

Introduction to Robotics

CSE461

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Course outline

- | | | | | |
|---|--|---|--|-----------------------------|
| 1 | Introduction to Robotics: (Week-1, 2) | 4 | Robot Vision and Perception: (Week-7, 8) | |
| | 1.1 Introduction | | 4.1 Image Processing | |
| | 1.2 Laws | | 4.2 Vision Sensors and modules | |
| | 1.3 Types of robots | | 4.3 LIDAR | |
| | 1.4 Application of robotics | | 5 | AI in Robotics: (Week-8, 9) |
| | 1.5 Robot Subsystem Components | | 5.1 Introduction to CNN | |
| | 1.6 Recent trends | | 5.2 Reinforcement Learning | |
| | 1.7 ROS | | 5.3 Robot Path Planning | |
| 2 | Mechanical Design of Robots: (Week-3, 4) | 6 | Robot Communication: (Week-10, 11) | |
| | 2.1 Review on Linear algebra and | | 6.1 Wireless, Bluetooth, RF | |
| | 2.2 Mechanics, kinematics and dynamics | | 6.2 GSM, GPRS | |
| | 2.3 Robot Arm Kinematics | | 6.3 5G | |
| | 2.4 Mobile Robot Vehicles | | 6.4 IOT | |
| | 2.5 Gear, Screw, Differential | 7 | Robot Case Study: (Week-12, 13) | |
| 3 | Control System of Robots: (Week-5, 6) | | 7.1 AUV and UGV: Duburi and ChandraBot | |
| | 3.1 PID control | | 7.2 Humanoid Robot: Asimo and Sophia | |
| | 3.2 Trajectory/Motion Planning | | 7.3 Interplanetary Robot: Perseverance and | |
| | 3.3 Localization | | Mongol-tori | |
| | 3.4 Manipulator Control | | | |
| | 3.5 Different types of Motor Control | | | |
| | 3.6 Navigation | | | |

Reference Books

- Robotics, Vision and Control: Fundamental Algorithms in MATLAB
 - by Peter Corke
- Modern Robotics: Mechanics, Planning, and Control
 - by Frank C. Park and Kevin M. Lynch

Project

- Design and Implement a Robot
 - Processing should be done on Raspberry PI or Jetson Nano or Laptop or Desktop preferably using ROS
 - Micro-controller and Arduino can be used as an interfacing
 - At least 3 Sensors including a camera and 3 Motor Action should be included in your Robot.
- Upload CAD design, Control algorithm and code to Github
- Upload Video Demonstration on Youtube
- Report writing in technical paper format

Marks Distribution

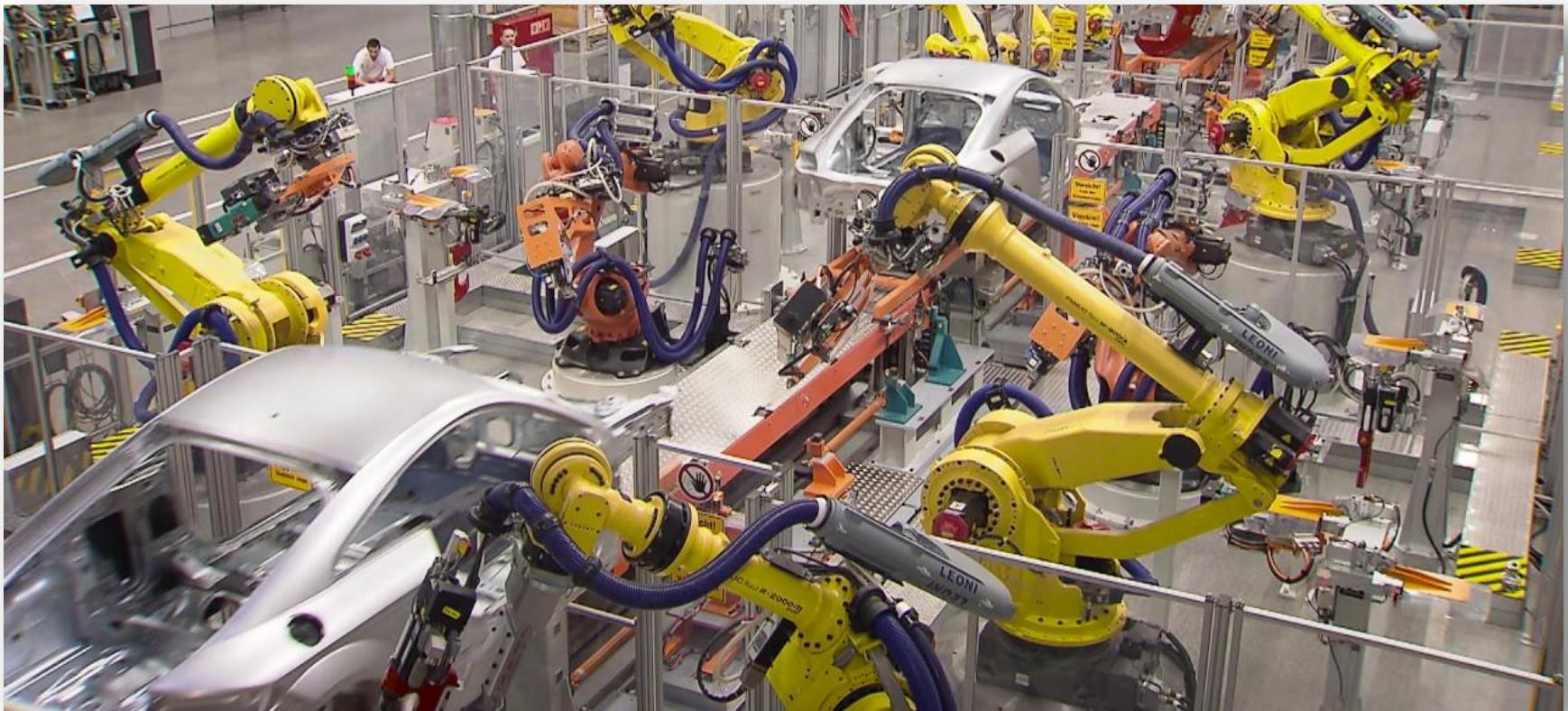
- **Quiz: 15%**
- **Assignments: 10%**
- **Lab performance: 10%**
- **Project: 15%**
- **Midterm: 20 %**
- **Final: 30%**
- **Total: 100**

Objective of Robotics

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

4th Industrial Revolution

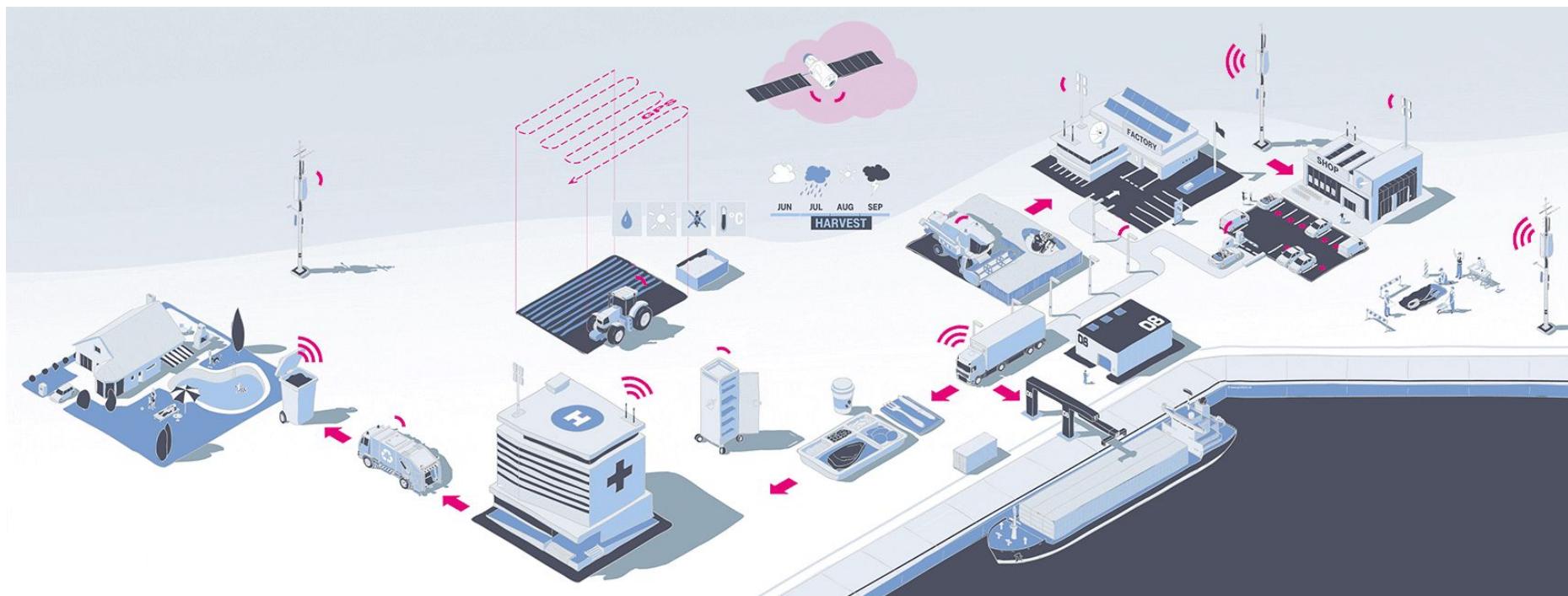
Industry Automation



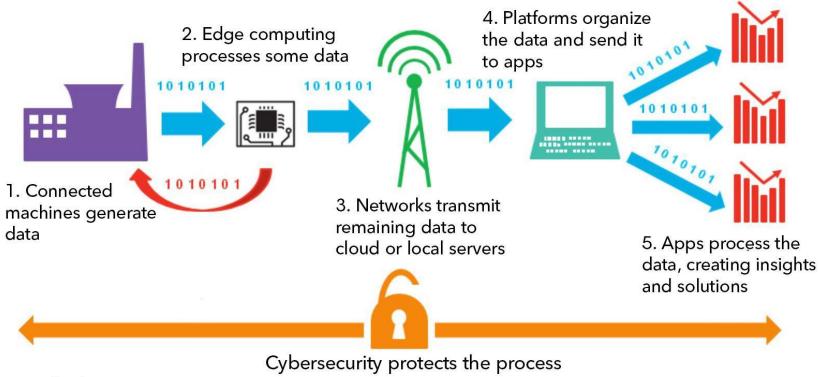


<https://www.youtube.com/watch?v=HX6M4QunVmA>

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



IoT+Cloud+Blockchain



Before 2005



Closed and centralized IoT networks

Today



Open access IoT networks,
centralized cloud

2025 and beyond

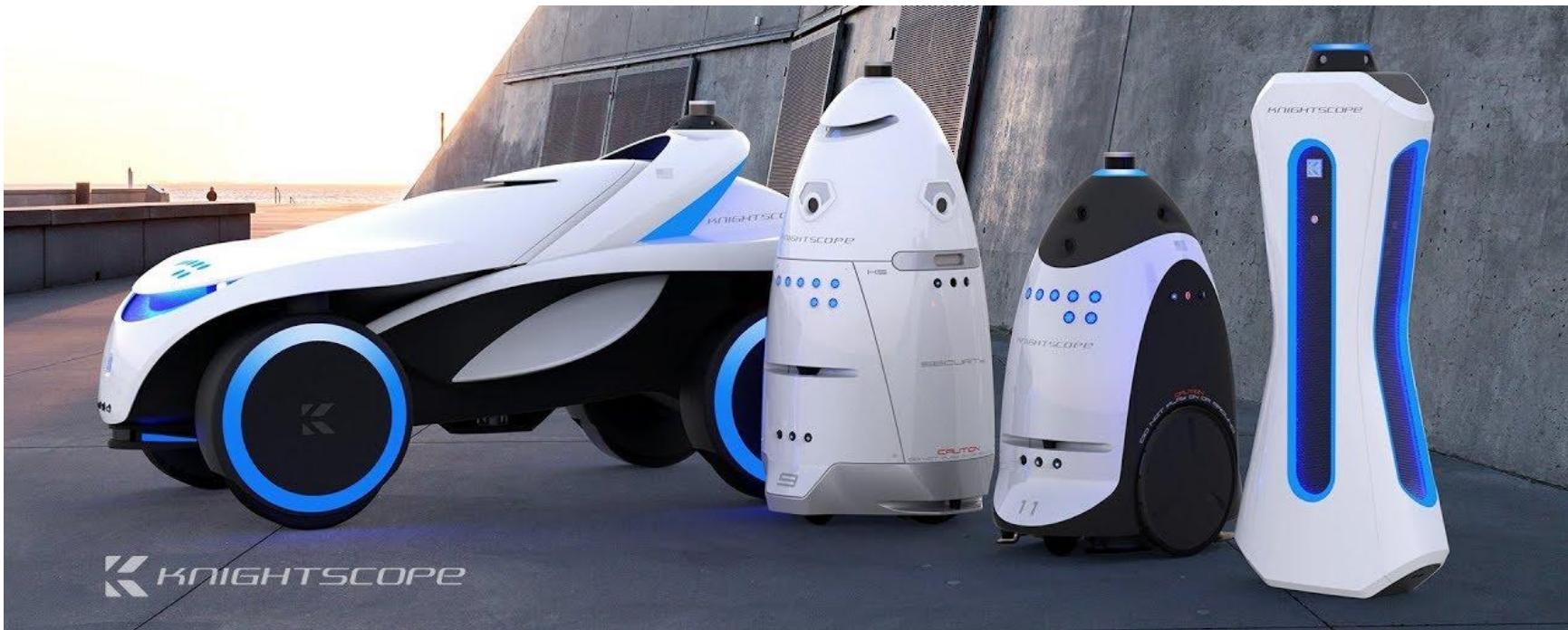


Open access IoT networks,
distributed cloud

By Fusion of technologies...



Application specific Robot



 KNIGHTSCOPE

Application specific Robot

Aibo

JIBO

Cozmo

Kirobo Mini

KUBO

Georgia Tech

Rovables

NAO Humanoid

Pepper

Moley

Rtoz.org

Top 10 Family Robots

Application specific Robot



Application specific Robot



the
coolest
medical
robots
in sci-fi

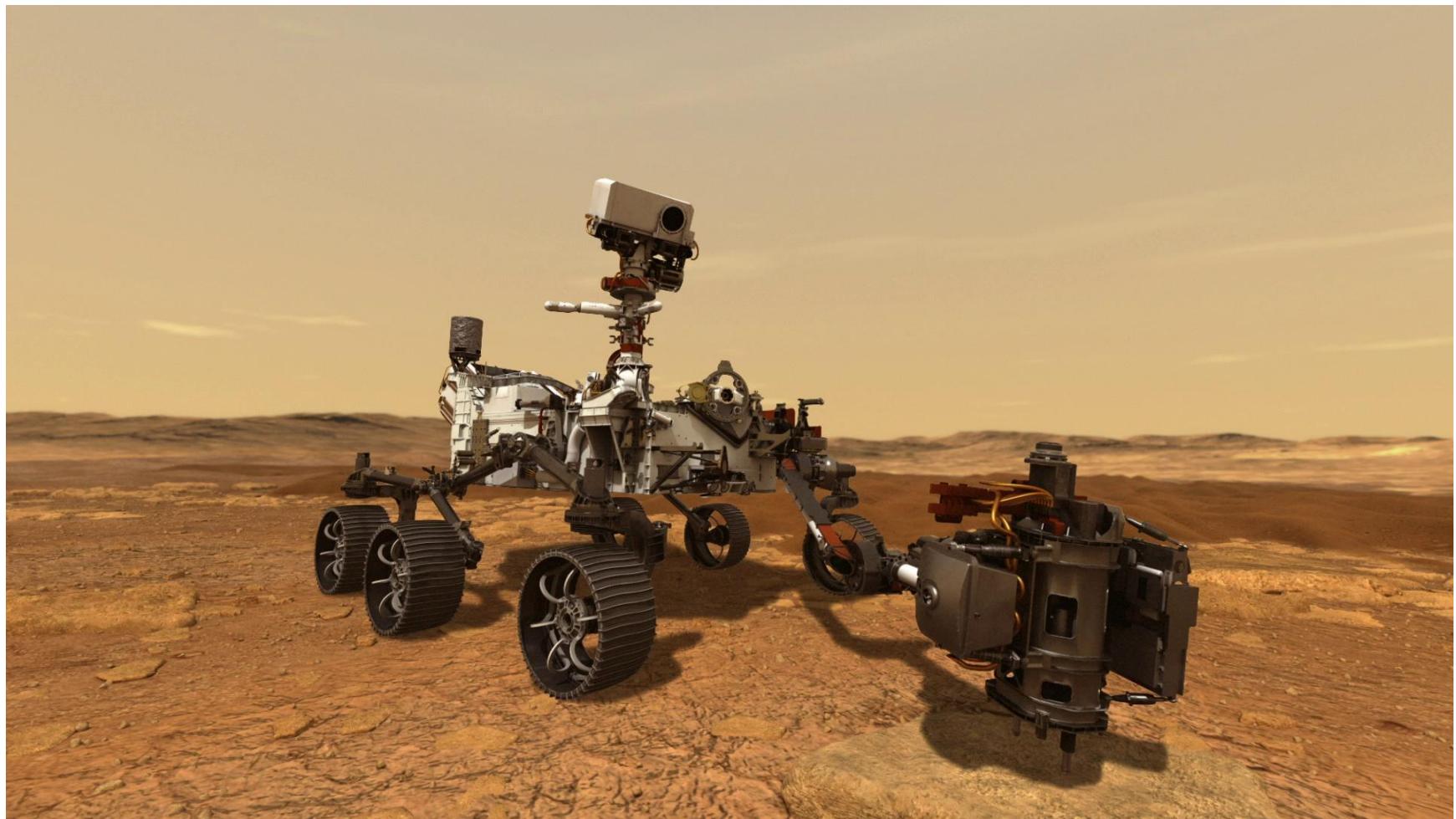
Application specific Robot



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



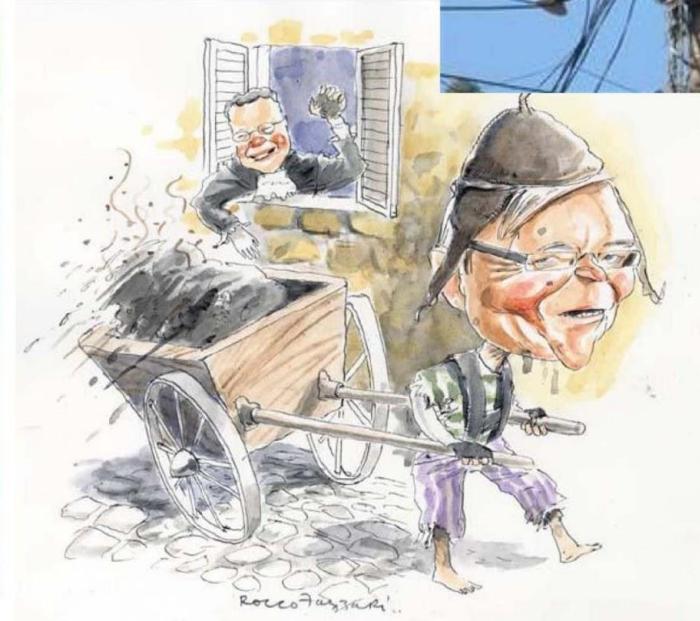
- Fukushima
- World Trade center
- RANA Complex
- Tajrin fashion



