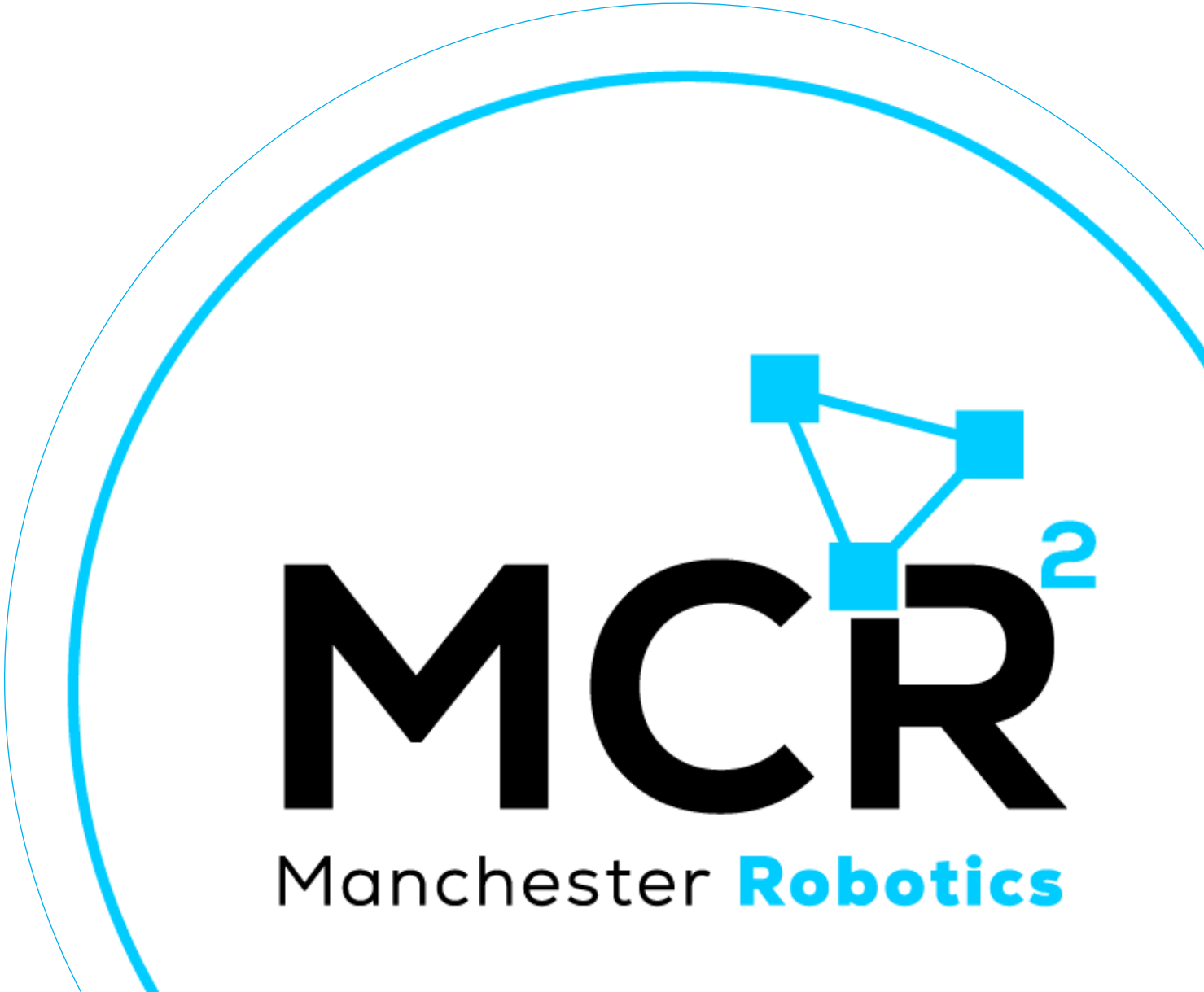
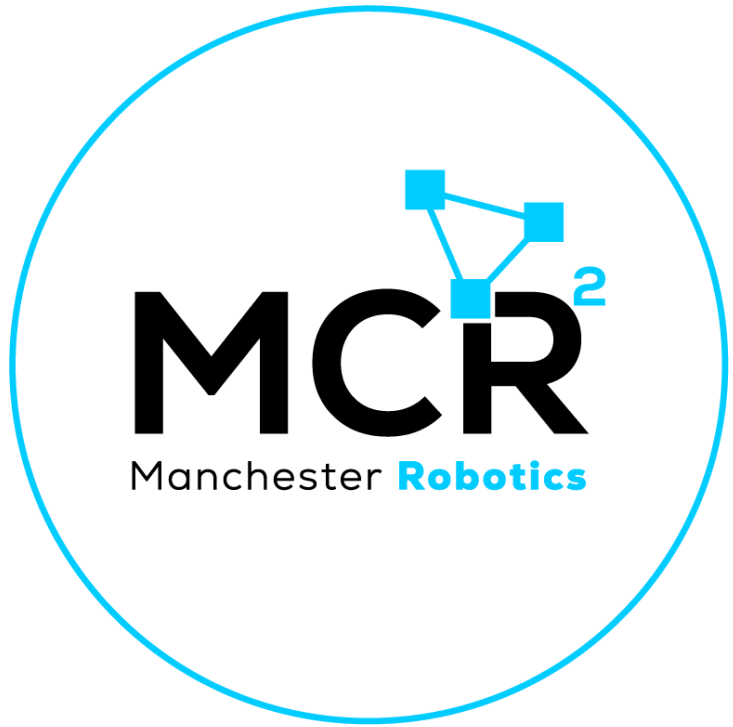
{Learn, Create, Innovate};

Robotics

An Introduction




MCR2
Manchester Robotics

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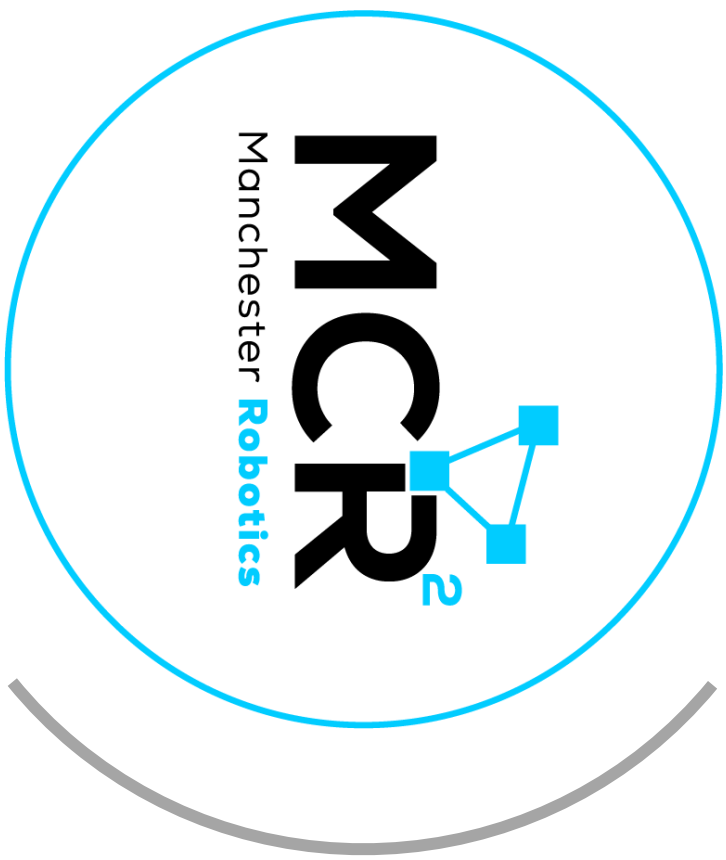

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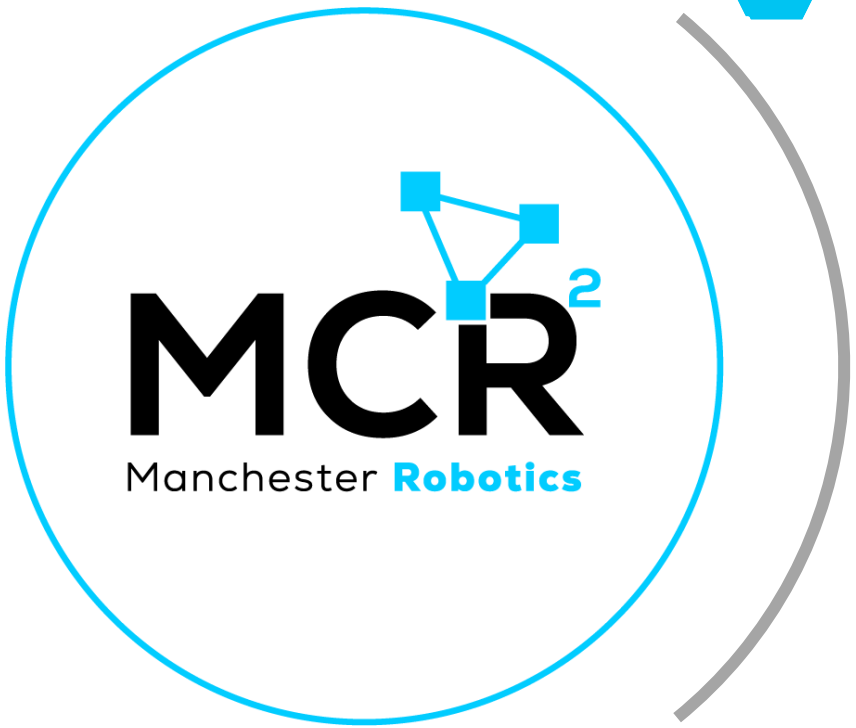

