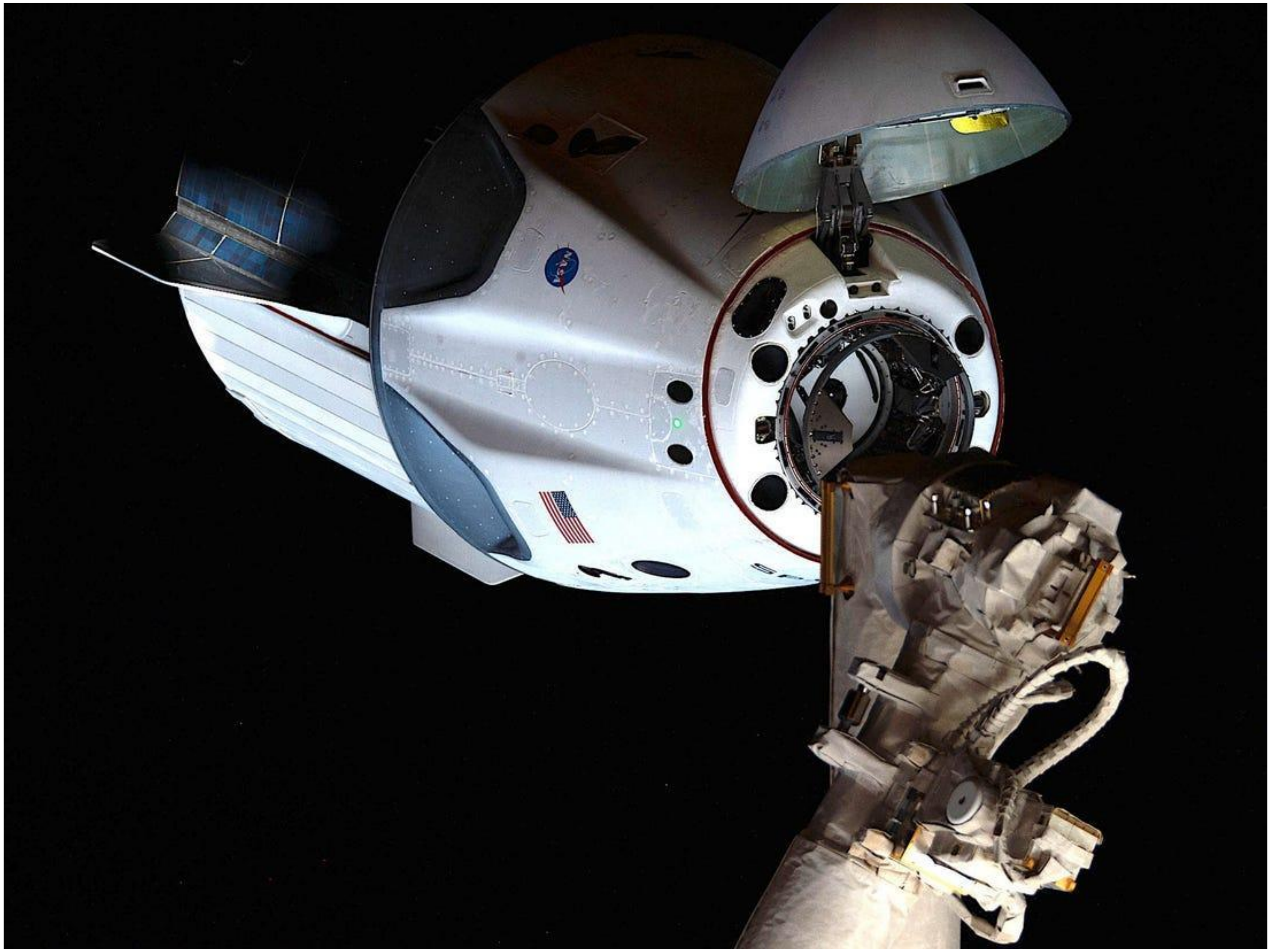


BRAC ONNESHA

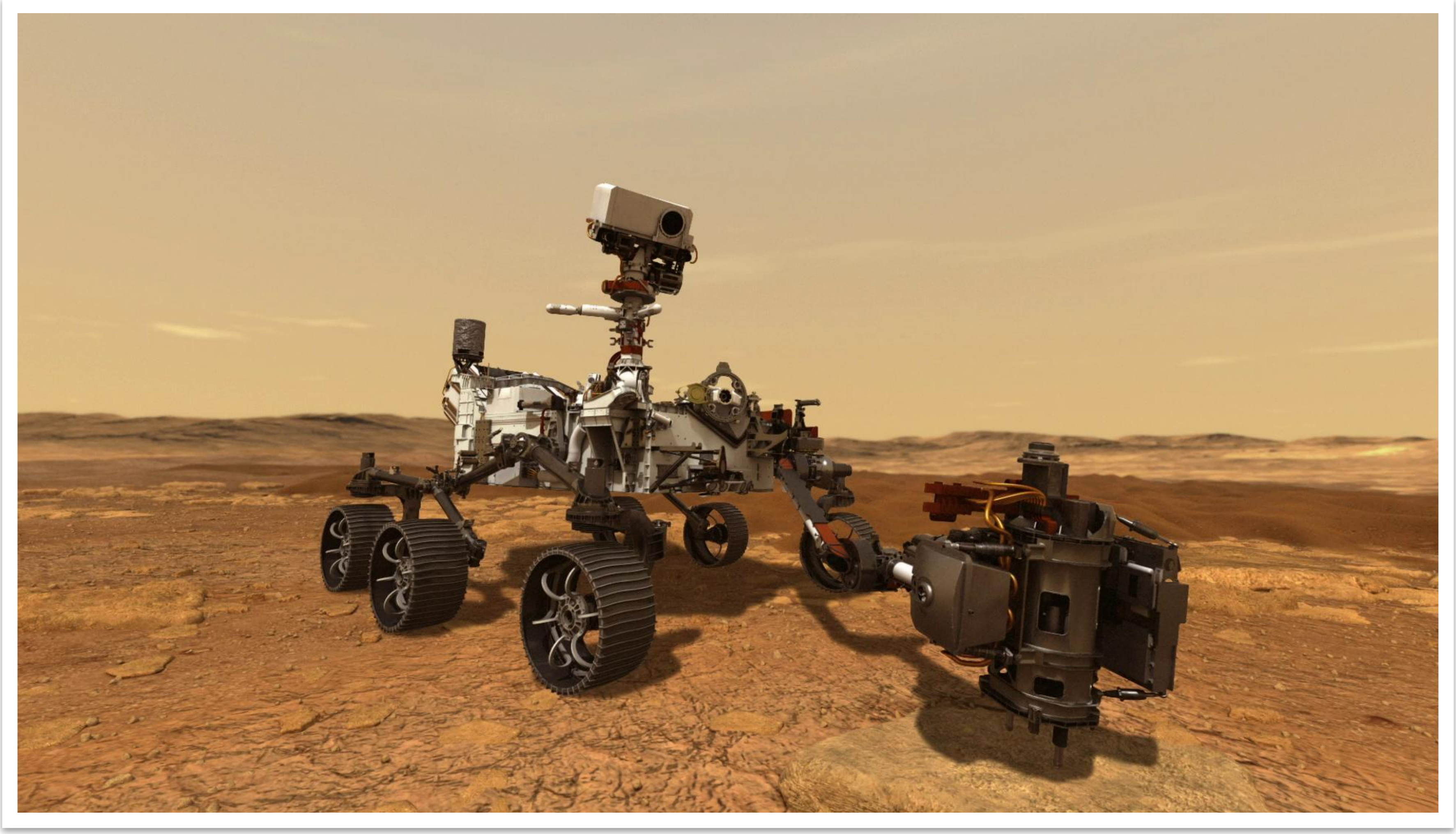