Dull, Dirty, difficult and Dangerous



Dull, Dirty, difficult and Dangerous



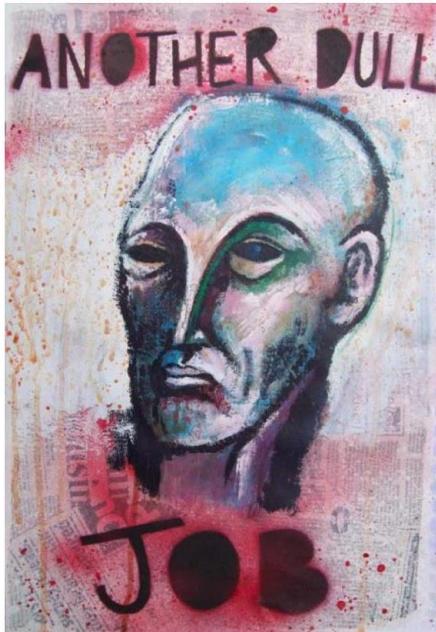
Dull, Dirty, difficult and Dangerous



Dull, Dirty, difficult and Dangerous



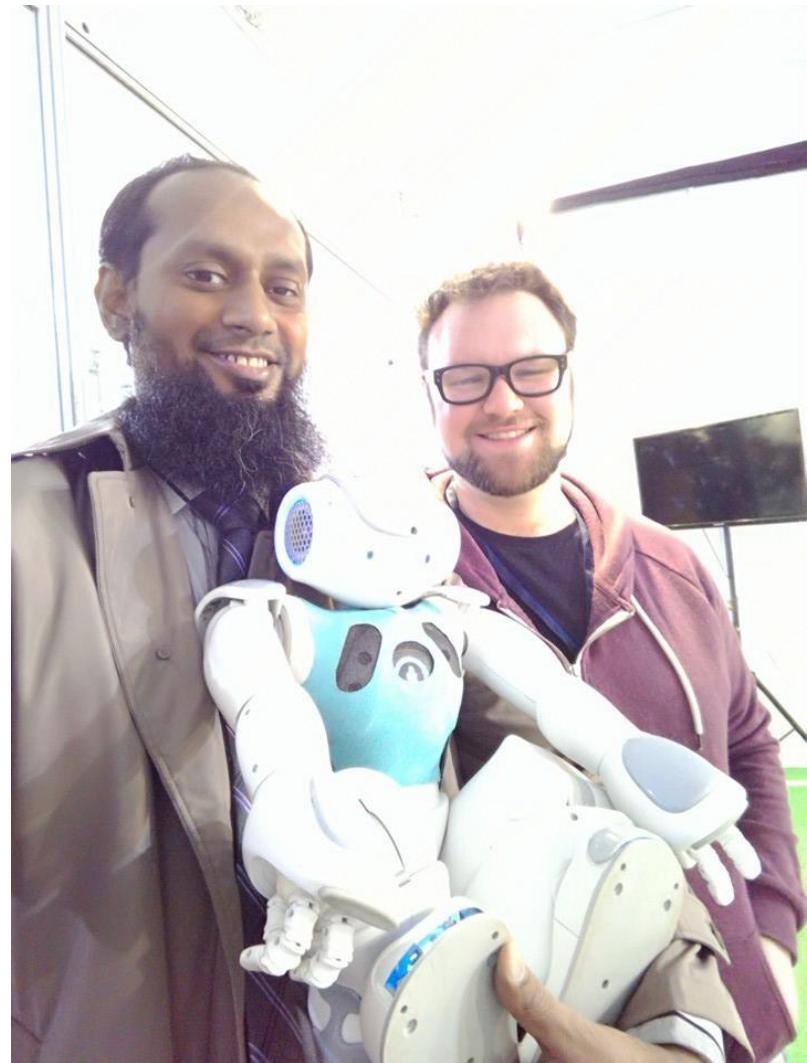
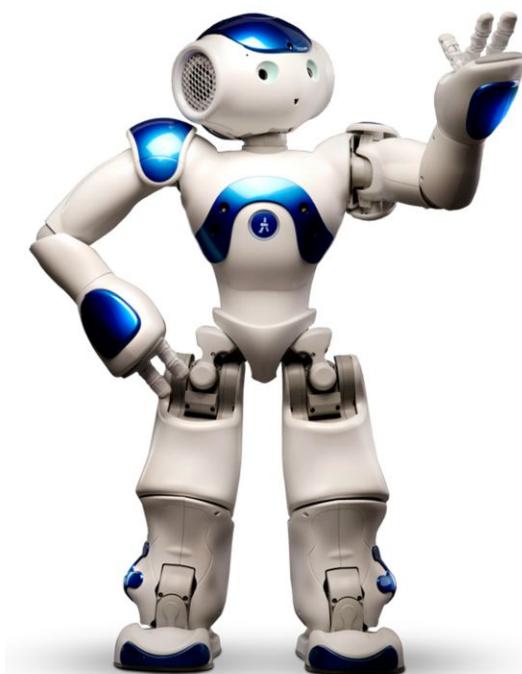
Dull, Dirty, difficult and Dangerous



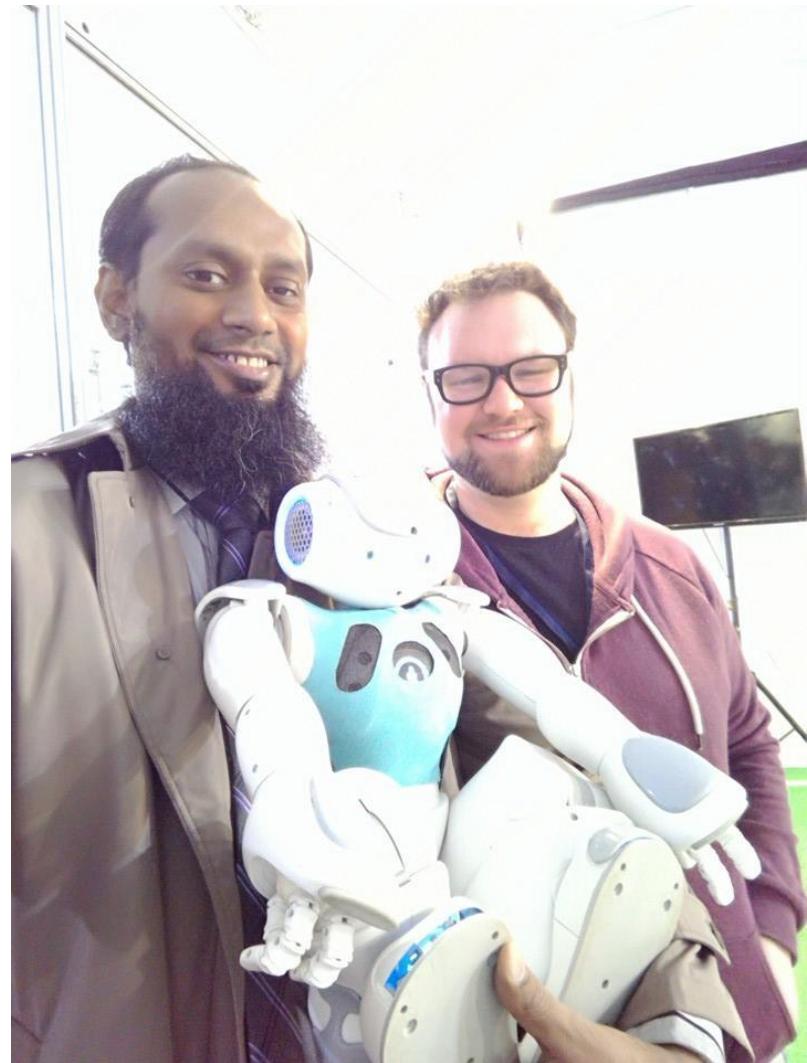
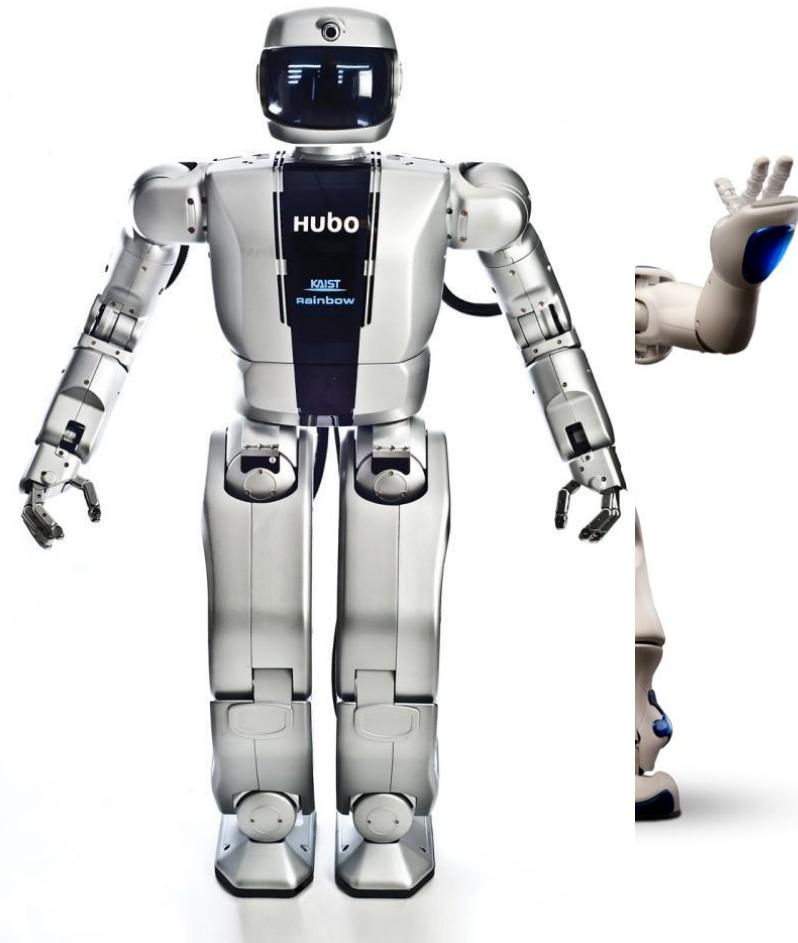
Why Superhuman?

- 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

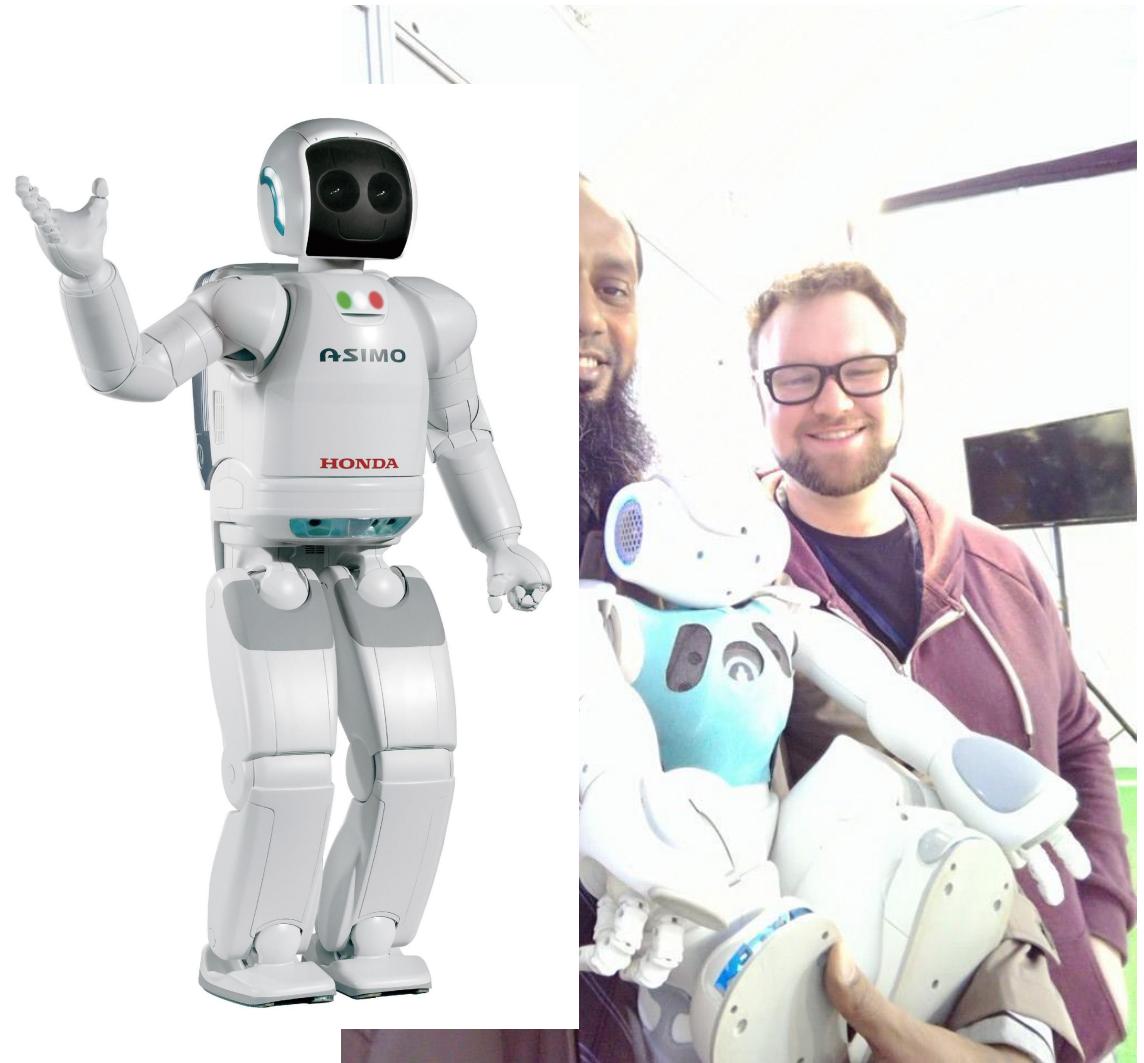
Popular Humanoid Robot



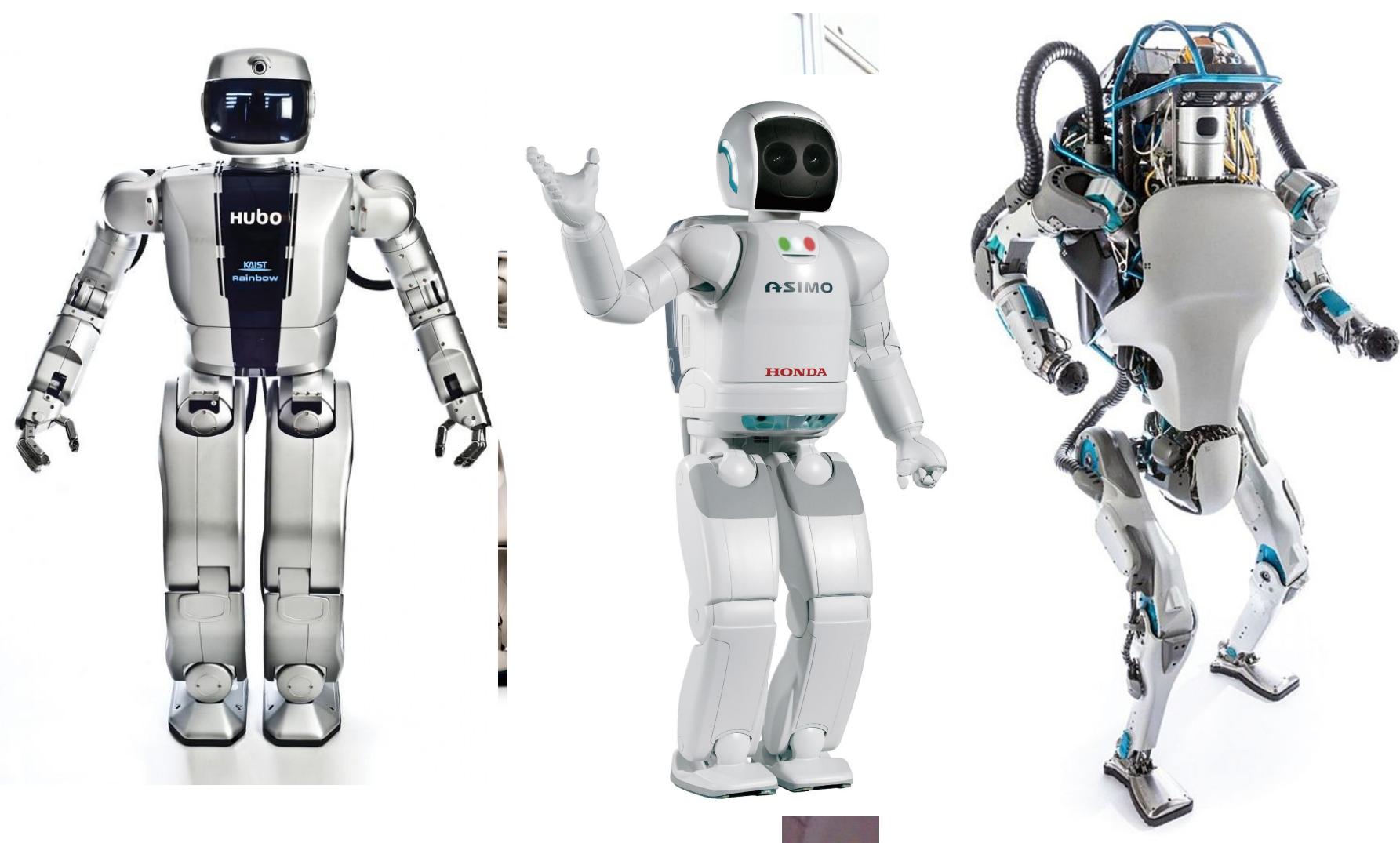
Popular Humanoid Robot



Popular Humanoid Robot



Popular Humanoid Robot



Popular Humanoid Robot



Popular Humanoid Robot



Pop



Robot



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

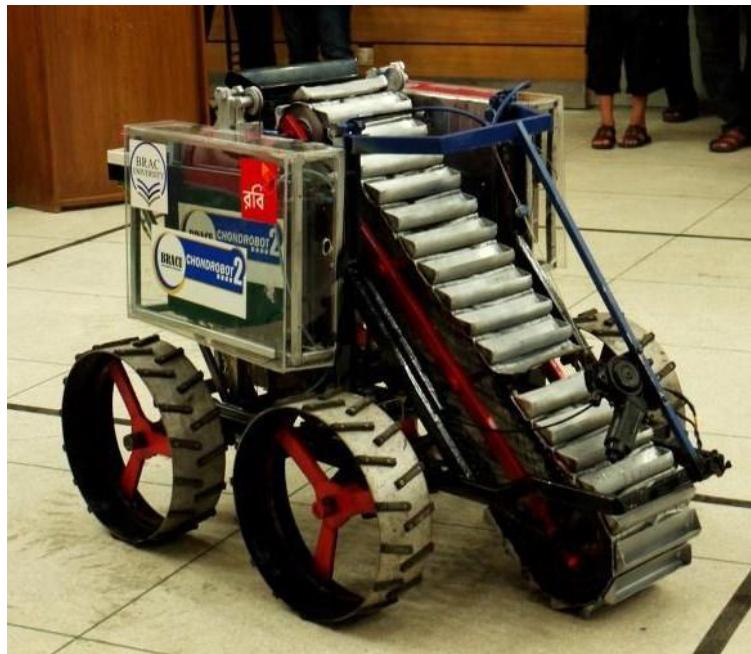
- The first rule to consider, what is known as the Four D of Robotics, i.e. is the task dirty, dull, dangerous, or difficult? If so, a human will probably not be able to do the job efficiently. Therefore, the job is appropriate for automation or for robotic labor.
- The second rule is that a robot may 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)
Delivery drone
Micro air vehicle (MAV)
Target drone



