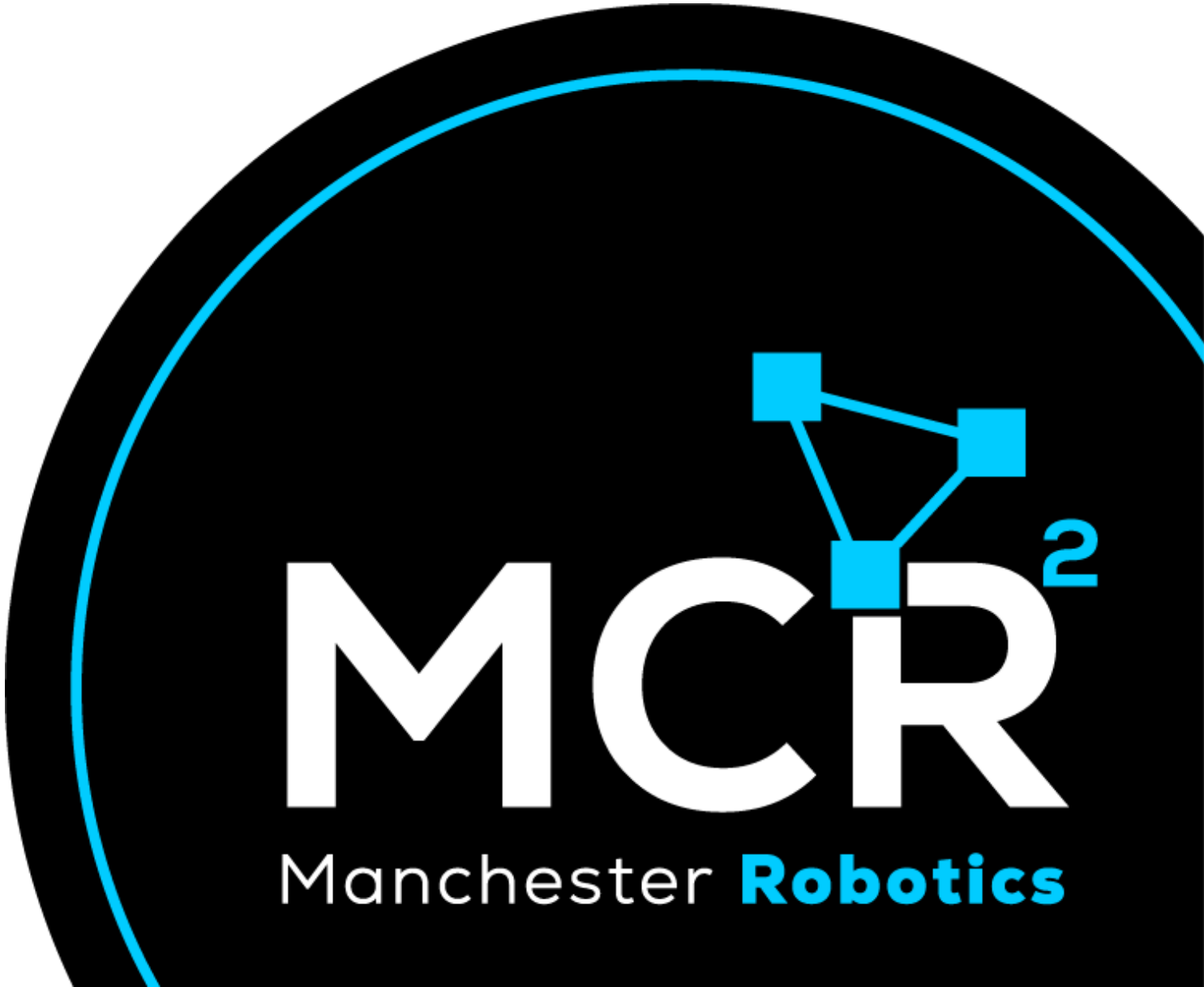
{Learn, Create, Innovate};

