Development of intelligent systems (RInS)

Introductory information

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University of Ljubljana
Faculty of Computer and Information Science

Academic year: 2024/25

About the course

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

- Lectures on Fridays 9:15 – 12:00 (in P4)
- Tutorials, 4 groups, in R2.38:
  - Mondays 12:15 - 14:00
  - Mondays 12:15 - 14:00 ?
  - Thursdays 17:15 – 19:00
  - Fridays 15:15 – 17:00

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

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: Fridays, 14:00-15:00 (or at other times, send an email)

ViCOS Visual Cognitive Systems Lab

Teching assistants

- as. dr. Matej Dobrevski
  - Visual Cognitive Systems Laboratory
  - e-mail: matej.dobrevski@fri.uni-lj.si
  - tel: 01 479 8245
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- as. dr. Jon Muhovič
  - Visual Cognitive Systems Laboratory
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- Vid Rijavec
  - Visual Cognitive Systems Laboratory
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  - tel: 01 479 8245
  - room: second floor, room R2.36

ViCOS
Visual Cognitive Systems Lab

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!

Ex development platform

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

ROS

Development platform

- Robot platform: Clearpath Robotics TurtleBot 4 Standard
- Software platform: ROS 2, Robot Operating System

ROS 2™

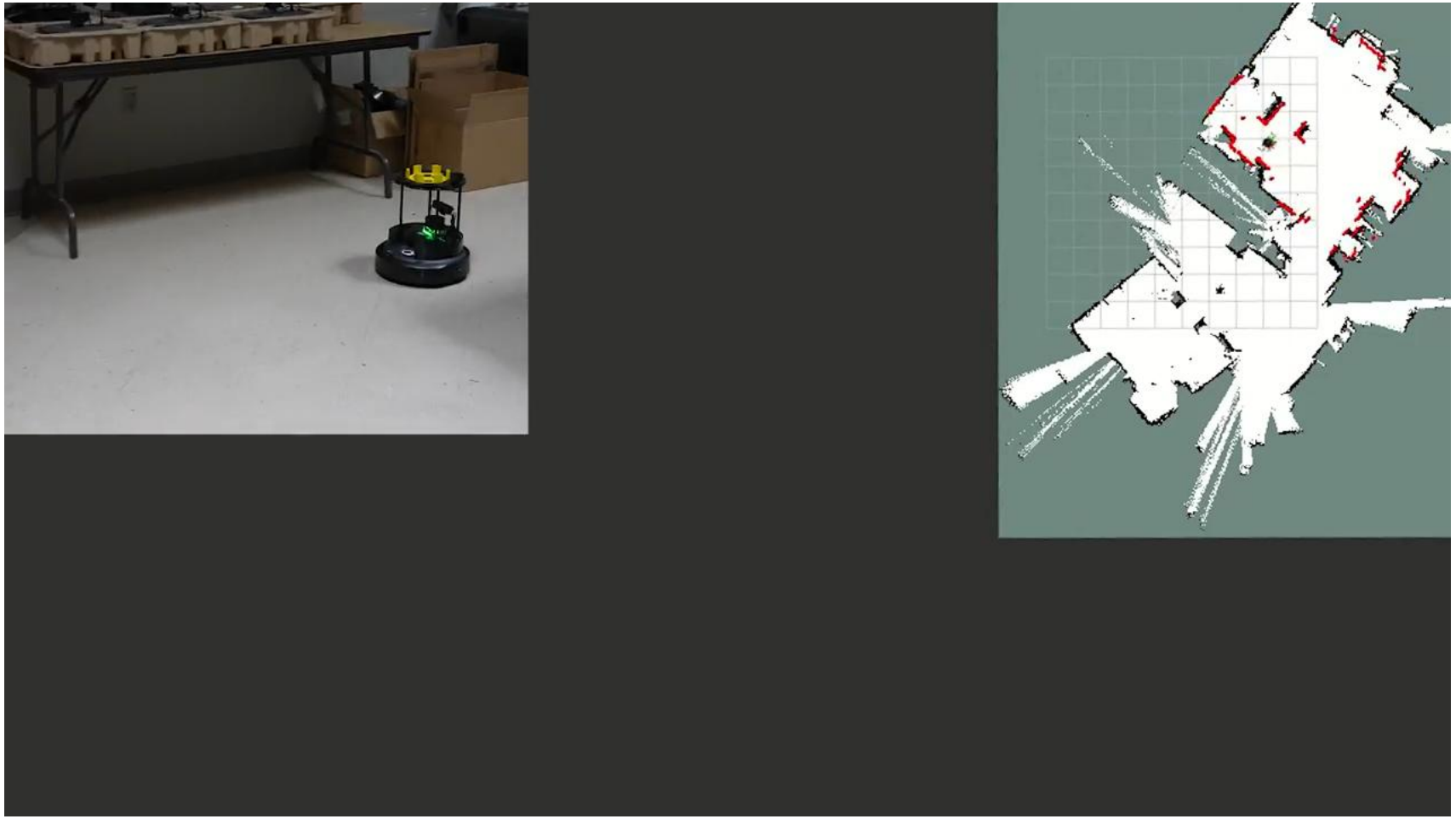
TurtleBot 4

Robot specifications

Dimensions	341 x 339 x 351 mm
Weight	3.9 kg
Max. Speed	0.31 m/s
Max. Payload	9 kg - Default 15 kg - Custom Configuration
Operating Time	2.5 - 4.0 hrs (load dependent)
Camera	OAK-D-PRO
LiDAR	RPLIDAR-A1
Accessible Power & USB Ports	Yes
OLED Display	Yes
Mounting Plate	Yes
Software	ROS 2
Computer	Raspberry Pi 4B (4 GB)

