Hochschule
Bonn-Rhein-Sieg
University of Applied Sciences

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Institute for AI and
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Autonomous Mobile Robots

Introduction

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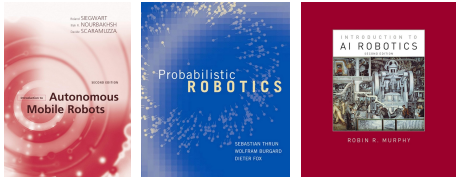
Structure

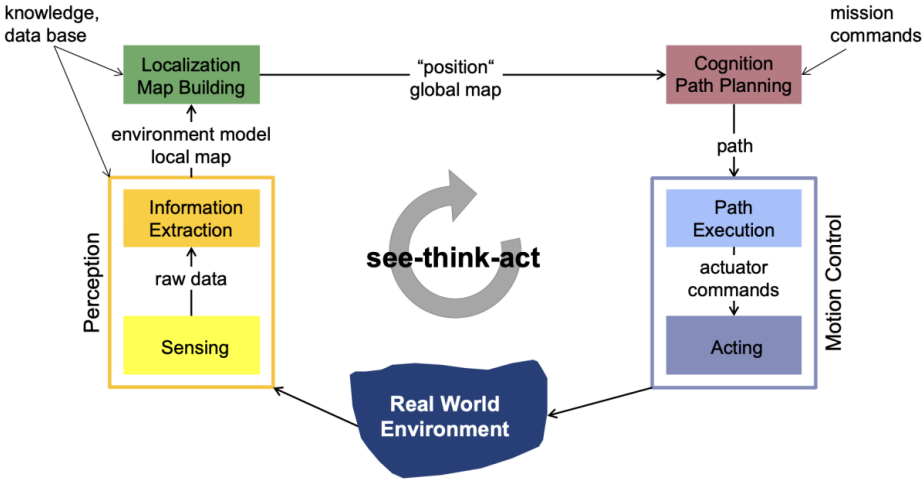


Parts of this slide set are adapted from an introductory AMR lecture by Dr. Björn Kahl from the WS 2013/14

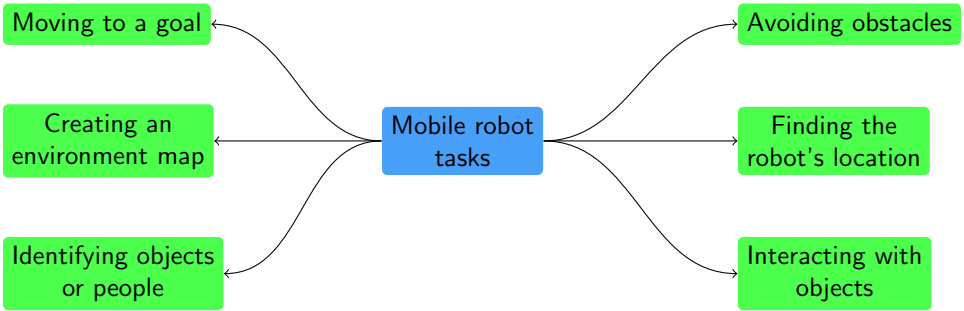
- Overview of autonomous mobile robots
- The anatomy of an autonomous mobile robot

Autonomous Mobile Robots Overview

Sense-Plan-Act Cycle



Common Tasks for Mobile Robots



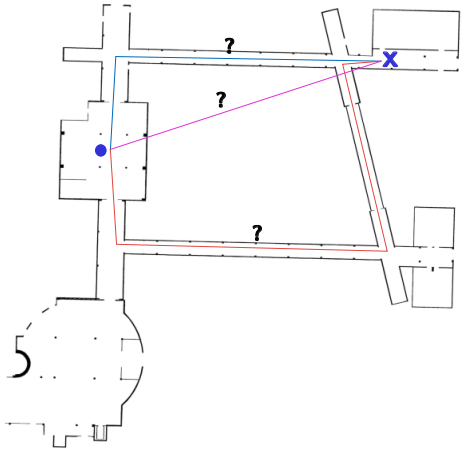
Moving to a Goal

Task

Move a mobile base from its current location to a desired goal location

Challenges

- How to represent the desired goal?
- How to actuate the motors to guarantee motion in the desired direction?
- How to recognise that the goal has been reached?
- What to do after reaching the goal?



