The *Sense-Think-Act* Loop

CS 3630

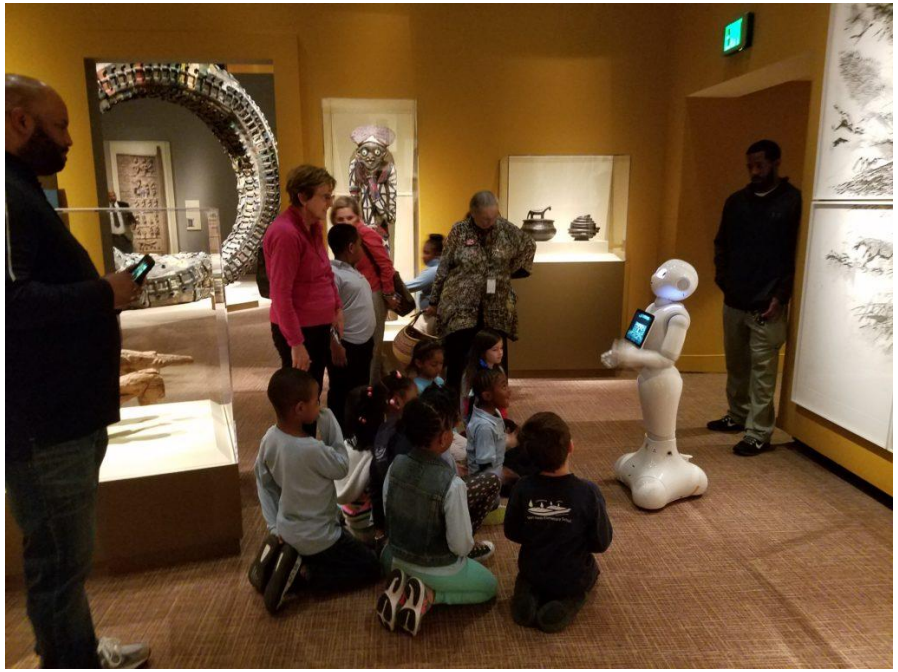
A Taxonomy of Robotics Topics

To develop a robot we must integrate six distinct aspects:

1. **State:** How does the robot represent its world, and itself?
2. **Actions:** What can the robot do, and how to represent this?
3. **Sensors:** What information about the world can be ascertained via sensing, and how do we model this process?
4. **Perception:** How can we combine sensor data with contextual knowledge to understand the current state?
5. **Planning:** What actions should the robot execute to transform the state of the world into a desired goal state?
6. **Learning:** How can the robot improve its knowledge over time, using information that it acquires during operation?

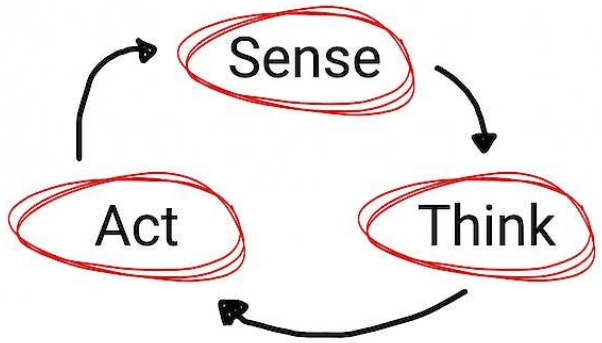
Museum Guide Robot example

- **State:** where is the robot, and where are the humans to be guided?
- **Actions:** move from room to room
- **Sensors:** cameras
- **Perception:** use computer vision to understand human intention, and to localize
- **Planning:** what path to take in order to guide humans to their desired exhibit
- **Learning:** which parts of the museum are crowded, and when to avoid these



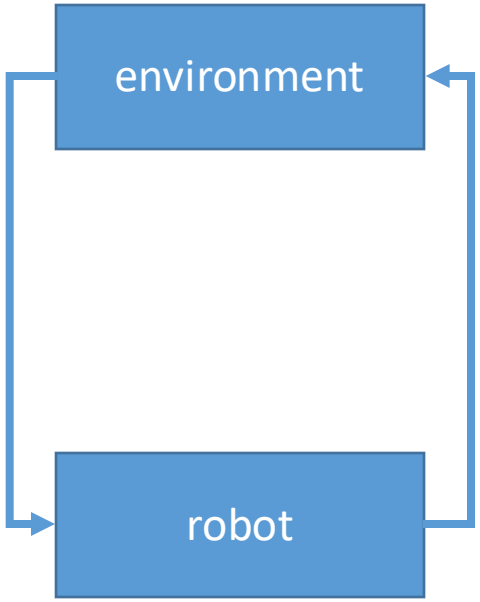
How do robots function in the world

When deployed in the world, most robots use the so-called ***Sense-Think-Act*** paradigm of operation.