TurtleBot 4

Robot platform



RInS 2012

- Slalom

RInS 2013

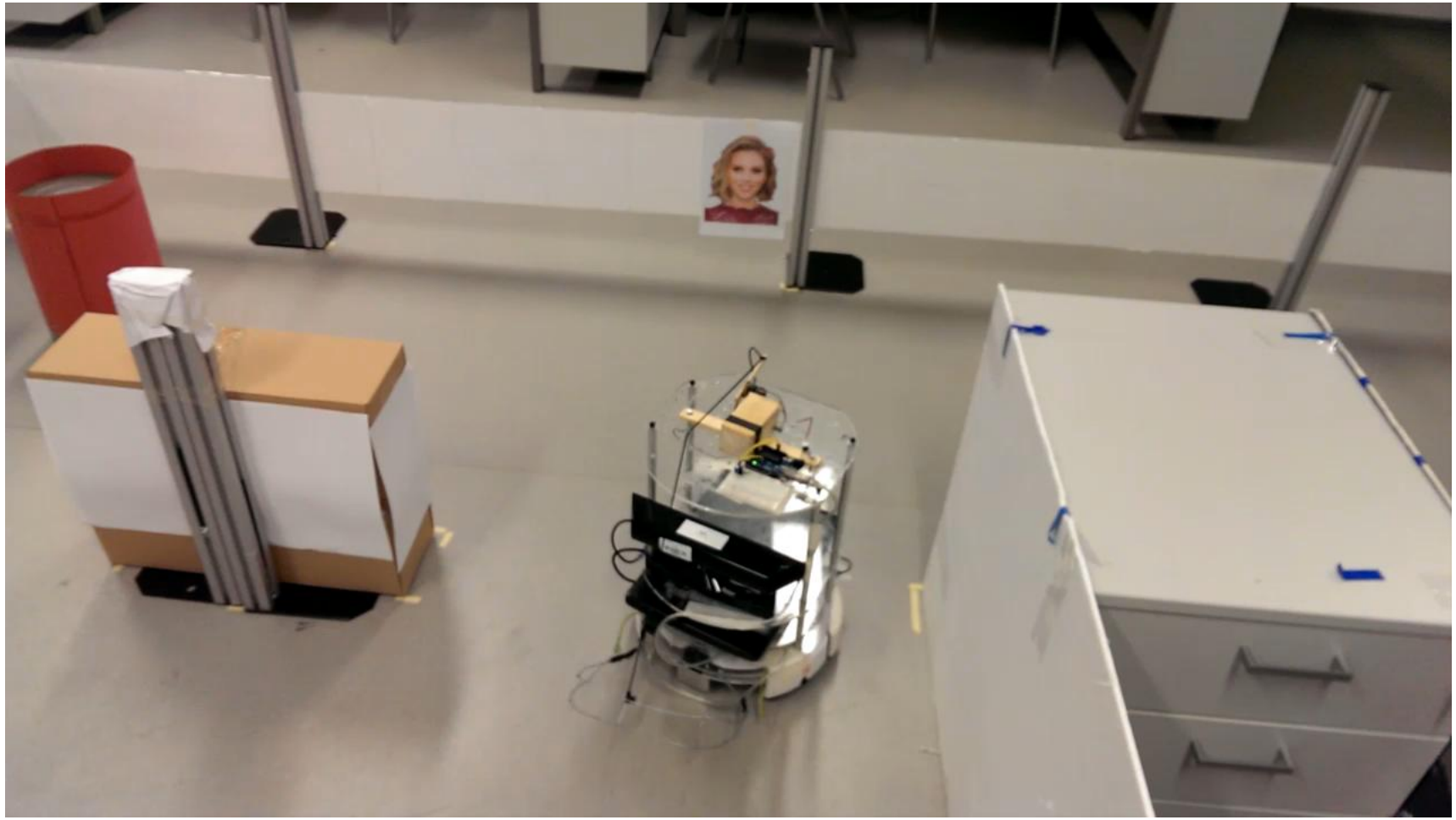
- Object search

RInS 2014

- Mini Cluedo

RInS 2015

- DeliveryBot



RInS 2016

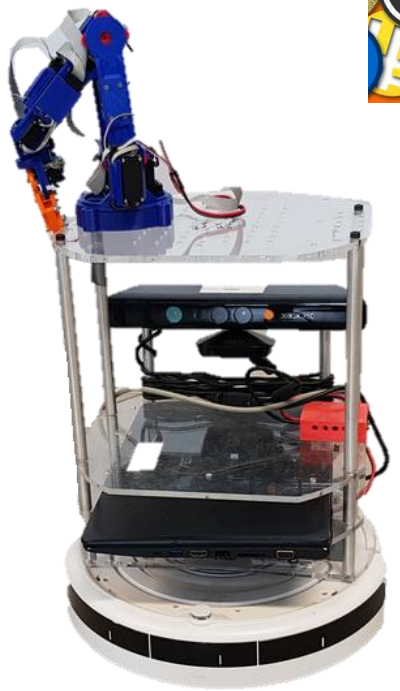
- TaxiBot

RInS 2017

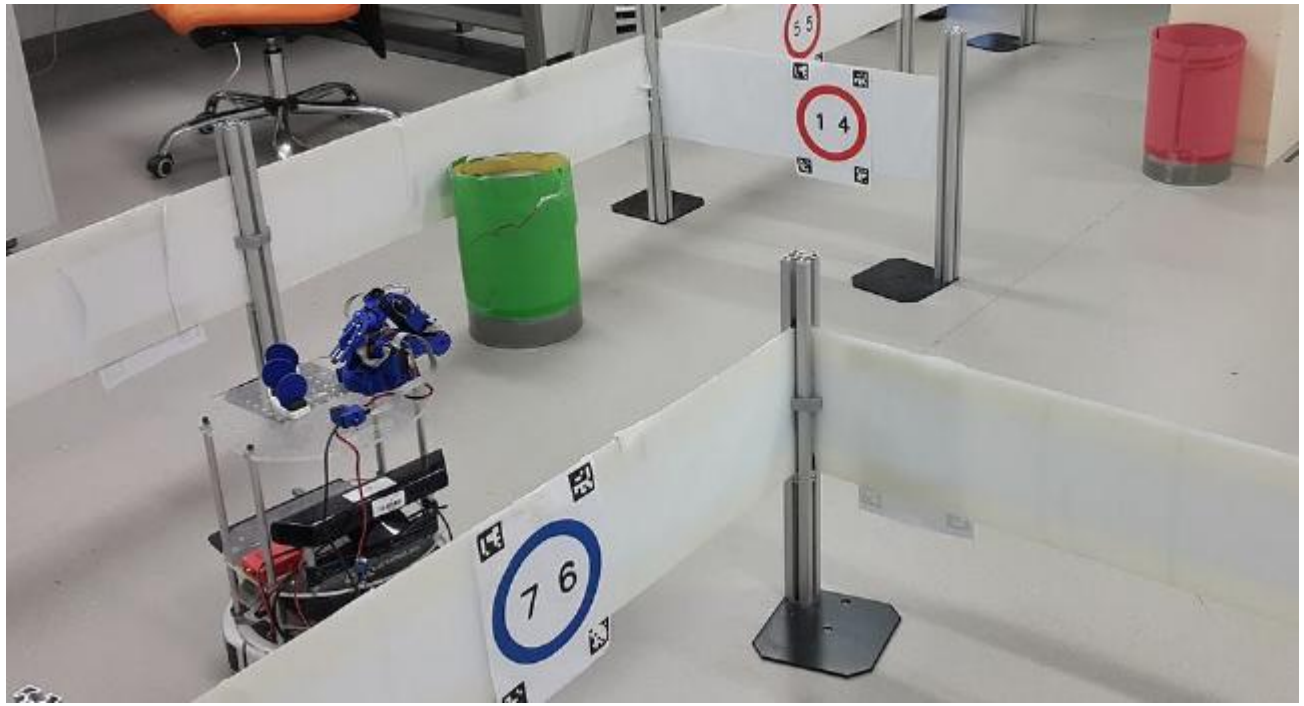
- Robot of the rings

RInS 2018

- CryptoBot

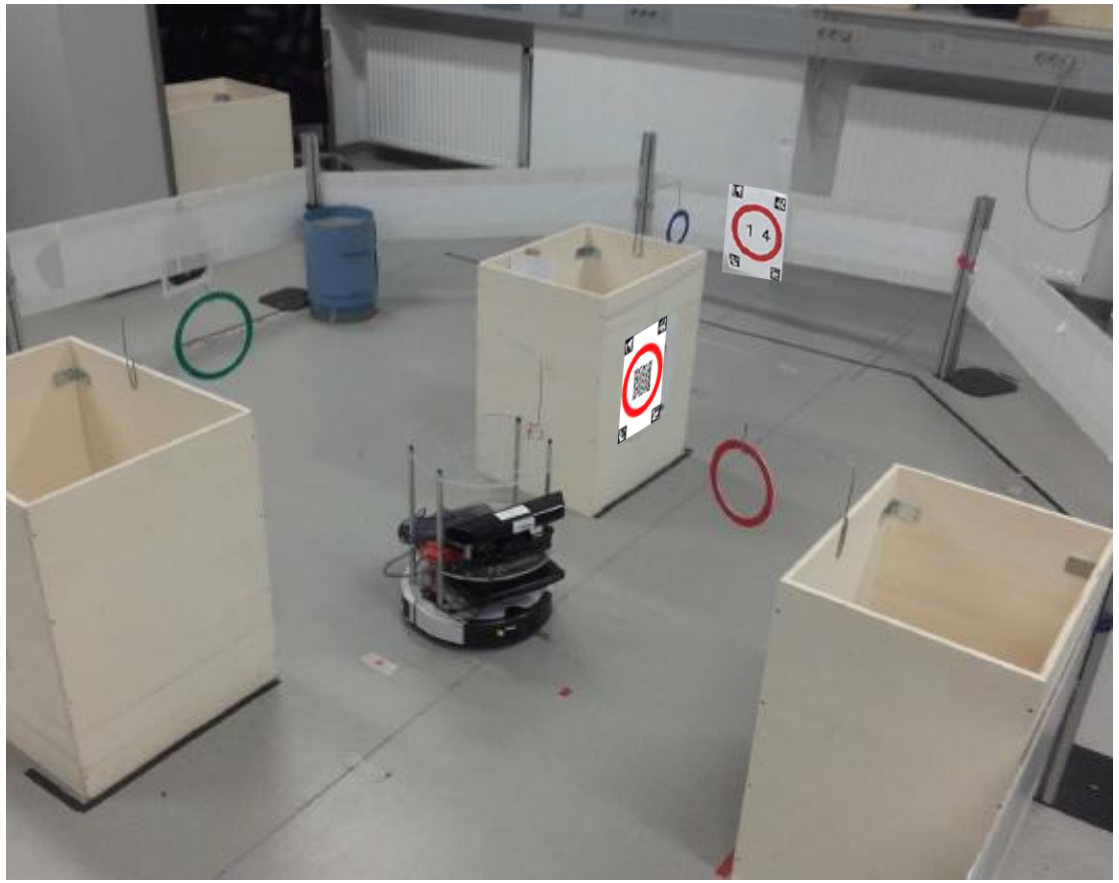


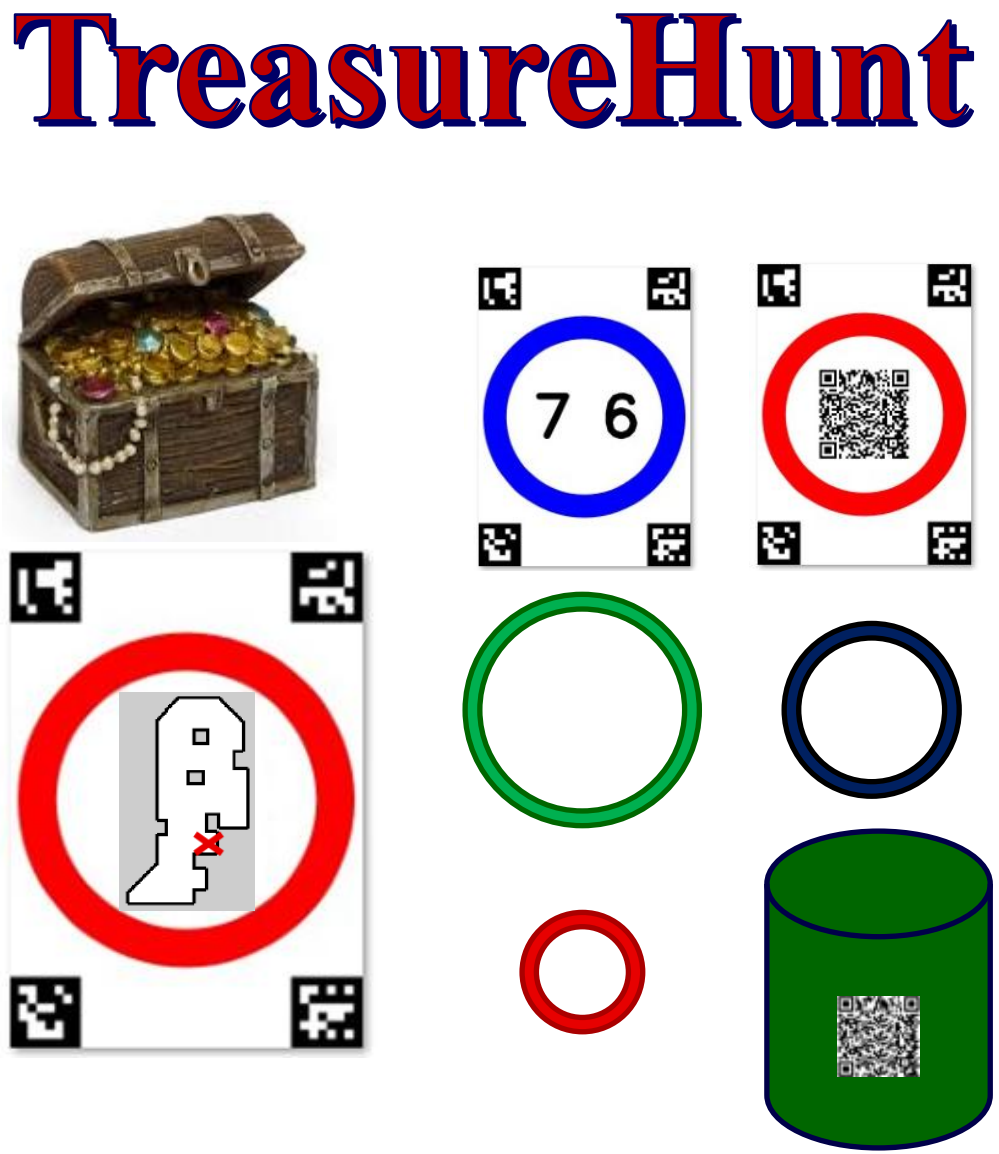