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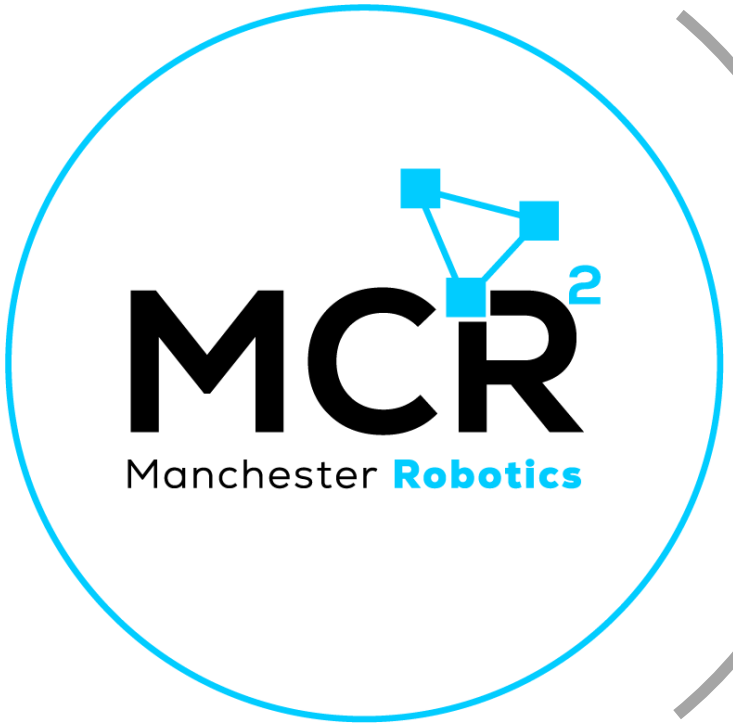

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2 Robots as Dynamical Systems

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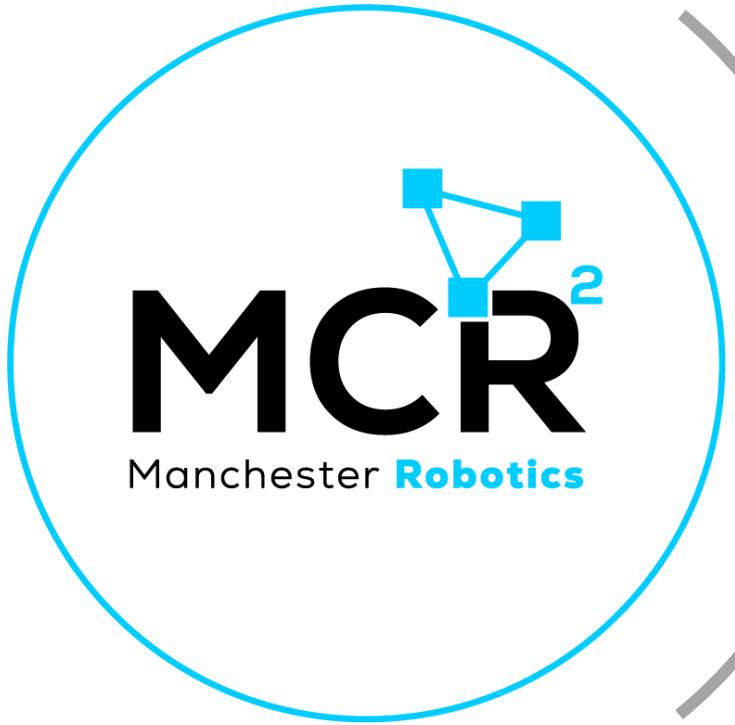
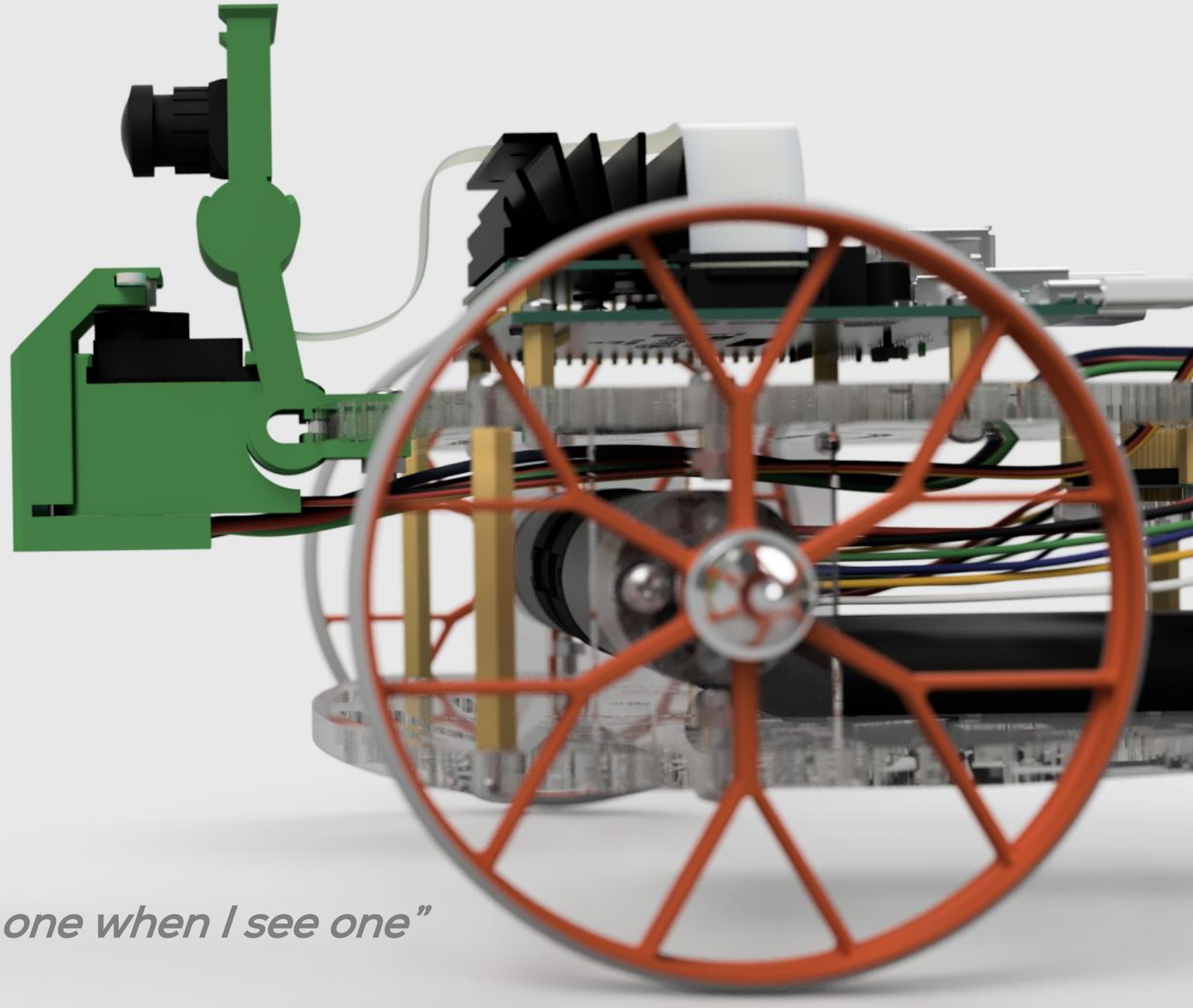


1 What is a robot?

What is a robot?

What is a robot?

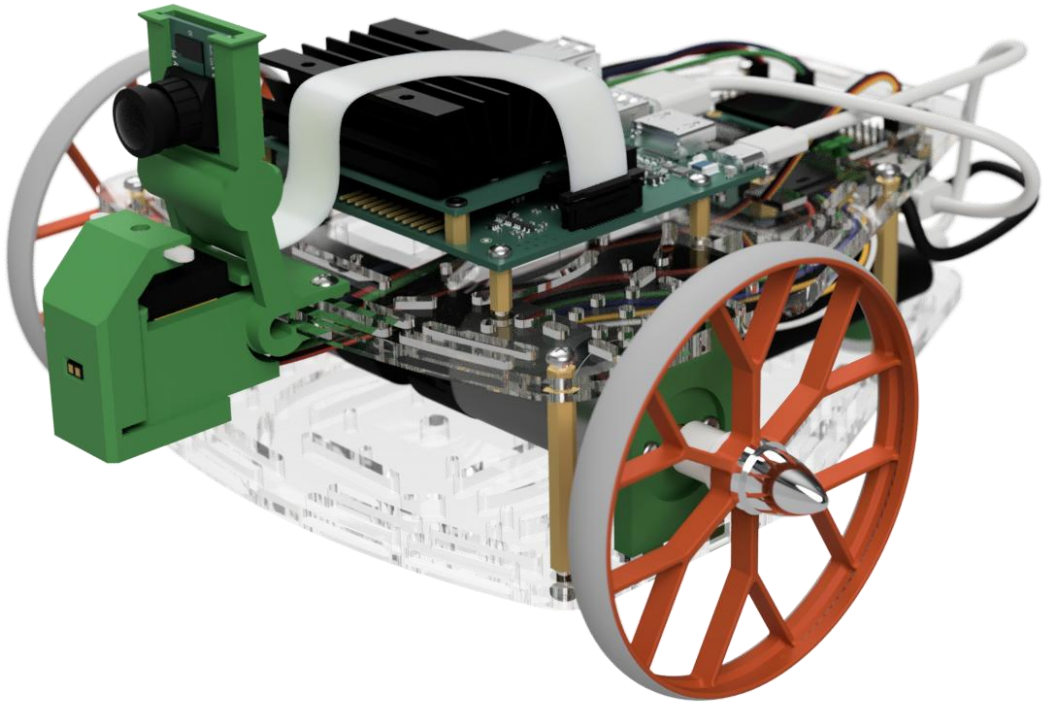


“I can’t define a Robot, but I know one when I see one”

-Joseph Engelberger (Physicist and Engineer)

What is a robot?