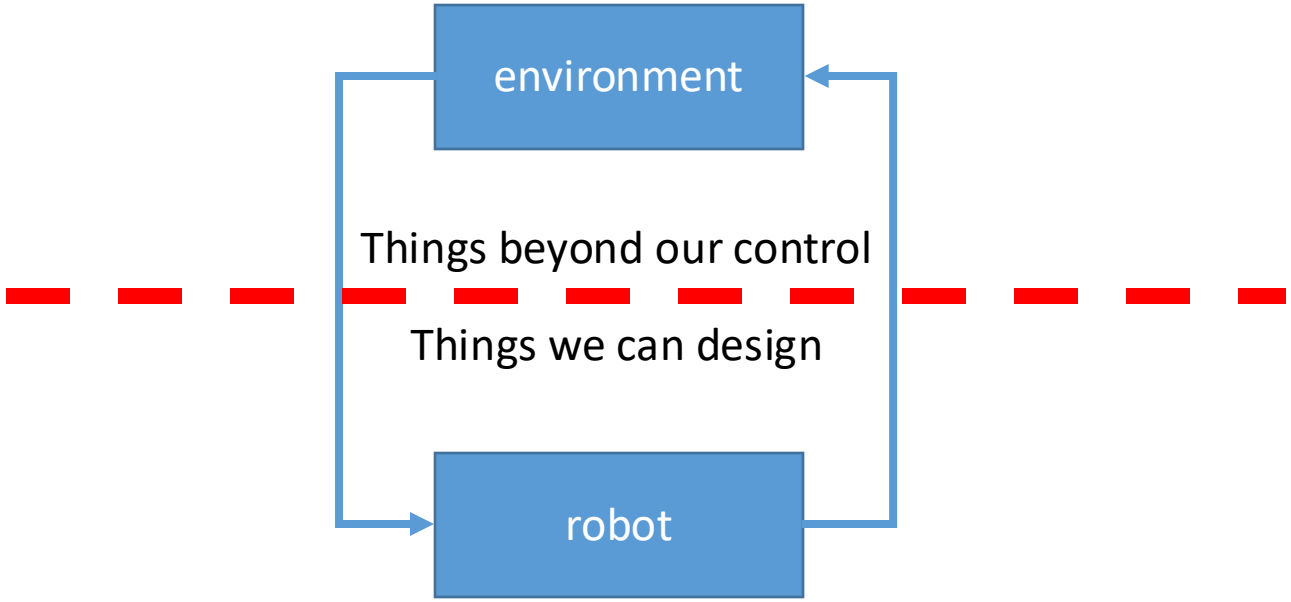


This can be viewed as an overall control structure, in which state, actions, sensors, perception, planning, and learning play specific roles.