Options for a robot to move from its current position to a goal position

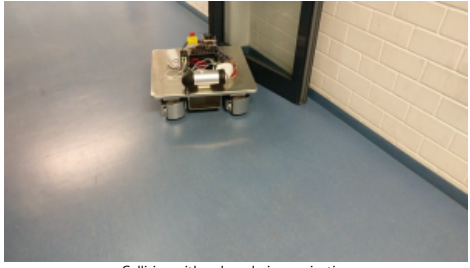
Avoiding Obstacles

Task

Prevent collisions with objects and people while moving

Challenges

- What sensor(s) to use for detecting obstacles?
- How to detect obstacles?
- How to move around static obstacles?
- How to move around moving obstacles?



Collision with a door during navigation

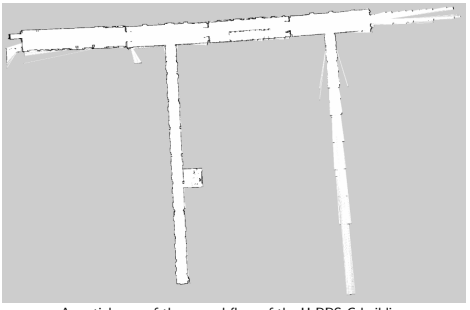
Environment Mapping

Task

Create a map that can be used to find a robot's location in the environment

Challenges

- What kind of map to create?
- Which sensor to use for creating the map?
- What information to represent in the map?
- How to identify and incorporate dynamic changes to the map?



A partial map of the second floor of the H-BRS C building

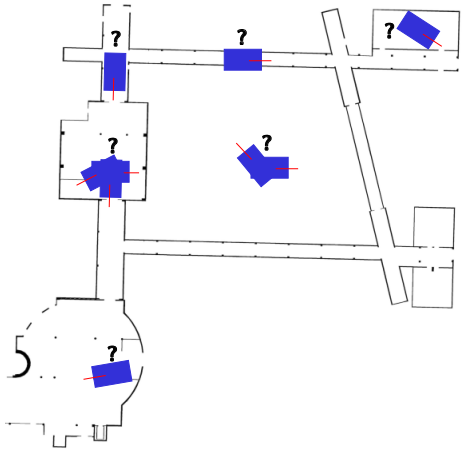
Localisation

Task

Find the location of a robot with respect to a given environment map

Challenges

- What sensor(s) to use for localisation?
- What kinds of feature to utilise?
- How to fuse perceptual features with information about the robot's motion?
- How to deal with uncertainty in the location?



A robot can be in different places in a map — how should it find its location?

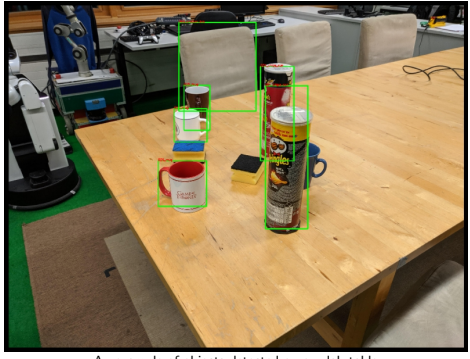
Identifying Objects or People

Task

Detect and (optionally) recognise objects and people in the environment

Challenges

- What kinds of perceptual features to use for detection and recognition?
- How to process such features?
- How to deal with incorrect detections?
- How to disambiguate information?
- What to do about unknown objects?



An example of objects detected on our lab table

Interacting with Objects

Task

Perform some (purposeful) actions with objects

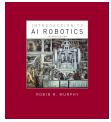
Challenges

- How to identify the correct object to handle?
- What motion(s) to perform for handling the object?
- What to do about other (occluding) objects?
- How to deal with unforeseen events during the object handling?

An HSR robot handling an object

The Anatomy of an Autonomous Mobile Robot

Robot

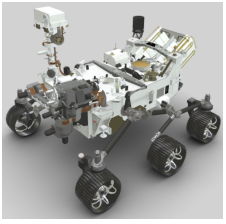


- There have been different definitions of what a robot is over the years
- The word "robot" is derived from the Czech word "robota", which means labour; thus, **robots were initially seen as labourers that can do menial human work** (first popular use in the 1920s)
- Over time, the focus on menial work has been replaced by a view of anthropomorphic machines, and later to any physical embodiment that can interact with the environment
- Bottom line: **Robots are physical agents** (i.e. they exist in the physical world) **that are able to influence the environment** (i.e. they can perform actions in the world)

A robot is a physically situated agent that can interact with the world through its own actions