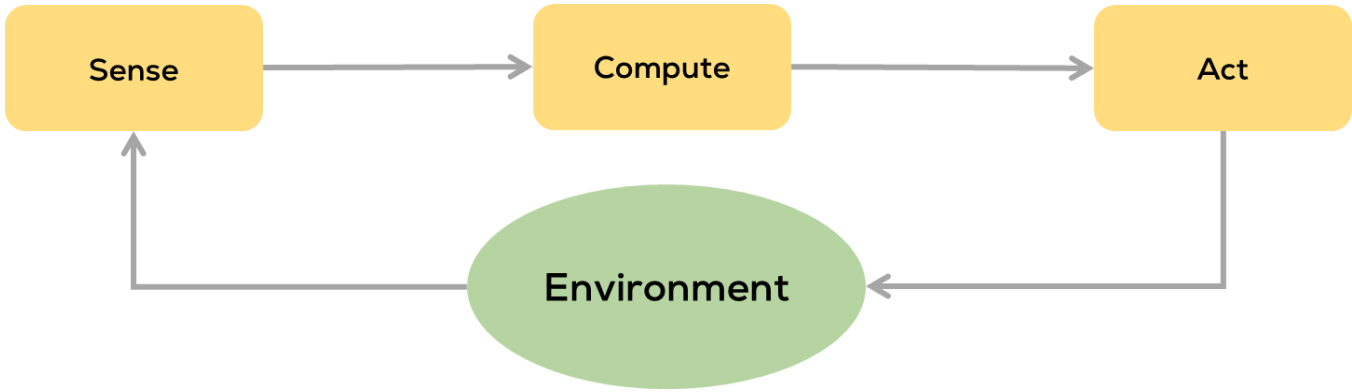
1. Can you describe in your own words what is a robot?
2. How would you differentiate a robot from another machine?
    1. E.g., Washing Machine, Dishwasher?
3. What makes/constitutes a robot?
4. Can any system be a robot? Yes/No? Why?
5. What is autonomy?
6. Is a robot a dynamical system?



What is a robot?

A robot is an autonomous machine capable of changing its environment by performing different actions.

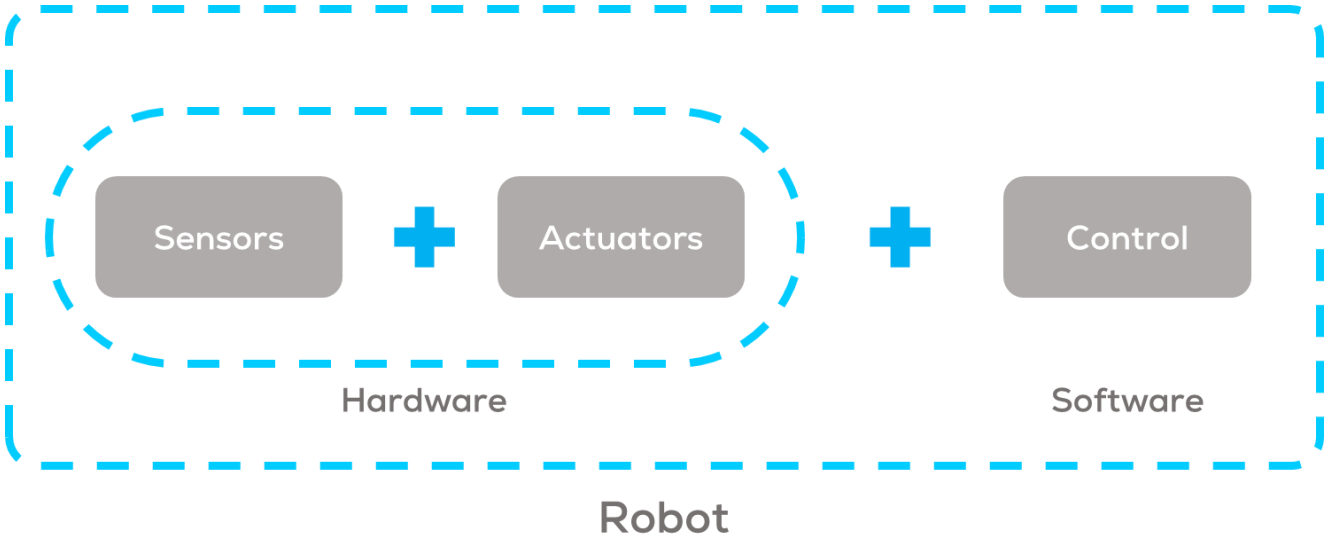
1. Sensing its environment.
2. Process information and perform computations to make decisions.
3. Perform actions to modify their environment.



What is a robot?

Robots come in a wide variety of forms:

- Humanoid, wheeled or animal-like devices.
- Generally, they prioritise functionality over appearance.
    - For example, under broad criteria, a home heating/cooling thermostat system automatically senses temperature and controls a furnace or AC, fitting a basic definition of a robot.

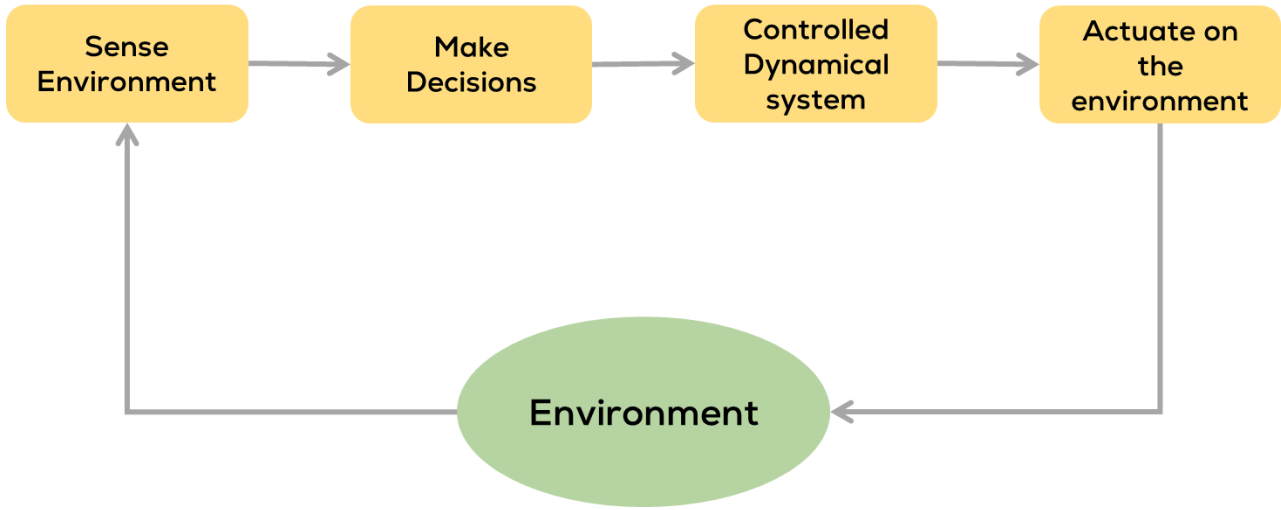


What is a robot?