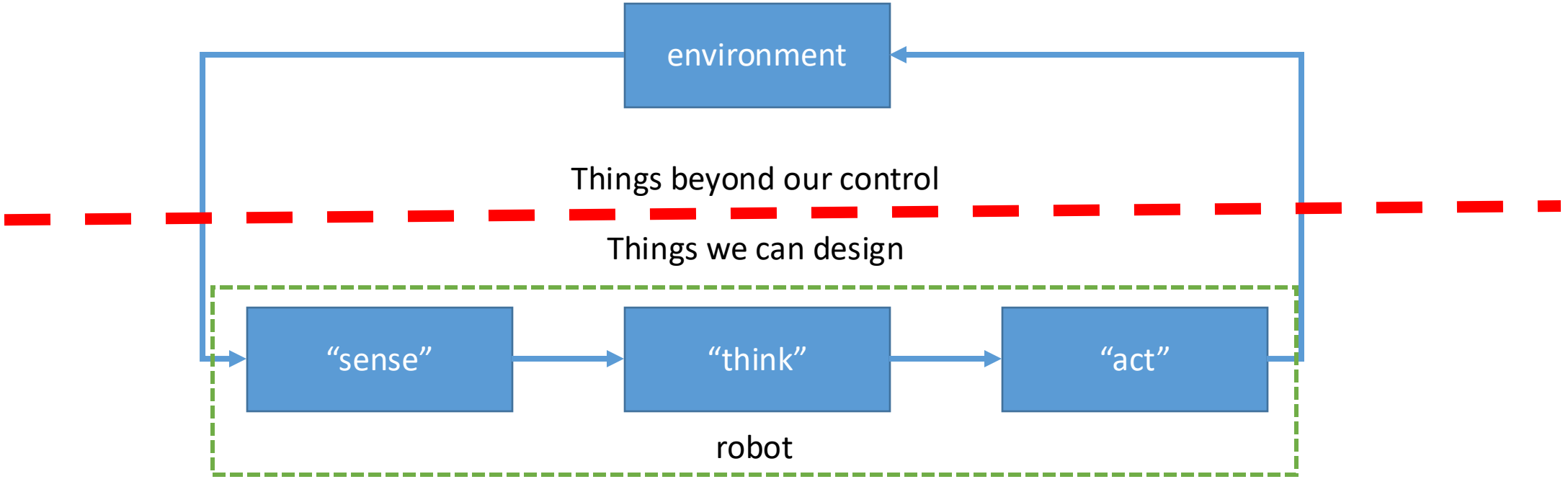
How do robots function in the world



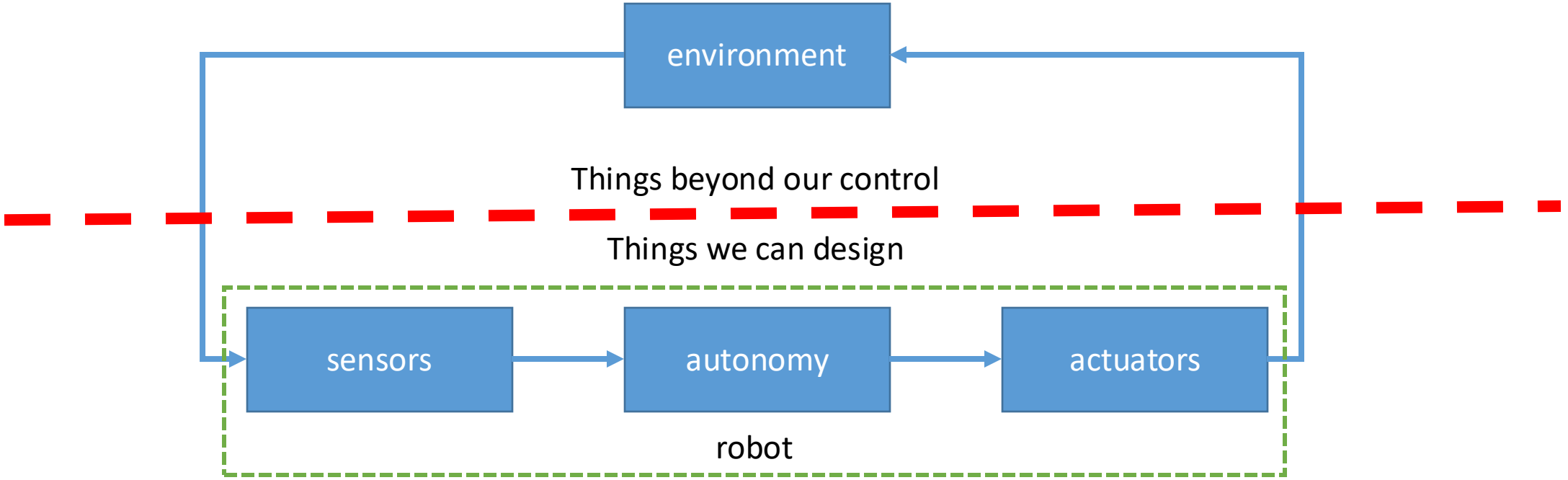
How do robots function in the world



How do robots function in the world



How do robots function in the world



Sense, Think, Act

Suppose you are given a task: *Rearrange the chairs in the room into a circle.* How would you proceed?

1. Look around the room and evaluate the situation.
   Where are the chairs? How many chairs are there?
2. Make a plan:
   1. Go the first chair, pick it up, place it in the desired position
   2. Repeat for all N chairs.
3. Execute the plan.

This is the basic strategy followed by almost all robots.

