# Development of intelligent systems (RInS)

# Introductory information

Danijel Skočaj
University of Ljubljana
Faculty of Computer and Information Science

Academic year: 2022/23

# About the course

- Development of Intelligent Systems

- University study program Computer and Information Science, 3rd year
- 3 hours of lectures and 2 hours of tutorials (practice classes) weekly
- 6 ECTS credits

- Lectures on Thursdays 8:15 – 11:00 (in P22)

- Tutorials, 5 groups, in R2.38:
  - Tuesdays 8:15 - 10:00 and 12:15-14:00
  - Wednesdays 15:15 – 17:00
  - Thursdays 15:15 – 17:00
  - Fridays 12:15 – 14:00

- Course home page:
  https://ucilnica.fri.uni-lj.si/course/view.php?id=69

# About the course

- Module Artificial intelligence

# Lecturer

- Prof. dr. Danijel Skočaj
  - Visual Cognitive Systems Laboratory
  - e-mail: danijel.skocaj@fri.uni-lj.si
  - url: http://www.vicos.si/danijels
  - tel: 01 479 8225
  - room: second floor, room R2.57
  - office hours: Thursday, 13:00-14:00

- Teaching assistants:
  Matej Dobrevski
  - e-mail: matej.dobrevski@fri.uni-lj.si
  - tel: 01 479 8245
  - room: second floor, room R2.37

  Assist. prof. Luka Čehovin Zajc
  - e-mail: luka.cehovin@fri.uni-lj.si
  - tel: 01 479 8252
  - room: second floor, room R2.35

# Goal of the course

The course aims at teaching the students to develop an intelligent system by integrating techniques from artificial intelligence and machine perception. Students will learn how to design an intelligent system, how to select which tools and methods to use, and how to implement new components and integrate them into a functional system.

# Course goals

- To learn about intelligent robot systems
  - requirements
  - methodologies
  - applications
  - middleware

- Development of an intelligent robot system
  - design
  - architecture
  - use of appropriate components
  - development of new components
  - integration
  - robot programming
  - testing, debugging

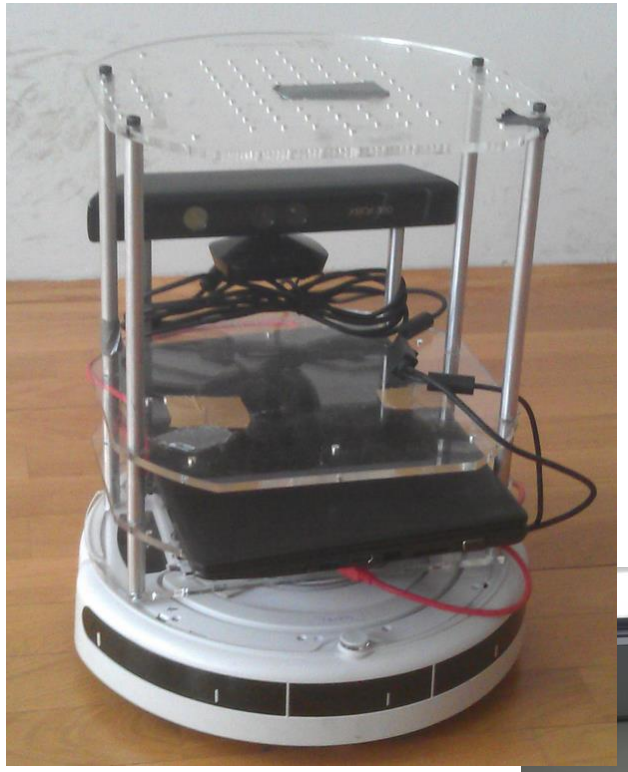
- Extremely practically oriented course!

# Development platform

- Robot platform: iRobot Roomba 531 + TurtleBot + Kinect
- Software platform: ROS, Robot Operating System