Robots as Dynamical Systems

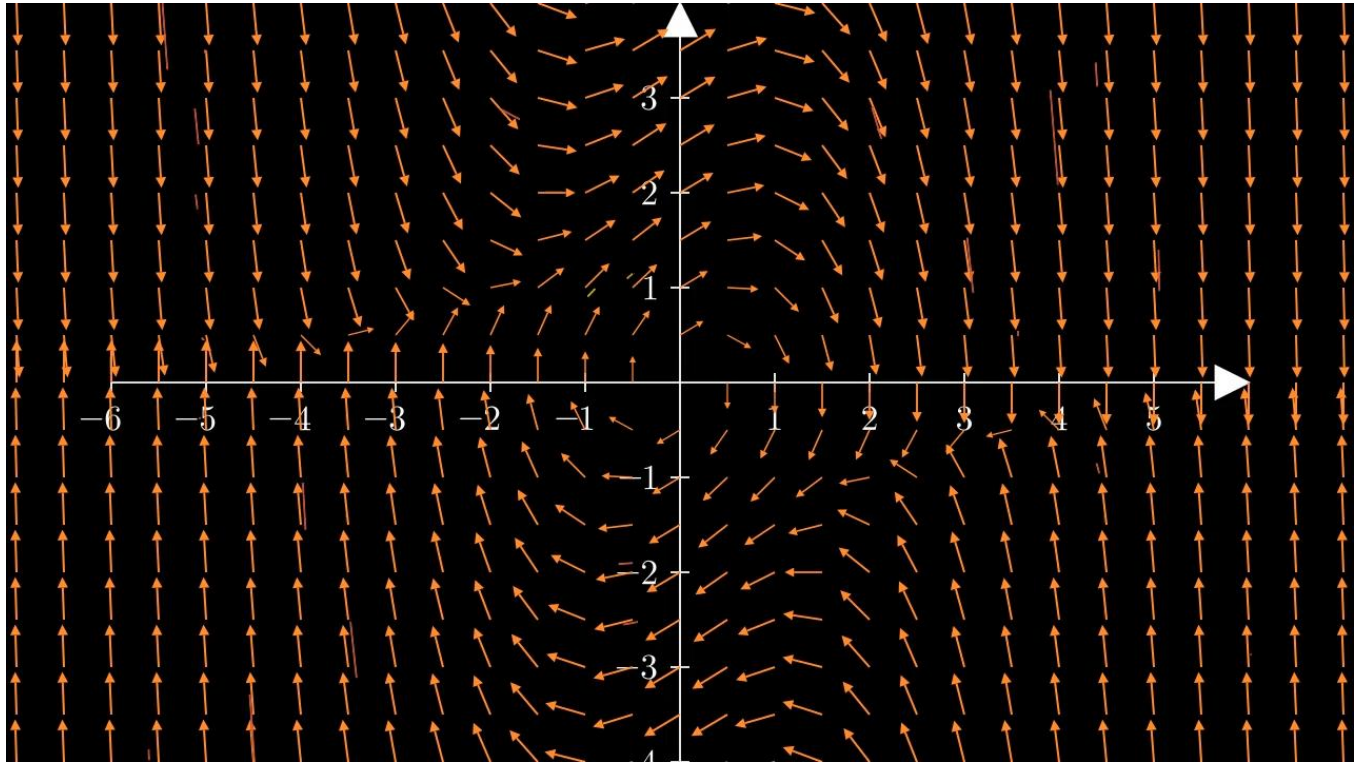
Robots as Dynamical Systems

- A robot is a dynamical system (its state evolves over time).
- Guided by a computer program or algorithm.
- Controls its inner state dynamics.
- Performs specific tasks autonomously or semi-autonomously.
- Modifies its environment.



Dynamical Systems

- 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”?

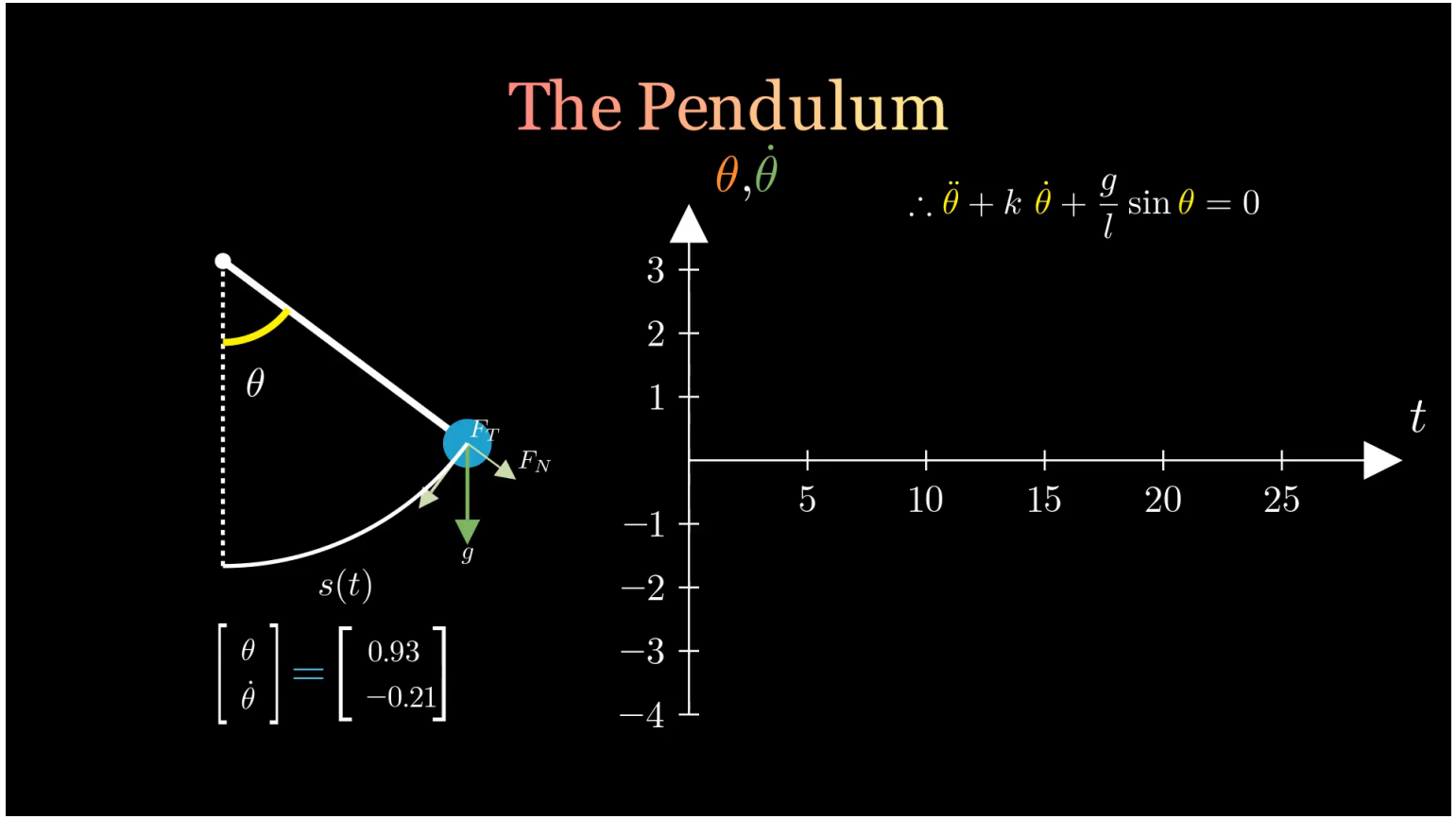


Dynamical Systems

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

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

- Changes over time
- Can have an inputs
- The outputs can be measured
- No because it has no control!



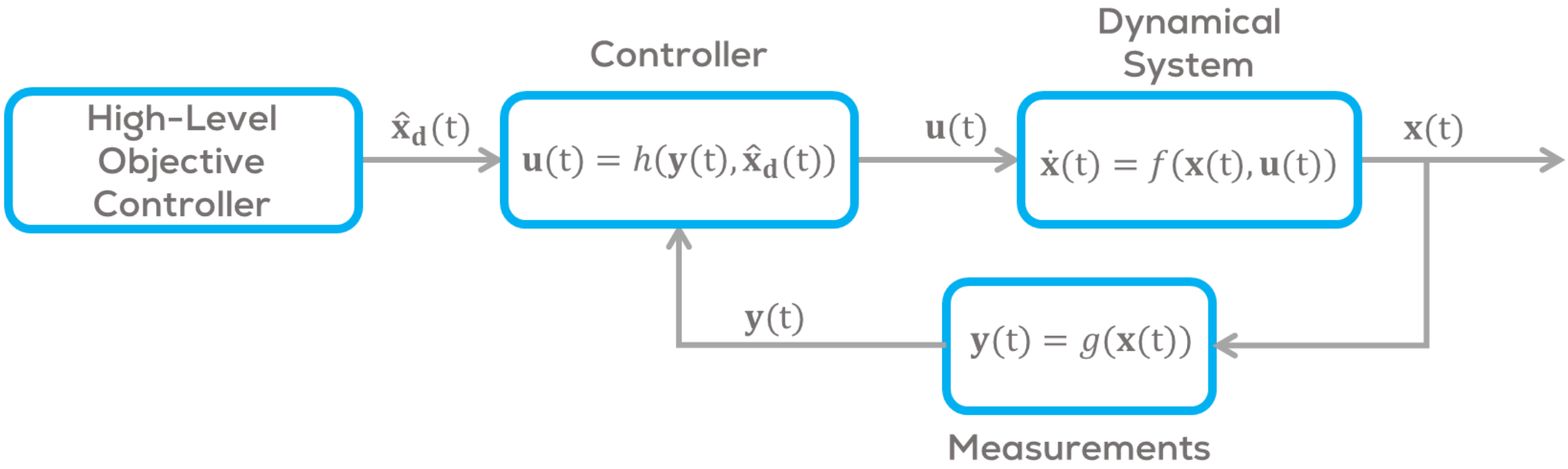
Controlled Dynamical Systems

- A controlled dynamical system that can be represented as:

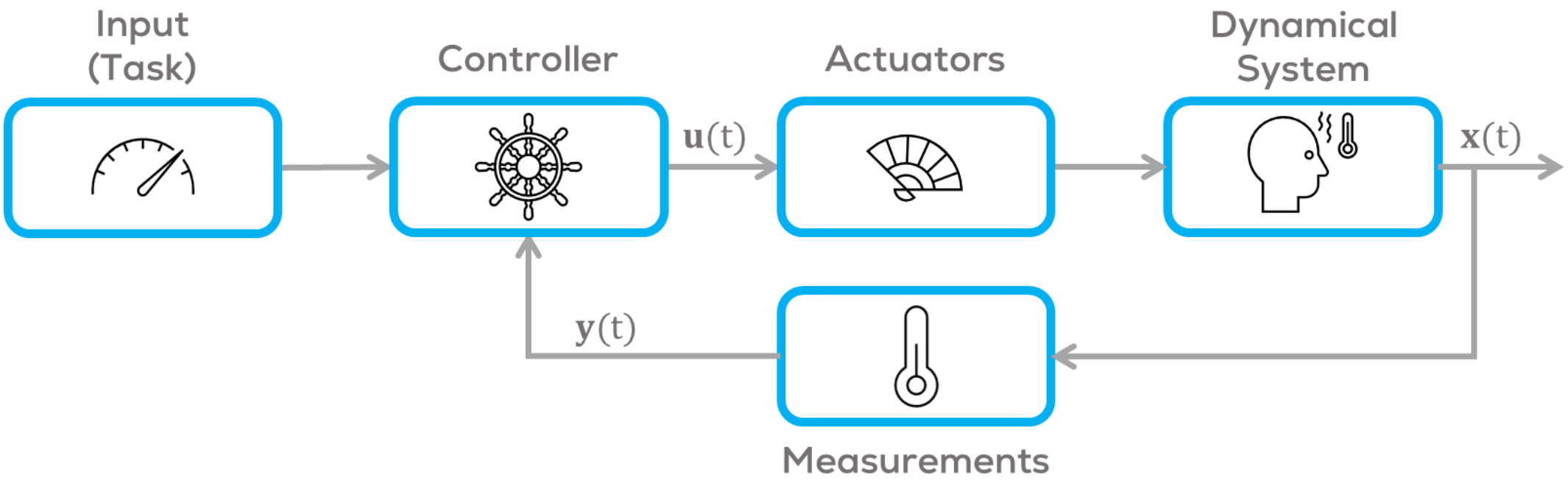
$$\dot{\mathbf{x}}(\mathrm{t}) = f(\mathbf{x}(\mathrm{t}), \mathbf{u}(\mathrm{t}))$$
$$\mathbf{y}(\mathrm{t}) = g(\mathbf{x}(\mathrm{t}))$$
$$\mathbf{u}(\mathrm{t}) = h(\mathbf{y}(\mathrm{t}), \hat{\mathbf{x}}(t))$$

- Where:
- $\dot{\mathbf{x}}(\mathrm{t}) = f(\mathbf{x}(\mathrm{t}), \mathbf{u}(\mathrm{t}))$ represent the systems' states (e.g. motor joint angles, speeds, accelerations) changes over time due to its current state and control inputs $\mathbf{u}$ (forces, voltages to motors, etc.).
- $\mathbf{y}(\mathrm{t}) = g(\mathbf{x}(\mathrm{t}))$ represent the inner sensors provide measurements (e.g. wheel encoders give wheel rotation, cameras give images) which are functions of the internal state.
- $\mathbf{u}(\mathrm{t}) = h(\mathbf{x}(\mathrm{t}))$ is the inner controller (the robot's program or "brain") computes control actions based on the current state $\mathbf{y}$ (or output). This could be a simple feedback law or a complex planning algorithm.

Controlled Dynamical Systems

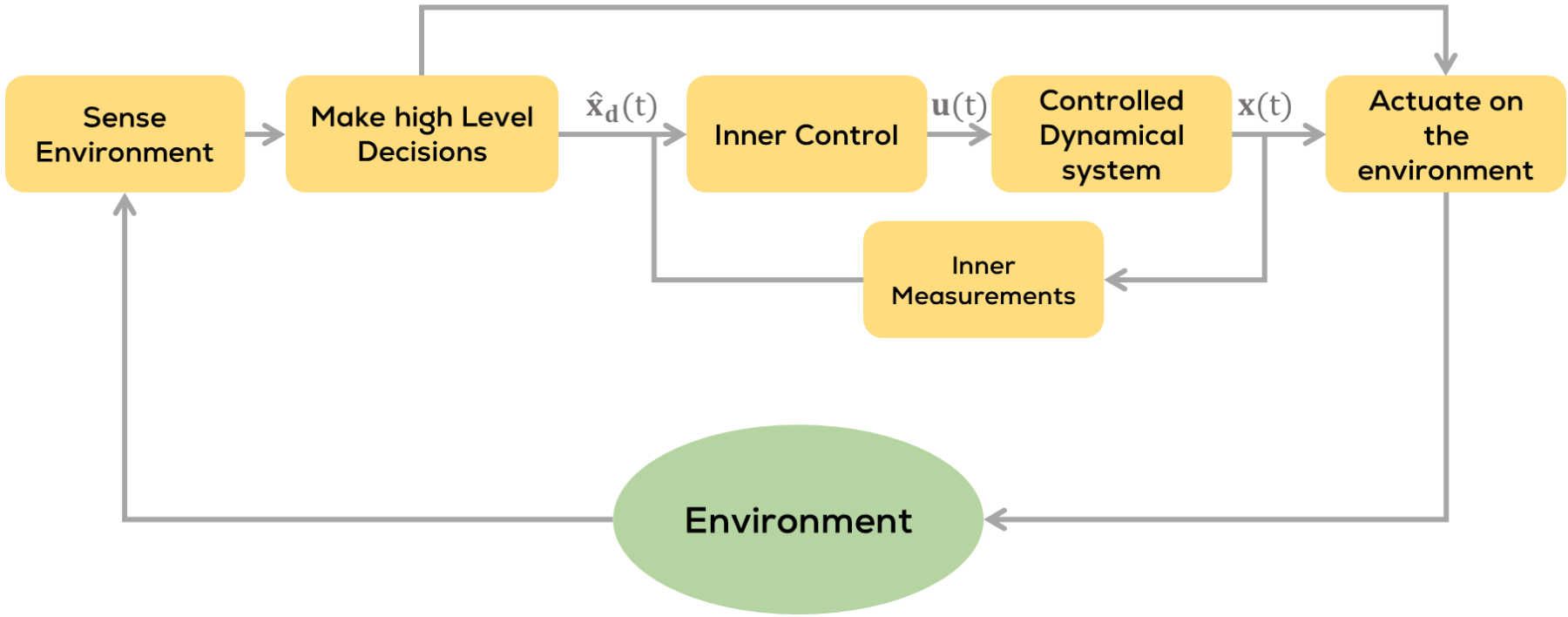


Controlled Dynamical Systems

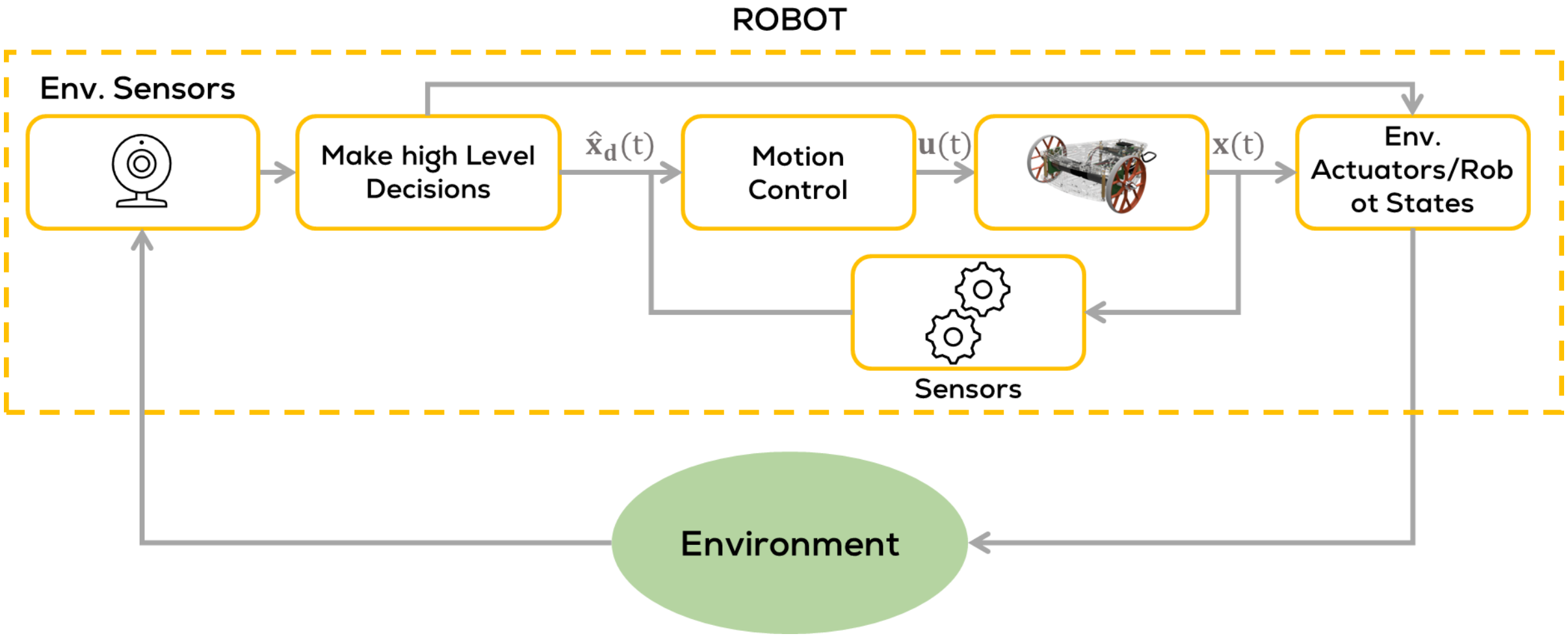


Then...What is a robot?