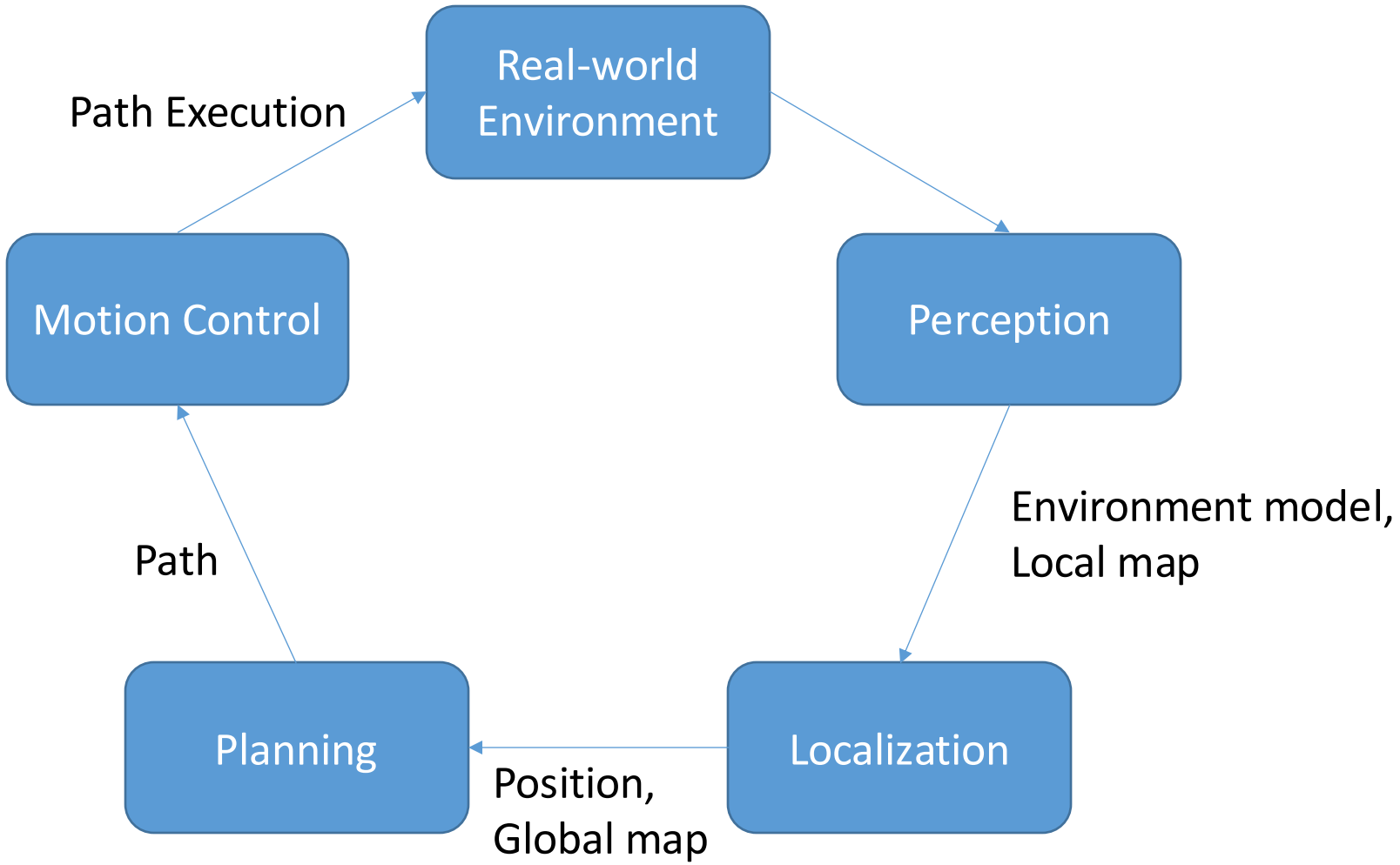
Sense, Think, Act

Suppose you are given a task: *Rearrange the chairs in the room into a circle.* How would you proceed?

1. Look around the room and evaluate the situation. Where are the chairs? How many chairs are there?	Sense
2. Make a plan: 1. Go the first chair, pick it up, place it in the desired position 2. Repeat for all N chairs.	Think
3. Execute the plan.	Act

This is the basic strategy followed by almost all robots.