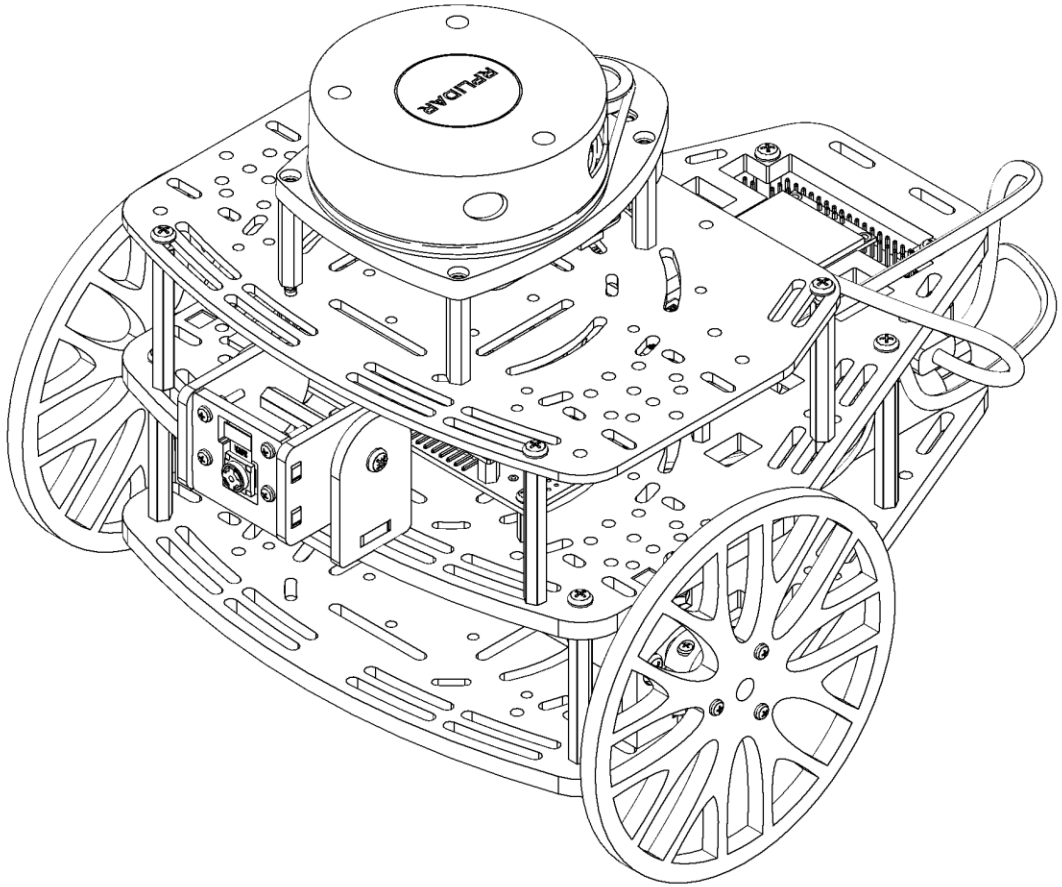
Robotic Fundamentals

Introduction



What is a dynamical system?

- A dynamical system is any system, man-made, physical or biological, that changes in time.
- In other words, particle or ensemble of particles whose state varies over time and is described using differential equations.
- What are the necessary characteristics for a system to be called a “robot”?



What is a dynamical system?

- Is an avalanche a robot?
- Is a dynamical system
- Described by an ODE

$$\dot{x} = f(x)$$

- Changes over time
- Can have an input

What is a robot?

Characteristics

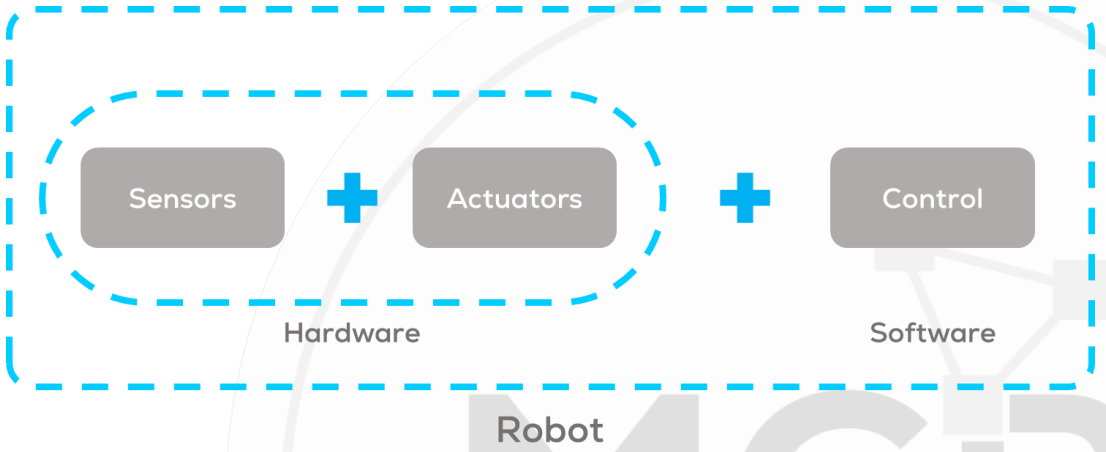
- A Robot is a dynamical system
- Guided by a computer program (an algorithm, or an agent)
- Performs some specific tasks.
- This is also known as a Control System.