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)
Delivery drone
Micro air vehicle (MAV)
Target drone

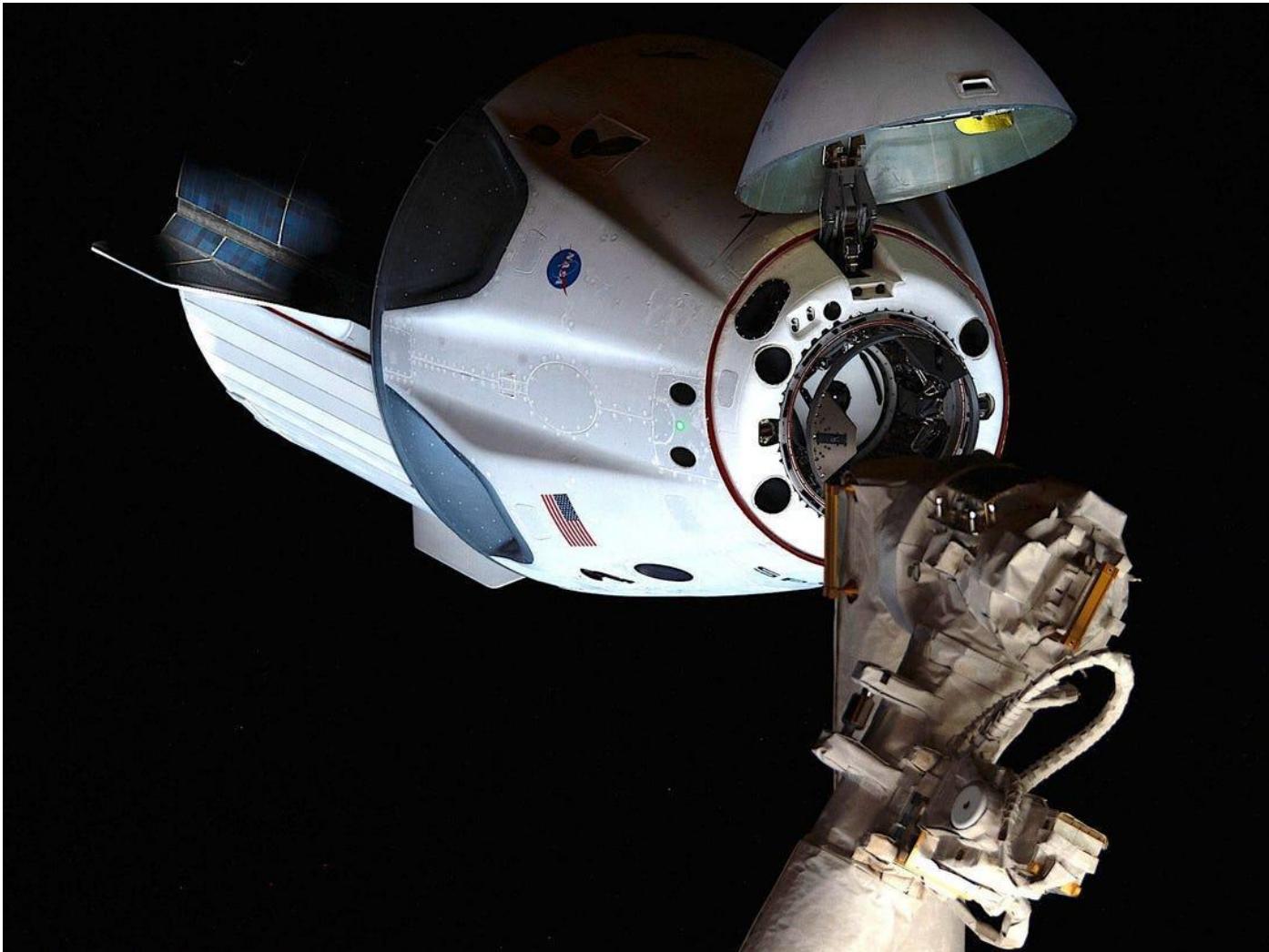


Unmanned aerial vehicle (UAV)



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

Uncrewed spacecraft



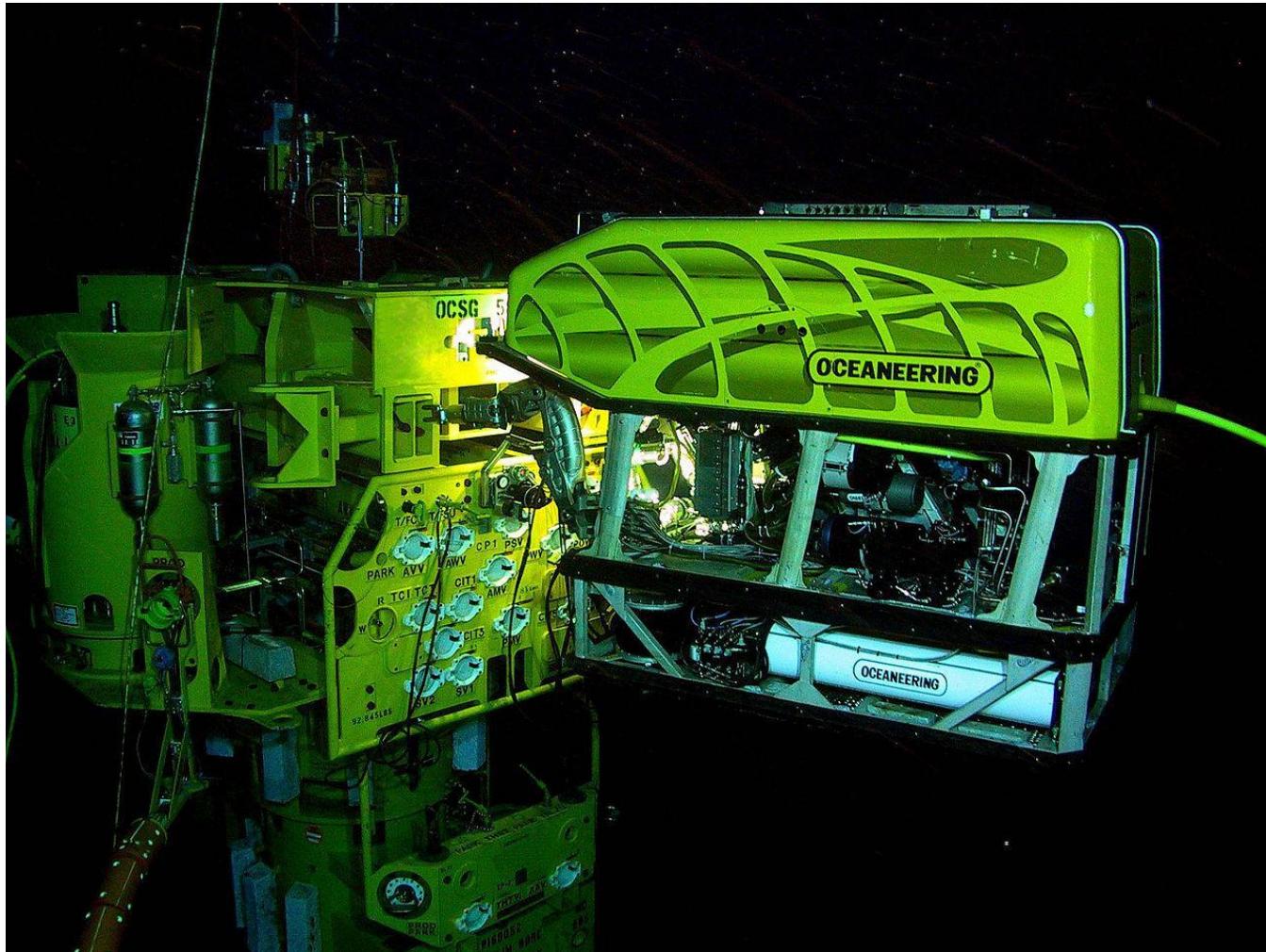
Autonomous spaceport drone ship



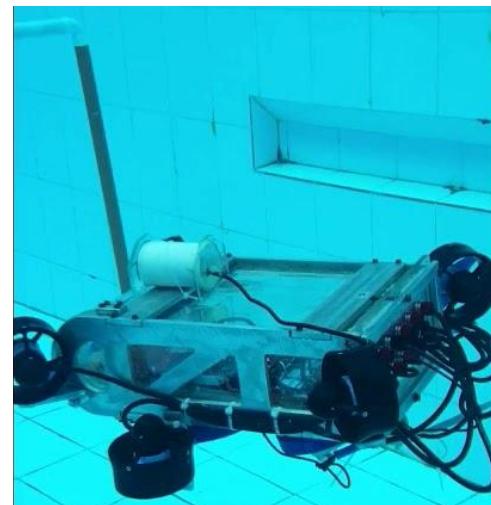
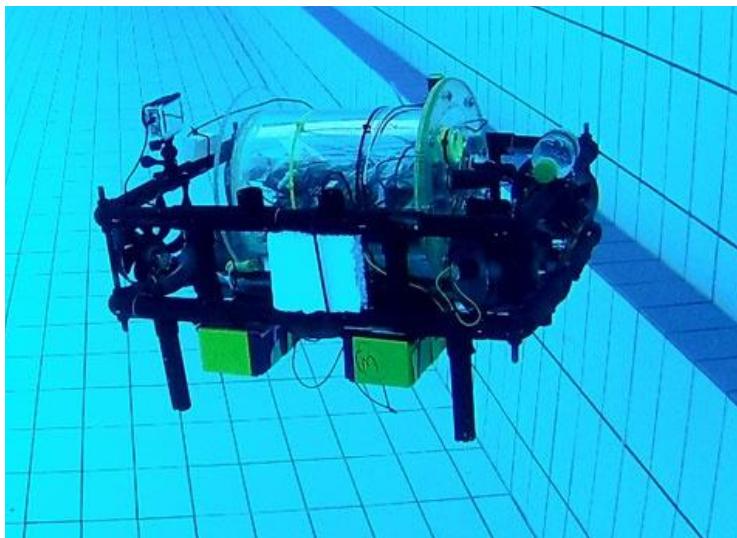
Unmanned surface vehicle (USV)



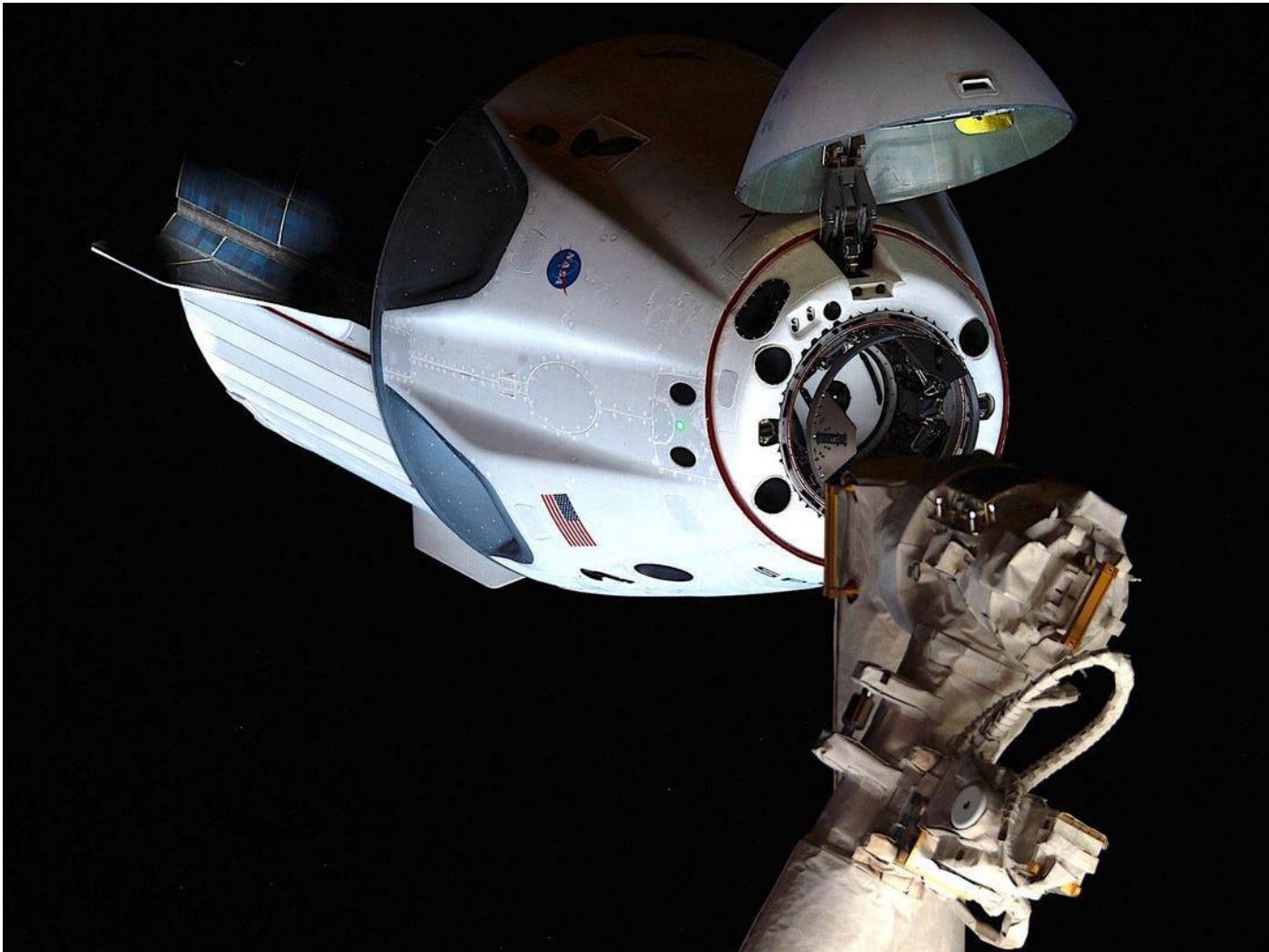
Remotely operated underwater vehicle (ROUV)



Autonomous underwater vehicle (AUV)

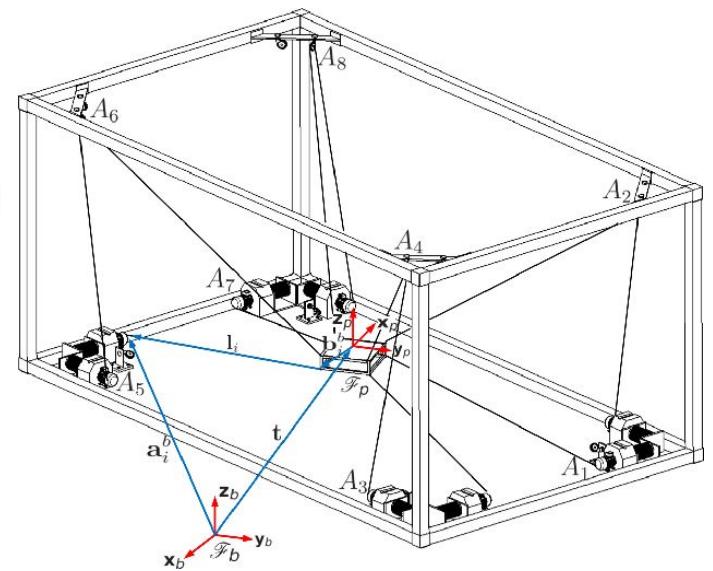
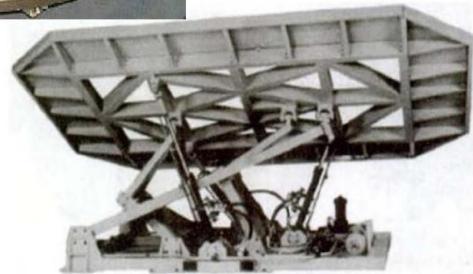
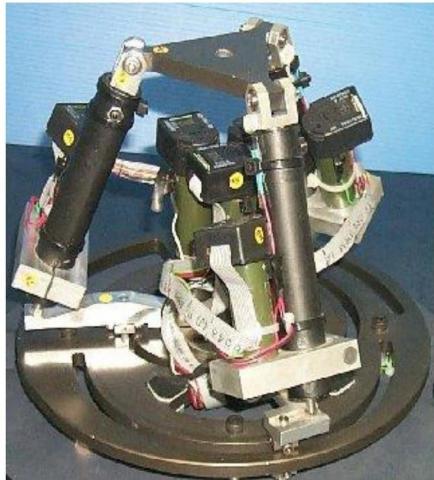