Example: Navigation in a Known Environment



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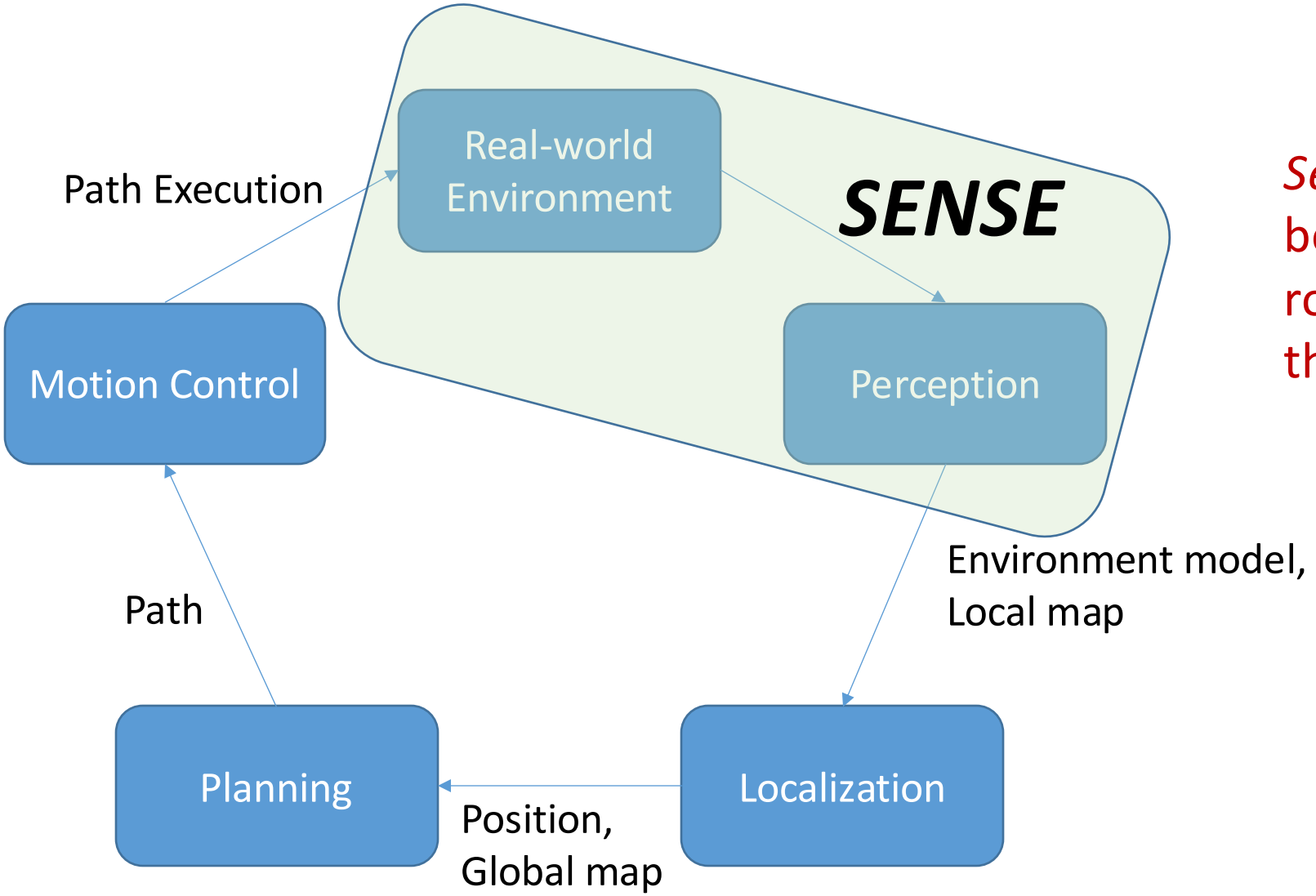
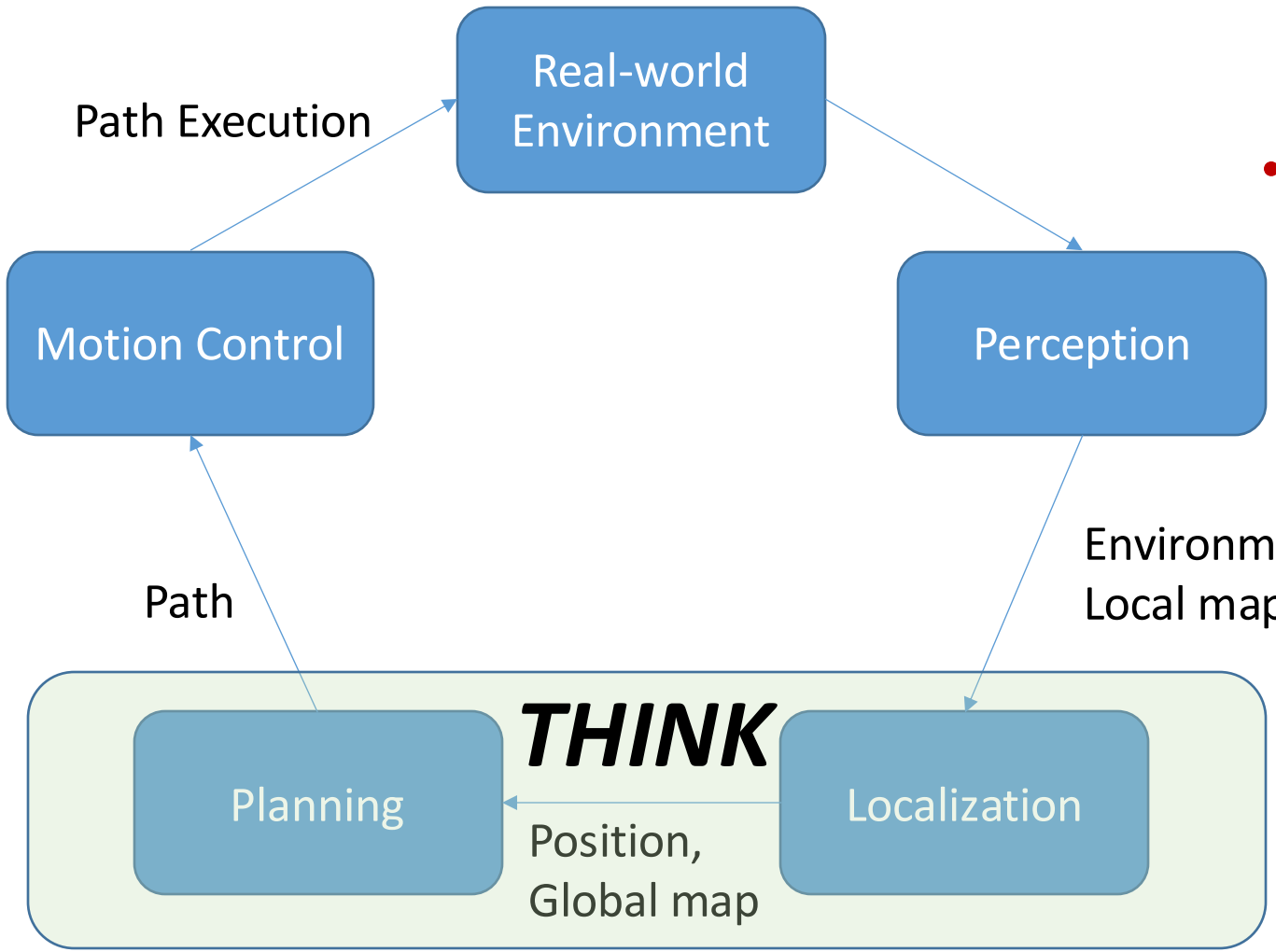


Sensing provides a connection between the real world and the robot's internal representation of the world.