$$\dot{\mathbf{x}}(t) = f(\mathbf{x}(t), \mathbf{u}(t))$$

$$\mathbf{y}(t) = g(\mathbf{x}(t))$$

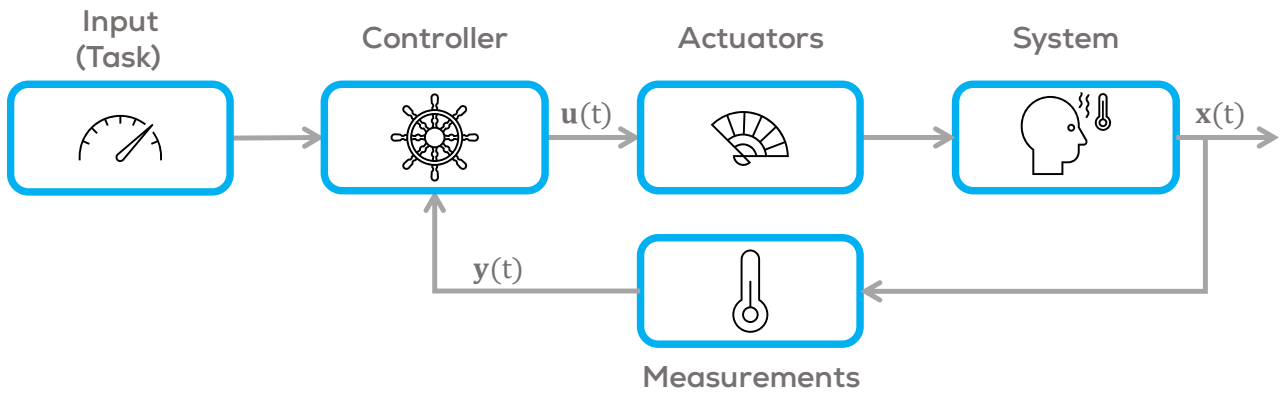
$$\mathbf{u}(t) = h(\mathbf{x}(t))$$

Robotic System



What is a robot?

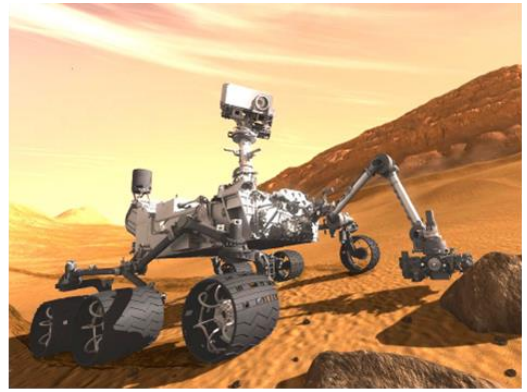
- Using the previous definition, it can be said that there exists many robots in the real world.
- Some robots may evoke human form, but most robots are task-performing machines, made with an emphasis on functionality, rather than aesthetics.
- One example would be a home heating/cooling system.



What is a robot?

- There are many classifications for robotic systems.
- Based on the environment and performance, the robots can be classified into industrial robots and mobile robots.
- An example of an industrial robot and a mobile robot can be seen in the side figure.
- This course will be focused on mobile robotics.

Industrial robotic arm for welding © KUKA Inc.