Uncrewed spacecraft



Parallel Robot

- Flight Simulator
- Milling Machine
- Cable Driven Parallel Robot



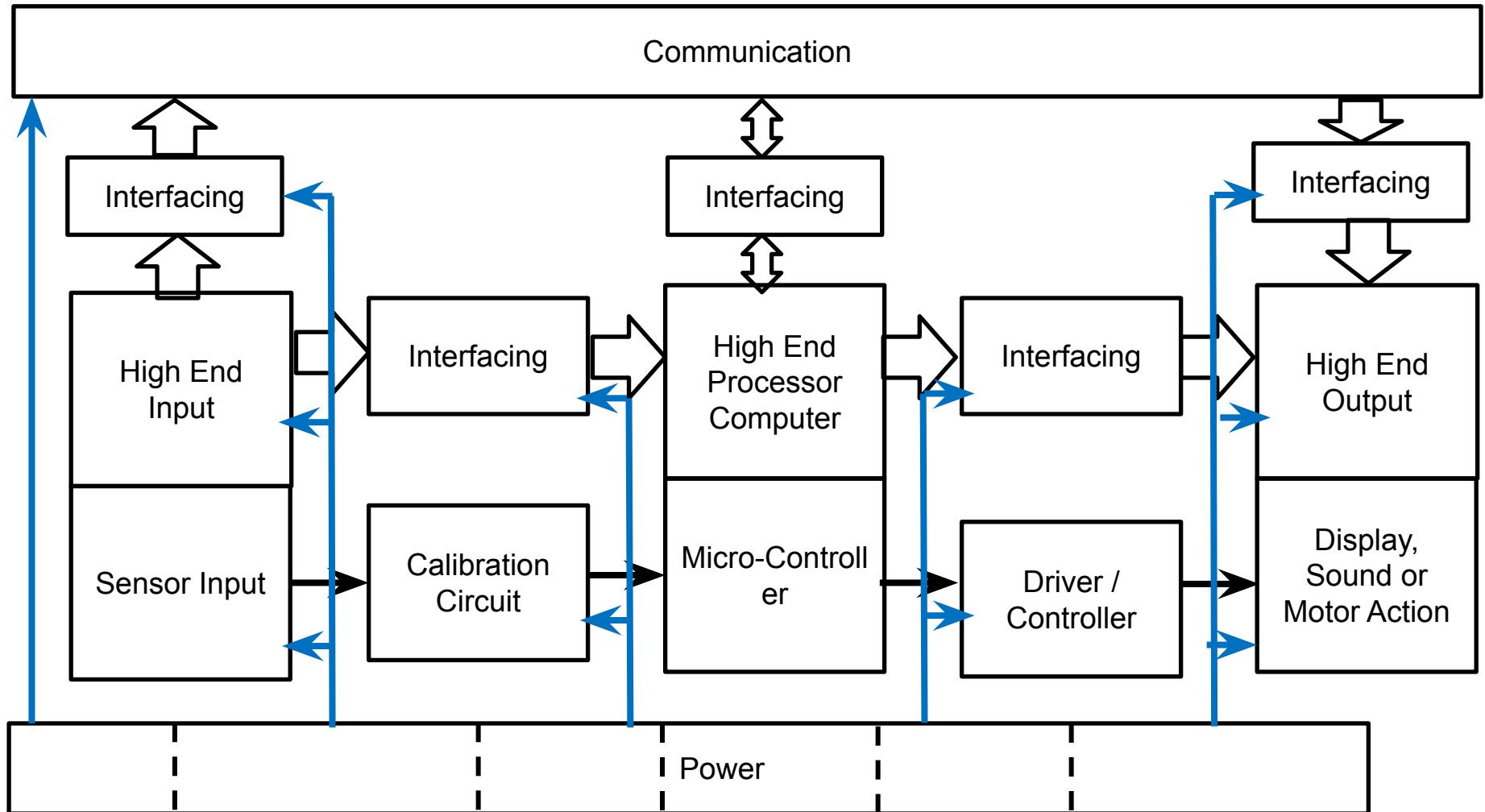
3D Printer



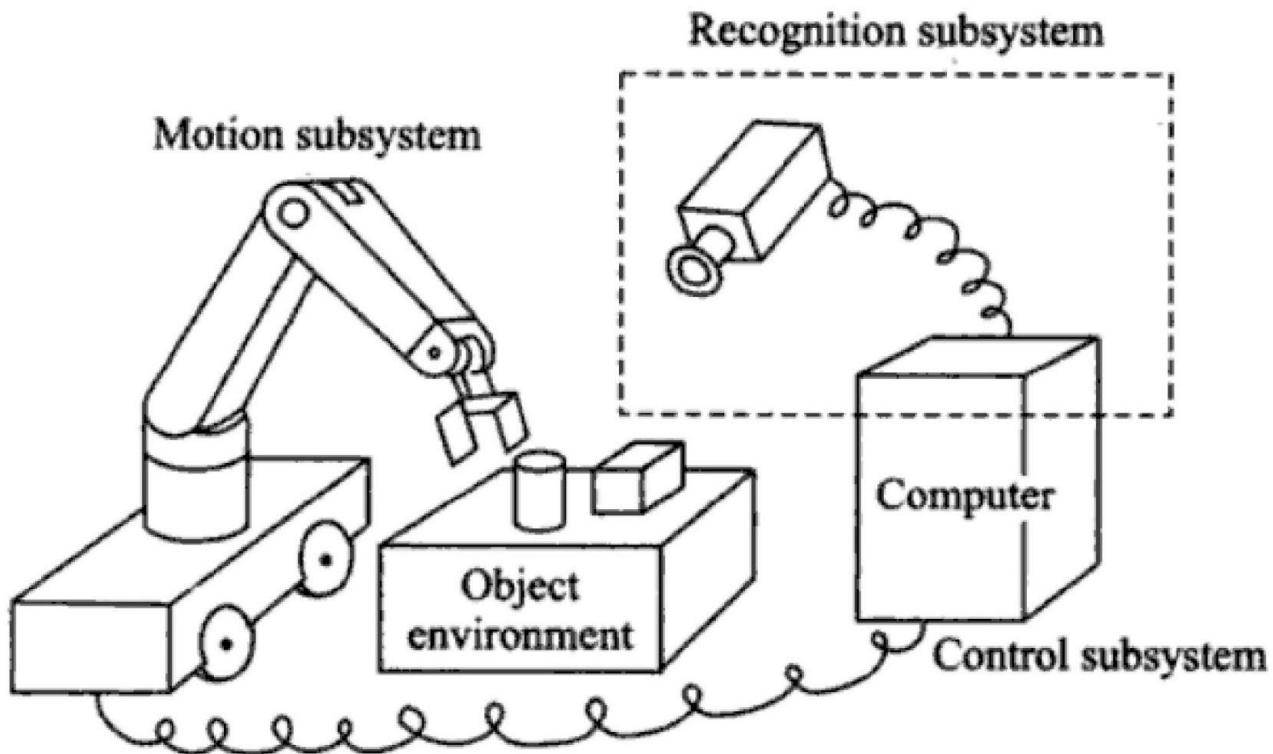
Sub-Systems

- 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

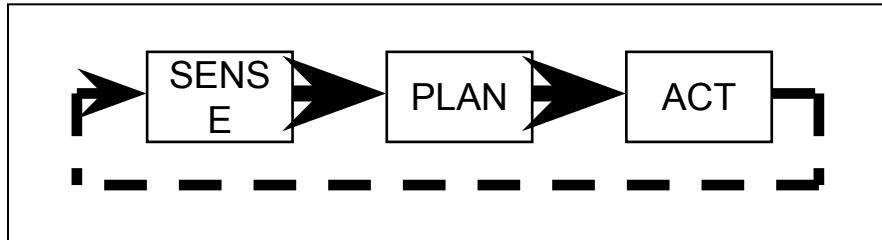
LEARN

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

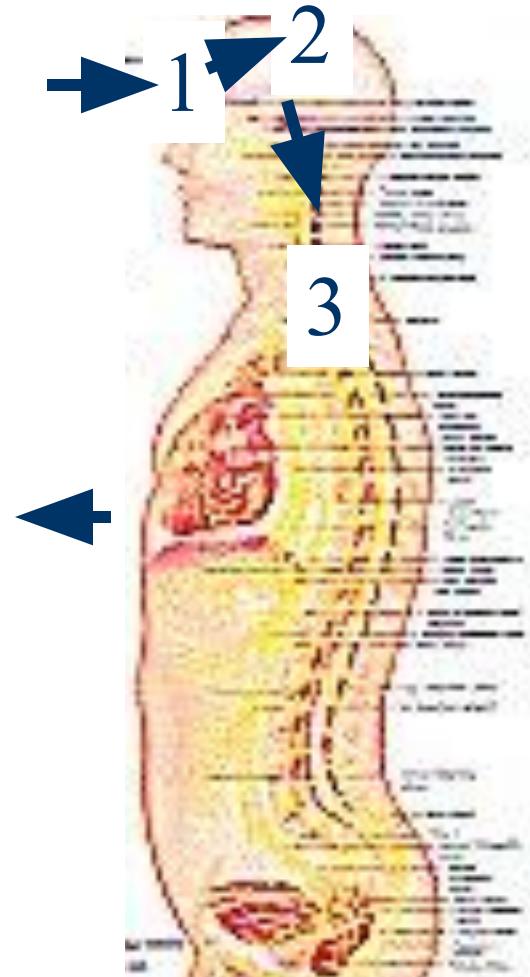


Hierarchical/deliberative paradigm

Control people hated because
didn't “close the loop”

AI people hated because
monolithic

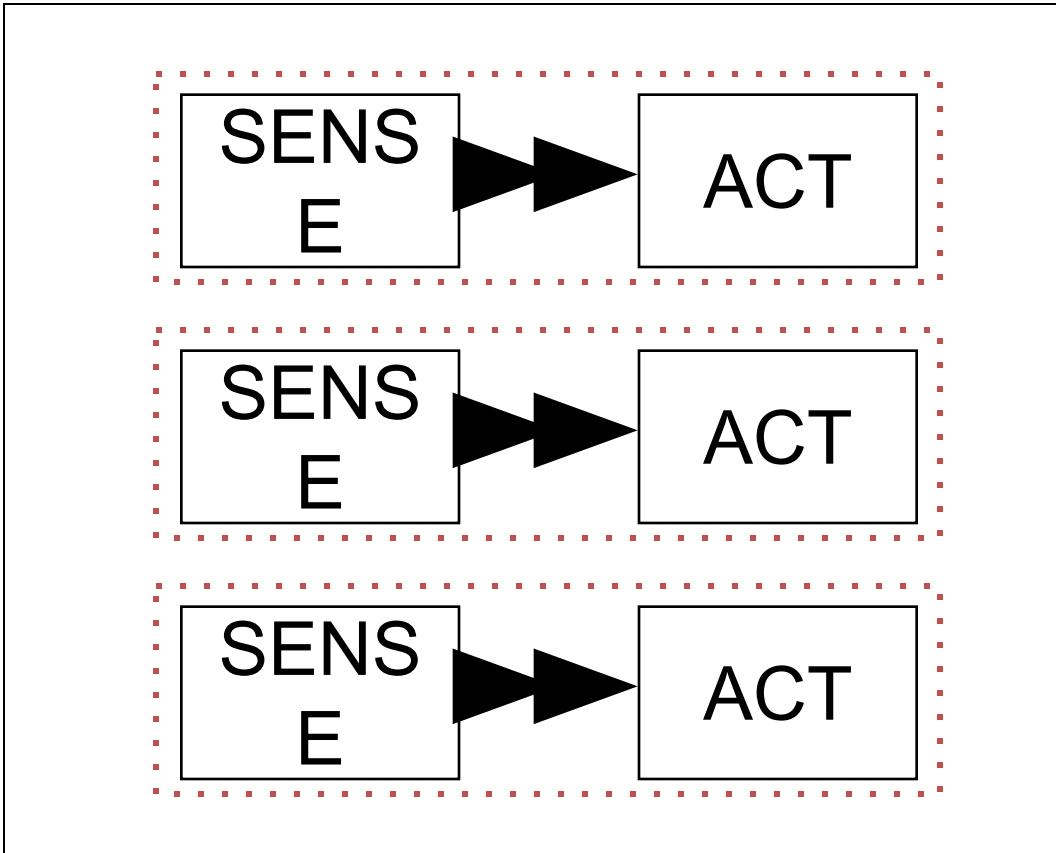
Users hated because very slow



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



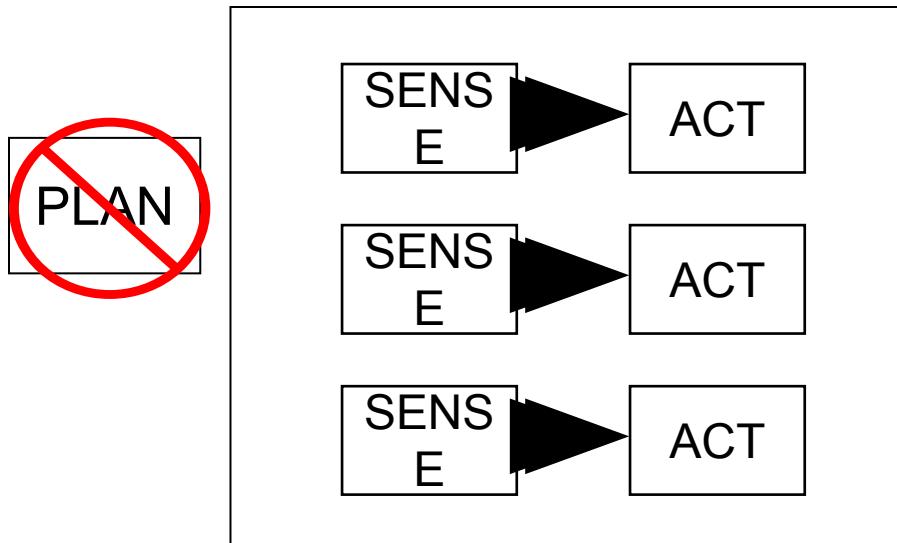
*SENSE-ACT
couplings are
“behaviors”*

*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.

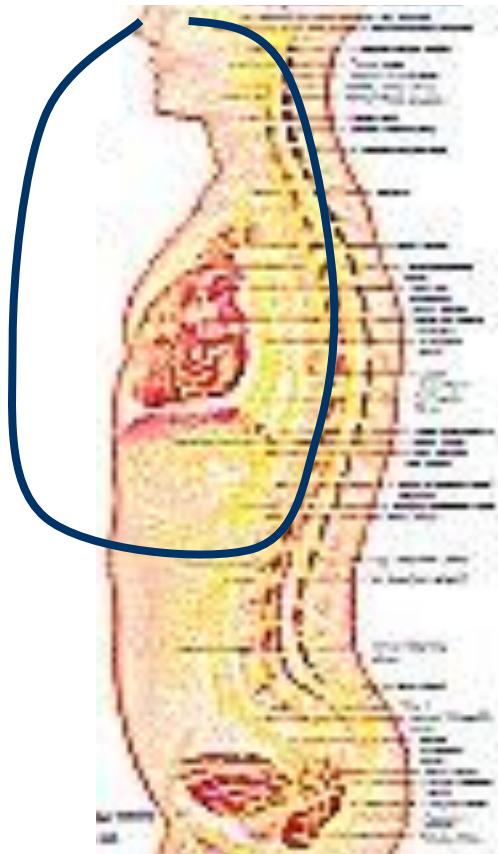
Reactive



Users loved it because it worked

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

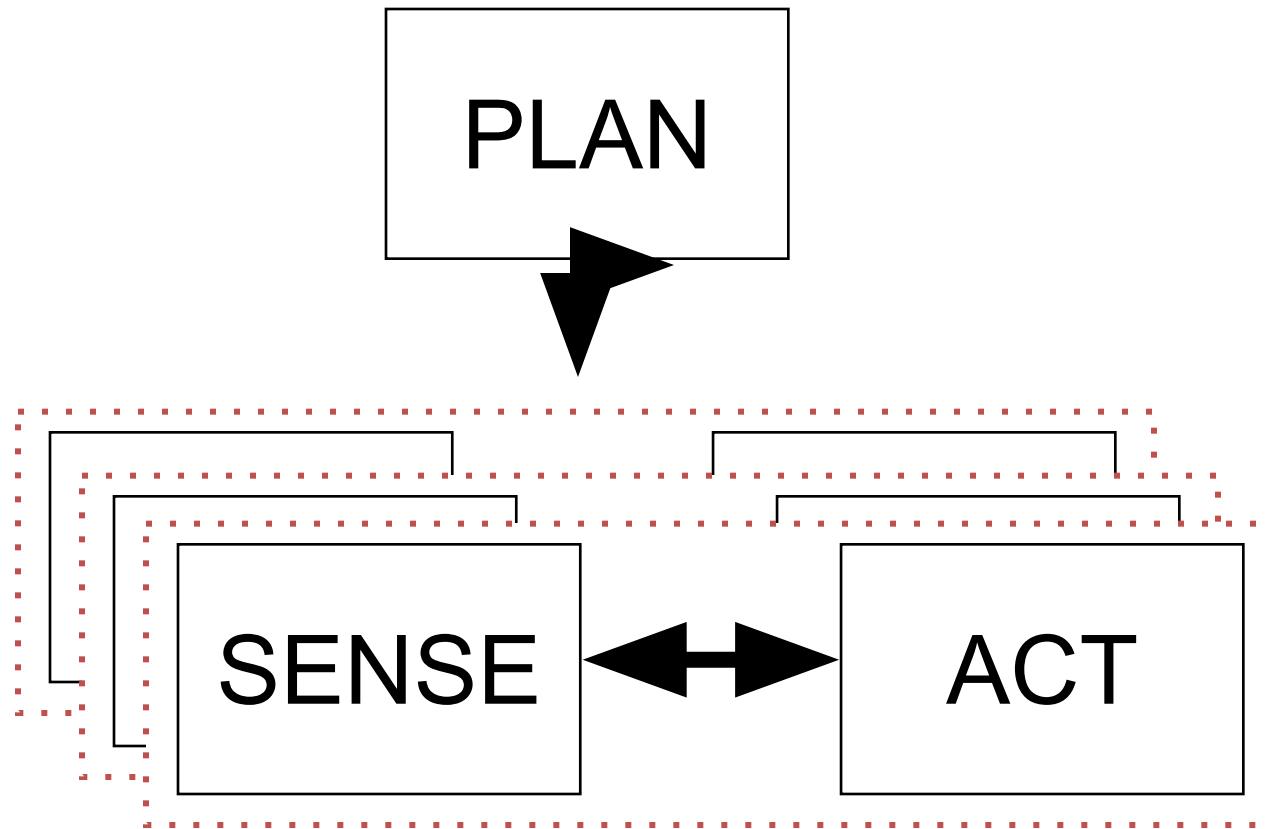
Control people hated it because couldn't rigorously prove it worked



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

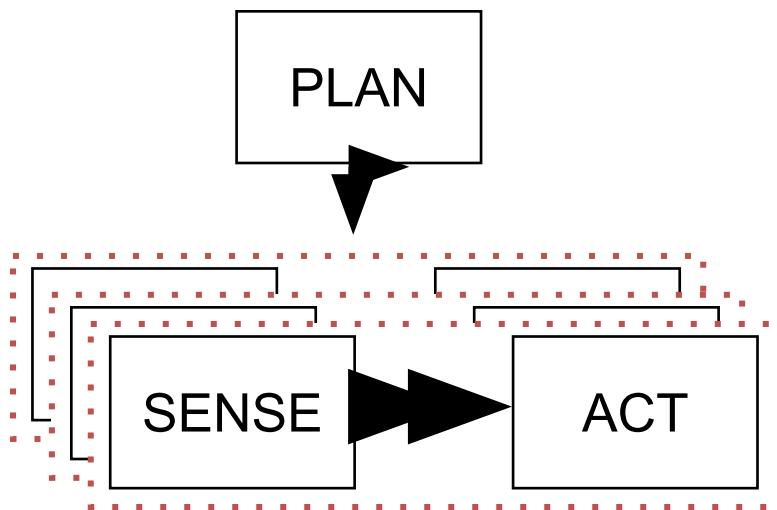


*Plan, then sense-act until task is complete or need to change;
Note movement towards event-driven planning rather than continuous*