ROS

# TurtleBot++



# Herd

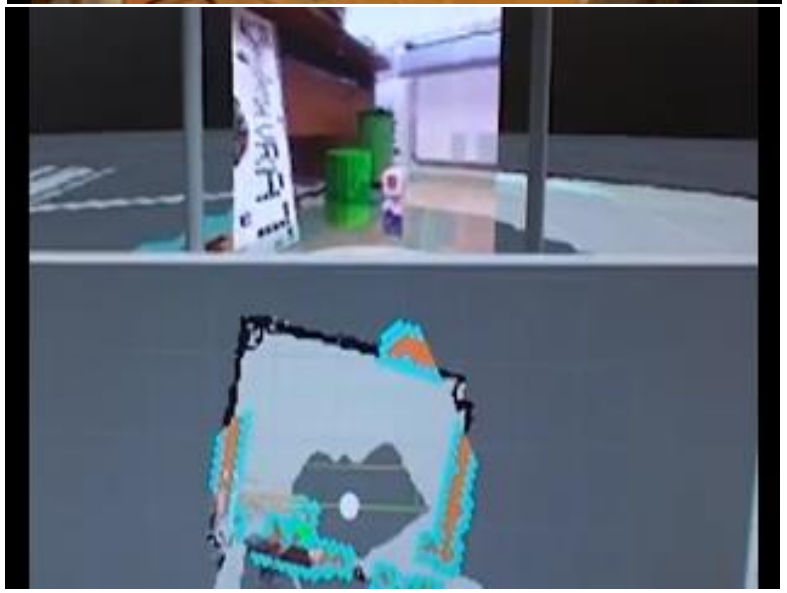
# Robot platform

# Diploma theses

G. Pušnik

A. Rezelj

D. Tratnik



J. Bizjak

# RInS 2012

- Slalom

# RInS 2013

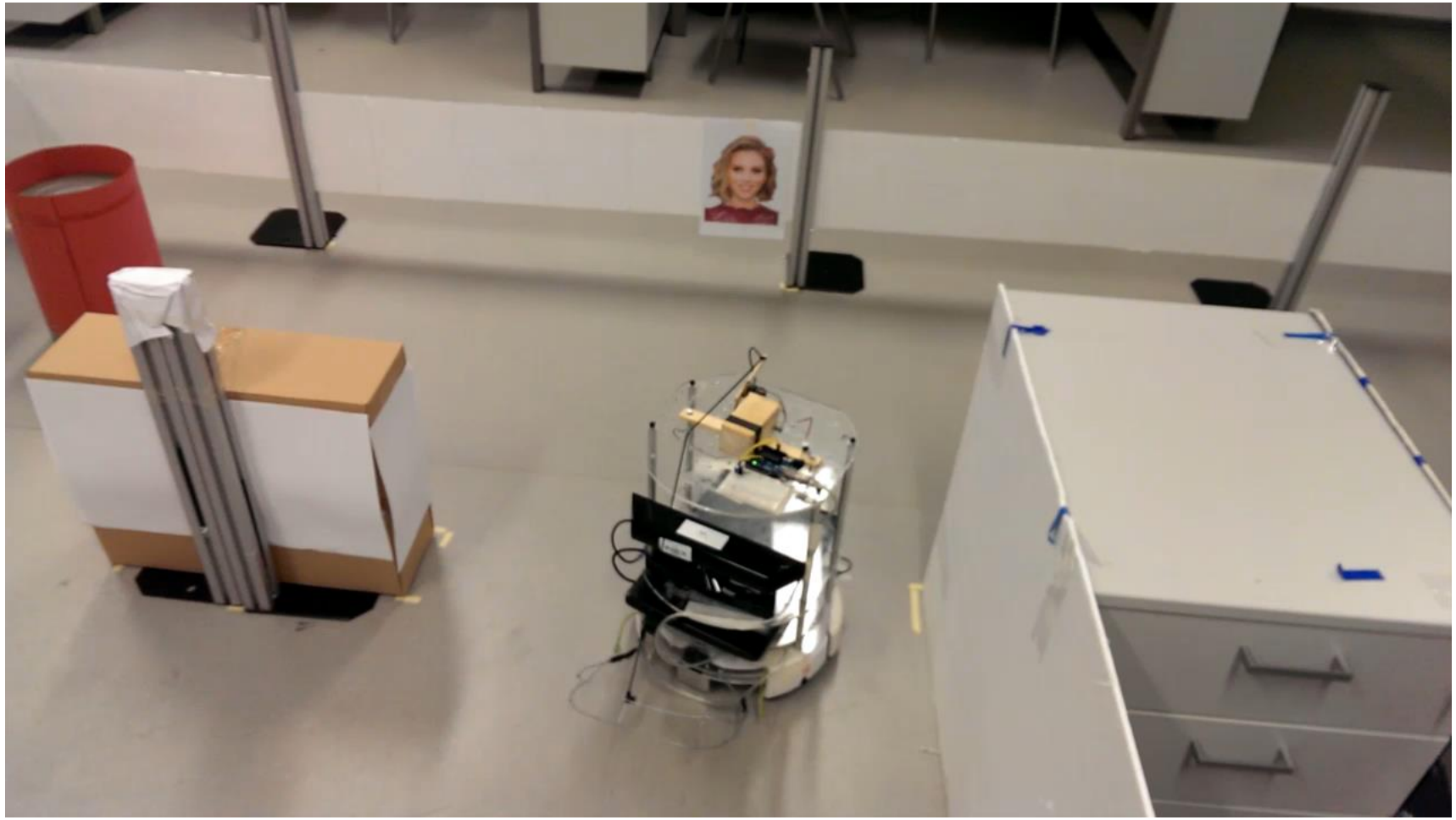
- Object search

# RInS 2014

- Mini Cluedo

# RInS 2015

- DeliveryBot



# RInS 2016

- TaxiBot

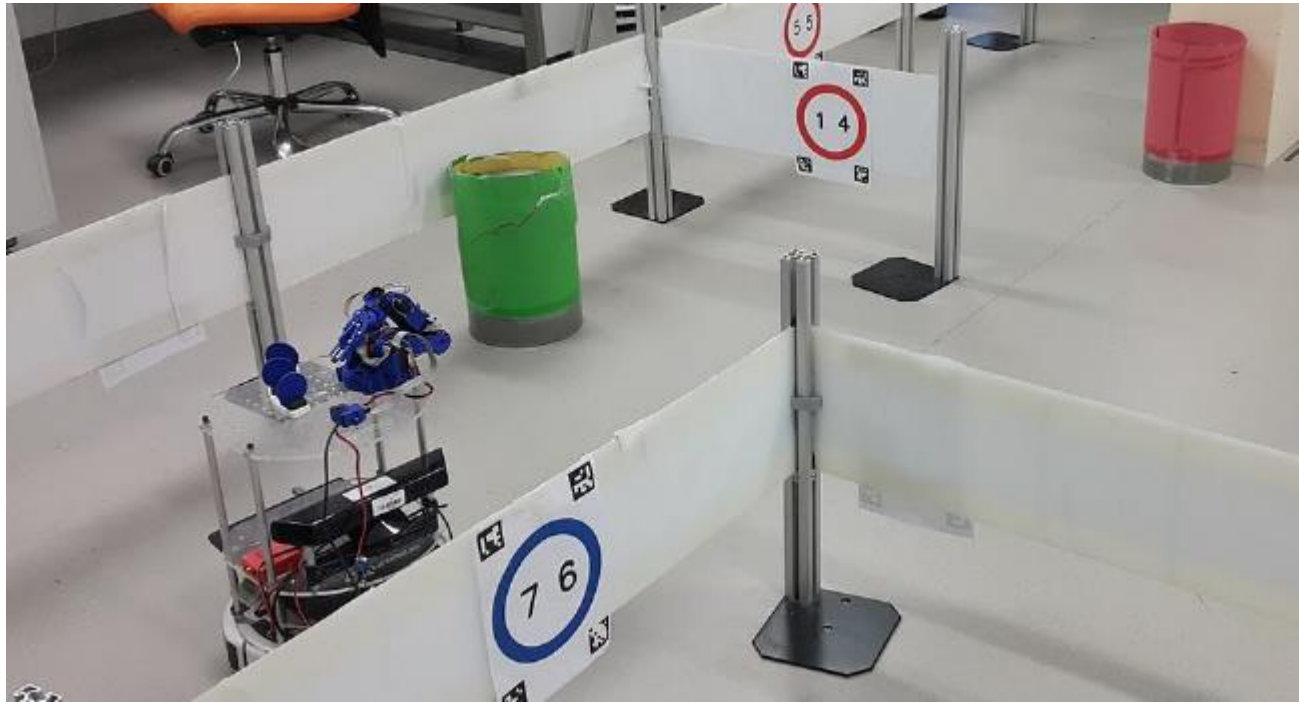
# RInS 2017

- Robot of the rings

# RInS 2018

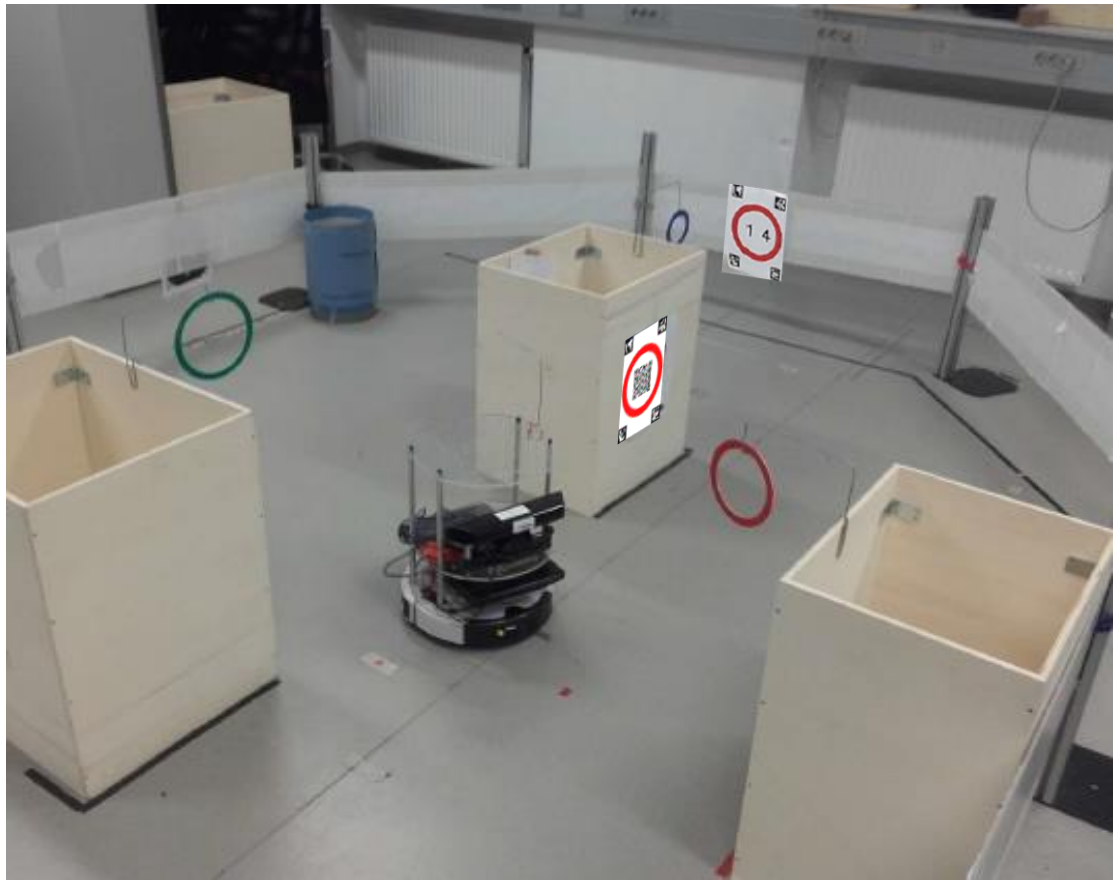
- CryptoBot

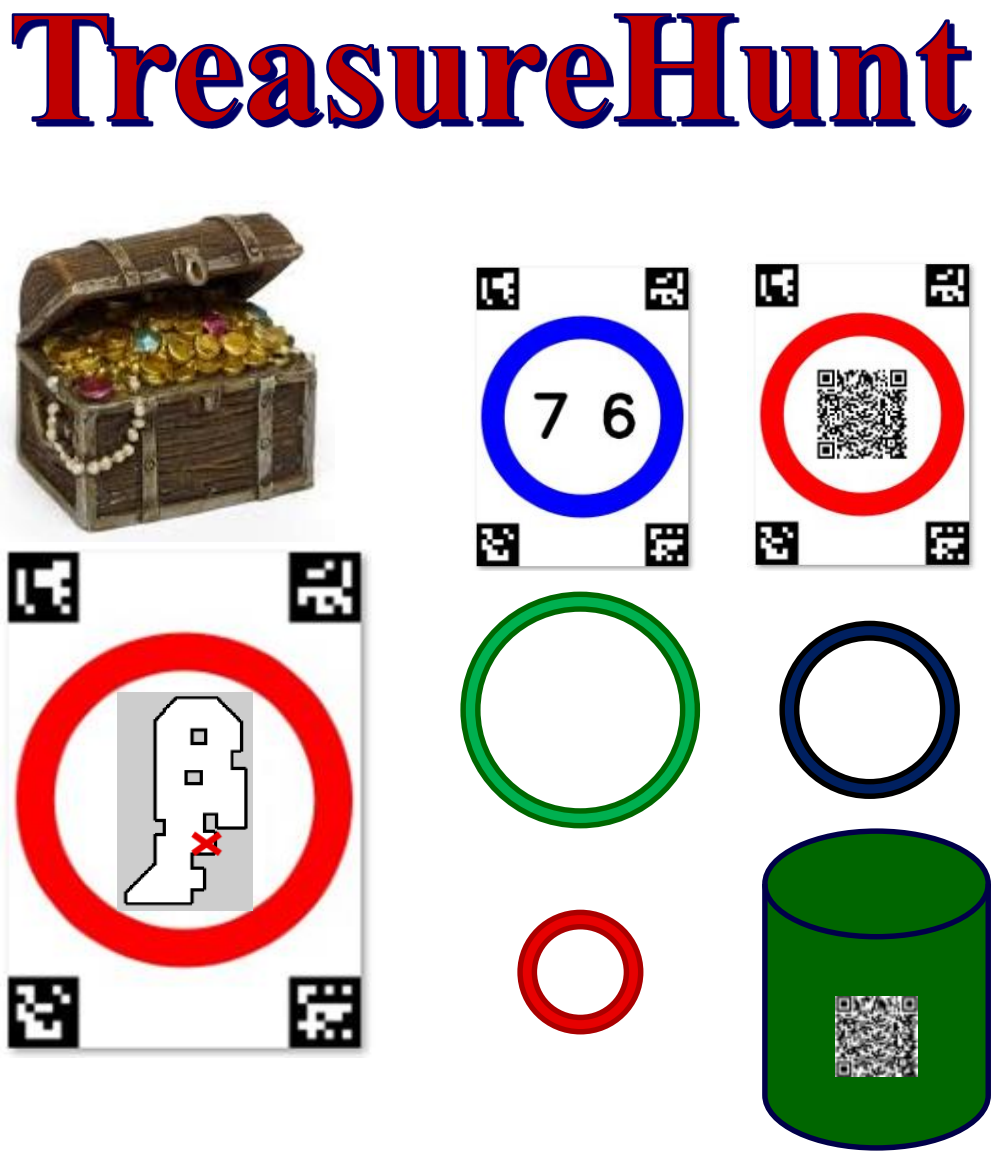
CryptoBot



# RInS 2019

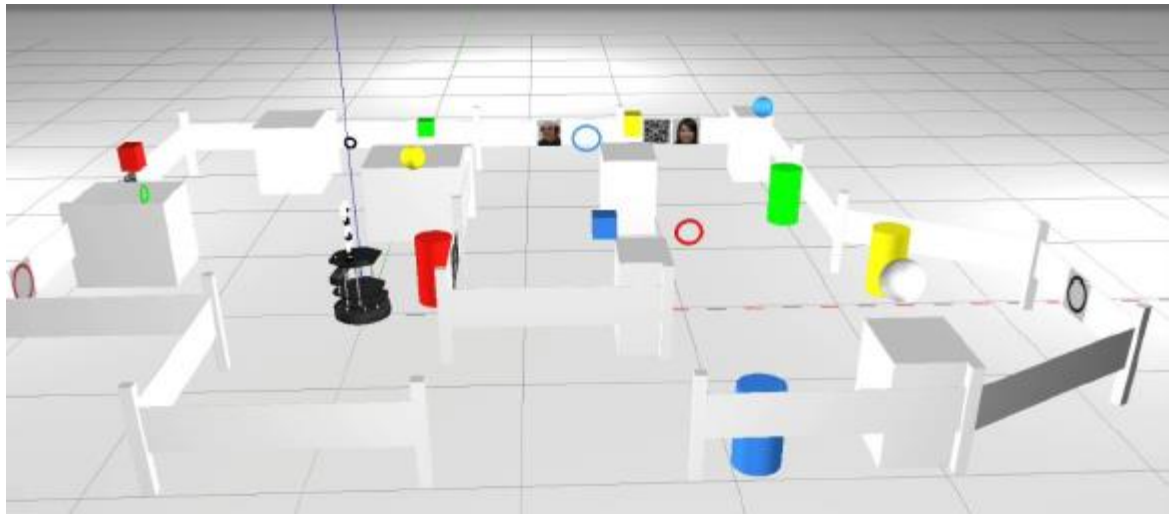
- TreasureHunt





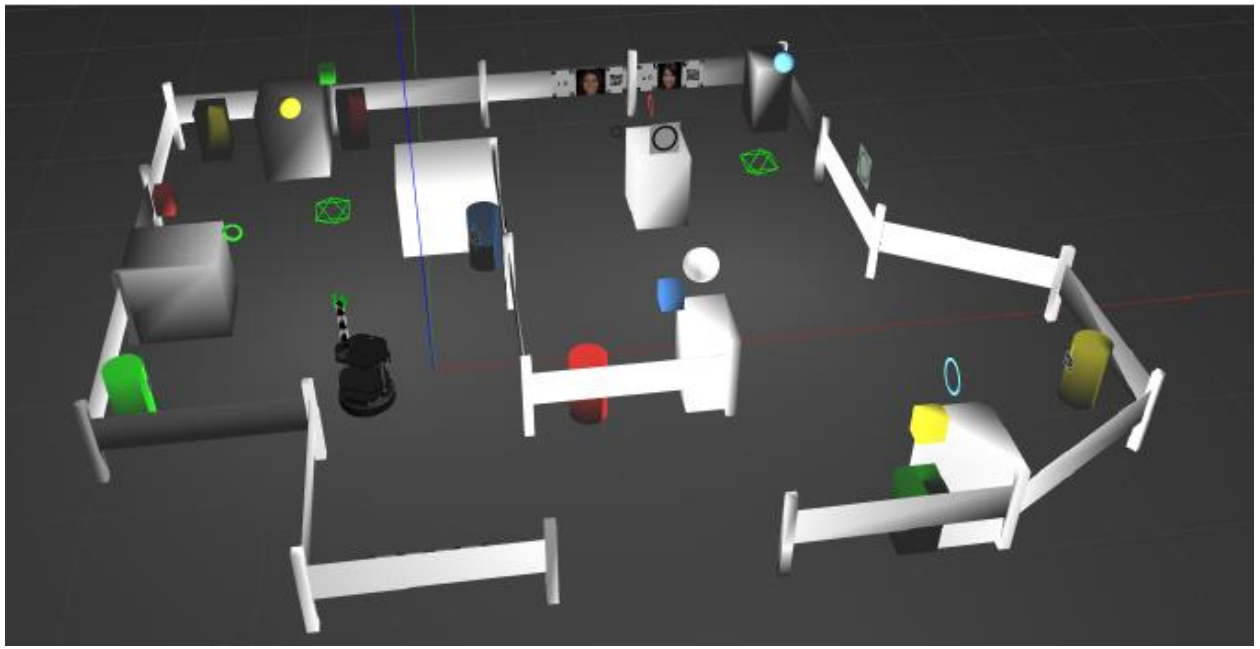
# RInS 2020

## Matchmaker

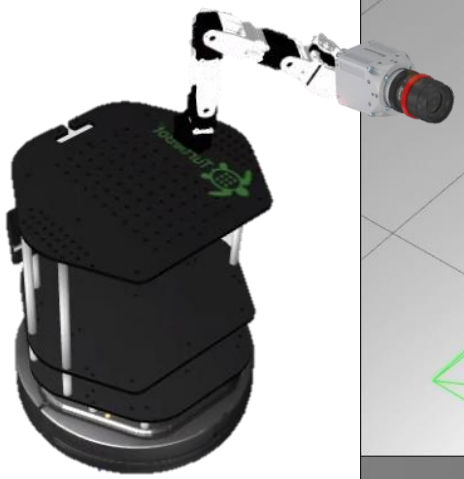


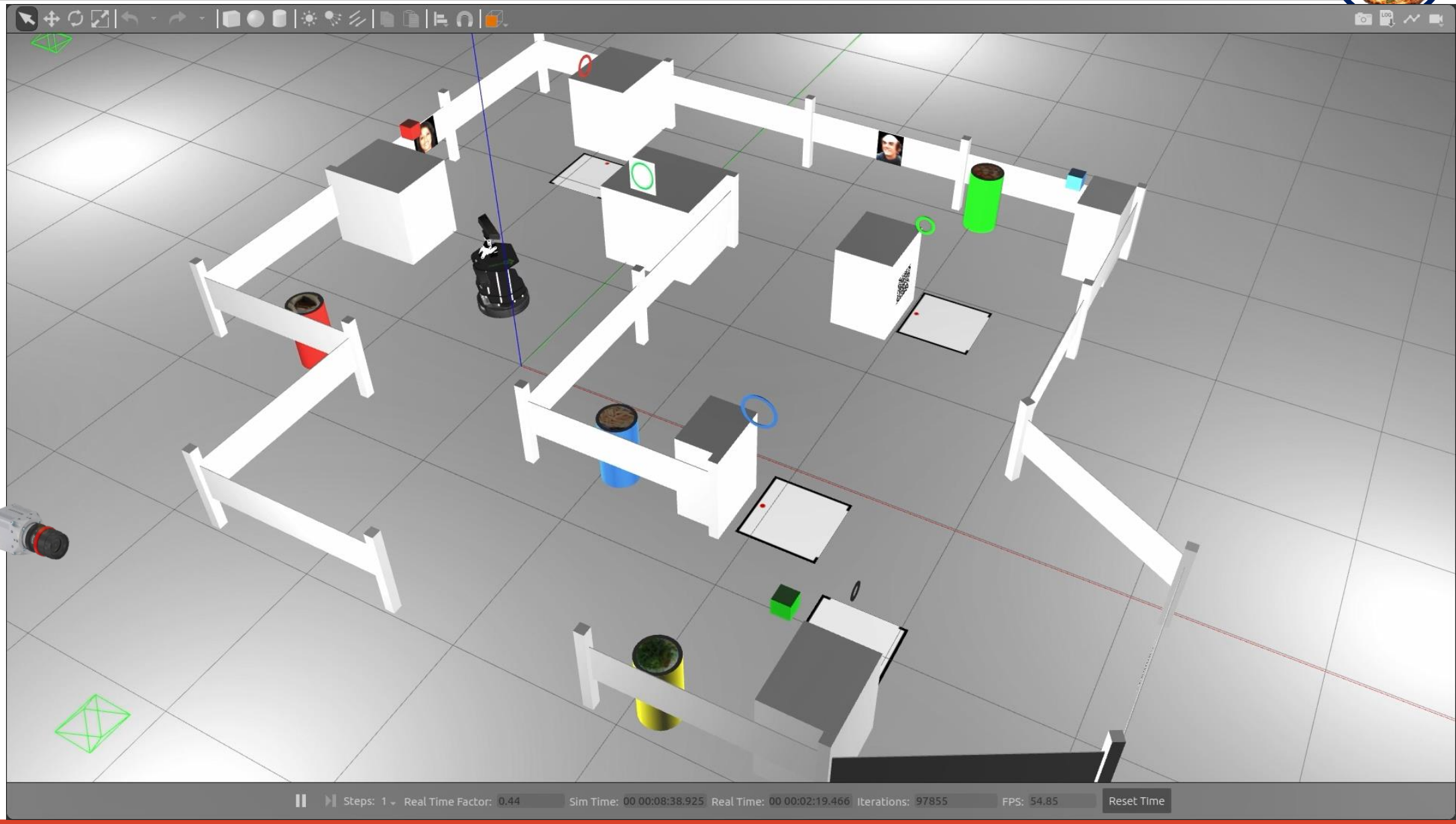
# RInS 2021

STOPCORONA