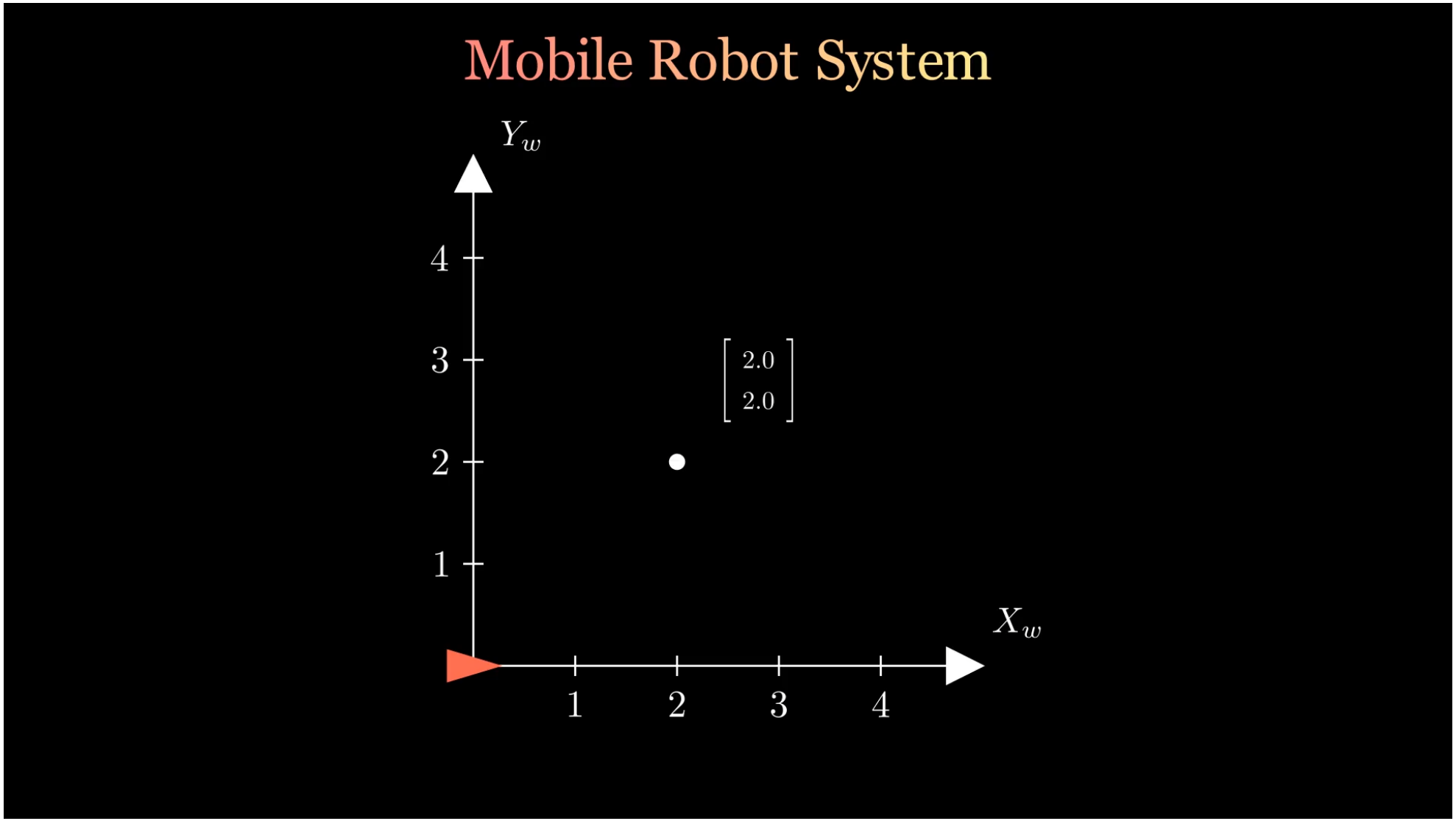
A robot is a controlled dynamical system that by sensing its environment, making some decisions, and providing some inputs to the controlled dynamical system, we can use its varying output states to modify its environment.



Then...What is a robot?

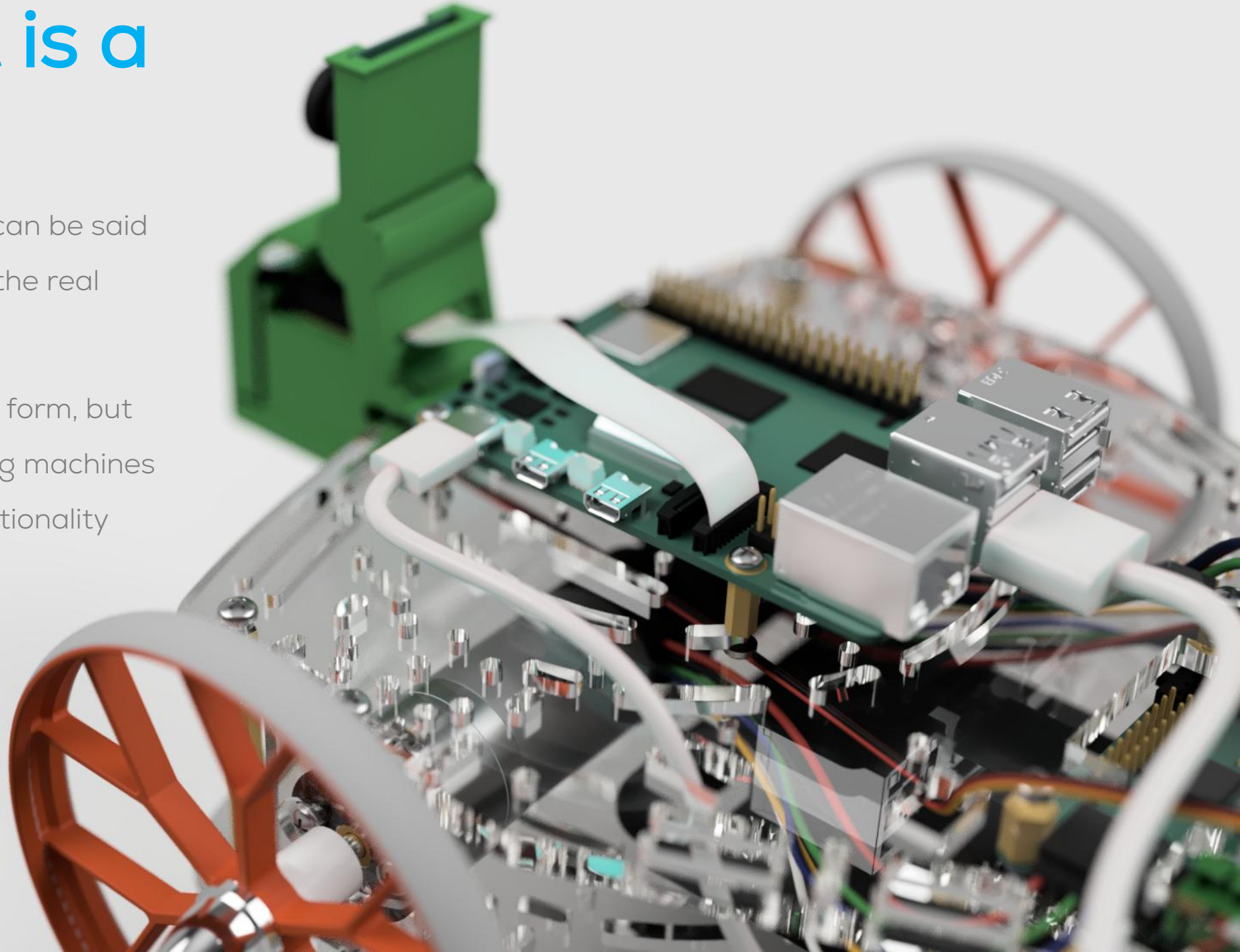


Then... What is a robot?



Then... What is a robot?

- Using the previous definition, it can be said that there exist 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.

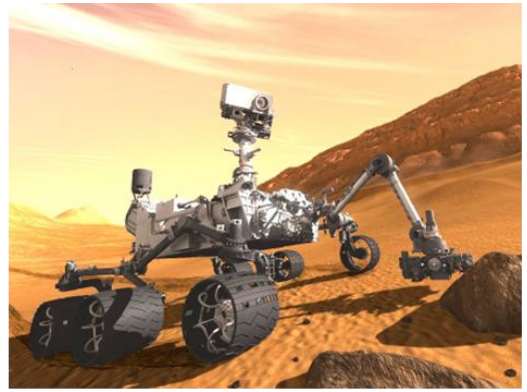


Types of Robots

Types of Robots

- Based on the environment and performance, the robots can be classified into fixed robots and mobile robots.
- **Fixed Robots:** They excel at repetitive, precise tasks in controlled settings – e.g. assembly, welding, and painting in automotive manufacturing.
- **Mobile robots** excel at tasks requiring exploration and free movement in the environment, e.g., exploration of unknown environments, search and rescue, and goods transportation.

Industrial robotic arm for welding © KUKA Inc.



Mobile robot: Curiosity Mars Rover 2012 © NASA/JPL

Mobile robots

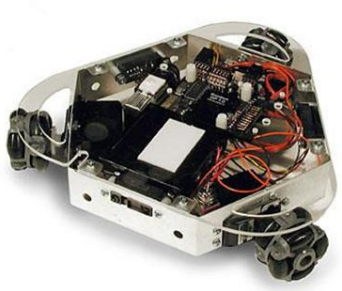
- Mobile robots can traverse anywhere in the environment without being bolted to a reference point in the environment.
- Ground mobile robots are categorized based on their *locomotion* mechanism into:
  - Legged robots
  - Wheeled robots
- This course will be focused on wheeled mobile robots

Legged Robot
© AIBO Sony Corp.