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

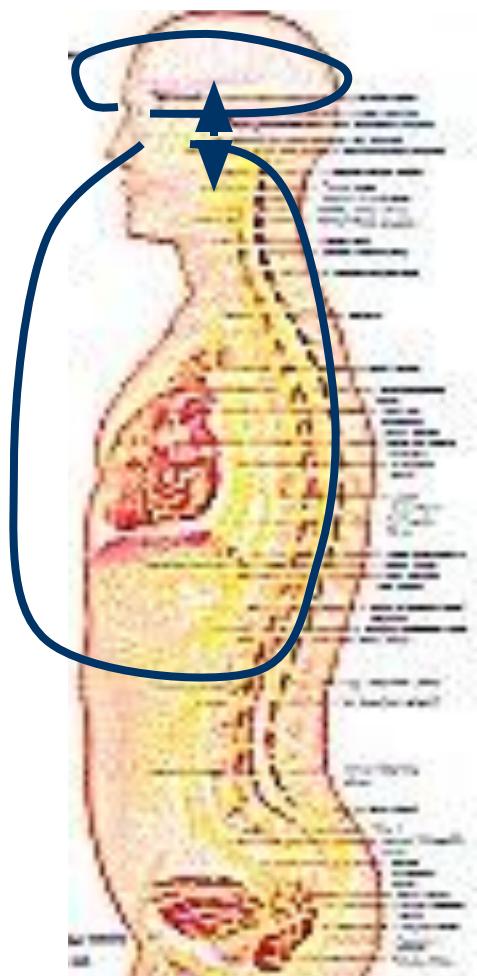
Hybrid



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

AI people loved it

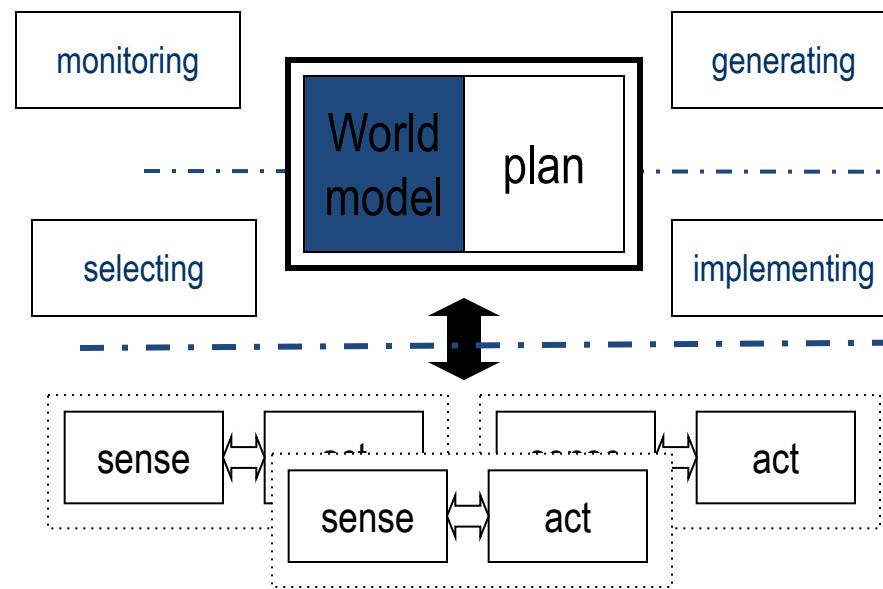
Users loved it



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



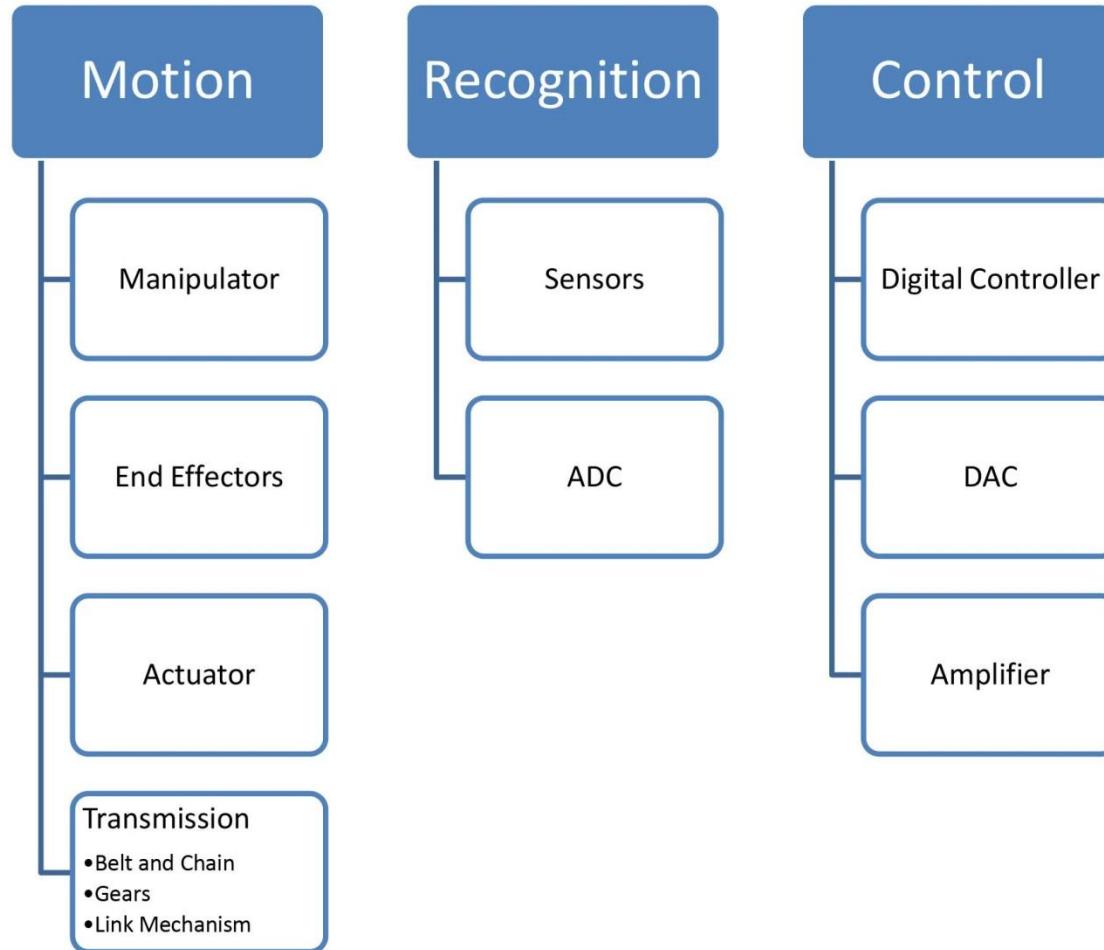
Deliberative:

- 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*

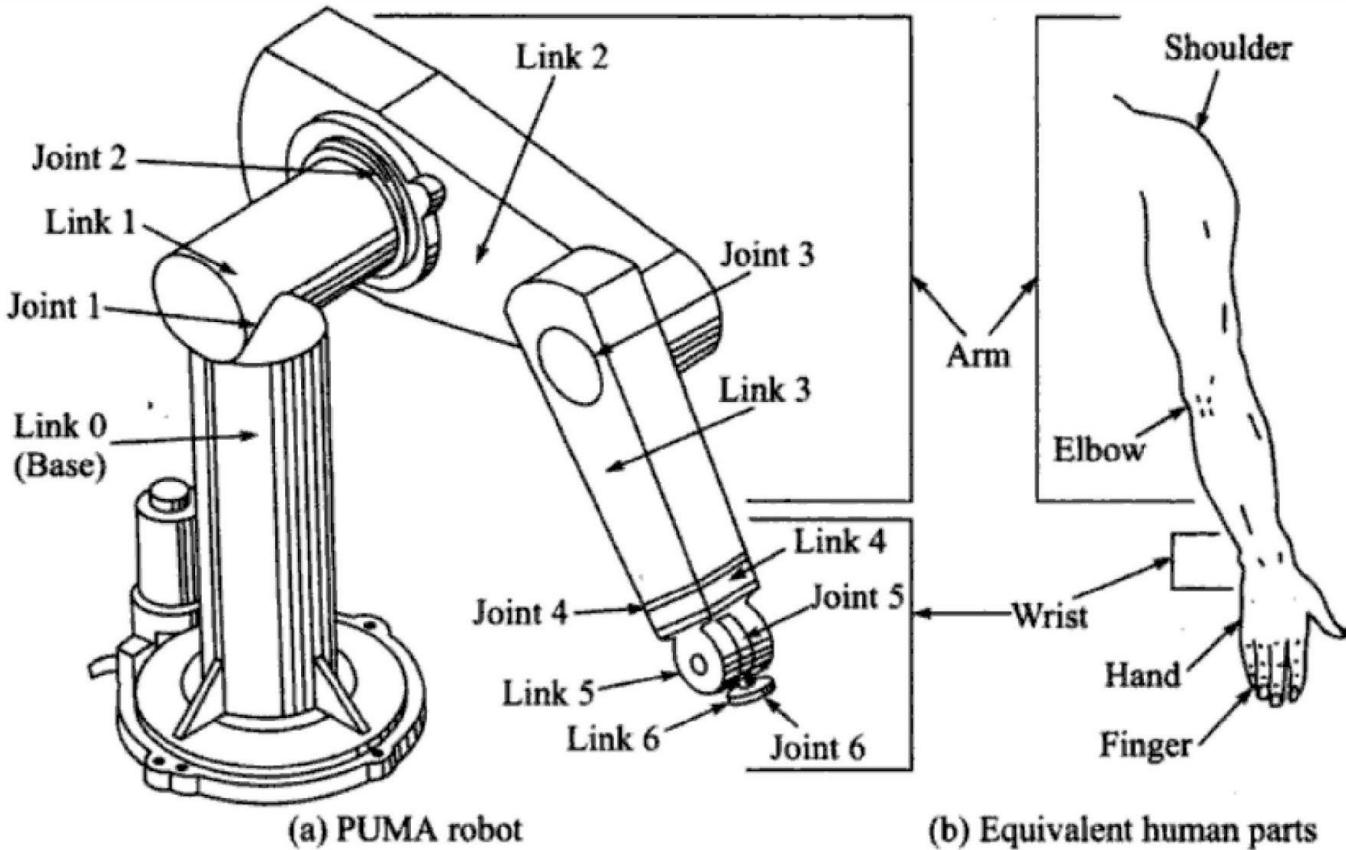
Reactive (fly by wire, inner loop control):

- 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



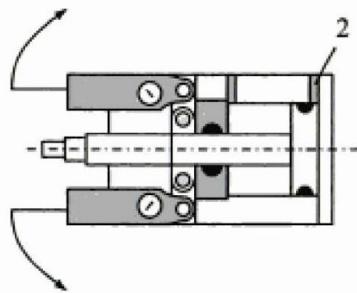
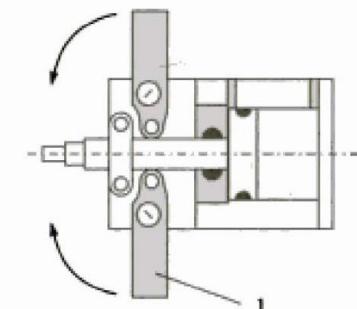
Manipulator



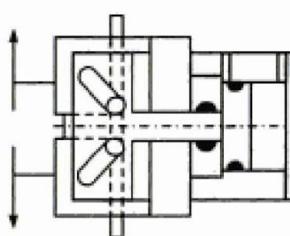
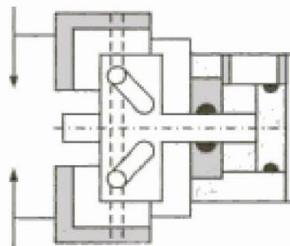
Manipulator



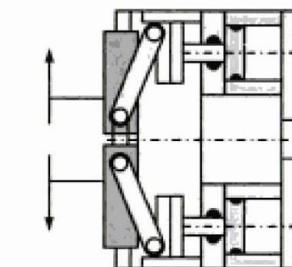
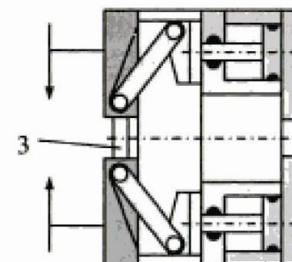
End-effector



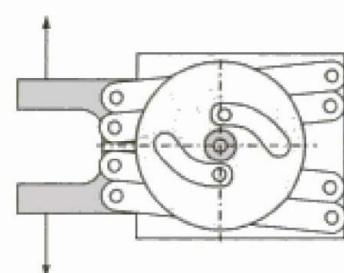
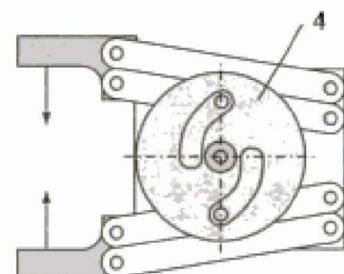
(a)



(b)



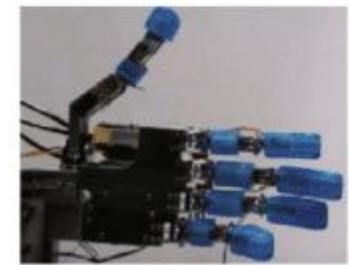
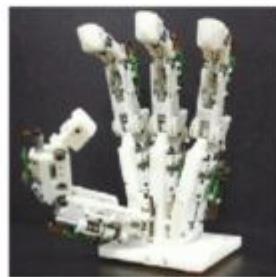
(c)



(d)

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

End Effector

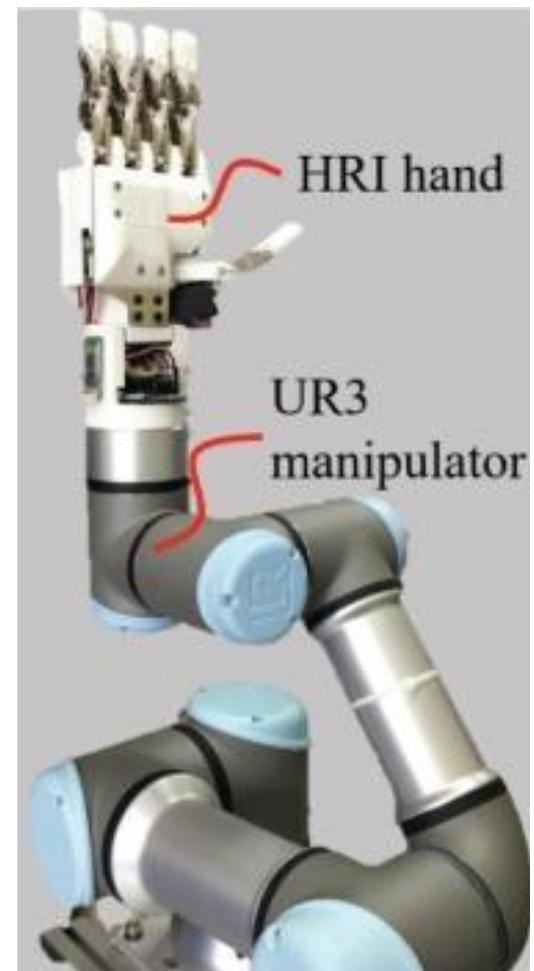
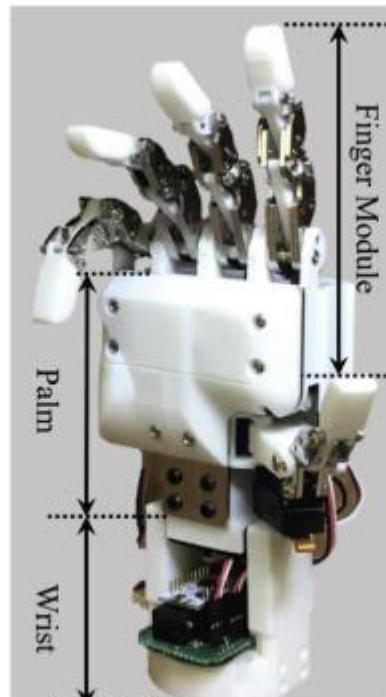
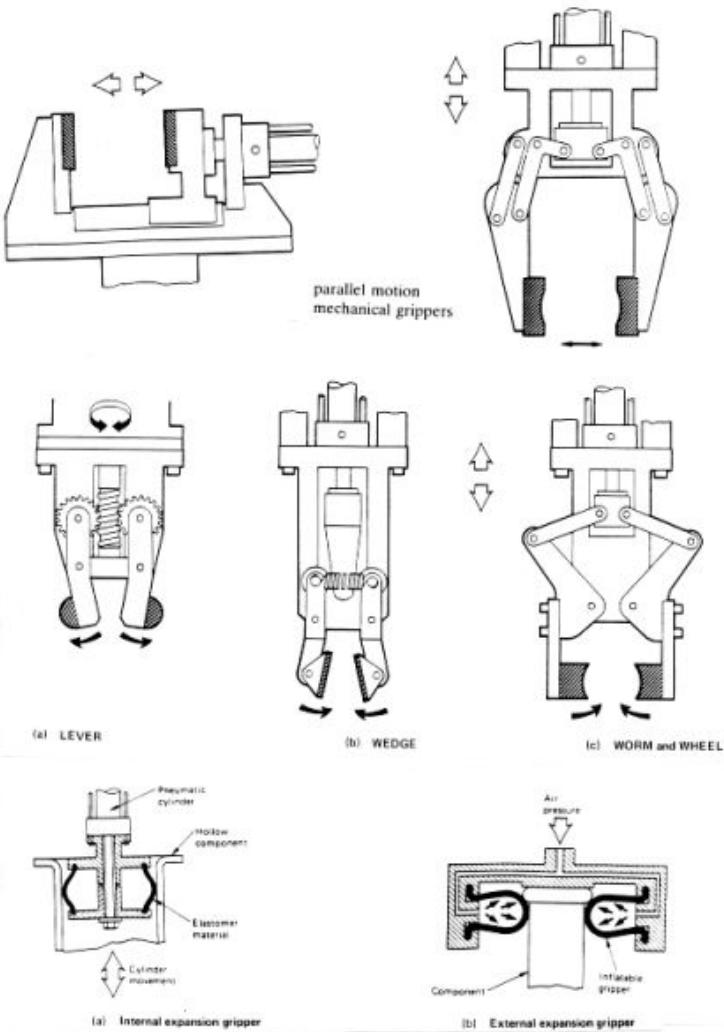


(a)

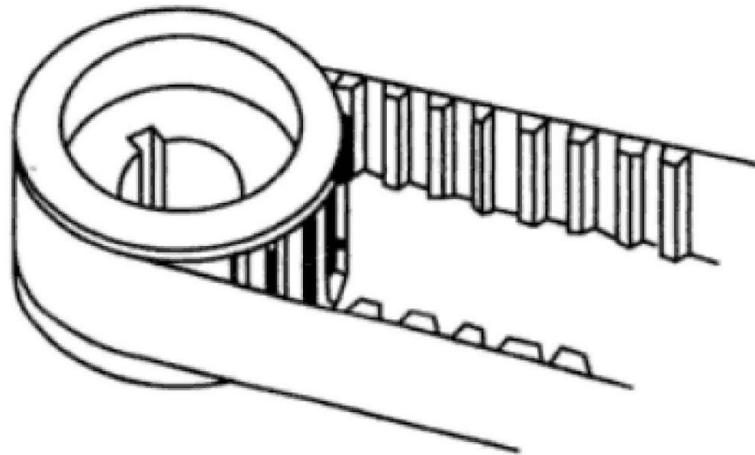
(b)

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

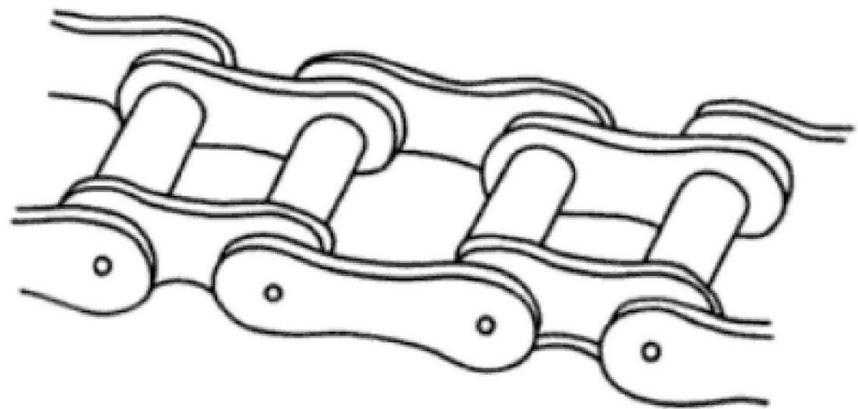
End Effector



Transmission (Belt and chain)

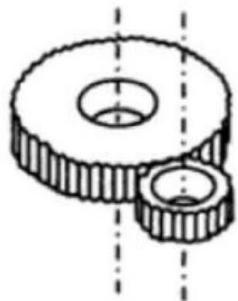


(a) Synchronous belt



(b) Roller chain

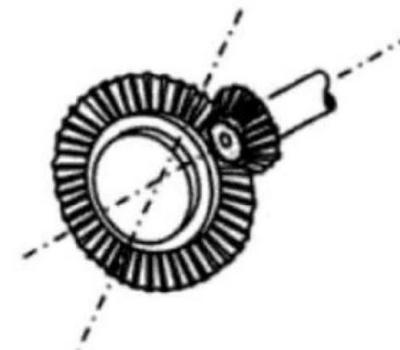
Transmission (Gears)