CryptoBot



RInS 2019

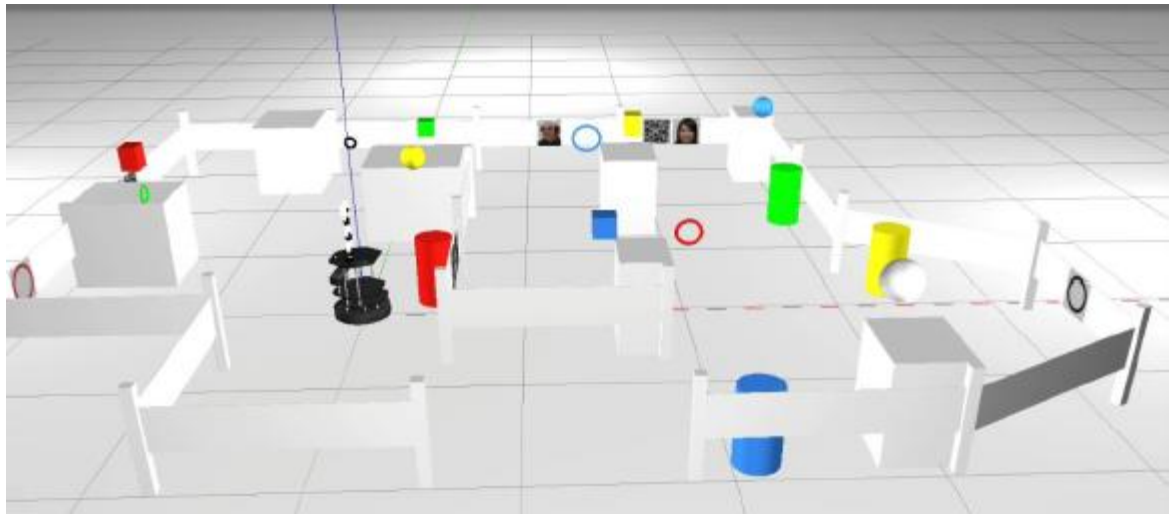
- TreasureHunt





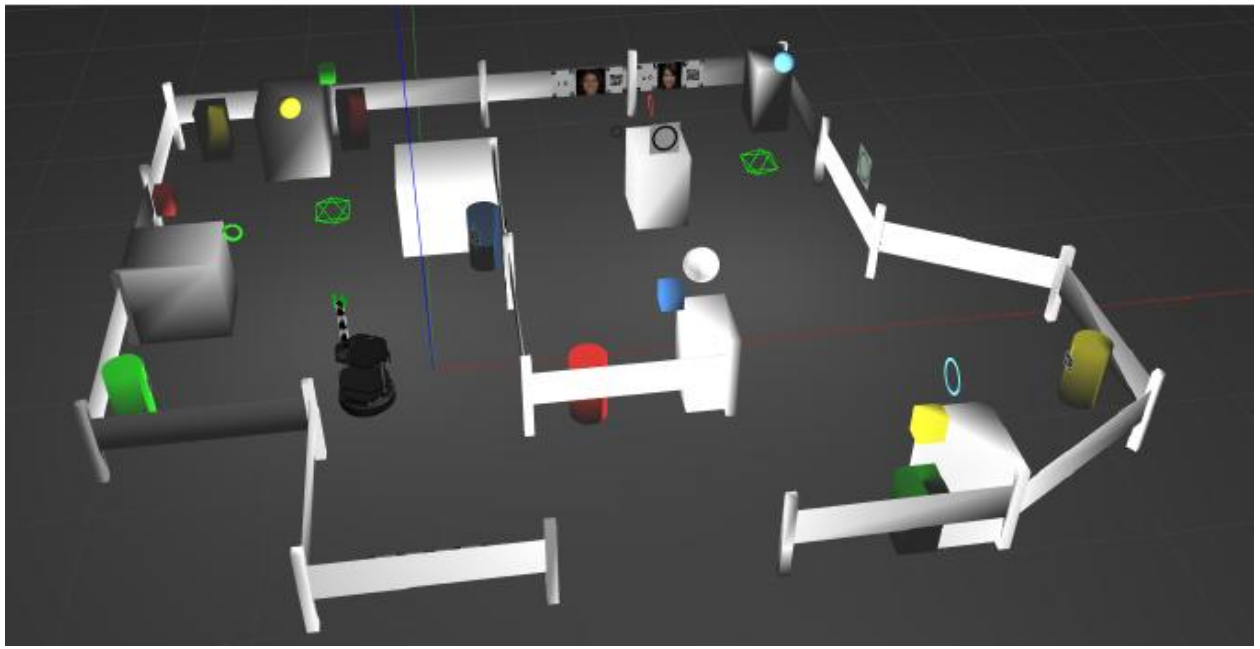
RInS 2020

Matchmaker

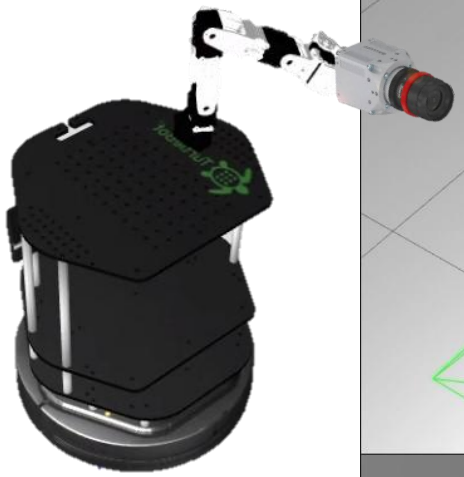


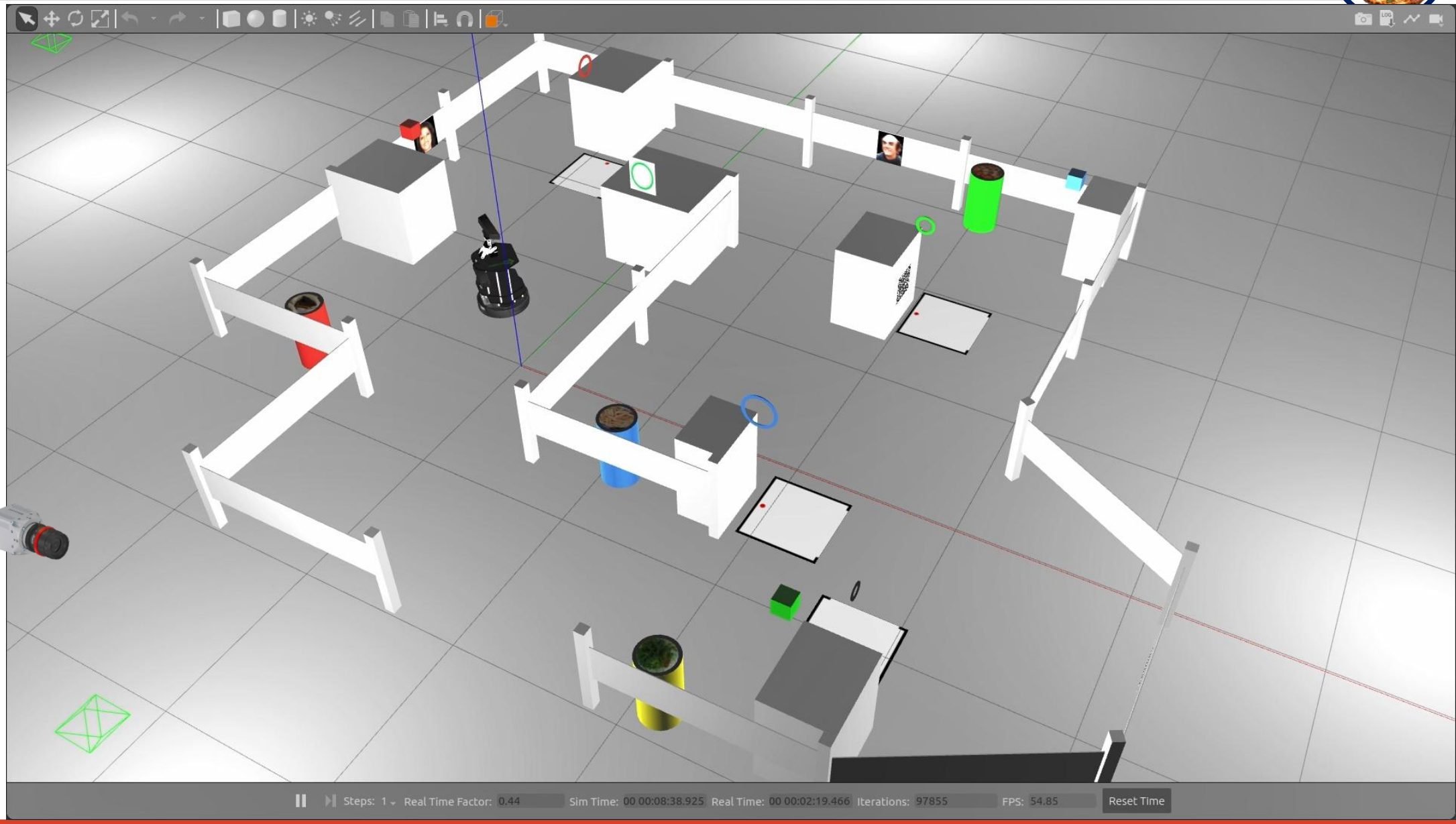
RInS 2021

STOPCORONA

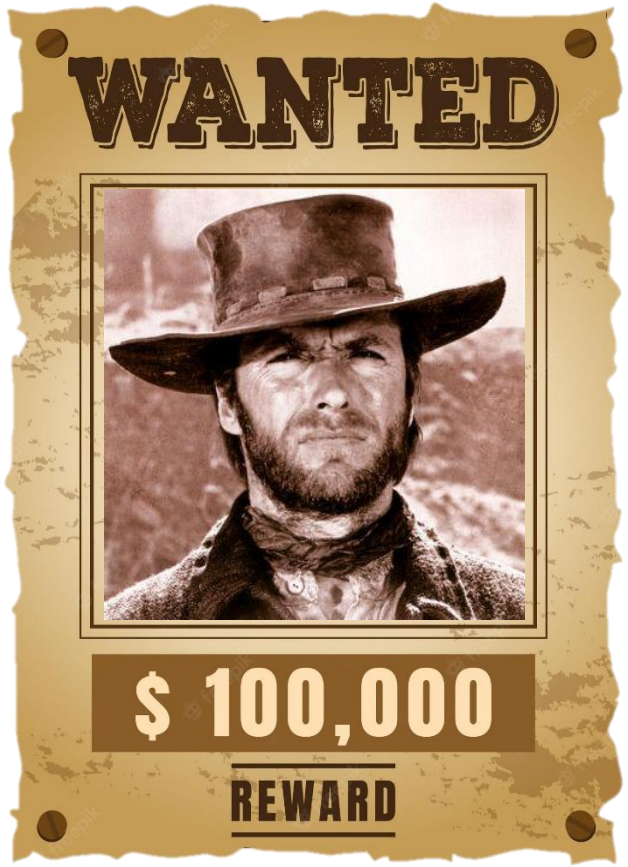


RInS 2022 FooDeRo



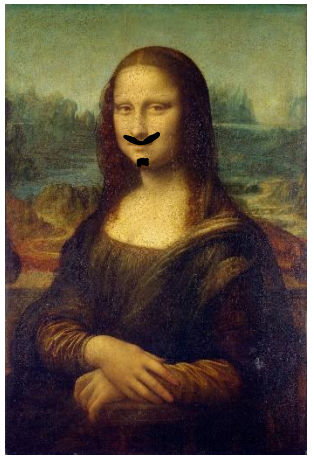


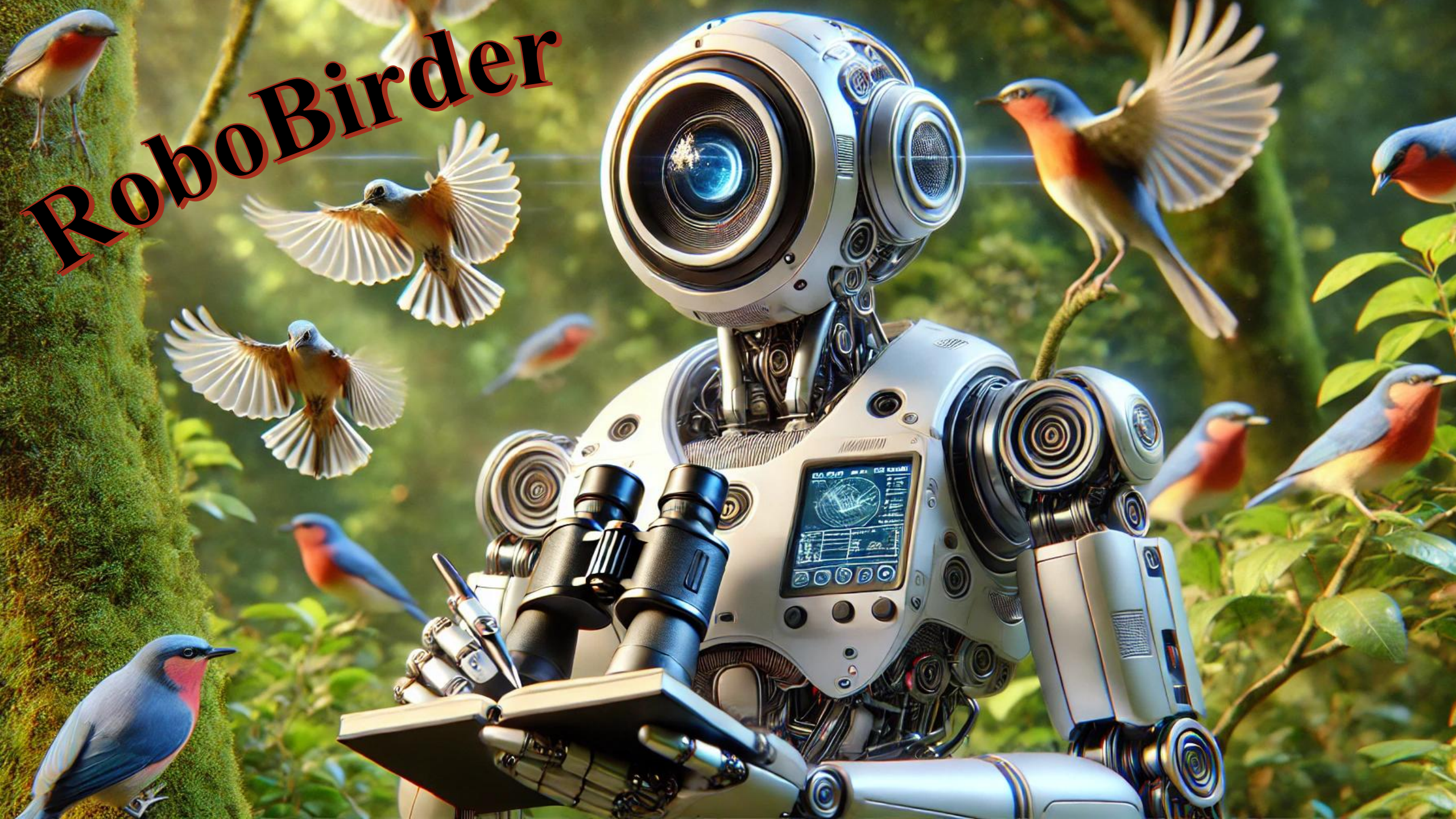
RoboScheriff



2024

