# Introduction to Robotics

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# Introduction

- Motivation: to introduce you to high-level keywords and concepts in robotics
- Outline: watch videos and create a mindmap on the board
- This is *not* a lecture; it is a discussion
- Further reading: Springer Handbook of Robotics (https://www.springer.com/de/book/9783540303015)
- Some more keywords: https://www.ieee-ras.org/publications/ra-l/keywords

# Videos!

- b-it-bots@Work Basic Transportation Test

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- b-it-bots@Work Basic Transportation Test
- Tech United Mid-sized League soccer

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- b-it-bots@Work Basic Transportation Test
- Tech United Mid-sized League soccer
- b-it-bots@Home Storing Groceries

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- Australian Centre for Robotic Vision Amazon Picking Challenge

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- Tech United Mid-sized League soccer
- b-it-bots@Home Storing Groceries
- Australian Centre for Robotic Vision Amazon Picking Challenge
- Nimbro at MBZIRC 2017

# Domains

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- Navigation
- Sensing
- Manipulation
- Task Planning

# Navigation

# Navigation

- World model

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- SLAM

Videos:

- [06-Mapping]

# Navigation

- World model
- SLAM
- Localisation

Videos:

- [06-Mapping]
- [06b-RopodNavigation]

# Navigation

- World model
- SLAM
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- Path planning

Videos:

- [06-Mapping]
- [06b-RopodNavigation]

# Navigation

- World model
- SLAM
- Localisation
- Path planning
- Motion planning - how do robots move?

Videos:

- [06-Mapping]
- [06b-RopodNavigation]

# Navigation

- World model
- SLAM
- Localisation
- Path planning
- Motion planning - how do robots move?
- Obstacle avoidance

Videos:

- [06-Mapping]
- [06b-RopodNavigation]

# Navigation

- World model
- SLAM
- Localisation
- Path planning
- Motion planning - how do robots move?
- Obstacle avoidance
- What about aerial, underwater and legged robots?

Videos:

- [06-Mapping]
- [06b-RopodNavigation]

# OpenStreetMap

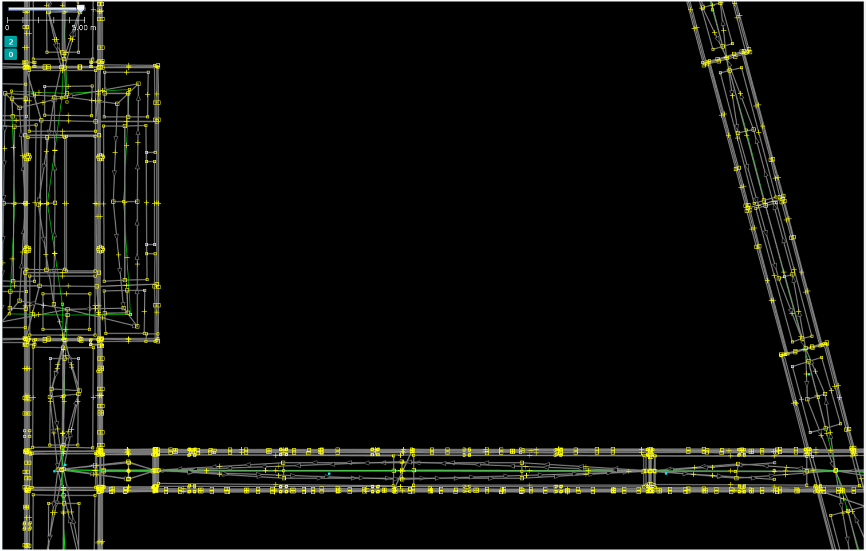


**Figure 1:** Indoor OpenStreetMap of university [1]

# Sensing

# Sensors

- Laser scanner
- 2D camera
- 3D camera
- Sonar
- IMU
- Microphone
- Tactile
- Force and torque

# Vision

- Object detection and recognition

Videos:

- [07-3D-Detection]
- [08-2D-Segmentation]
- [09-2D-Detection]

# Sensing
## Vision

- Object detection and recognition
- Person / face detection and recognition

Videos:

- [07-3D-Detection]
- [08-2D-Segmentation]
- [09-2D-Detection]

# Sensing

## Vision

- Object detection and recognition
- Person / face detection and recognition
- Visual servoing

Videos:

- [07-3D-Detection]
- [08-2D-Segmentation]
- [09-2D-Detection]
- [10-Visual-Servoing]

- Object detection and recognition
- Person / face detection and recognition
- Visual servoing
- Motion detection

Videos:

- [07-3D-Detection]
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- [09-2D-Detection]
- [10-Visual-Servoing]

- Object detection and recognition
- Person / face detection and recognition
- Visual servoing
- Motion detection
- Tracking

Videos:

- [07-3D-Detection]
- [08-2D-Segmentation]
- [09-2D-Detection]
- [10-Visual-Servoing]

- Object detection and recognition
- Person / face detection and recognition
- Visual servoing
- Motion detection
- Tracking
- Action recognition

Videos:

- [07-3D-Detection]
- [08-2D-Segmentation]
- [09-2D-Detection]
- [10-Visual-Servoing]
- [11-Action-Recognition]

# Sound

- Speech recognition

# Sensing
## Sound

- Speech recognition
- Speaker identification

# Sensing

## Sound

- Speech recognition
- Speaker identification
- Sound localization

# Sensing

## Sound

- Speech recognition
- Speaker identification
- Sound localization
- Anomalous sound classification

# Sensing

- Force / load sensing

# Sensing

- Force / load sensing
- Tactile
  - Compliant motion
  - Grasp verification

# Sensing

- Force / load sensing
- Tactile
    - Compliant motion
    - Grasp verification
- Inertial

# Sensing

- Force / load sensing
- Tactile
  - Compliant motion
  - Grasp verification
- Inertial
- Range

# Manipulation

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- Model identification

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- Motion planning

Videos:

- [12-Motion-Planning]

# Manipulation

- Model identification
- Motion planning
- Motion control

Videos:

- [12-Motion-Planning]

# Manipulation

- Model identification
- Motion planning
- Motion control
- Force control

Videos:

- [12-Motion-Planning]
- [13-Force-Control]

# Manipulation

- Model identification
- Motion planning
- Motion control
- Force control
- Grasping

Videos:

- [12-Motion-Planning]
- [13-Force-Control]

# Manipulation

- Model identification
- Motion planning
- Motion control
- Force control
- Grasping
- Insertion

Videos:

- [12-Motion-Planning]
- [13-Force-Control]
- [14-Peg-in-Hole-Task]