Spur gears



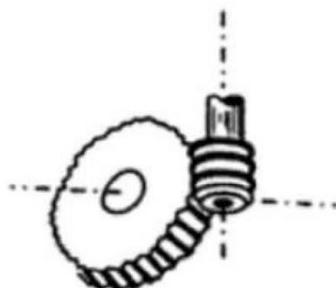
Helical gears



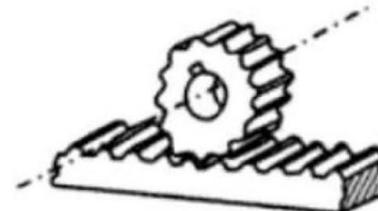
Straight bevel



Spiral bevel

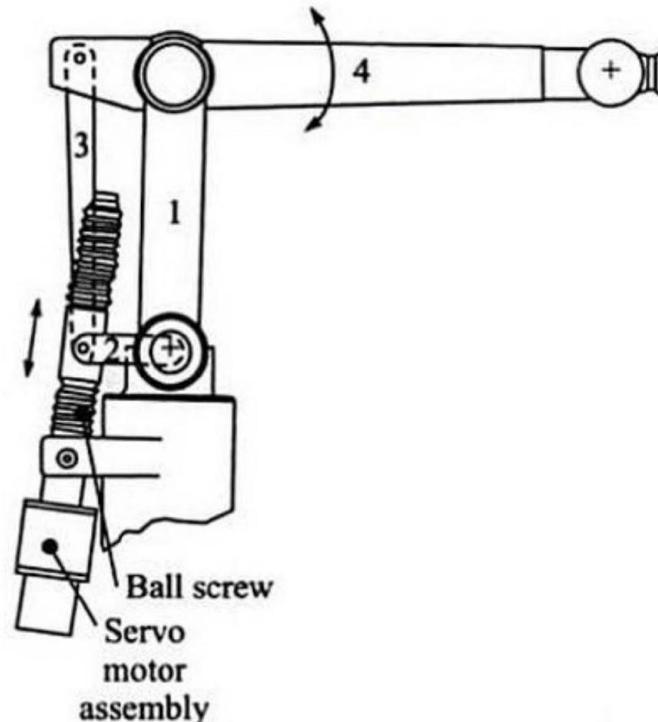
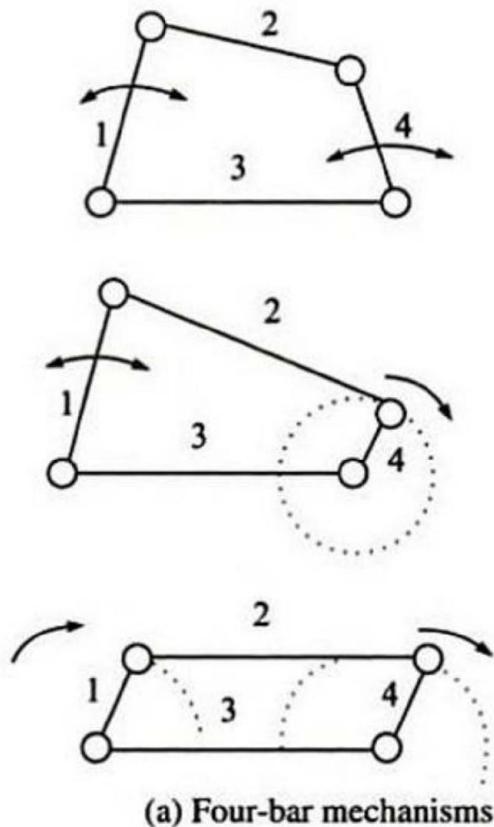


Worm



Rack and pinion

Transmission (Link Mechanism)



(b) Use of mechanisms in robot manipulator

Fig. 2.7 Mechanisms and their use in robot manipulator

DC, Stepper, Servo, Induction Motor

Motion

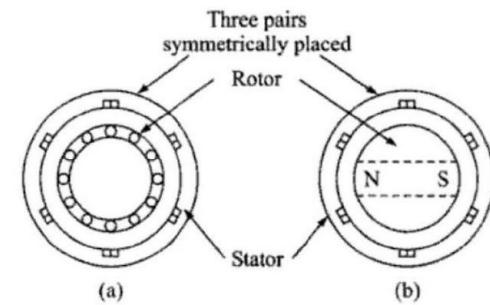
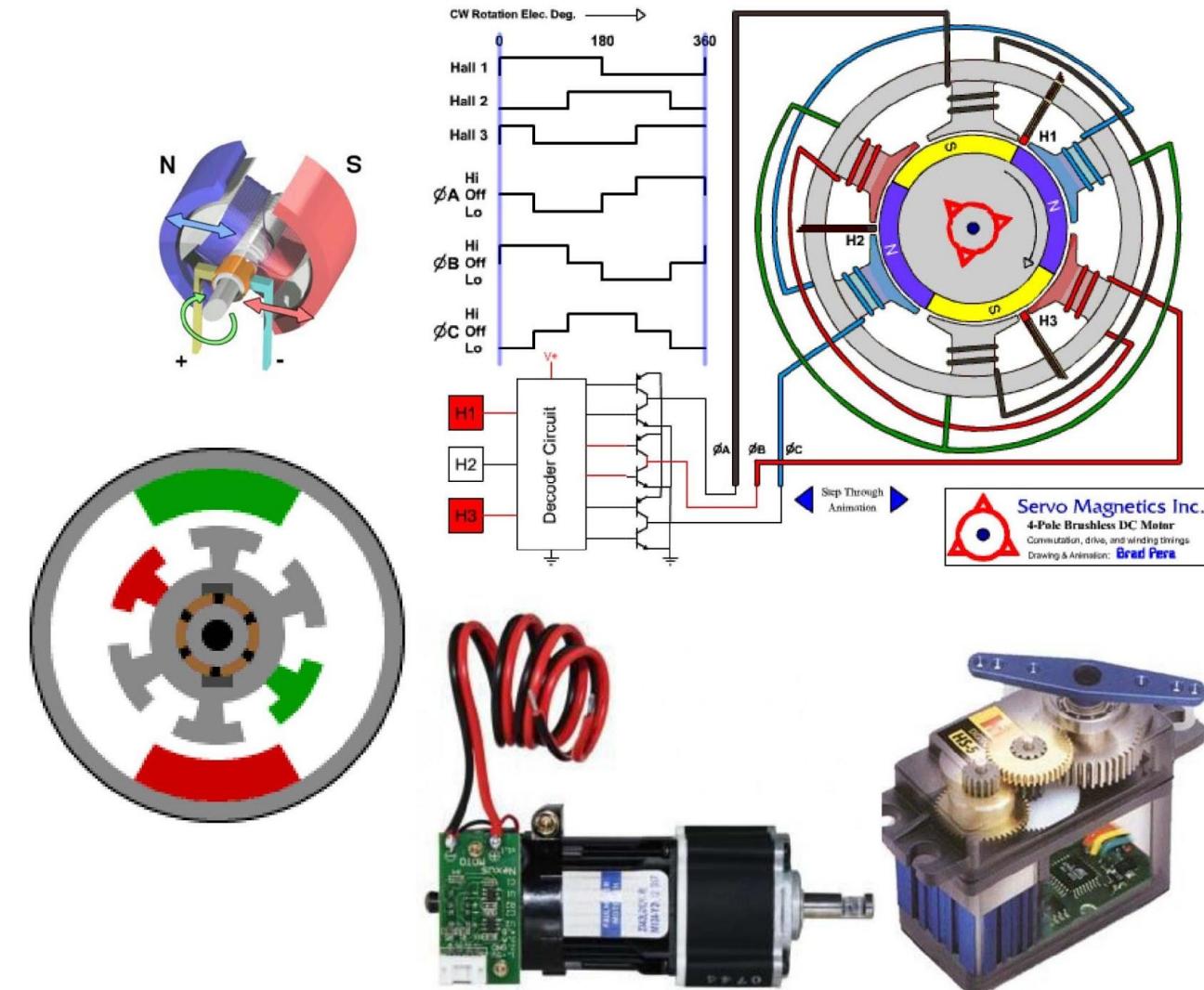


Fig. 3.13 AC three-phase motor

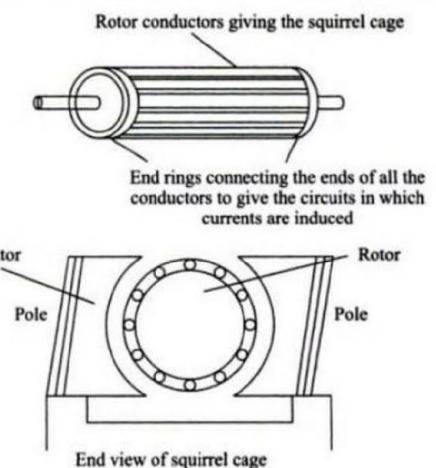


Fig. 3.12 Single-phase induction motor

Servo Magnetics Inc.
4-Pole Brushless DC Motor
Concentric, drive, and winding strings
Drawing & Animation: Brad Pera

Actuators



Pneumatic Actuator

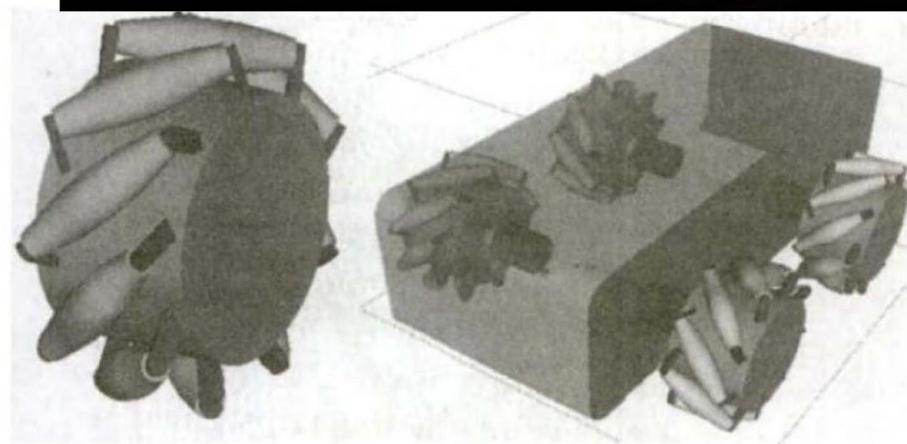
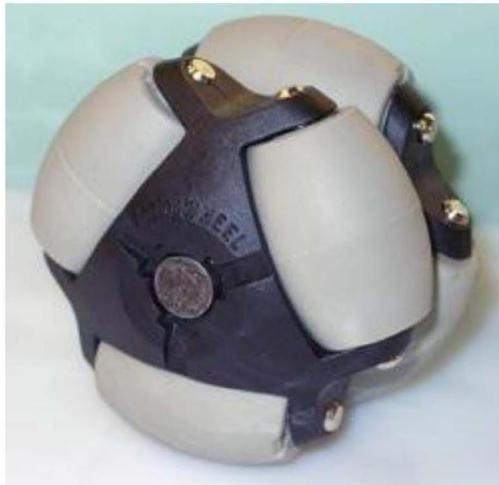


Hydraulic Actuator



Electric Actuator

AGV with Multi Directional Wheel

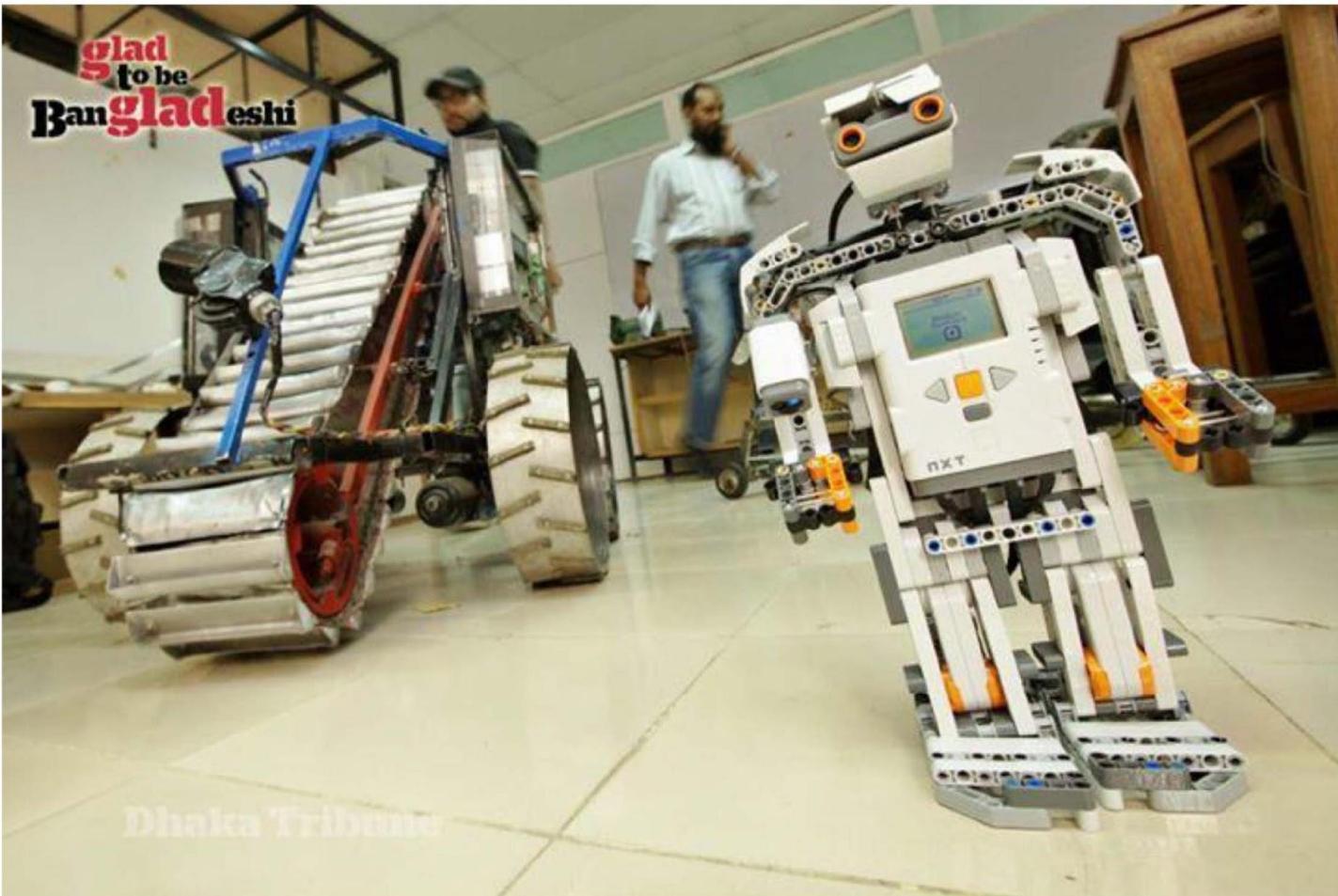


(a) A Mekanum wheel

(b) An AGV

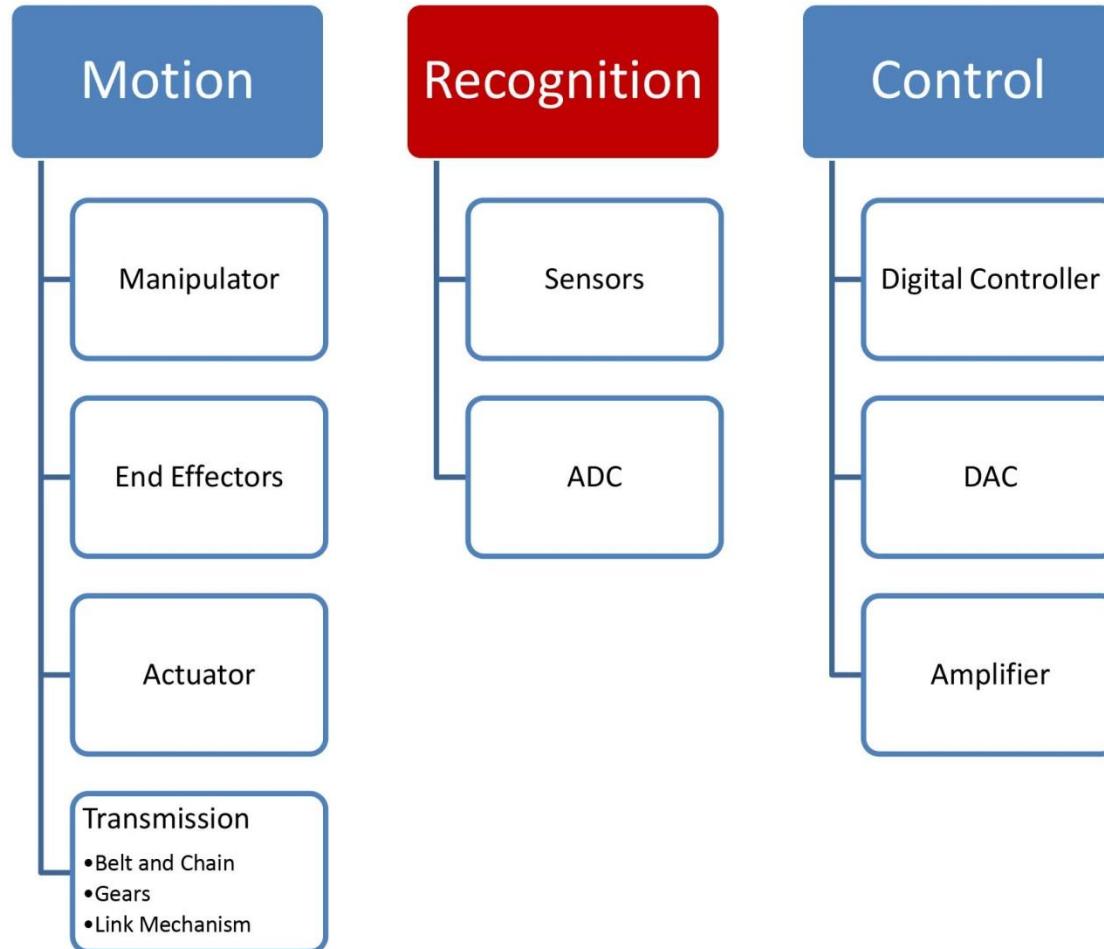
Fig. 1.5 An Automatic Guided Vehicle (AGV) with Mekanum wheels
[Courtesy: Angeles (2003)]

LEGO: MINDSTROM



Dhaka Tribune

Subsystems



Recognition

Sensors



Sensor Examples

Recognition

Physical Property

contact
distance
light level
sound level
rotation
acceleration

Sensor

switch
ultrasound, radar, infrared
photocells, cameras
microphone
encoders and potentiometers
accelerometers gyroscopes