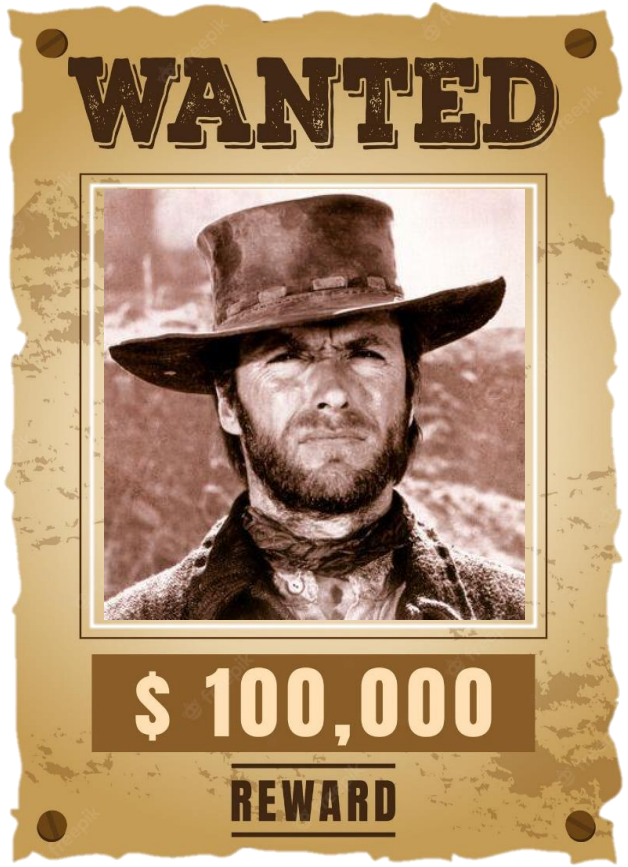
# RInS 2022 FooDeRo





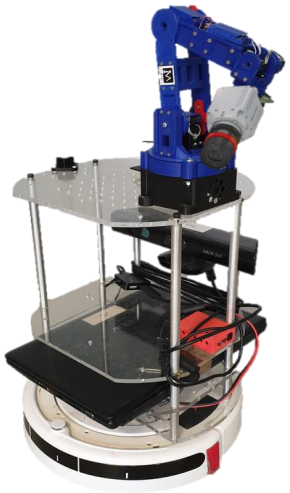
# 2023 Final task

## RoboScheriff

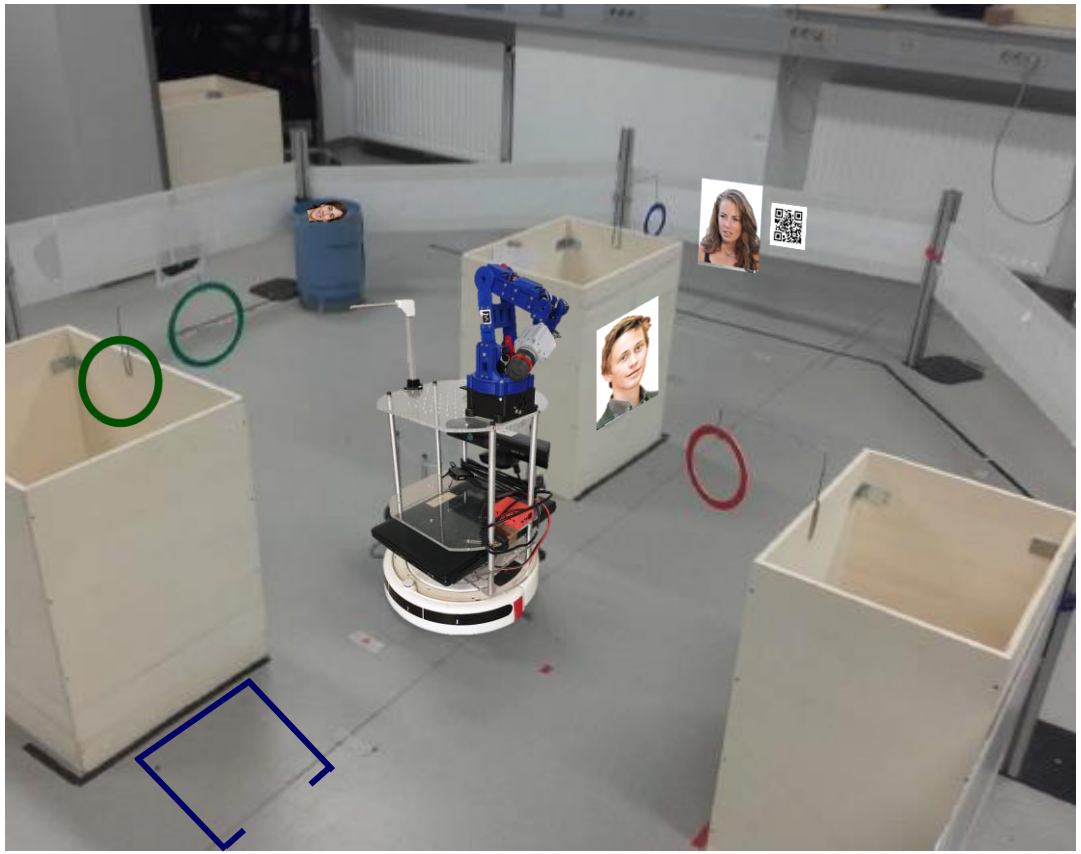


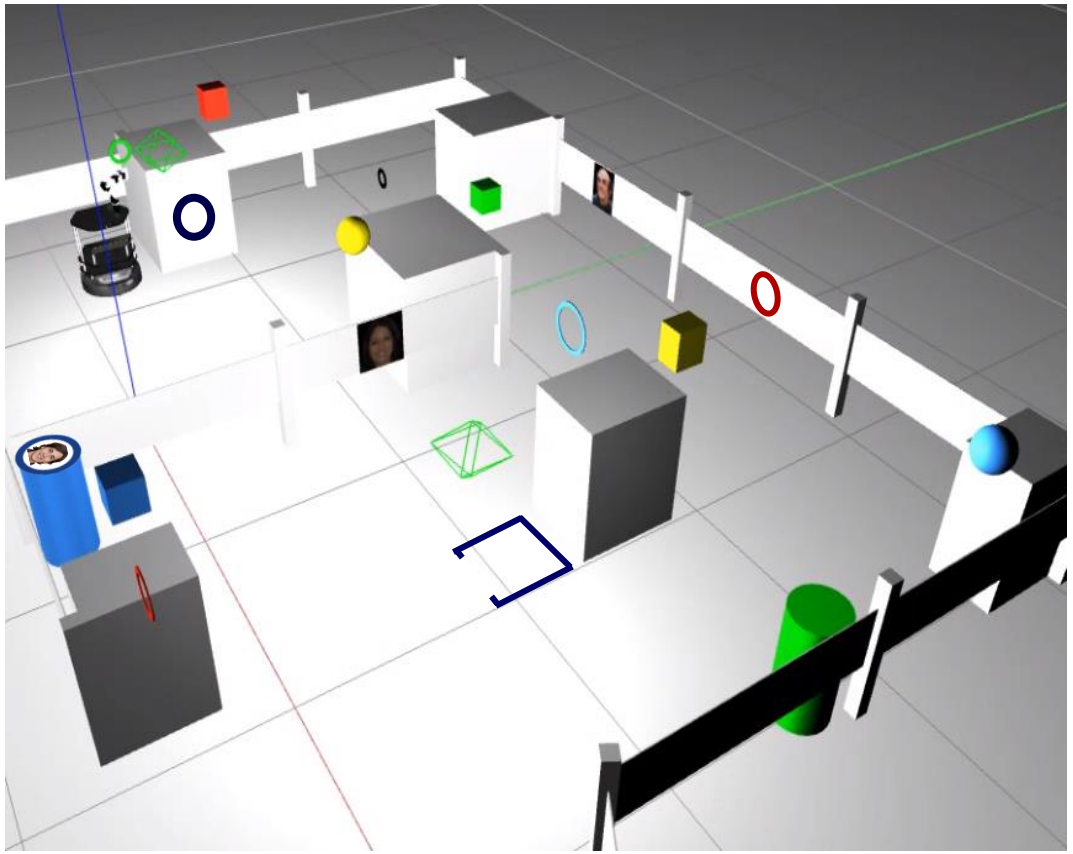
# 2023 Final task

- Setup:
  - „Small wild west city“ scene (fenced area).
  - Several persons (faces) in the scene.
  - Several „Wanted“ posters in the scene.
  - Four „buildings“ (cylinders) of different colours.
  - Four parking slots marked with rings of different sizes and colours.
- Goal:
  - Imprison the robbers.
- Task:
  - Find all persons in the city.
  - Find the posters and decide which robbers to find and catch.
  - Talk to persons to find out where the robbers are potentially hiding.
  - Look on the top of buildings (cylinders) if the are robbers hidden.