Mobile robot: Curiosity Mars Rover 2012 © NASA/JPL

Mobile robots

- Mobile robots can traverse anywhere in the environment without being bolted to a reference point in the environment.
- Ground mobile robots are categorized based on their *locomotion* mechanism into:
  - Legged robots
  - Wheeled robots
- This course will be focused on wheeled mobile robots

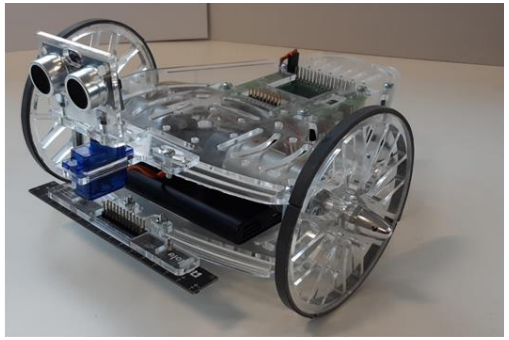
Legged Robot
© AIBO Sony Corp.

Wheeled Robot
© NASA/JPL.

Wheeled mobile robots

- There exists many types of wheeled robotic platforms
  - Differential-Drive robots
  - Omnidirectional robots
  - Ackermann-steering robots
  - and many others…
- In this course we will focus on differential drive robots, also known as “differential wheeled robots”.

Holonomic Robot
Acroname ©.



Differential-drive
Puzzlebot ©.

Autonomy in robotics

- Fundamental question: How much information and support must be provided by human to ensure that the robot is able to achieve its goals?

- The level of autonomy of a robot depends on the amount of information the robot requires from a human to perform its tasks.

Levels of Autonomy	
Human Operated : Human operator makes all the decisions.	**Remote Control**
Human Delegated : Robot can perform several functions independent of human control when delegated. **Human Supervised :** The system can perform wide variety of activities when given top level permission or direction by a human.	**Semi-Autonomous**
Fully Autonomous : The system receives goals form humans, translating them into tasks to be perfomed without human interaction.	**Autonomous System**

Autonomy in robotics

- Some examples of tele-robotics are
  - Cranes.
  - Drones.
  - Robotic exoskeletons.
  - some robotic arms, etc.

- In the case of semi-autonomous systems, we can have
  - Some mobile robots,
  - Industrial robotic arms, etc.

Kraft TeleRobotics, Inc©.

Exoesqueleto Exo-H3©. Technaid

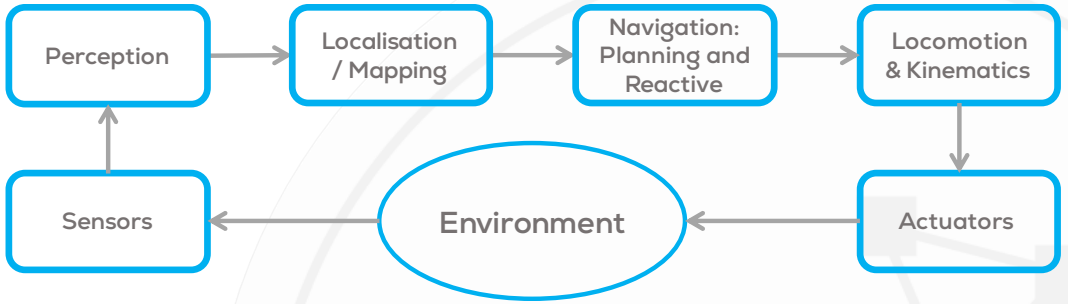
Honda ASIMO©.

Autonomy in robotics

- Autonomous systems enable companies to further optimise the manufacturing and development processes of their products.
- This can result in less waste, better energy efficiency and improved quality.
- Certain plants, such as nuclear plants, require robots for handling dangerous materials/chemicals, and processes.
- Autonomous systems, improve the safety of the work environment and help reduce risks.

Autonomous system in an unknown environment

- Autonomous systems in unknown environments, require different methods to interact with their environment.
- From sensors to read information from the environment, to actuators to interact with it.
- The other methods help the autonomous system to retrieve information from the environment (Perception).
- Localize the robot in the space whilst mapping an unknown environment.
- Once the robot knows its positions; it can plan the trajectory to follow to achieve its objective.
- Estimate the required inputs to the actuators based on the dynamical behavior of the system.



Hierarchy in autonomy