More Sensor Examples

Recognition

Physical Property

magnetism

smell

temperature

inclination

pressure

altitude

strain

Sensor

compass

chemical

thermal, infra red

inclinometers, gyroscopes

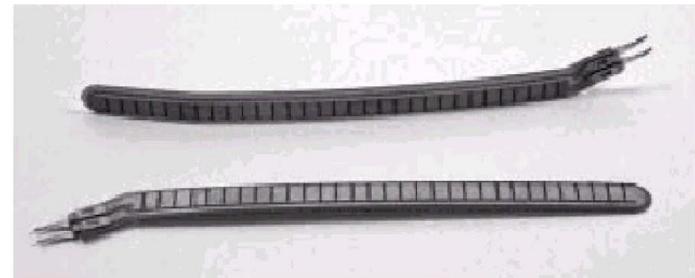
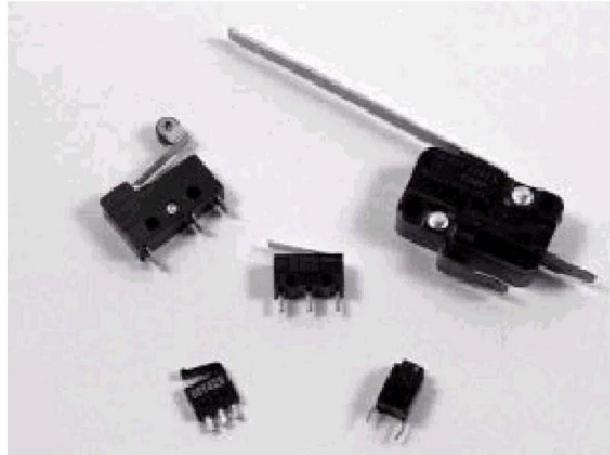
pressure gauges

altimeters

strain gauges

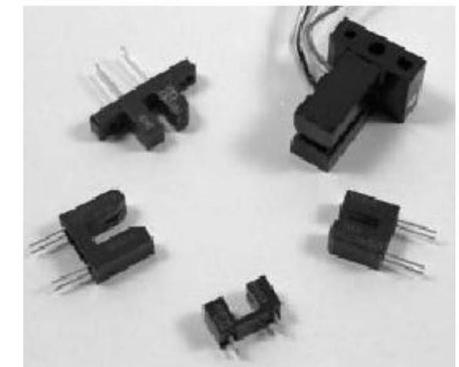
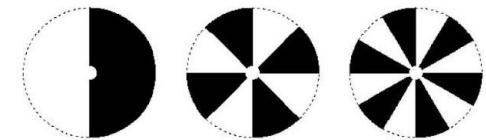
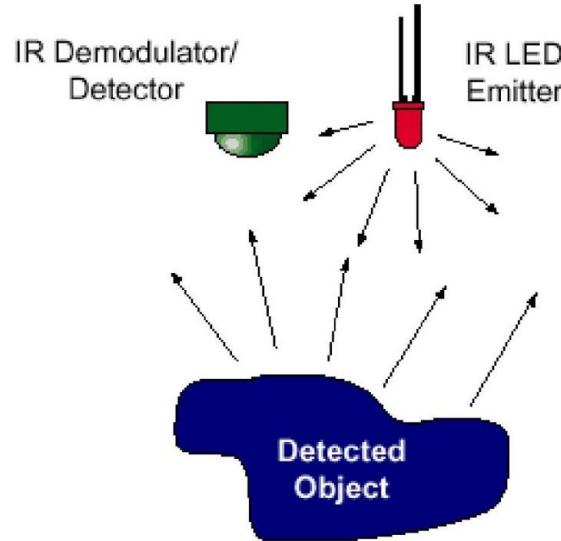
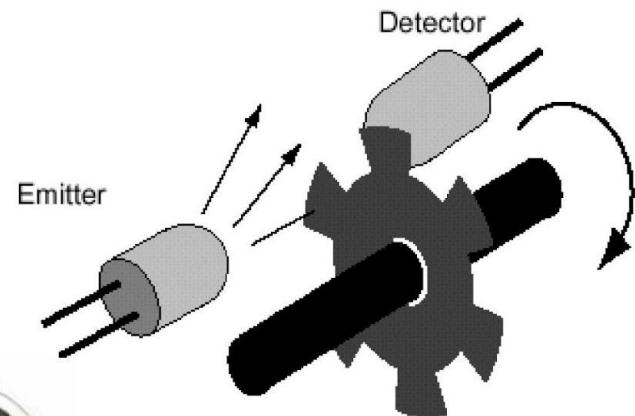
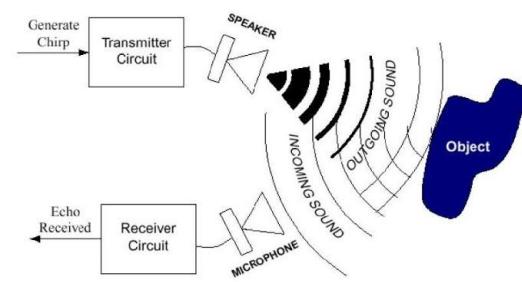
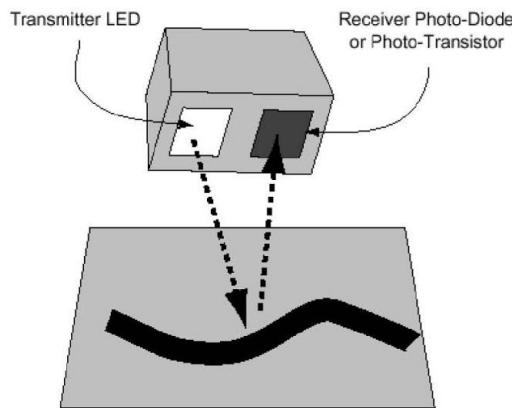
Recognition

Passive Sensor

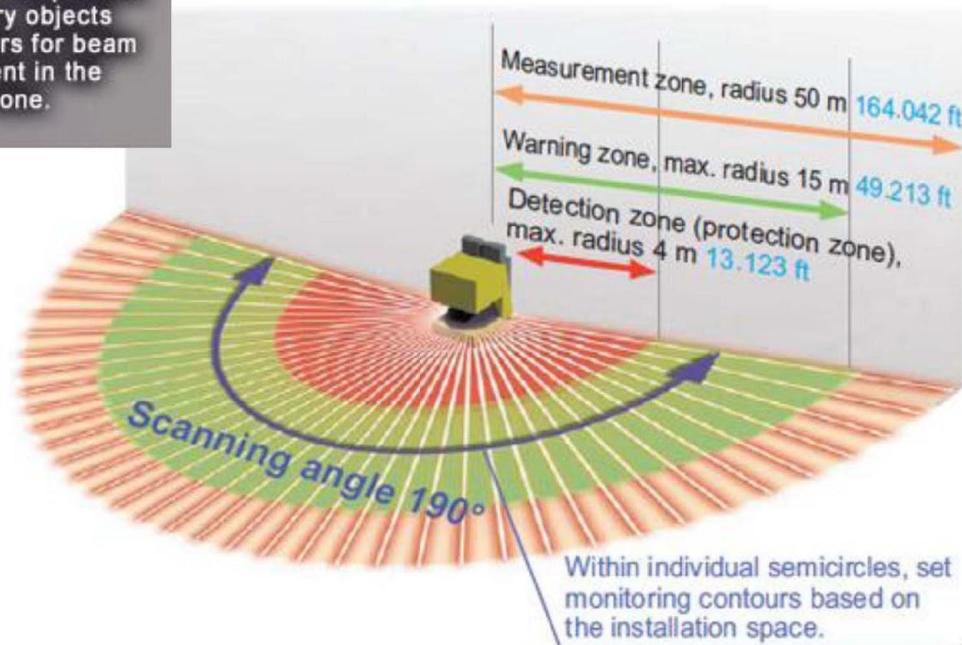


Recognition

Active Sensors



Laser Scanner

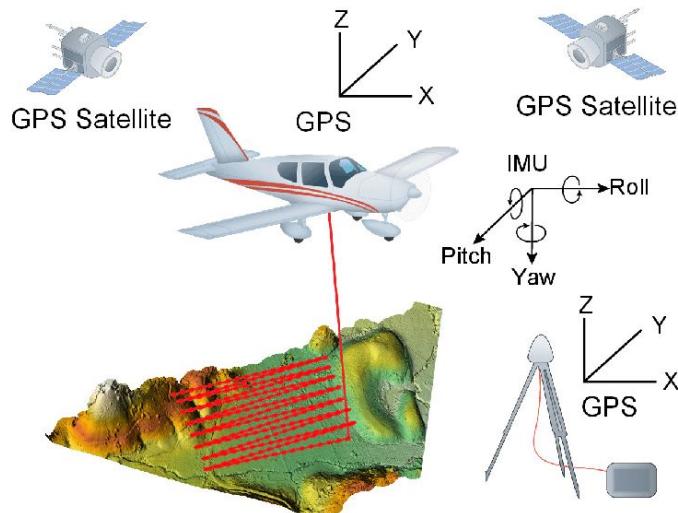


Detection zone: Instantly stops the machine upon intrusion (control output)

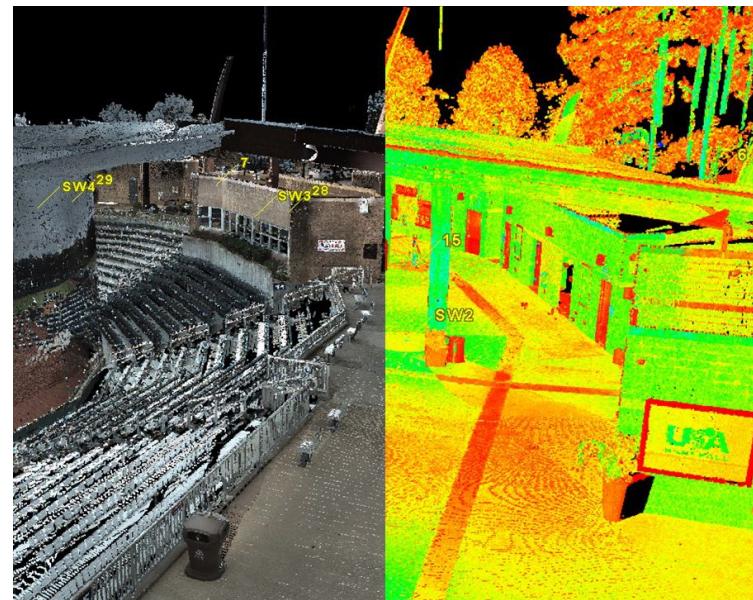
Warning zone: Releases warning upon intrusion (warning output)

LIDAR

Airborne LiDAR



Terrestrial LiDAR



Emotiv Electroencephalography (EEG) Headset

emotiv
you think, therefore, you can



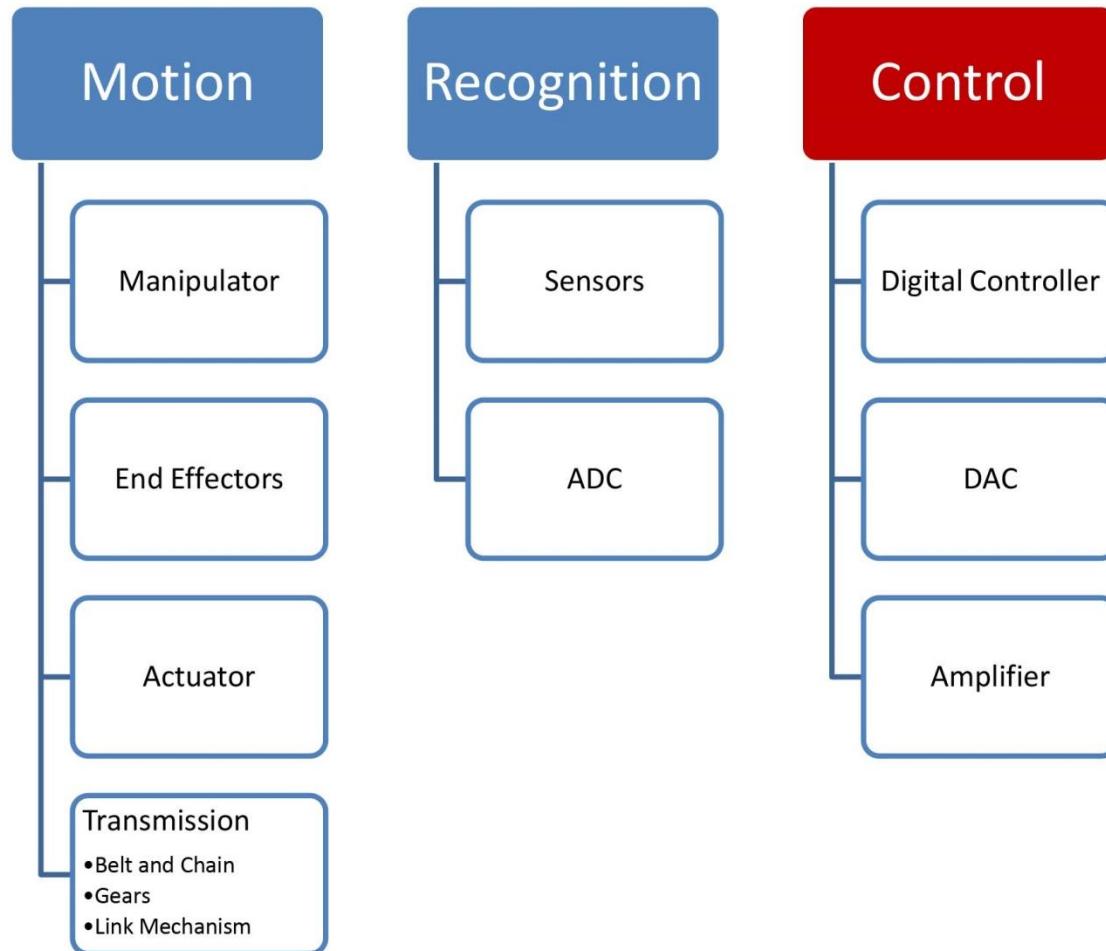
LEAP Motion Sensor



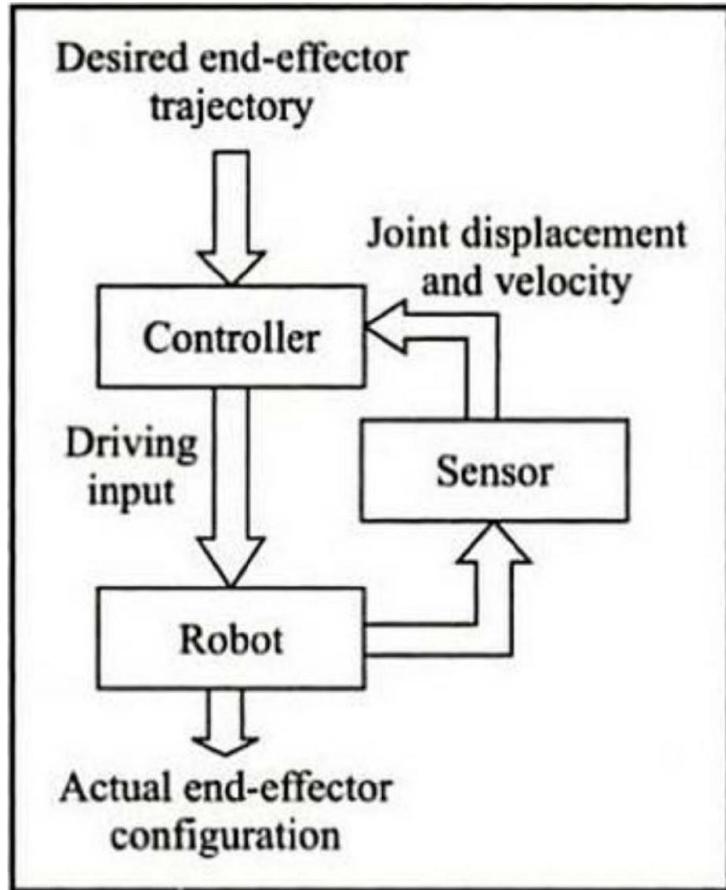
MYO



Subsystems



Control Software



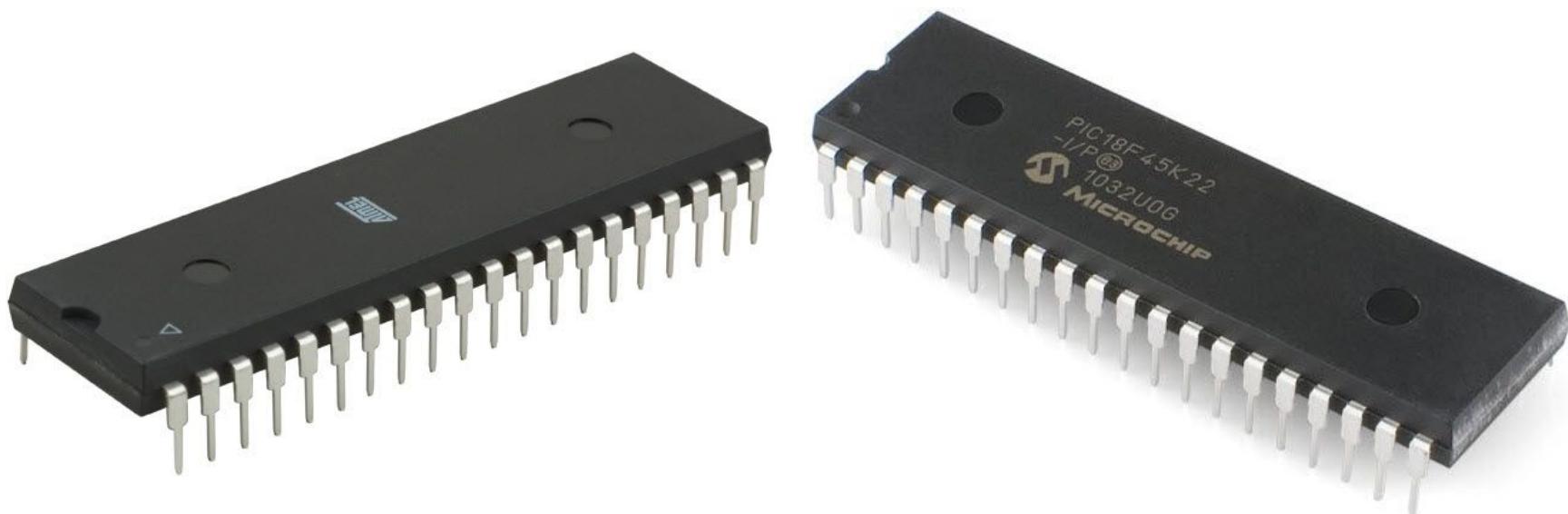
(a) Control scheme of a robot

- 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



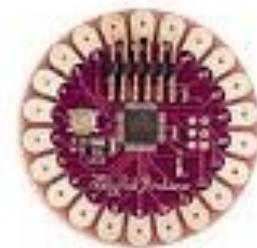
Arduino Uno



Arduino Leonardo



Arduino Mega 2560



Arduino LilyPad



Arduino Mega ADK



Arduino Fio



Arduino Ethernet



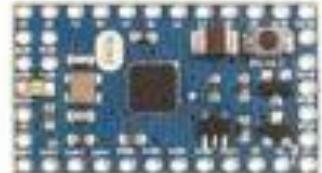
Arduino Pro



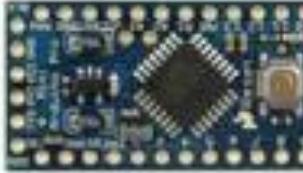
Arduino BT



Arduino Nano



Arduino Mini

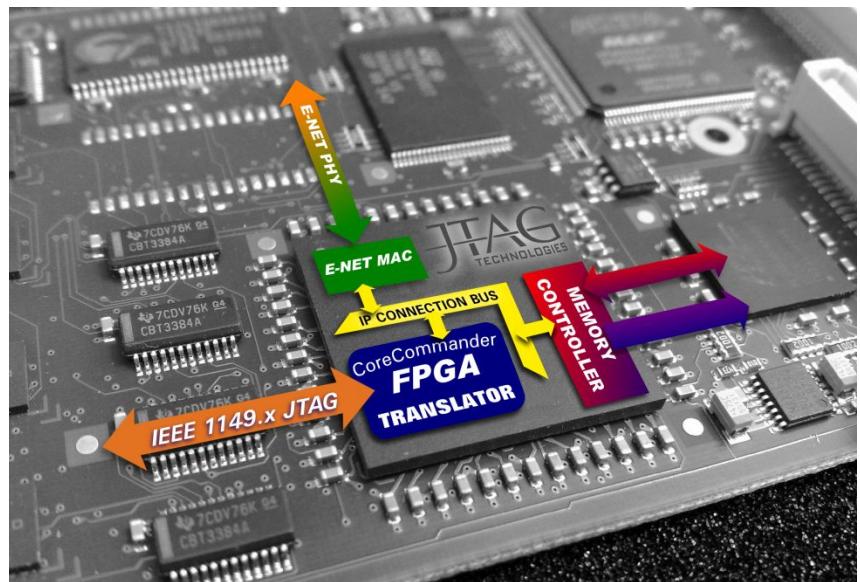


Arduino Pro Mini

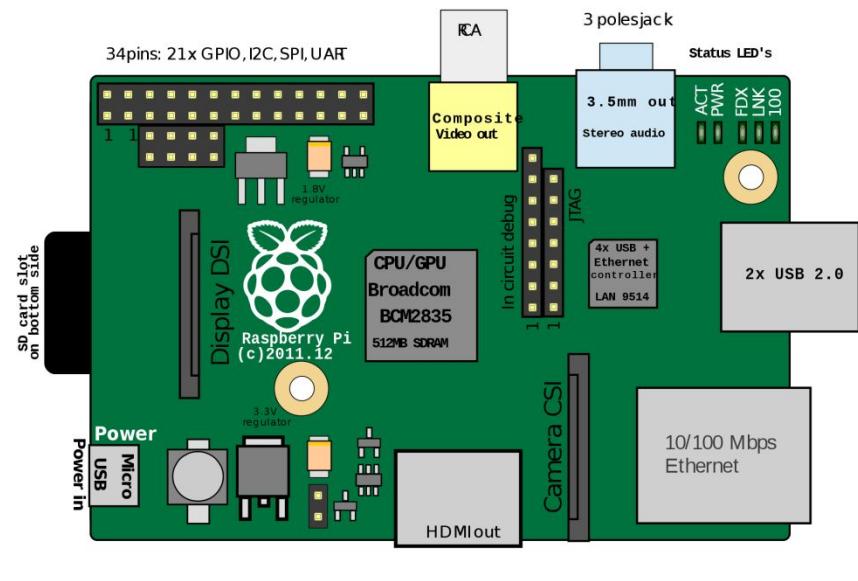
Programmable Logic Controller (PLC)