  - When a robber is found, „take“ him to the prison.
  - Find out which building is the prison.
  - Park the robot in front of the prison.

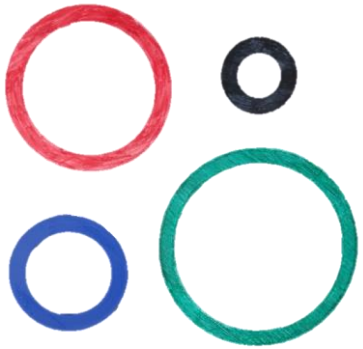


# 2023 Final task



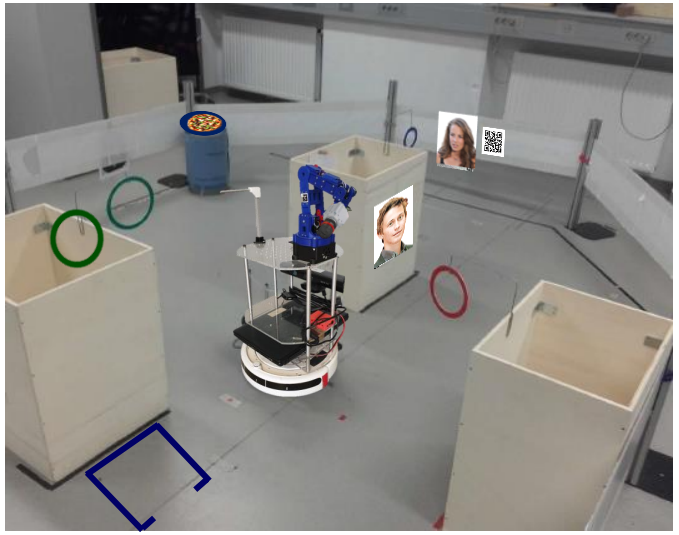


# 2023 Final task

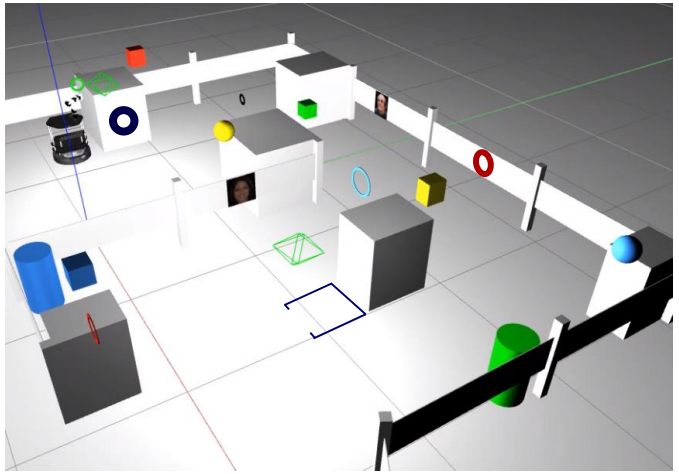


# Intermediate tasks

- Task 1: Autonomous navigation and human search
  - The robot should autonomously navigate around the competition area
  - It should search and detect faces
  - It should approach every detected face
  - It should be completed in simulator AND with a real robot in real world



- Task 2: Parking
  - Detect rings
  - Recognize and say the colour of the rings
  - Approach the green ring
  - Detect the marked parking place below the ring