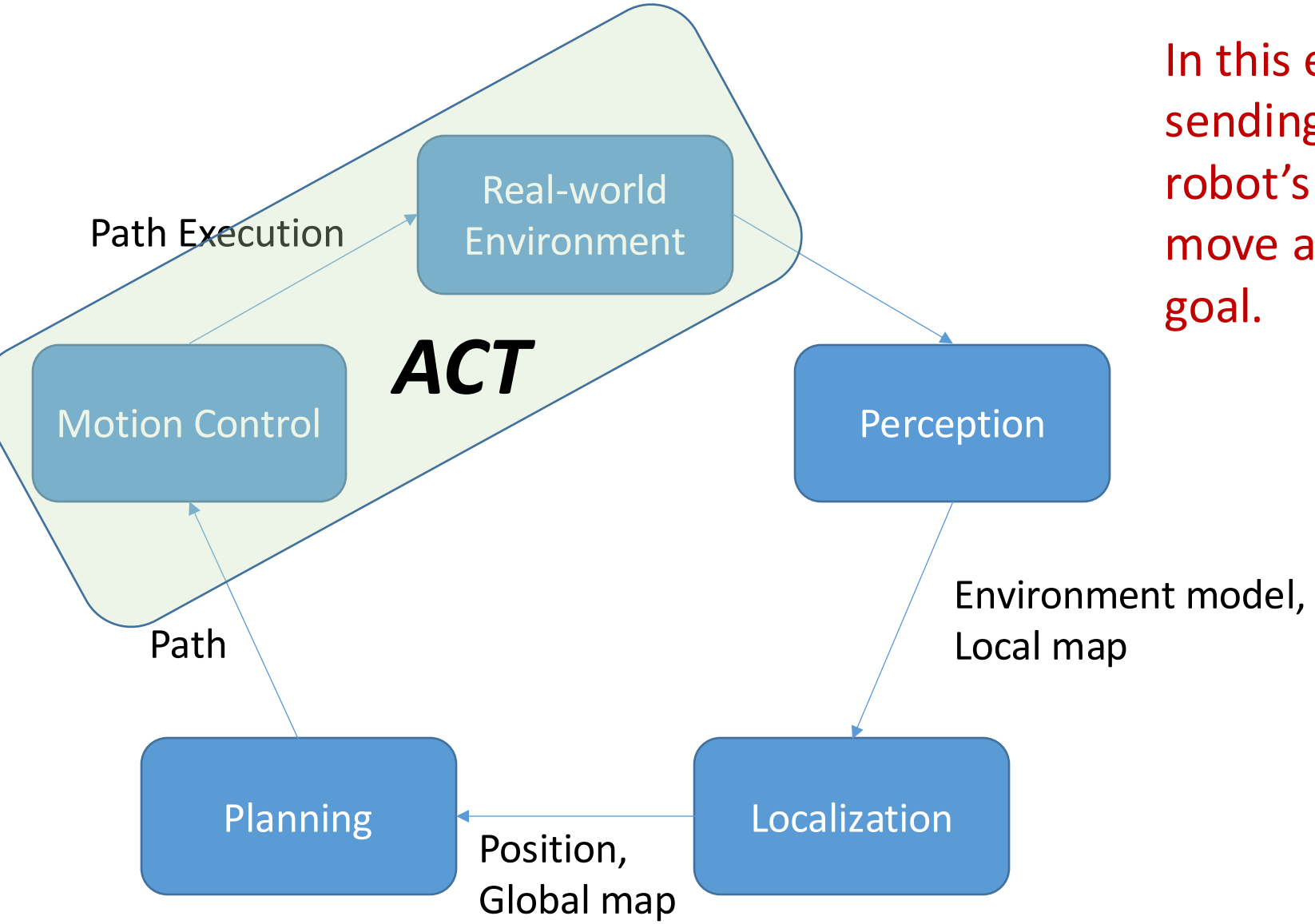
Example: Navigation in a Known Environment



In this example, *thinking* involves:

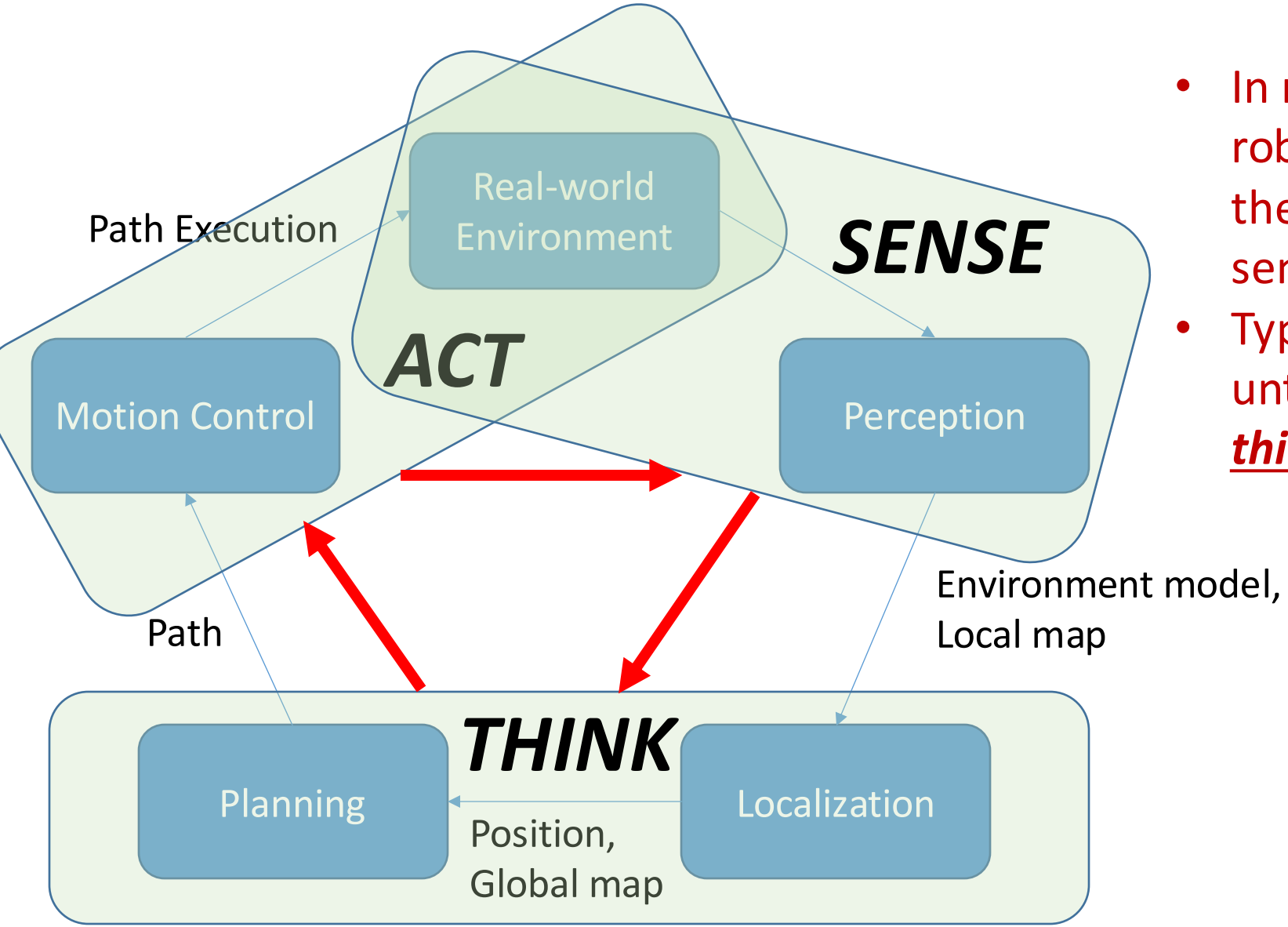
- Processing perceptual information to determine the position of the robot in its environment
- Constructing a motion plan to move from the current position to the goal position.