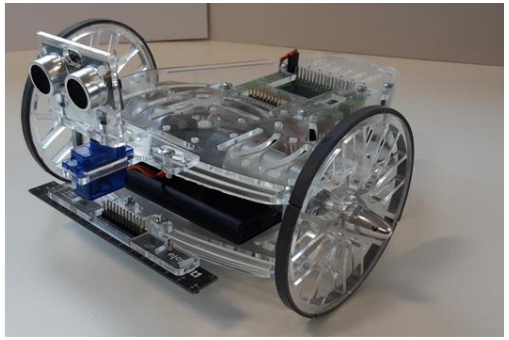
Wheeled Robot
© NASA/JPL.

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

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©.

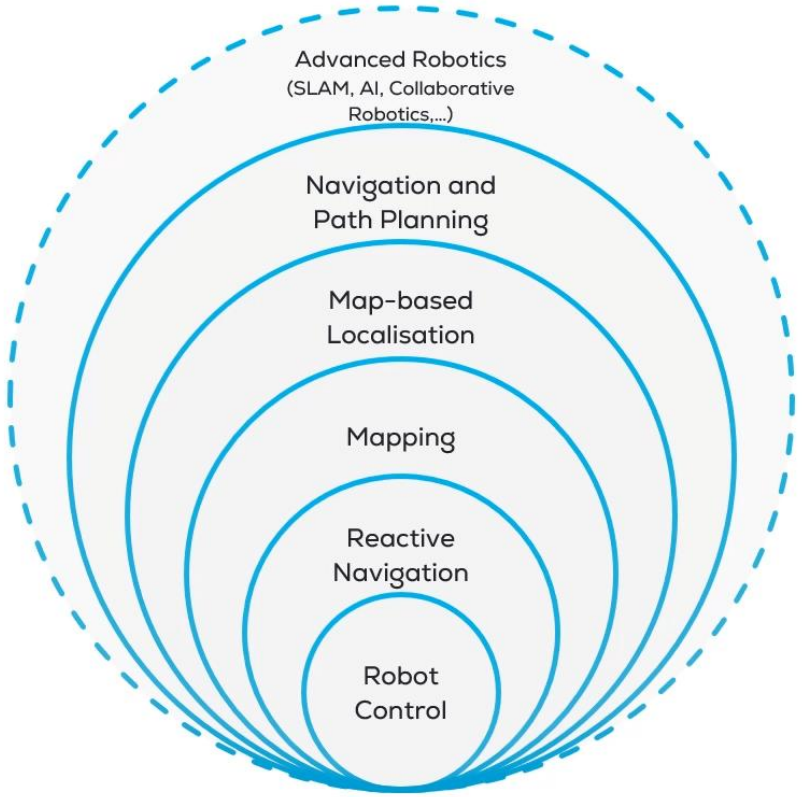
Autonomy in Robotics

- 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.