  - Park in the marked parking place

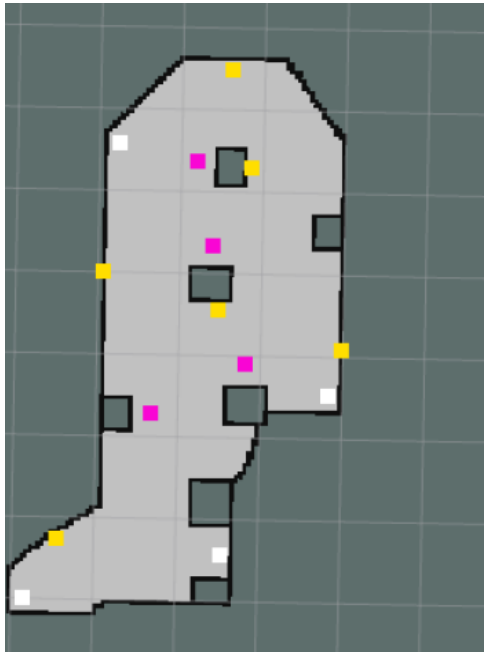


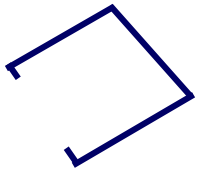
# Competencies to be developed

- System setup
  - Running ROS
  - Tele-operating TurtleBot
- Autonomous navigation
  - Autonomous control of the mobile platform
  - Acquiring images and 3D information
  - Simultaneous mapping and localization (SLAM)
  - Path planning, obstacle avoidance
  - Advanced fine manoeuvring
  - Basic mobile manipulation
  - Intelligent navigation and exploration of space
- Advanced perception and cognitive capabilities
  - Detection of faces, circles, 3D rings, 3D cylinders
  - Recognition of faces, digits, colour
  - Speech synthesis, speech recognition, dialogue processing (reading QR codes)
  - Belief maintenance, reasoning, planning