Example: Navigation in a Known Environment



In this example, *acting* involves sending motion commands to the robot's motors, so that the robot will move along the desired path to its goal.

Example: Navigation in a Known Environment

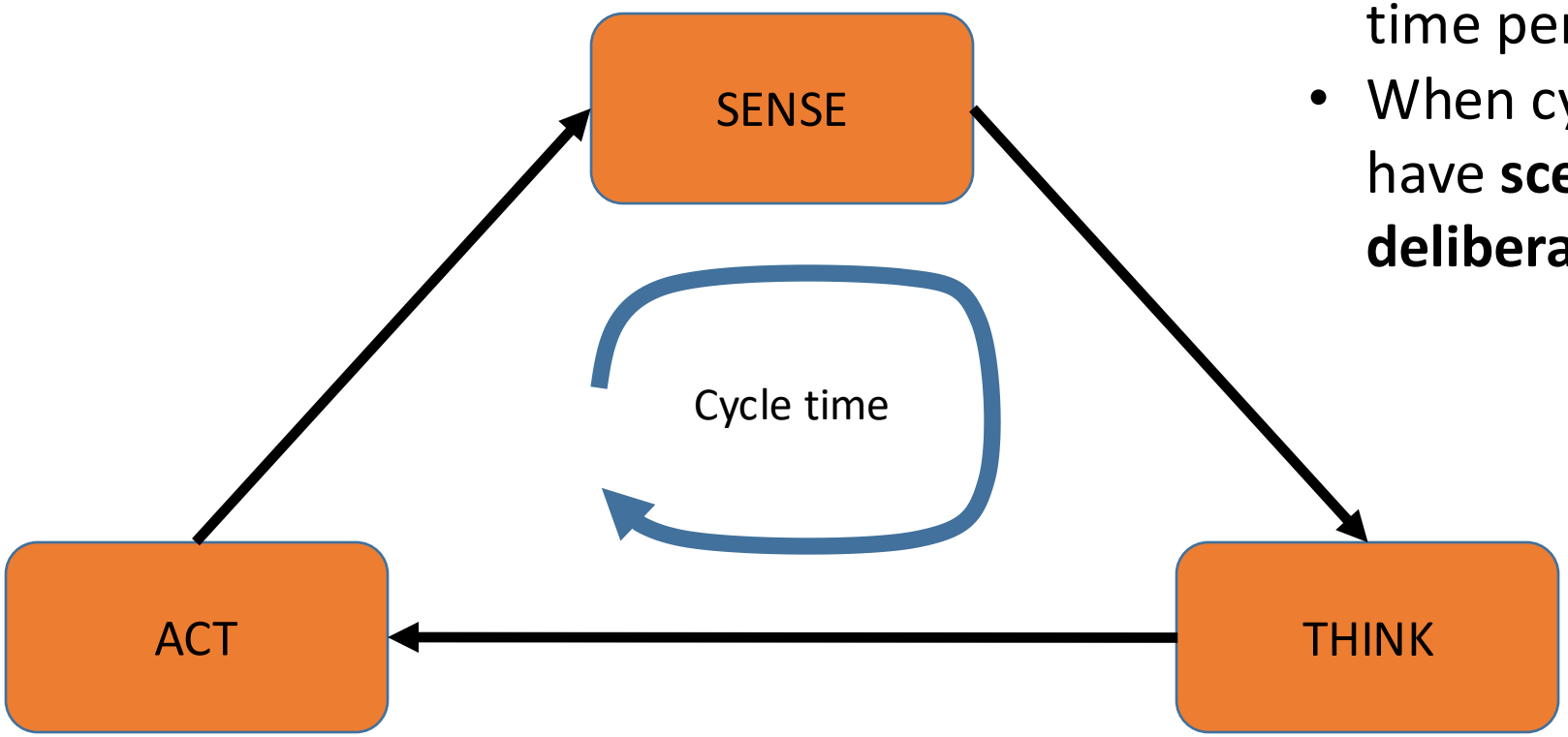


- In most robotics applications, the robot does not succeed to perform the task using a single episode of sense, think, act.
- Typically, these stages are repeated until the task is achieved: the ***sense, think, act loop.***

