Introduction to Mobile Robotics

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Some examples of mobile robots
Some examples of mobile robots

The robot of the day: robair(1/2)

- Robair project: 100% designed, built and developed in the LIG+FabLab Mstic

  Research

  Public events

  Teaching
The robot of the day: robair(1/2)

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Research

@RobairLig sur tweeter

Teaching

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The robot of the day: robair(2/2)

- Sensors
  - 2 laserscanners

- Actuators
  - 2 wheels driven by 2 motors + encoders
  - 1 tablet Ubuntu + ROS

- 1 PC Ubuntu + ROS
  - In charge of sensor data acquisition, processing & visualization;
  - In charge of controlling actuators.

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Outline

1. Sensors + actuators
2. Perception
3. Decision
4. Action
5. Conclusion

Sensor (1/2)

- A sensor is an instrument measuring a physical property of the environment;
- Sensors are imprecise and limited;
- The environment of a robot is generally complex, changing, unpredictable and uncertain;
- Understanding the world in which a robot evolves remains a challenge.

Courtesy of sick
Sensor (1/2)

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Courtesy of sick

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Sensor (2/2)

- Robair is equipped with a 2D laser scanner;
- The laser scanner has:
  - a range of about 5.5 meters;
  - a field of view of 240 degrees;
  - an angular resolution of 1/3 degrees;
  - Frequency: 20-25 hz
- The laser scanner costs about 1200 euros.
- Output: a table with 720 elements \((r, \theta)\)
- Quality of data depends on distance, angle…
- Polar to cartesian:
  - \(X = r \cos(\theta)\);
  - \(Y = r \sin(\theta)\).

Actuators of a mobile robot

- An actuator is a component of a machine that is responsible for moving or controlling a mechanism or system;
- An actuator controls a degree of freedom (rotation, translation);

- Actuators could be complex.
Actuators of robair

- **Robair** has 2 wheels controlled by 2 motors;
- Robair is a differential drive robot;
- Simplest and most used kinematic model of robot.

\[
\begin{align*}
V_r & = V_l \\
\omega & = 0
\end{align*}
\]

- Controlling \((V_l, V_r)\), we can determine \((V, \omega)\)
  - If \(V_l = V_r\) then \(\omega = 0\)
  - If \(V_l = -V_r\) then \(\omega = 0\)

- But it is easier and more intuitive to control \((V, \omega)\) and determine \((V_l, V_r)\) (inverse kinematic model)
- Combining \((V, \omega)\), any motion is possible

Estimation of motion: encoder/odometer

- While Robair is moving in its environment, we would like to know its position in this environment;
- Its position is determined by its position \((x, y)\) in the environment + its orientation \(\theta\): \((x, y, \theta)\)

\[
\begin{align*}
y & \uparrow \\
x & \downarrow \\
\theta &
\end{align*}
\]

- On each wheel, there is a system (named encoder) able to estimate the distance traveled by each wheel over a short time \(\Delta t\)
Estimation of motion: encoder/odometer

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On each wheel, there is a system (named encoder) able to estimate the distance traveled by each wheel over a short time \(\Delta t\)

\[
x_t = x_{t-1} + d \cos(\theta) \\
y_t = y_{t-1} + d \sin(\theta) \\
\theta_t = \theta_{t-1} + \theta
\]

This is an estimation: with time the error associated to this estimation increases: **Drift problem**
Outline

1. Sensors + actuators
2. Perception
   1. Introduction
   2. DATMO: algorithm + example
3. Decision
4. Action
5. Conclusion

Perception: introduction

Goal
- Robot perception in dynamic environments
- Laser scanner
- Speed and robustness

Present Focus: interpretation of raw and noisy sensor data
- Identify static and dynamic part of sensor data
- Modeling dynamic part of the environment
  - Detection And Tracking of Moving Objects (DATMO)
- Modeling static part of the environment
  - Simultaneous Localization And Mapping (SLAM)
  - Not presented today; see lecture on Localization on my web page
Detection And Tracking of Moving Objects

1. Cluster data to form objects
2. Detection of (moving) objects
   • Motion based detection of objects
   • Model based detection of objects
   • Motion+model based detection of objects
3. Tracking of objects
   • Detection is never perfect: false alarm, missed detection
   • Not only one object is present in the environment
   • Integration of detection in time improves robustness
   • Some theoretical tools to perform tracking: Kalman filter, particle filter

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Most of the time, a mobile robot has to move in its environment:
- It needs to plan its future actions.
- The mobile robot has a map and it knows where it is in the map (position A for instance);
- It should reach another position in the map (position B for instance);

**Question**: How to get there?

**Answer**: sequence of actions to go from A to B that is feasible and without collision.

```
north
```

```
West, South, East (12 times), North (6 times), West (twice)
```

**Outline**

1. Sensors + actuators
2. Perception
3. Decision
4. **Action**
5. Conclusion
**Action/control/navigation**

- The mobile robot has a sequence of actions to execute, to reach its goal: it has to execute this sequence of actions;
  - Monitoring of execution: we monitor what happen and react if needed.
  - We need to localize the mobile robot to monitor the actions;
  - Collision detection/avoidance: the mobile robot should be able to detect and avoid collision.

*Courtesy of T. Fraichard*

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**Control of robair**

- Robair has to reach a position \((x_{\text{goal}}, y_{\text{goal}})\) in its surrounding environment;
  - We determine the translation and rotation to reach \((x_{\text{goal}}, y_{\text{goal}})\)
  - \(V\) is proportional to the translation to do: PID controller
  - \(\omega\) is proportional to the rotation to do: PID controller
  - We use odometry to monitor the control
  - We combine translation and rotation to have smooth motions

*rotation*
Control of robair

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![Diagram](image1)

Obstacle detection

- Robair has to detect obstacles while it moves
  - We build a virtual corridor surrounding robair
  - If there is an obstacle in this corridor, we decrease \(V\)

![Diagram](image2)
Obstacle detection

- Robair has to detect obstacles while it moves
  - We build a virtual corridor surrounding robair
  - If there is an obstacle in this corridor, we decrease $V$
  - If the obstacle is too close, robair stops

Summary (1/2)

- A mobile robot is equipped with 2 kind of sensors:
  - **Exteroceptive sensors** that give information about the environment (ie, laser scanner);
  - **Proprioceptive sensors** that give information about the internal state of the robot (ie, odometer);
- A mobile robot is equipped with some actuators characterized by their degree of freedom;
  - Robair is a differential drive robot;
- Sensors and actuators are imprecise and limited;
- The environment of a robot is generally complex, changing, unpredictable and uncertain.
Summary (2/2)

- The link between sensors and actuators is done in 3 steps:
  - Sensors → Perception → Decision → Action → Actuators

- A mobile robot control architecture is a finite state automaton;
- Architecture of « follow me » behavior.