# Autonomous navigation

- Autonomous control of the mobile platform
  - components for controlling the robot
- Acquiring images and 3D information
  - using Kinect
  - OpenCV for processing images
  - Point Cloud Library for processing 3D information
- Simultaneous mapping and localization (SLAM)
  - building the map of the environment, navigation using the map
  - transformations between coordinate frames
- Path planning, obstacle avoidance
  - setting the goals, approaching to the specific local goals
  - detect and avoid the obstacles
- Advanced maneuvering
  - precise maneuvering
- Intelligent navigation and exploration of space
  - autonomus exploration, setting the goals

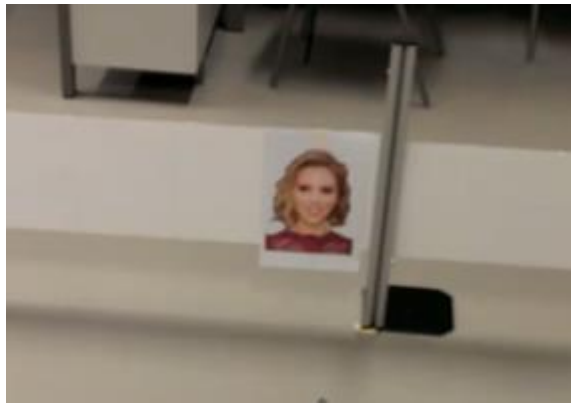


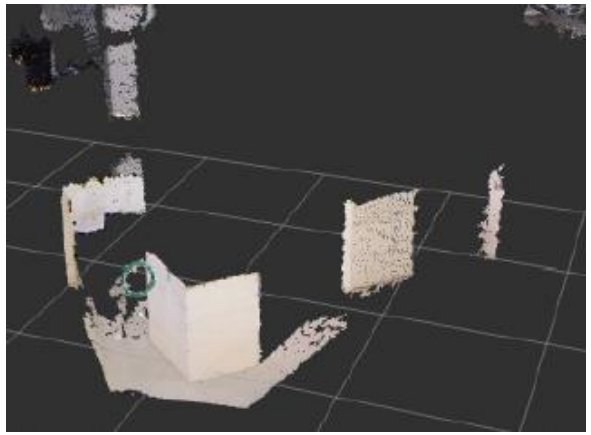


# Perception and recognition

- Face detection and recognition
- One-shot learning/enrolment
- Circle detection
- Detection of buildings
  - detection of 3D cylinders
- Detection of rings/shapes
  - localization of rings/shapes in 3D space
- Colour learning and recognition
  - Circles, cylinders, rings
- (QR code reading)

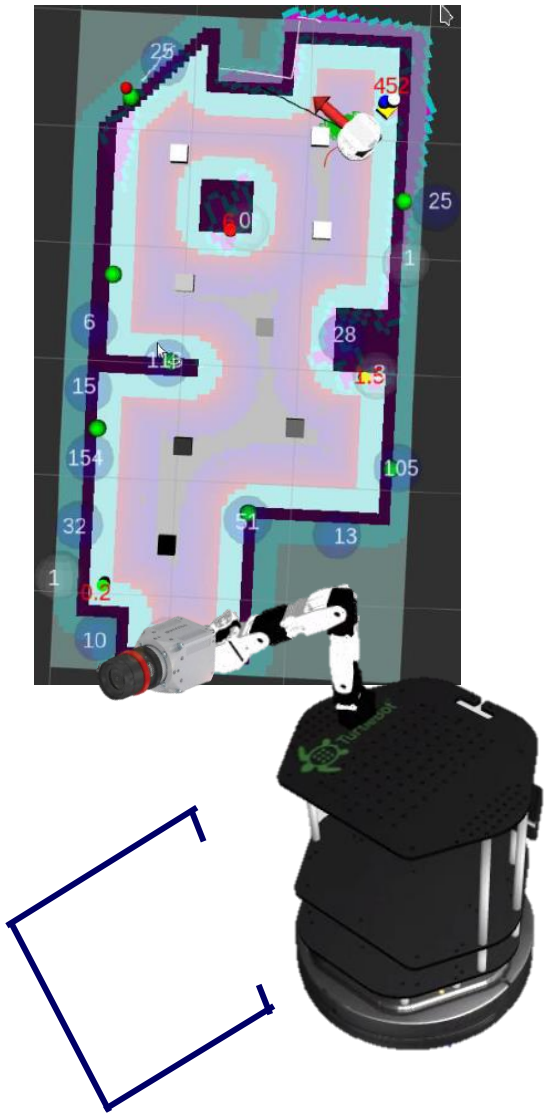
- Dialogue processing
  - Speech synthesis
  - Speech recognition
  - Speech understanding





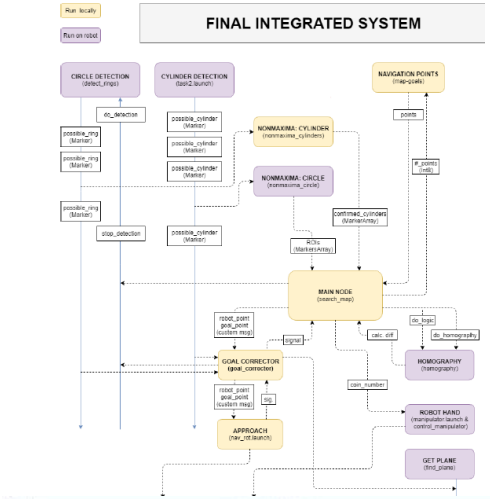
# Advanced perception and cognition

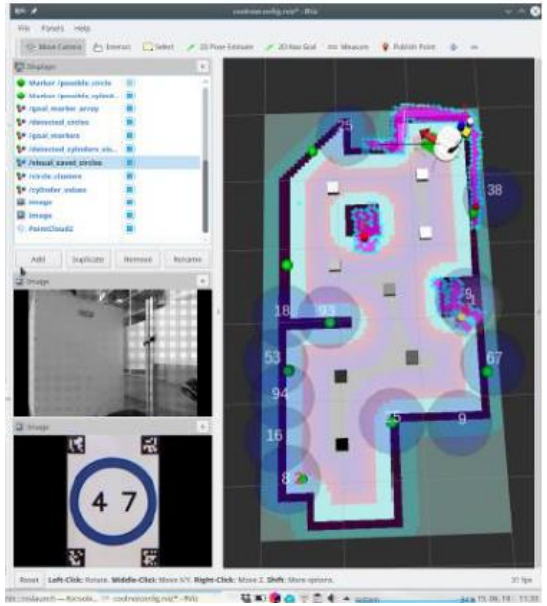
- Belief maintenance, reasoning, planning
  - anchoring the detected objects to the map
  - creating and updating the beliefs
  - reasoning using the beliefs
  - planning for information gathering
  - What to do next?
- Intelligent navigation
  - considering the map
  - optimize the exploration of space
  - optimize the distance travelled needed
  - Where to go next?
- Visual servoing
  - move the mobile camera to optimise perception
  - visual servoing while parking



# Challenges

- Robot control (ROS)
  - „engineering“ issues
  - robot system (actuators, sensors,…), real world
- Selection of appropriate components for solving subproblems
  - many of them are given, many of them are available in ROS
- Development of new components
  - implementing algorithms for solving new problems
- **Integration**
  - integrating very different components
  - „Estimate the time needed for integration, multiply it by 3, but you have still probably underestimated the time actually needed.“
  - Difficult debbuging; visualize, log!
- Very heterogeneous distributed system
  - mobile robotics, navigation, manipulation
  - computer vision, machine learning
  - reasoning, planning



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# Types of challenges

- System setup
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engineering issues

integration of components

development of components

# Research areas

- System setup
  - Running ROS
  - Tele-operating TurtleBot
- Autonomous navigation
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Mobile robotics