# Planning

# Task Planning

## Hardcoded state machine for Basic Transportation Task

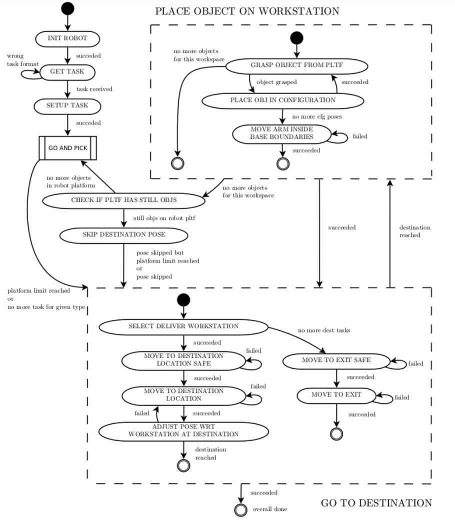


**Figure 2:** Basic Transportation Task [2]

# Task Planning

## Hardcoded state machine for `pick object`

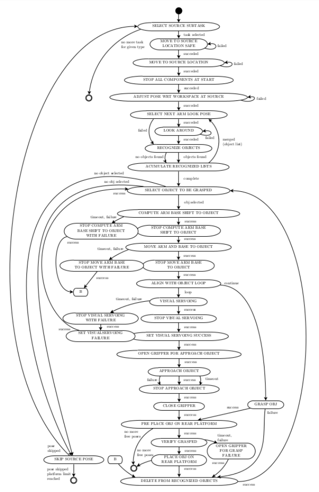


**Figure 3:** Pick object [2]

## Sample plan for Basic Transportation Task

```
(move_base youbot-brsu start ws02)
(perceive youbot-brsu ws02)
(pick youbot-brsu ws02 bearing-00)
(stage youbot-brsu platform_left bearing-00)
(move_base youbot-brsu ws02 ws04)
(unstage youbot-brsu platform_left bearing-00)
(place youbot-brsu ws04 bearing-00)
```

# Task Planning

## Sample plan for making peppermint tea

**Listing 1** A successfully generated plan for making peppermint tea

```
[1] (!goto kettle1 ForGrasping)
[2] (!access kettle1)
[3] (!open kettle1)
[4] (!grasp kettle1 ForTransport)
[5] (!goto kitchenSink ForFilling)
[6] (!position kettle1 ForFilling)
[7] (!opentap coldtap ForFilling)
[8] (!closetap coldtap)
[9] (!grasp kettle1 ForTransport)
[10] (!goto kettleBase ForReplacing)
[11] (!access kettleBase1)
[12] (!replace kettle1 kettleBase)
[13] (!close kettle1)
[14] (!boilWaterInKettle kettle1)
[15] (!goto teacup2 ForGrasping)
[16] (!access teacup2)
[17] (!grasp teacup2 ForTransport)
[18] (!placeNextTo teacup2 kettle1)
[19] (!goto peppermintTeabag ForGrasping)
[20] (!access peppermintTeabag)
[21] (!grasp peppermintTeabag ForMakingTea)
[22] (!placeIn peppermintTeabag teacup2)
[23] (!pourhot kettle1 teacup2)
[24] (!goto kettleBase1 ForReplacing)
[25] (!access kettleBase1)
[26] (!replace kettle1 kettleBase)
```

**Figure 4:** Plan for making peppermint tea [3]

# Software

- Languages: C++, Python, Java

[1] https://wiki.ros.org/kdl

# Software

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- Frameworks: ROS, Orocos, Fawkes

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- Simulators: Gazebo, Stage, V-Rep, OpenRAVE

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# Software

- Languages: C++, Python, Java
- Frameworks: ROS, Orocos, Fawkes
- Simulators: Gazebo, Stage, V-Rep, OpenRAVE
- Useful libraries: KDL[1], OpenCV, PCL, ZeroMQ, etc.

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# Some other topics

- Natural language processing

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- Natural language processing
- Fault detection and error recovery

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- Learning

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- Human-robot interaction
- User interfaces

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- Fault detection and error recovery
- Learning
- Sensor fusion
- Probabilistic reasoning
- Active perception
- Multi-robot systems
- Logging and databases
- Communication
- Human-robot interaction
- User interfaces
- Learning by demonstration

# References I

[1] L. Naik, S. Blumenthal, N. Huebel, H. Bruyninckx, and E. Prassler, "Semantic mapping extension for openstreetmap applied to indoor robot navigation," in *IEEE International Conference on Robotics and Automation (ICRA)*, May 2019.

[2] O. L. Carrion, "Task planning, execution and monitoring for mobile manipulators in industrial domains," Master's thesis, Bonn-Rhein-Sieg University of Applied Sciences, Grantham-Allee 20, 53757 St. Augustin, Germany, April 2016.

[3] I. Awaad, G. K. Kraetzschmar, and J. Hertzberg, "The role of functional affordances in socializing robots," *International Journal of Social Robotics*, vol. 7, pp. 421–438, March 2015.

**The End!**