Robo da Vinci

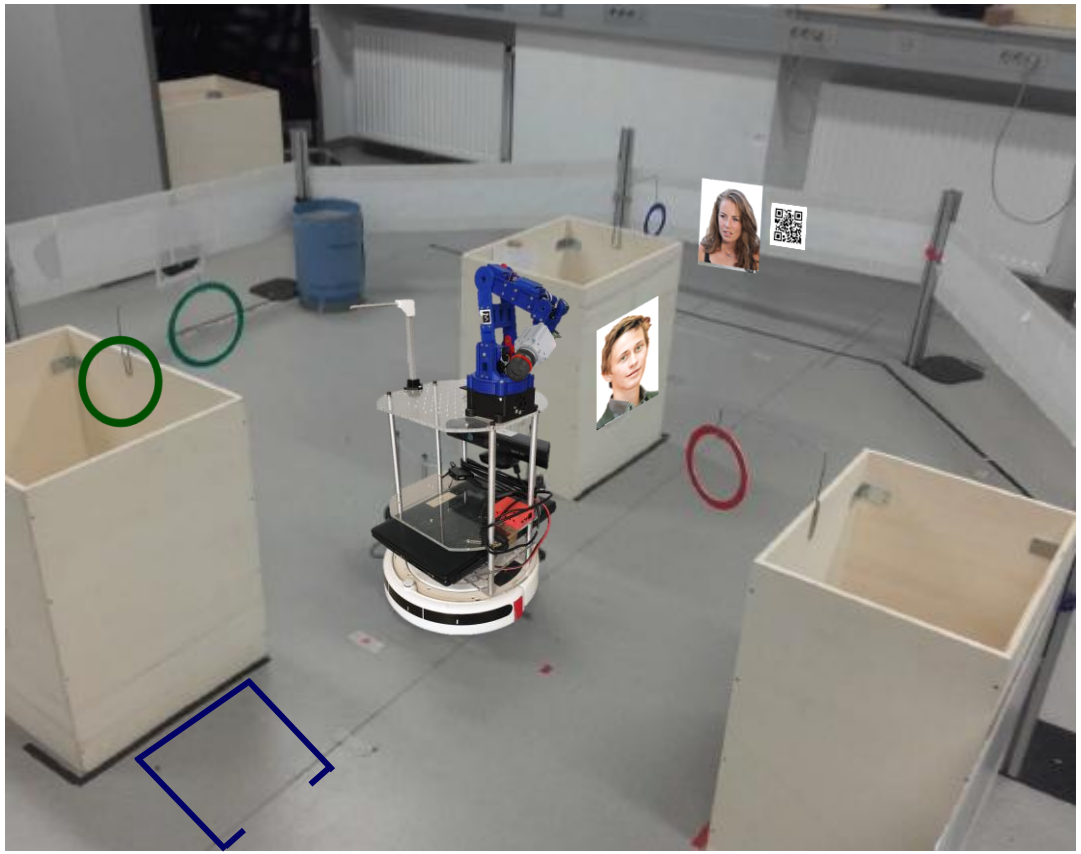



RoboBirder

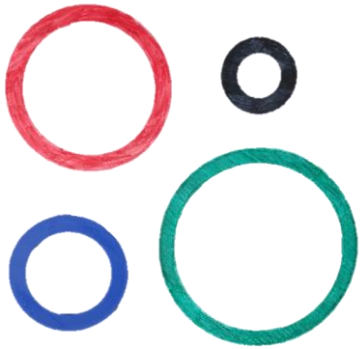
2025 Final task

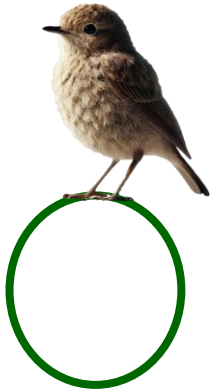
- Setup:
  - „A park“ scene (fenced area).
  - Pathways, bridges, grass area, river.
  - Several persons (faces) in the scene.
  - Several birds in the scene standing on the rings of different colours.
- Goal:
  - Find and recognise all the birds.
- Task:
  - Navigate safely around the park and look around.
  - Pay attention to stay on a pathway and not to drive in the grass or water.
  - Find all birds in the park.
  - Approach every bird and take a photo with hi-res camera.
  - Recognise the bird and say its name.
  - Find all persons in the park.
  - Talk to persons to find out which are their preferred birds.
  - Tell the persons where their preferred bird is and what is the colour of the ring it is standing on.
  - Create a catalogue of the detected birds.

2025 Final task



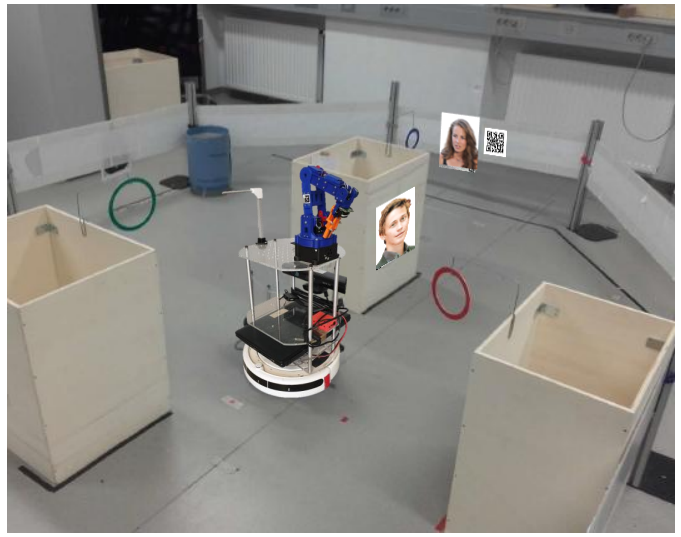
2025 Final task



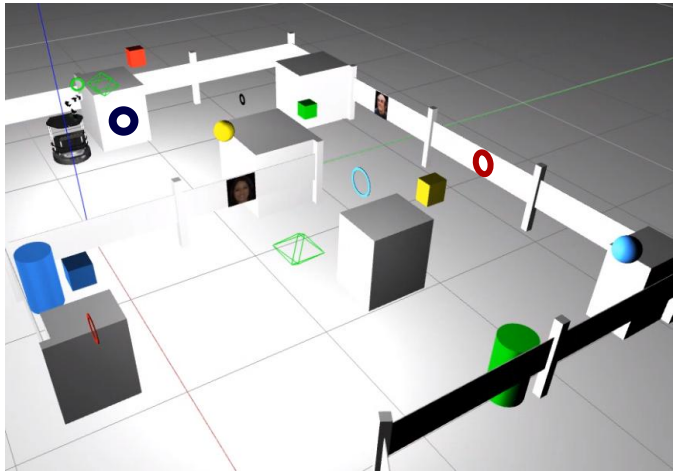


Intermediate tasks

- Task T1r: 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 greet every approached face



- Task T1s: T1a +
  - it should detect 3D rings
  - it should recognise the colours of the rings