Computer vision, ML

Dialogue processing, AI

# Requirements

- System setup
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For 6

For + max. 2

For + max. 2

# Tasks

- System setup
  - Running ROS
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  - Autonomous control of the mobile platform
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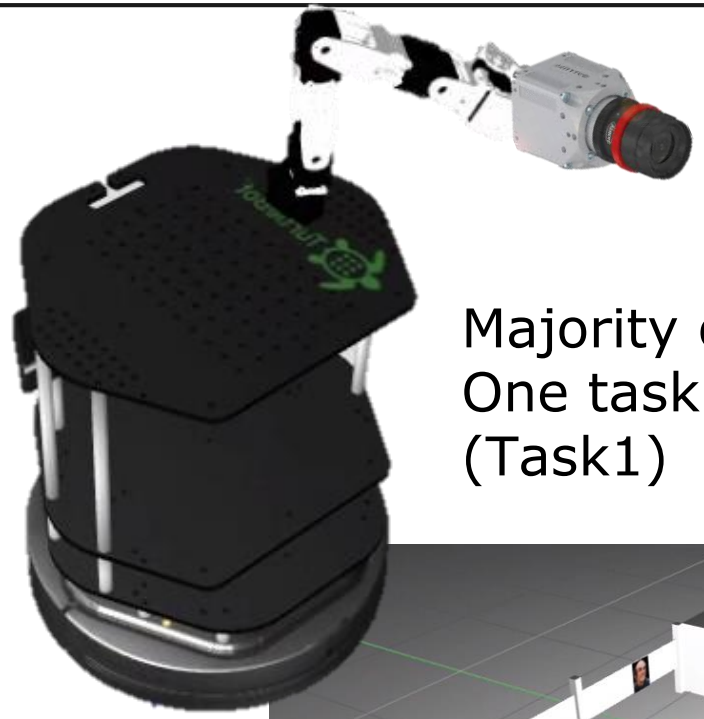
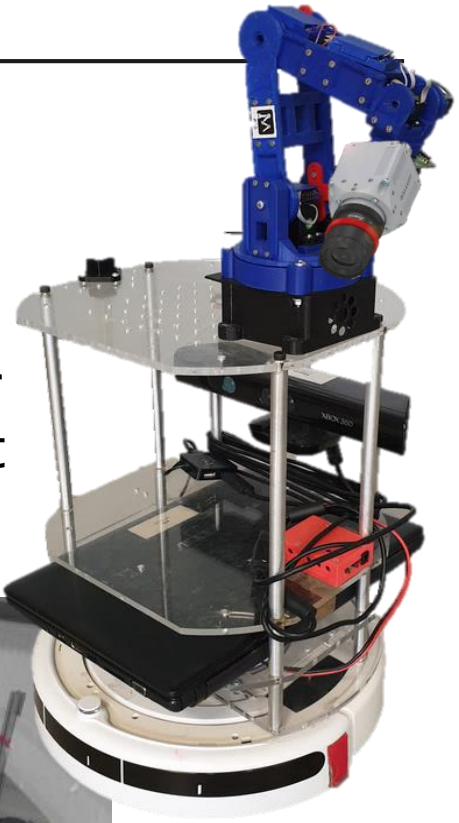
Task 1

Task 2

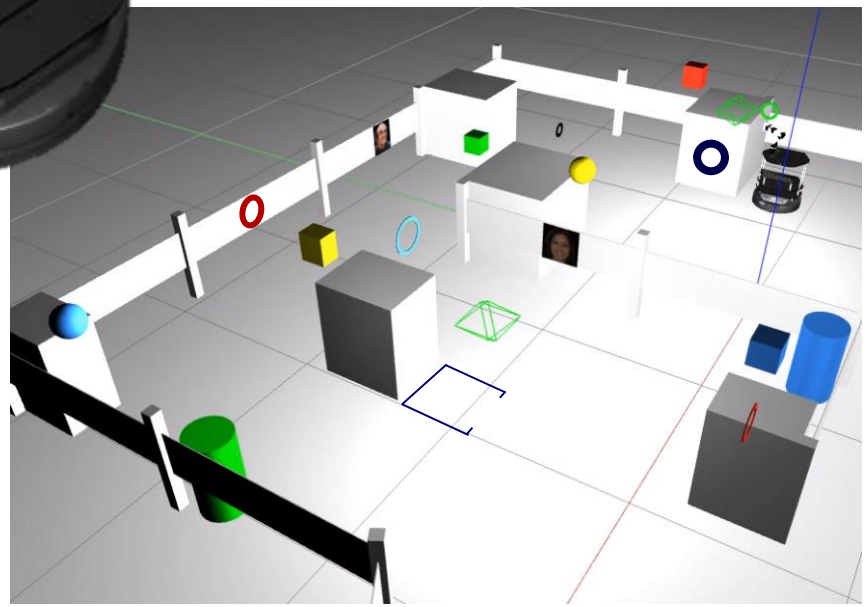
Task 3

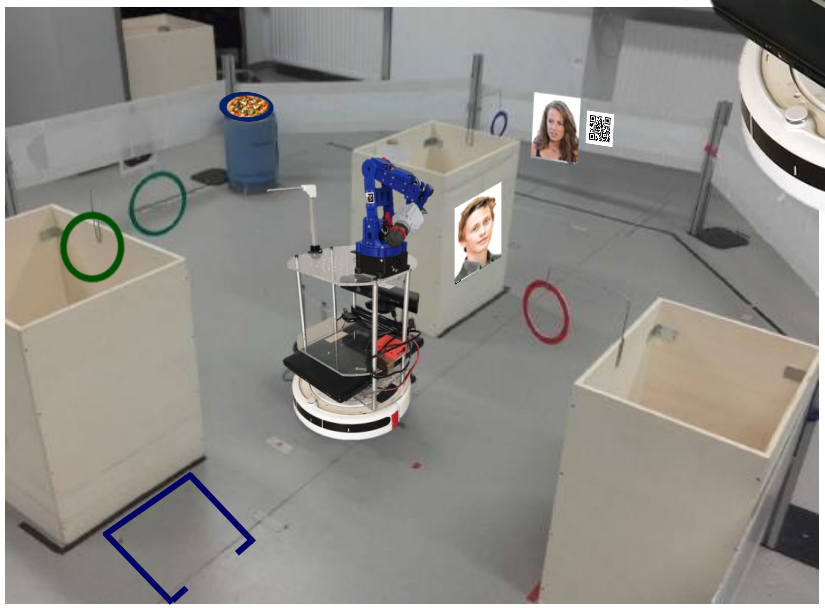
# Simulation vs. real-world robot





Majority of the tasks to be implemented in simulator
One task has also to be implemented on a real robot (Task1)





# Simulation vs. real-world robot

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  - Belief maintenance, reasoning, planning

Sim.+real
Sim. only

Task 1
Task 2
Task 3

Optional: also parts of Task 2 and Task 3

# Lectures

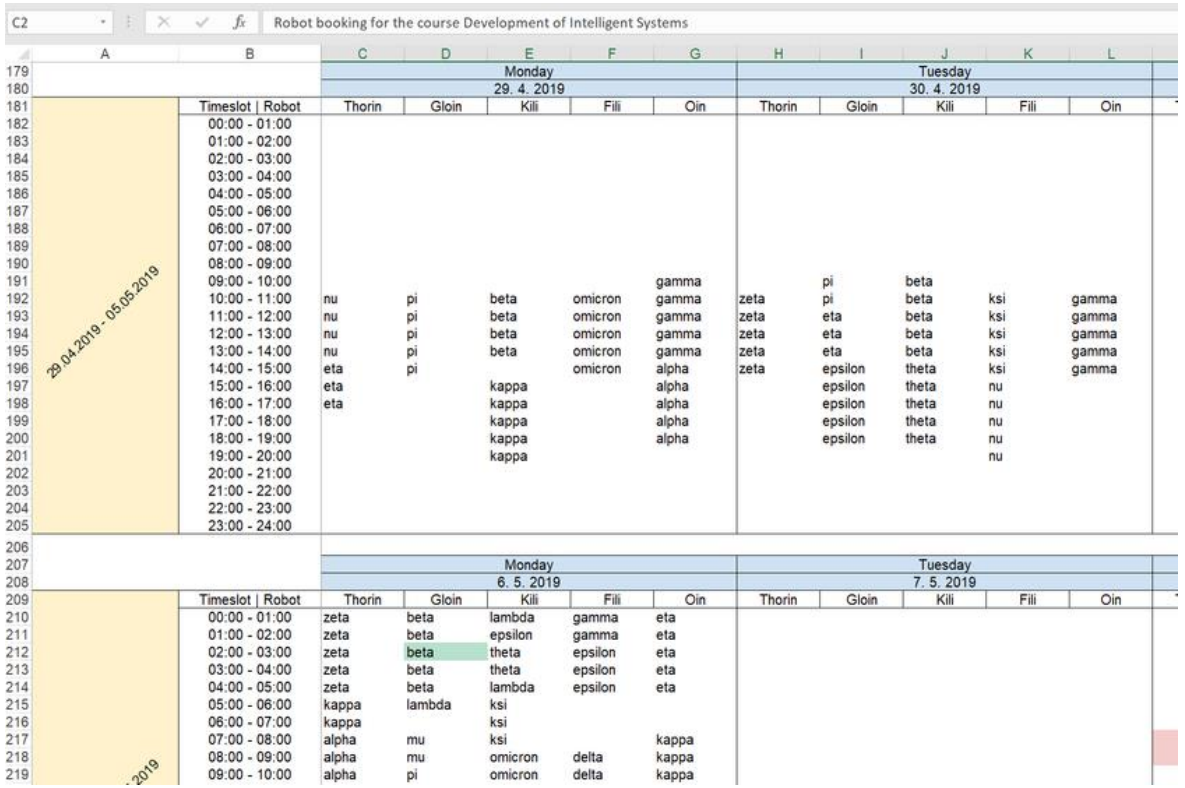
- Additional knowledge needed for understanding and implementation of the individual components of the system:
  - introduction to intelligent systems
  - ROS
  - sensors
  - transformations between the coordinate frames
  - mobile robotics
  - computer vision and machine learning
  - robot manipulation
  - artificial cognitive systems