Hierarchy in Autonomy

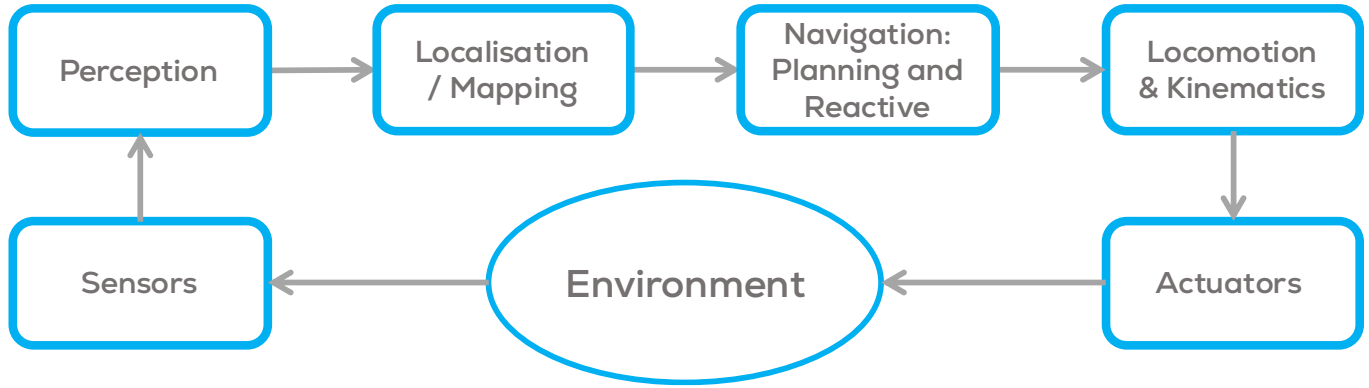
Hierarchy in autonomy

Puzzlebot SDK

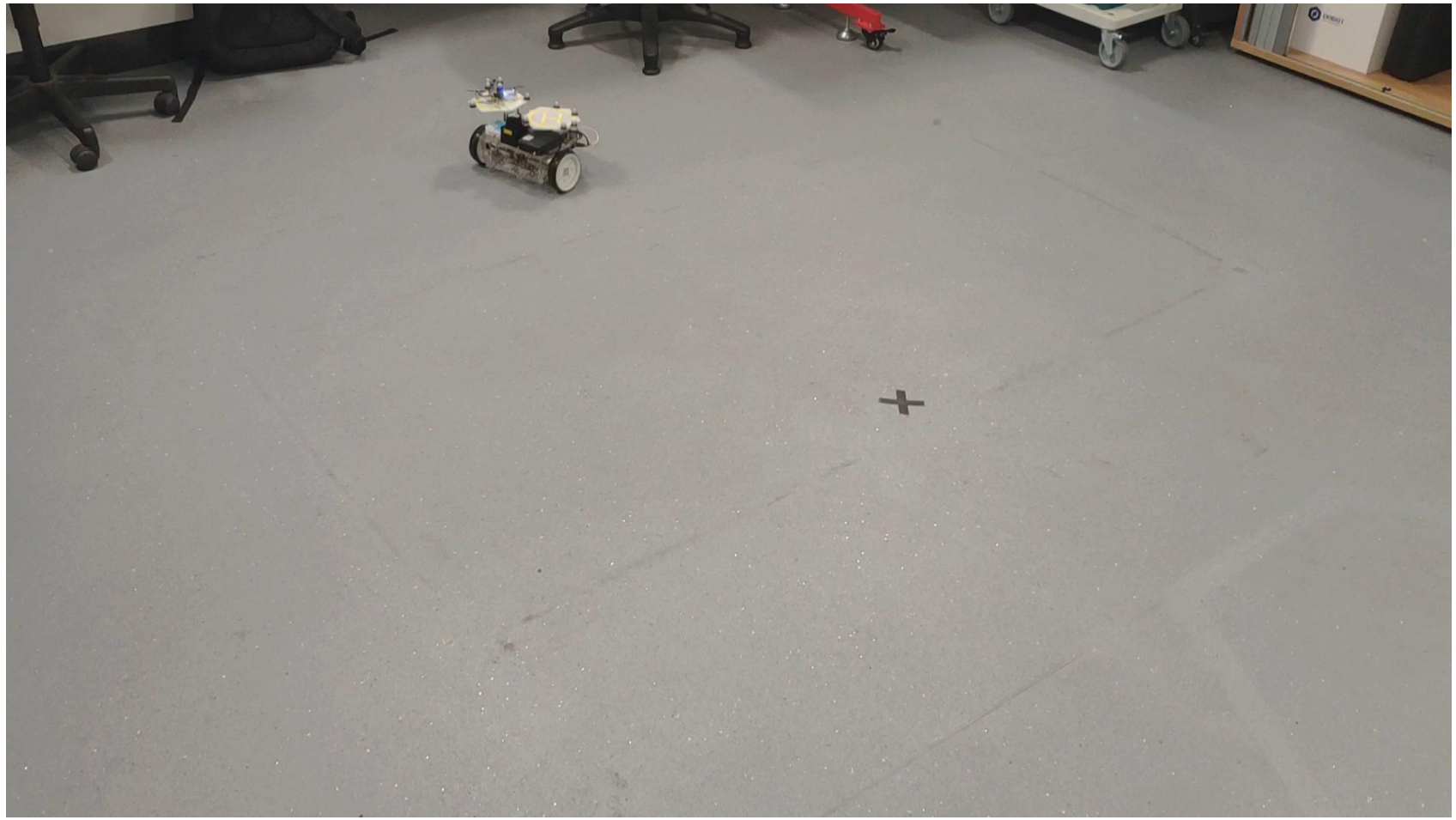


Autonomous systems in an unknown environment

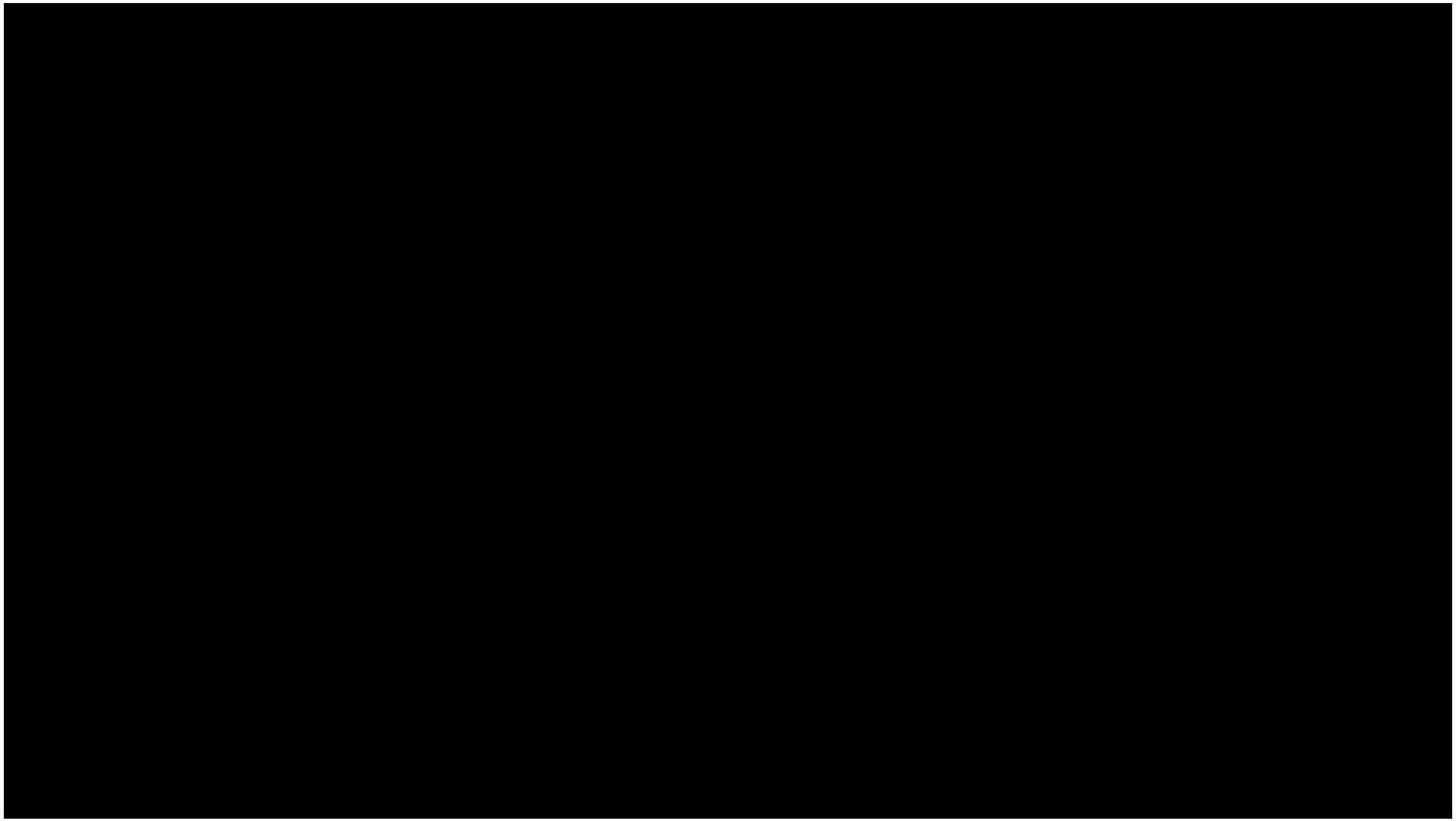
- From sensors to read information from the environment, to actuators to interact with it.
- The other methods help the autonomous system to retrieve information from the environment (Perception).
- Localize the robot in the space whilst mapping an unknown environment.
- Once the robot knows its positions; 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.



Examples of mobile autonomous systems



Examples of mobile autonomous systems



Thank you

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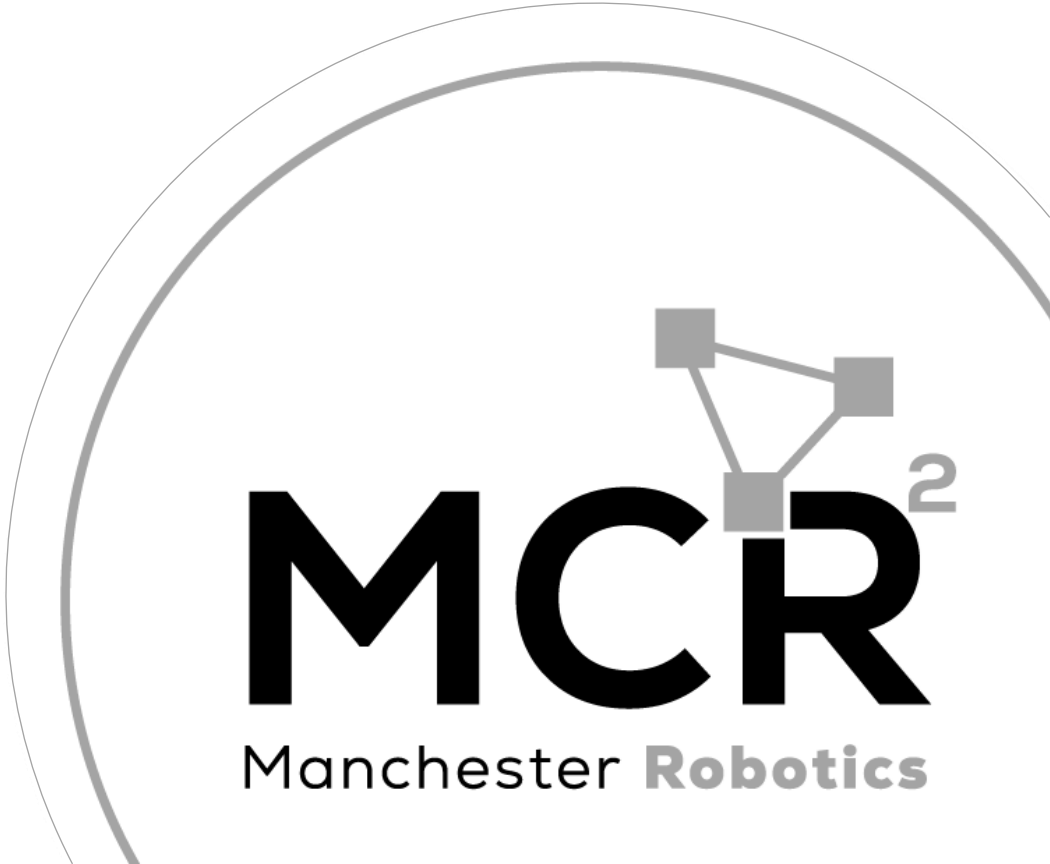

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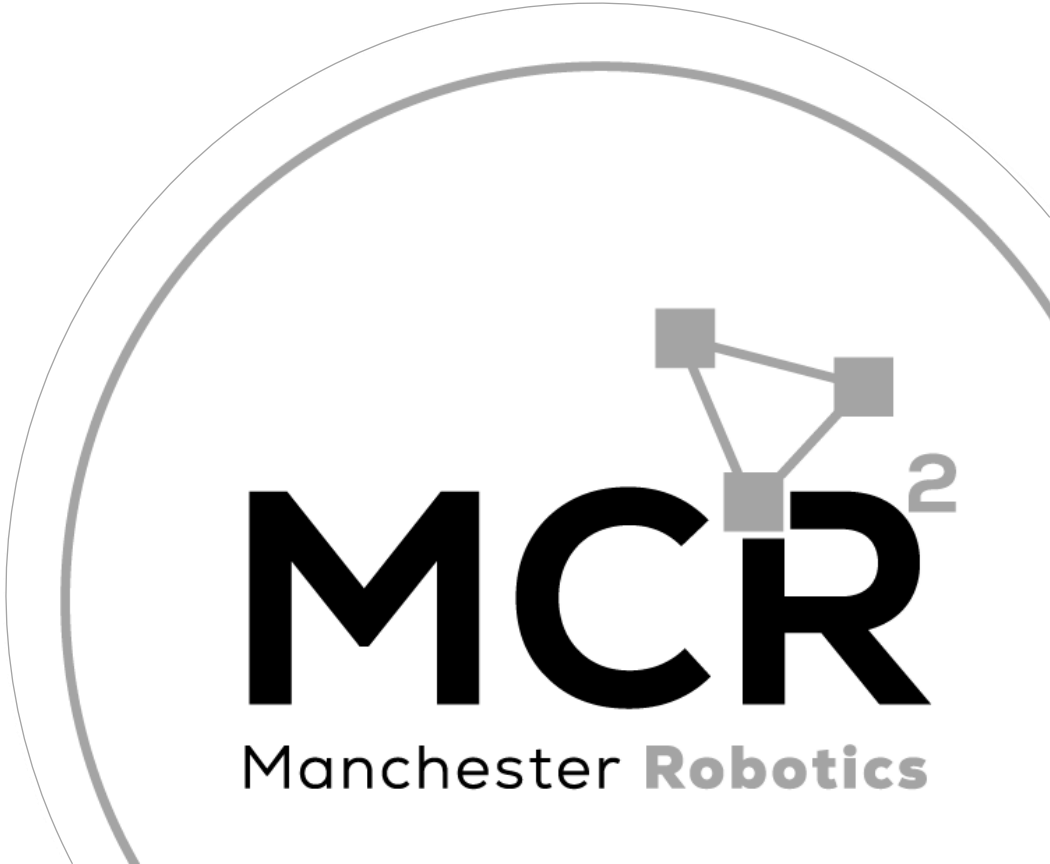

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