- Task T1r - on a real robot in real world
- Task T1s – in simulation only

Practical implementation

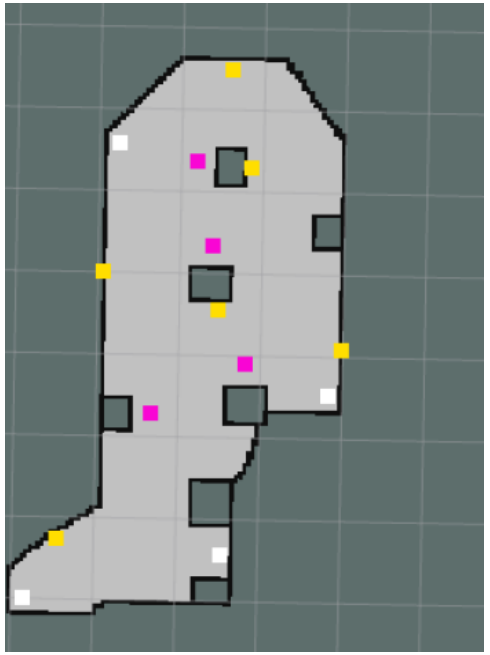
- Five robots are available
- Teams of three students
- Each team
  - there is at least one good Python/C++ programmer
  - there is at least one member who can work with Linux and robots/hardware
  - there is at least one member good in computer vision and machine learning
  - all the members are equivalent – 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 22.04,…; ROS 2 Humble)
- Mobile platforms are available
  - during the practice classes (tutorials)
  - at other times in RoboRoom R2.38 (booking required)

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, 3D rings, birds
  - Recognition of birds and ring colours
  - Segmentation of the ground
  - Speech synthesis, speech recognition, dialogue processing (reading QR codes)
  - Belief maintenance, reasoning, planning

Autonomous navigation

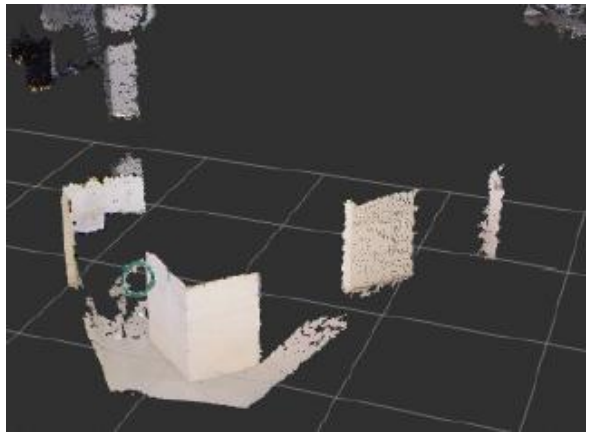
- Autonomous control of the mobile platform
  - components for controlling the robot
- Acquiring images and 3D information
  - using OAK-D-PRO
  - OpenCV for processing images
  - Point Cloud Library for processing 3D information
- Simultaneous mapping and localization (SLAM)
  - building the map of 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, visual servoing
- Intelligent navigation and exploration of space
  - autonomus exploration, setting the goals



Perception and recognition

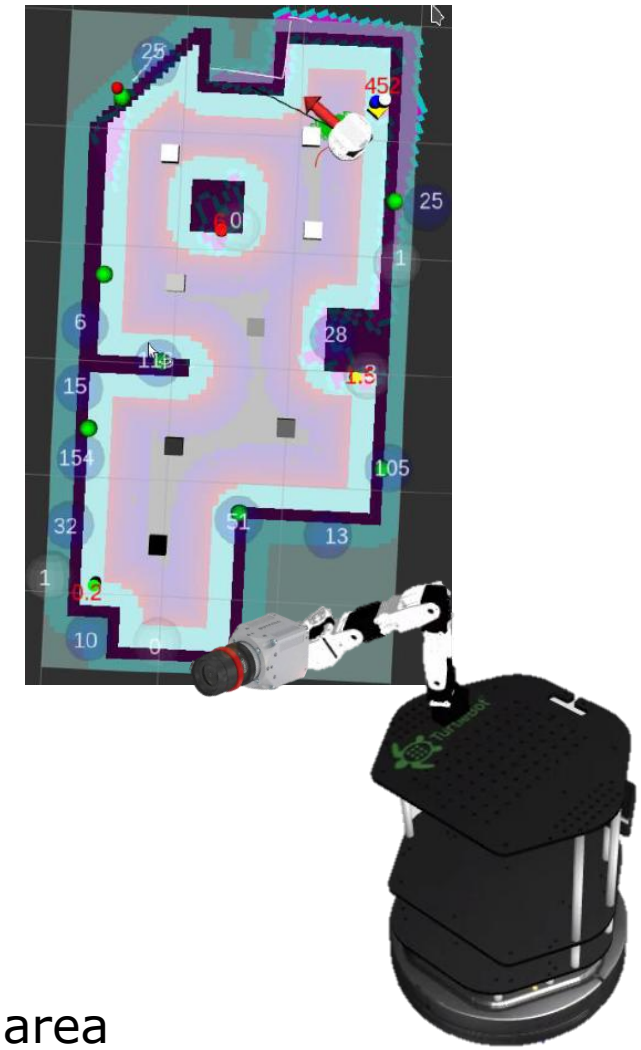
- Face detection
- Detection of rings/shapes
  - localization of rings/shapes in 3D space
- Detection of birds
- Segmentation of the ground
  - determining traversable area
- Colour learning and recognition
  - rings
- (QR code reading)

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



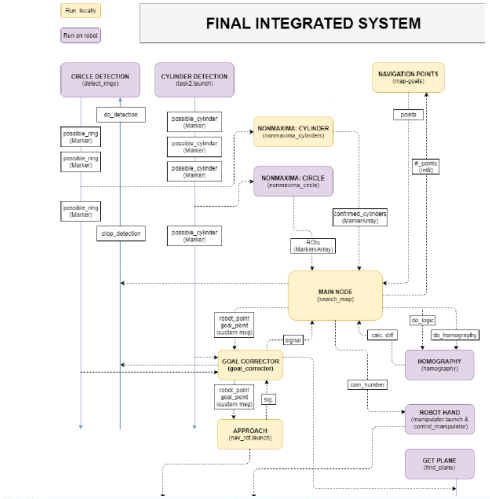
Advanced perception and cognition

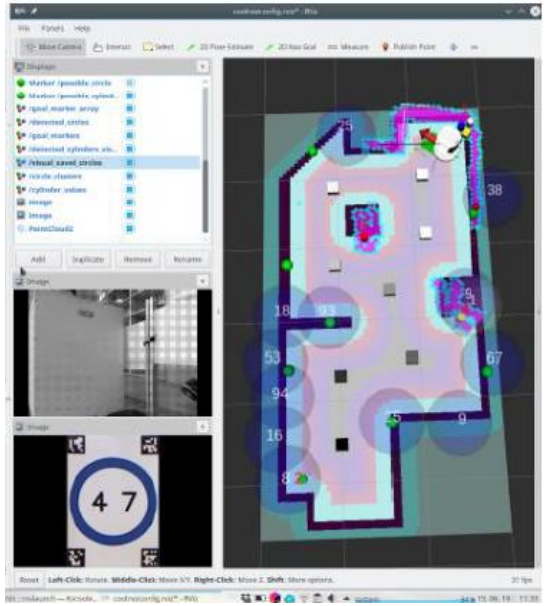
- Belief maintenance, reasoning, planning
  - anchoring the detected objects to the map
  - creating and updating the beliefs
  - reasoning using the beliefs
  - planning for information gathering
  - What to do next?
- Intelligent navigation
  - considering the map
  - optimize the exploration of space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



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
  - Running ROS
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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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  - Tele-operating TurtleBot
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For 6