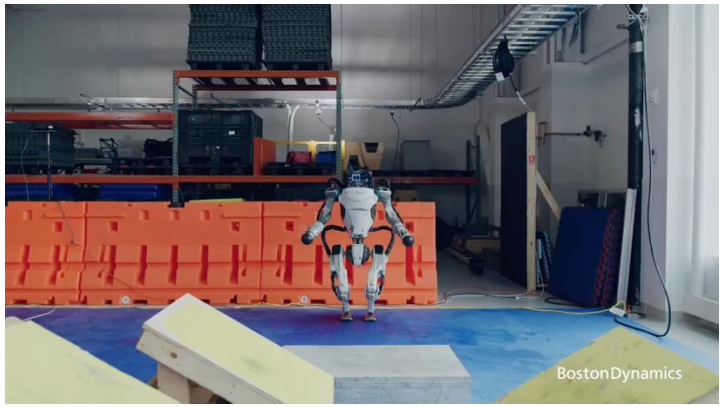
Sense, Think, Act at Different Time Scales

The time to complete one cycle of this loop depends on the task:

- Playing chess: minutes
- Hand-eye coordination: 30 Hz
- Force controlled robot: Order of KHz



- When cycle time is very fast, we use tools from **control theory**, and model systems using differential equations (continuous time performance).
- When cycle time is very slow, we might have **scene understanding** and **deliberative planning**.



Boston Dynamics Atlas

Boston Dynamics Spot

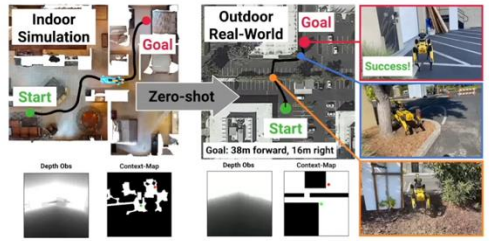
Ocado

hello robot™

Stretch™ RE1
Home Teleoperation

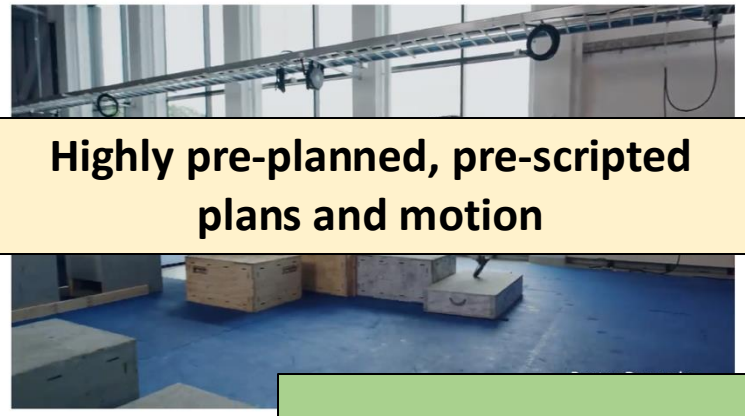
Hello Robot Stretch

IndoorSim-to-OutdoorReal: Learning to Navigate Outdoors without any Outdoor Experience



Boston Dynamics Spot
(visual navigation @GT/Google)

Starship



Highly pre-planned, pre-scripted plans and motion

Boston

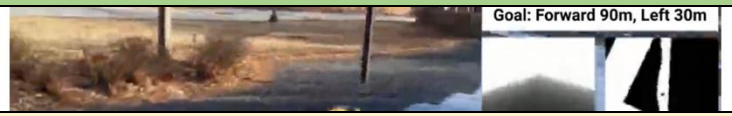
Full Sense-Think-Act loop

Centralized planning system, individual robots make few decisions

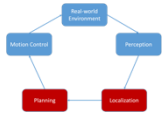
The Sense-Think-Act loop can take many forms!

Teleoperated by a human!

Hello Robot Stretch



No explicit localization and planning, vision→ motion



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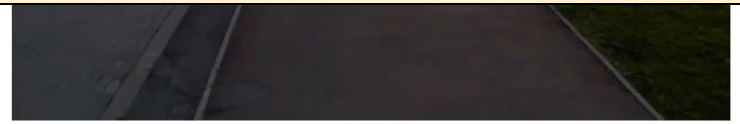
Full Sense-Think-Act loop



Starship

Course Overview

- Sensing and Perception
- Modeling Robot State
- Decision Making and Planning
- Actuation

We will progress through the sense-think-act loop in order, while additionally exploring the role of learning, adaptation and multi-robot environments.