# Practical implementation

- Five robots are available
- Teams of three students
- Each team
  - there is at least one good Python/C++ programmer
  - there is at least one member who can work with Linux and robots/hardware
  - there is at least one member good in computer vision and machine learning
  - all the members are equivalent – the work should be fairly distributed – no piggybacking!
  - all the members of the groups attend the same tutorial group
  - preferably also have their own laptop /powerful desktop
    - sufficiently powerful
    - native Linux (Ubuntu 20.04 Focal Fossa,…; ROS Noetic Ninjemys)
    - USB port
- Mobile platforms are available
  - during the practice classes (tutorials)
  - at other times in RoboRoom R2.38 (booking required)

# Continuous integration

- It is essential to work during the entire semester
- Time during the official classes does not suffice
- Book the robot and work at other times in RoboRoom R2.38



C2 — Robot booking for the course Development of Intelligent Systems

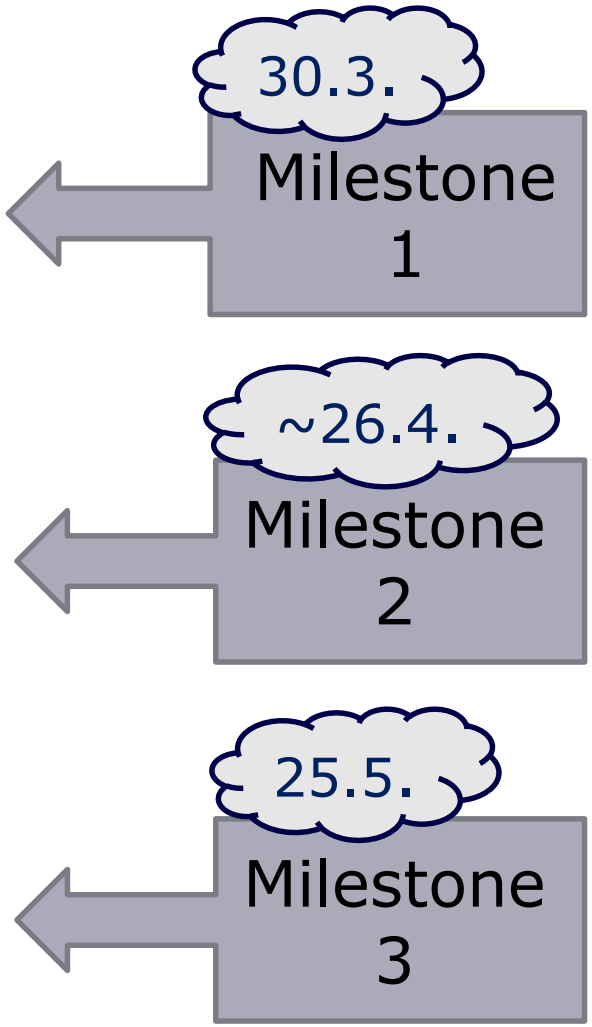
| | | Monday 29. 4. 2019 | | | | | Tuesday 30. 4. 2019 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29.04.2019 - 05.05.2019 | Timeslot \| Robot | Thorin | Gloin | Kili | Fili | Oin | Thorin | Gloin | Kili | Fili | Oin |
| | 00:00 - 01:00 | | | | | | | | | | |
| | 01:00 - 02:00 | | | | | | | | | | |
| | 02:00 - 03:00 | | | | | | | | | | |
| | 03:00 - 04:00 | | | | | | | | | | |
| | 04:00 - 05:00 | | | | | | | | | | |
| | 05:00 - 06:00 | | | | | | | | | | |
| | 06:00 - 07:00 | | | | | | | | | | |
| | 07:00 - 08:00 | | | | | | | | | | |
| | 08:00 - 09:00 | | | | | | | | | | |
| | 09:00 - 10:00 | | | | | gamma | | pi | beta | | |
| | 10:00 - 11:00 | nu | pi | beta | omicron | gamma | zeta | pi | beta | ksi | gamma |
| | 11:00 - 12:00 | nu | pi | beta | omicron | gamma | zeta | eta | beta | ksi | gamma |
| | 12:00 - 13:00 | nu | pi | beta | omicron | gamma | zeta | eta | beta | ksi | gamma |
| | 13:00 - 14:00 | nu | pi | beta | omicron | gamma | zeta | eta | beta | ksi | gamma |
| | 14:00 - 15:00 | eta | pi | | omicron | alpha | zeta | epsilon | theta | ksi | gamma |
| | 15:00 - 16:00 | eta | | kappa | | alpha | | epsilon | theta | nu | |
| | 16:00 - 17:00 | eta | | kappa | | alpha | | epsilon | theta | nu | |
| | 17:00 - 18:00 | | | kappa | | alpha | | epsilon | theta | nu | |
| | 18:00 - 19:00 | | | kappa | | alpha | | epsilon | theta | nu | |
| | 19:00 - 20:00 | | | kappa | | | | | | nu | |
| | 20:00 - 21:00 | | | | | | | | | | |
| | 21:00 - 22:00 | | | | | | | | | | |
| | 22:00 - 23:00 | | | | | | | | | | |
| | 23:00 - 24:00 | | | | | | | | | | |

| | | Monday 6. 5. 2019 | | | | | Tuesday 7. 5. 2019 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Timeslot \| Robot | Thorin | Gloin | Kili | Fili | Oin | Thorin | Gloin | Kili | Fili | Oin |
| | 00:00 - 01:00 | zeta | beta | lambda | gamma | eta | | | | | |
| | 01:00 - 02:00 | zeta | beta | epsilon | gamma | eta | | | | | |
| | 02:00 - 03:00 | zeta | beta | theta | epsilon | eta | | | | | |
| | 03:00 - 04:00 | zeta | beta | theta | epsilon | eta | | | | | |
| | 04:00 - 05:00 | zeta | beta | lambda | epsilon | eta | | | | | |
| | 05:00 - 06:00 | kappa | lambda | ksi | | | | | | | |
| | 06:00 - 07:00 | kappa | | ksi | | | | | | | |
| | 07:00 - 08:00 | alpha | mu | ksi | | kappa | | | | | |
| | 08:00 - 09:00 | alpha | mu | omicron | delta | kappa | | | | | |
| | 09:00 - 10:00 | alpha | pi | omicron | delta | kappa | | | | | |

# Milestones

- Milestone 1: Autonomous navigation and human search
  - Autonomous navigation around the competition area
  - Find and approach the faces
- Milestone 2: Parking
  - Detect the 3D rings
  - Basic visual servoing
  - Fine manoeuvring and parking
- Milestone 3: RoboSheriff
  - Imprison the robbers
  - Computer vision, machine learning
  - Dialogue, mobile manipulation
  - Belief maintenance, reasoning, planning

+ Autonomous navigation and human search on a real robot



# Evaluation

- Huge emphasis on practical work
- Continuing work and assessment during the semester
- Different levels of requirements available
- There is no written exam!
- Oral exam

- Grading:
  - 10 points: M1 in simulator (system operation)
  - 10 points: M1 on real robot (system operation)
  - 15 points: M2 in simulator (system operation)
  - 25 points: M3 in simulator (concepts used, system operation, system performance)
  - 10 points: Final report (description of the methods used, experimental results, implementation, innovation)
  - 10 points: Active participation (participation at the practice classes, active work in the lab, active problem solving, homeworks)
  - 20 points: Oral exam (concepts presented during the lectures, discussion about theoretical and implementation details of the developed system, experimental results)

# Requirements

- Requirements:
  - at least 30 points (50%) earned at milestones
  - at least 5 points (50%) for the final report
  - at least 50 points (50%) altogether
- If the student fails to carry out the work in time (fails to successfully demonstrate the robot at the milestones), he/she can not pass the course in the current academic year.
- If the student does not pass the oral exam, he/she is allowed to take it again (this year).
- If it is determined that the student has not contributed enough to the development of the system in his/her team, he can not pass the course in the current academic year.
- The students have to participate in the continuous assessment of their work (at milestones M1, M2, M3).
- Attendance at the practice classes is compulsory.
- Completed requirements are only valid in the current academic year.

# Conclusion

- Very „hands-on“ course
- Gaining practical experience on a real robot
- Real-world problems
- Collaboration
- Creative thinking
- Problem solving
- Innovativeness
- Practical skills