Self-Driving Car



Autonomous Docking

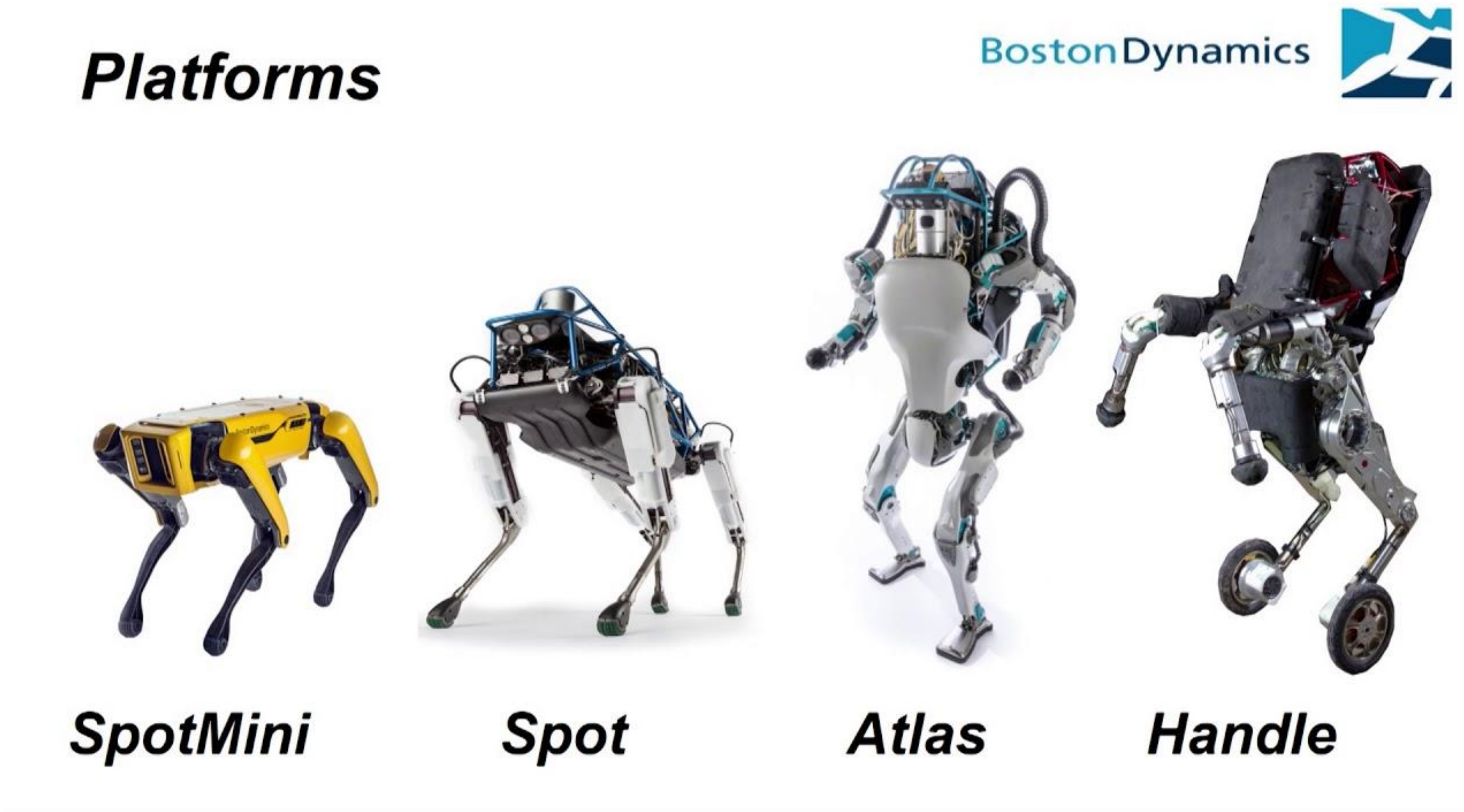


Perseverance Mars Rover



Roomba

Boston Dynamics



The da Vinci Robotic Surgical System