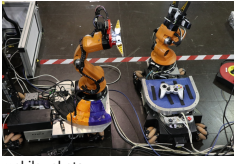
Mobile Robot

- All robots can interact with their environment in some manner, but **not all robots are able to move around** (e.g. a static factory manipulator has a fixed position)
- **A robot that is able to physically change its location during its operation is a mobile robot**
- **Mobile robots come in a variety of shapes and have different motion mechanisms** (e.g. mobile bases, mobile manipulators, or humanoids)



https://mars.nasa.gov/mars2020/spacecraft/rover/

https://www.aldebaran.com/en/pepper



Examples of mobile robots

A robot that is able to change its location in its environment is called a mobile robot

Robot Autonomy

- The term "autonomous" means that a robot has **some means of choosing its actions without external intervention**
- **The selection of actions can happen at different levels** — it can concern the selection of high-level actions (e.g. pick up a plate) or low-level motor actions (e.g. wheel velocities)
- Note that **autonomy is different from automation**
  - Automation is a process of replacing human effort with machines, such as robots or even smart sensors
  - Autonomy is a property that a robot may or may not possess

Autonomy is the ability of a robot to make decisions about how to act independently of other agents in its environment

Perception: Sensors

- **To make informed decisions about its actions, a robot needs to perceive its environment** (i.e. collect measurements and interpret those)
- Measurements are collected using devices called sensors, which can **measure either internal variables (interoceptive sensors) or external variables (exteroceptive sensors)**
- Contemporary mobile robots use a wide variety of sensors (e.g. encoders, cameras, laser scanners)
- The development of new sensors can sometimes simplify the implementation of robot functionalities or lead to new types of algorithms (e.g. laser scanners have largely replaced sonars)

https://www.robosense.ai/en/rslidar/RS-Ruby_Plus

https://www.hokuyo-aut.jp

https://www.intelrealsense.com/depth-camera-d435/

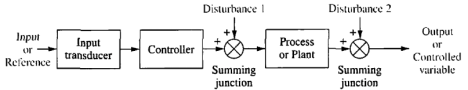
https://www.microsoft.com/en/accessories/products/webcams/lifecam-studio

Examples of sensors used on mobile robots

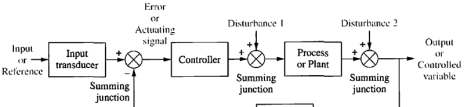
A sensor is a device that a robot can use for perceiving its environment

Robot Control

- To move based on certain objectives, **a robot needs to know how to convert the desired motion commands to individual motions of its joints**
- **The motion of robots is performed by robot control algorithms**
- **Control can be performed either in an open loop** (without considering external input) **or in a closed loop** (by considering external input to, for instance, reduce some error signal)
- Depending on the controlled variables, different types of control algorithms may be necessary



Open-loop system



Closed-loop system

N. S. Nise, "System Configurations" in *Control Systems Engineering*, 6th ed. John Wiley & Sons, Inc. 2011, ch. 1, p. 8.

A robot control algorithm processes certain input variables to produce robot motion as its output

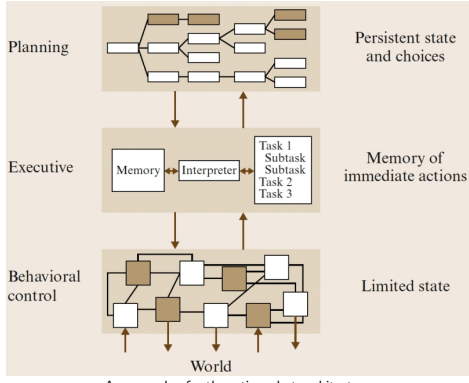
Decision-Making

- To complete complex tasks in its environment, an autonomous robot needs to perform **purposeful actions**
- The selection of actions to perform is driven by **decision-making algorithms**
- Decision-making can be done **through deliberation** (by performing explicit reasoning) or **by reactivity** (by acting directly based on sensory inputs)

Decision-making is a process of using relevant information available to a robot for selecting how to act in the environment

Robot Software Architectures

- An autonomous robot typically has numerous components, each of which is responsible for particular aspects of the robot's operation
- **The communication and combination of such components is organised in a robot software architecture**
- **There is a large variety of robot software architectures, each of which emphasises different aspects of the operation** (or represents a different philosophical point of view about what an autonomous robot should do)



An example of a three-tier robot architecture

B. Siciliano and O. Khatib (eds.), "Robotic Systems Architectures and Programming" in *Springer Handbook of Robotics*, 1st ed. Springer 2008, ch. 8, p. 191.

A robot software architecture combines and manages the different components that make up an autonomous robots