Field-Programmable Gate Array (FPGA)



Single board Computer



Raspberry PI 4, Tinkerboard



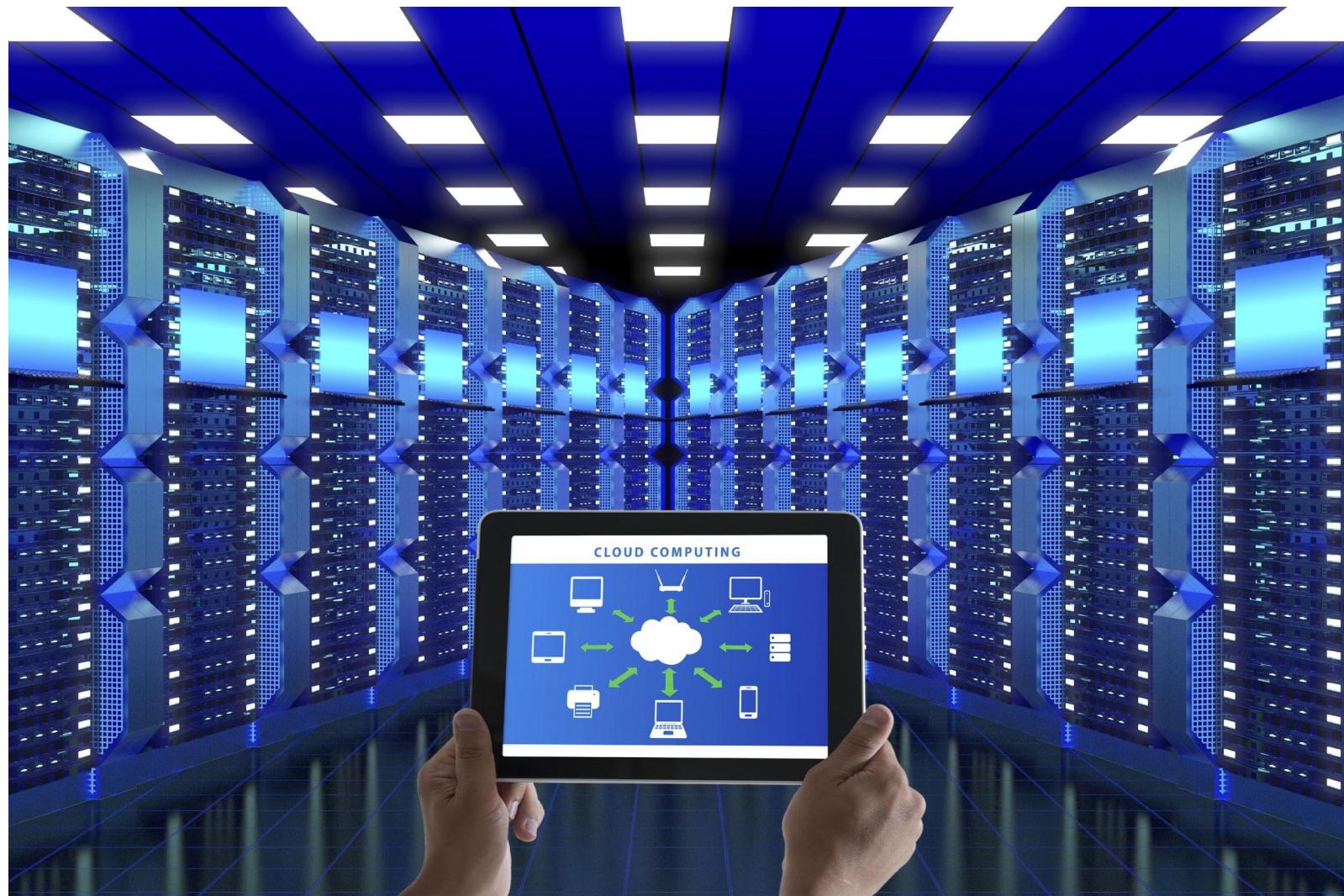
Little Panda and Jetson nano



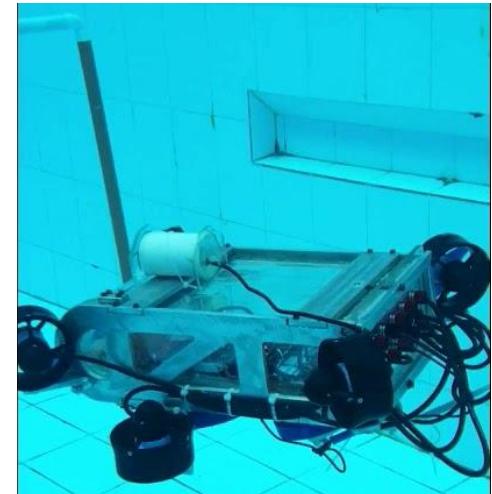
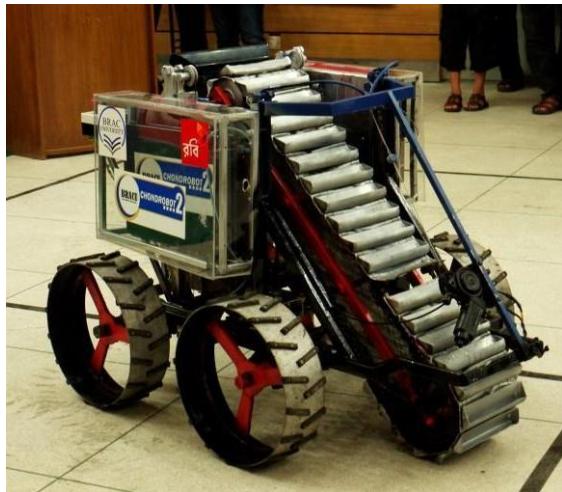
Intel Nuc and BRIX



Cloud Computing Infrastructure



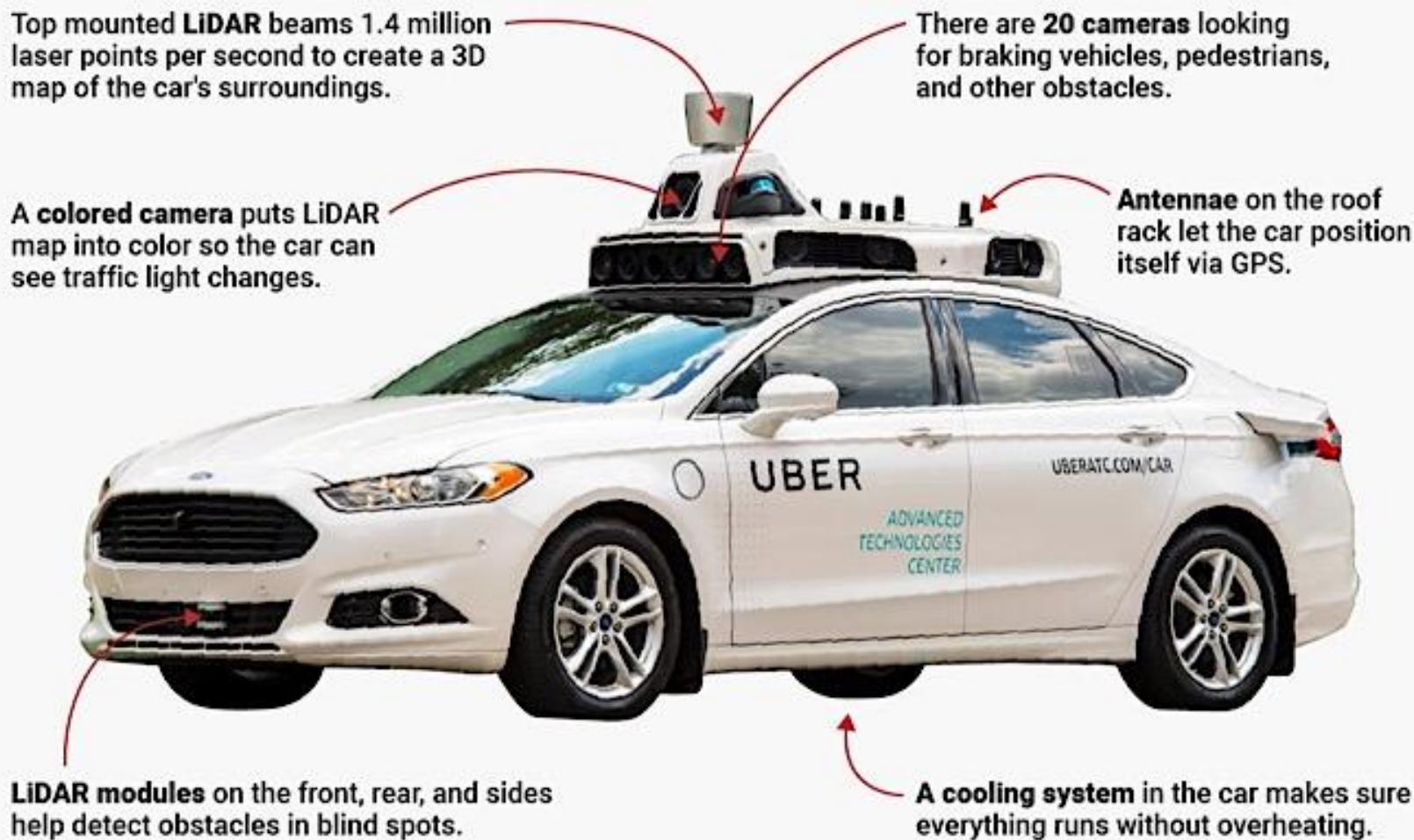
Projects we can proud of



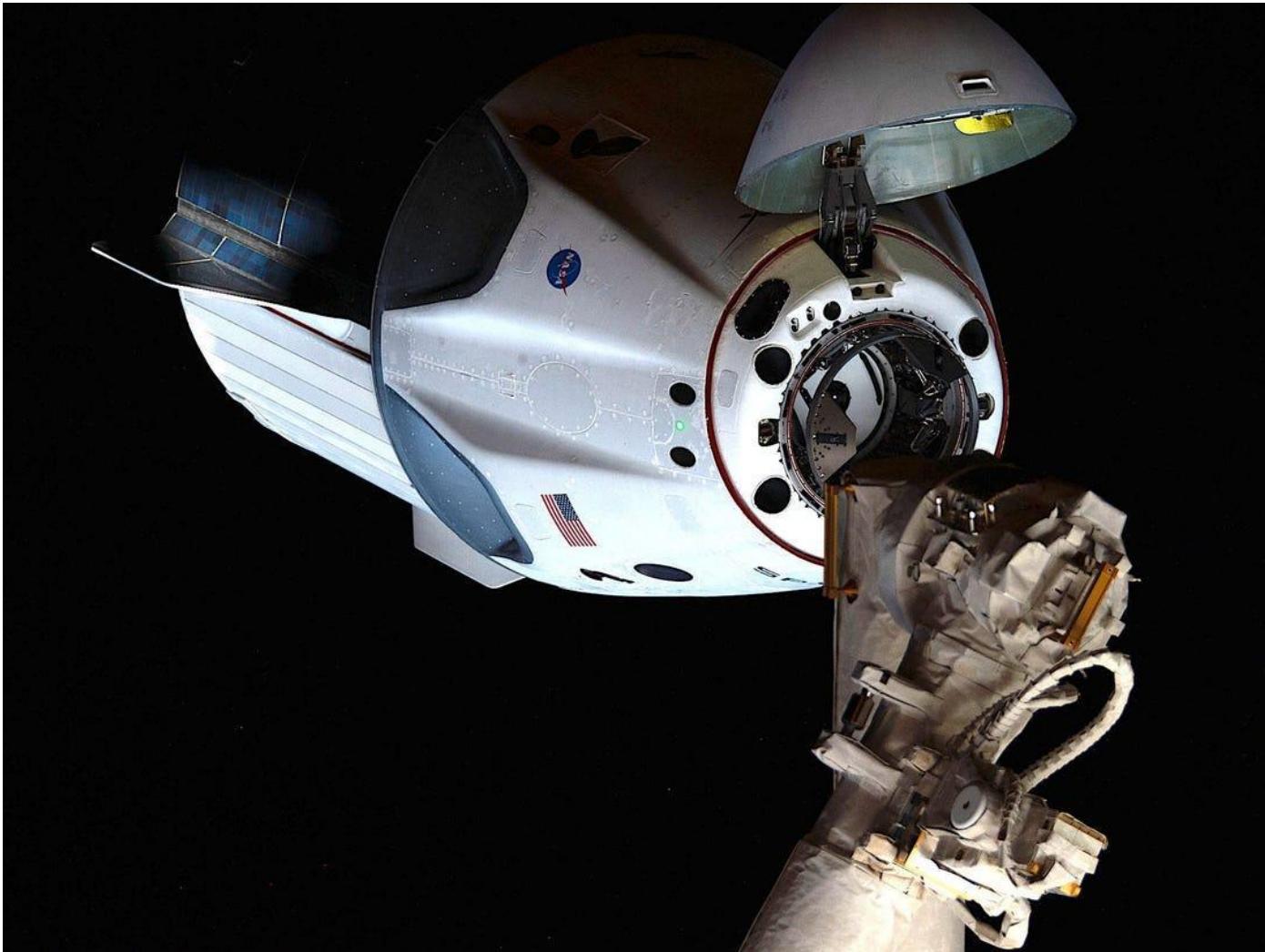
BRAC ONNESHA



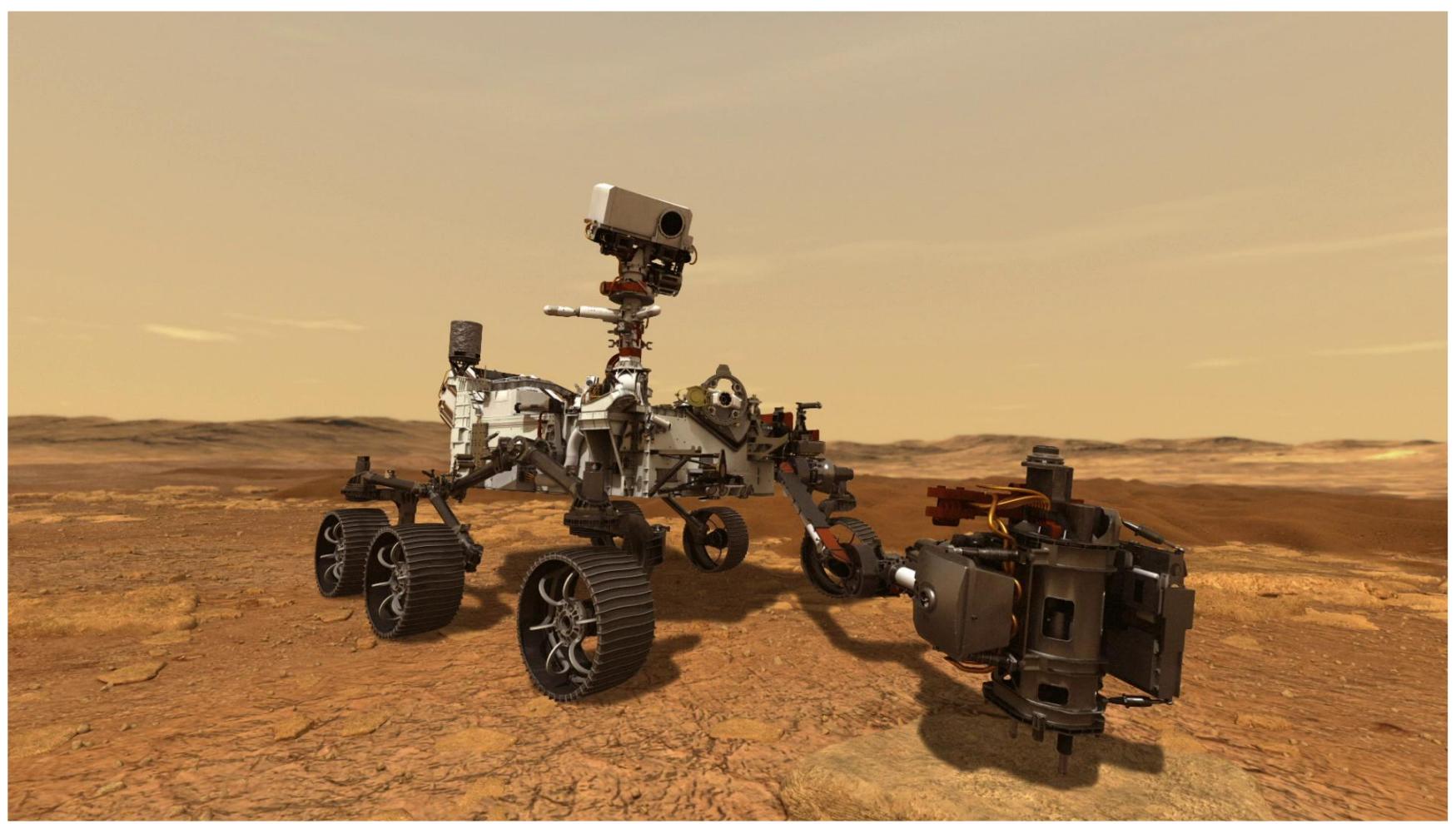
Self-Driving Car



Autonomous Docking



Perseverance Mars Rover



Roomba



Boston Dynamics

Platforms

BostonDynamics



SpotMini



Spot



Atlas



Handle

The da Vinci Robotic Surgical System