For + max. 2

For + max. 2

Tasks

- System setup
  - Running ROS — Task 1r
  - Tele-operating TurtleBot — Task 1s
- Autonomous navigation — Task 2
  - Autonomous control of the mobile platform
  - Acquiring images and 3D information
  - Simultaneous mapping and localization (SLAM)
  - Path planning, obstacle avoidance
  - Advanced fine manoeuvring
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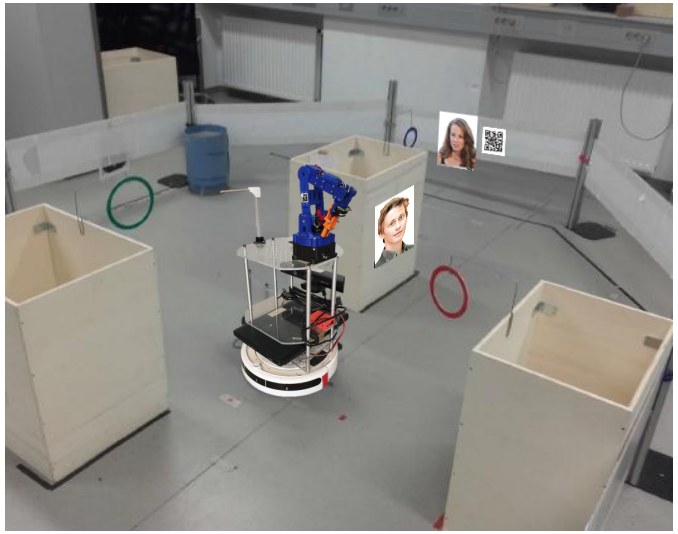
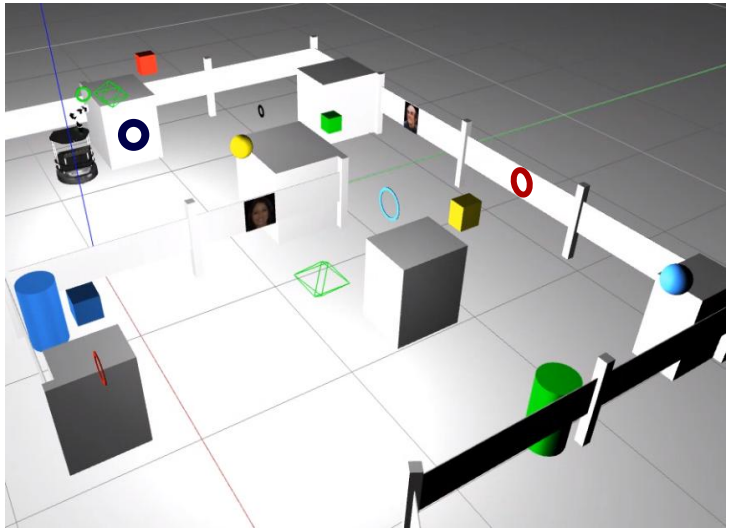
Real-world robot vs. simulation

Majority of the tasks to be implemented in simulator
One task has also to be implemented on a real robot (Task1r)





Simulation vs. real-world robot

- System setup
  - Running ROS
  - Tele-operating TurtleBot
- Autonomous navigation
  - Autonomous control of the mobile platform
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Sim.+real

Sim. only

Optional: also parts of Task 2 and Task 3

Plan B for Task2

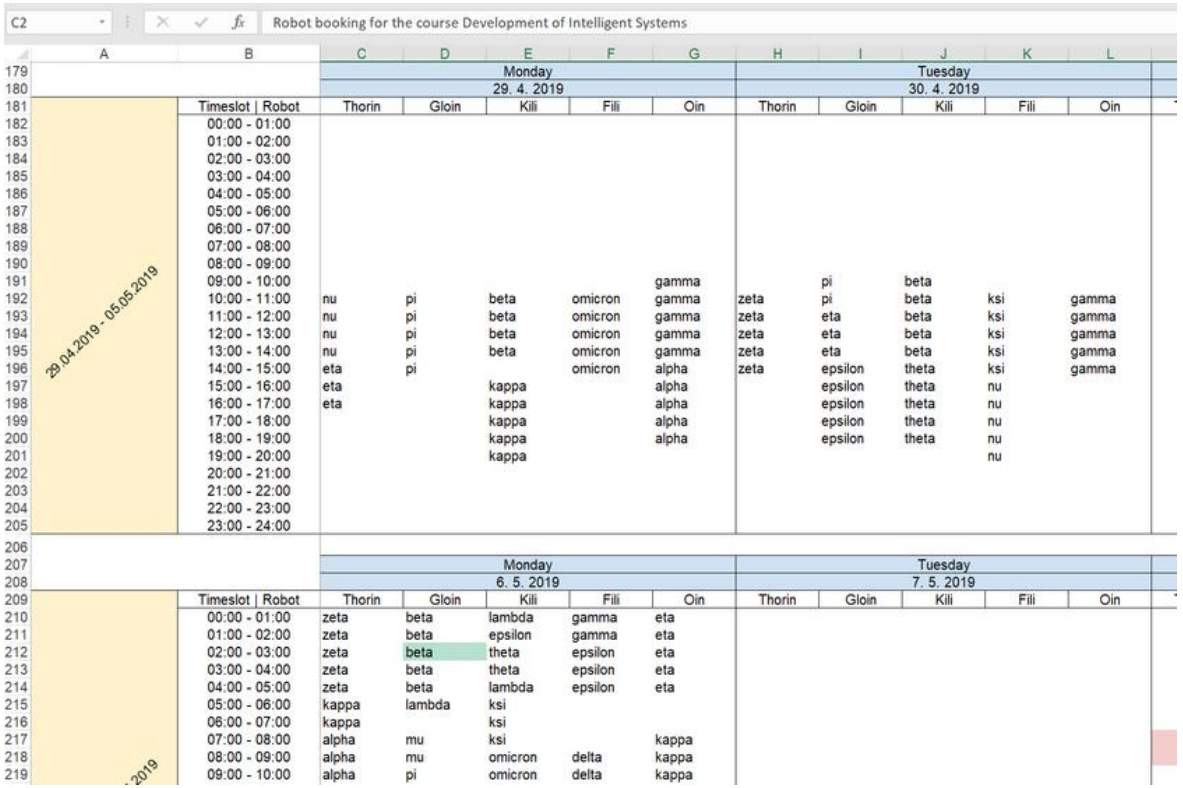
- Alternativelly, 6 students (two teams) can take more research-oriented path
  - Complete tasks T1s and T1r
  - Instead of working on Task T2 in simulator, work on specific tasks on a real robot
- Examles of tasks:
  - Visual SLAM
  - Image-based localisation
  - Working with other robots
  - Integration of LLMs on the robot
  - TBD
- If more than two teams will be interested, the teams with a higher score on the task T1s will be allowed to take this path
- Presentation of the robot at the end of the semester

Lectures

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

Continuous integration

- It is essential to work during the entire semester
- Homeworks
- 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

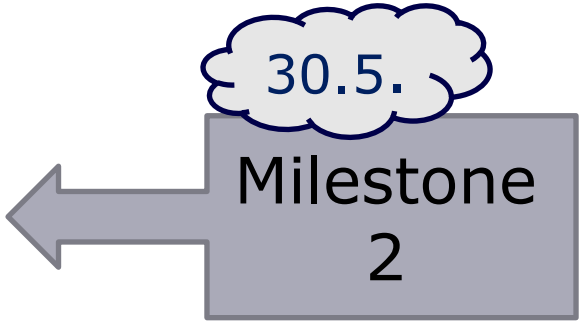
		Monday 29. 4. 2019					Tuesday 30. 4. 2019				
29.04.2019 - 05.05.2019	Timeslot | Robot	Thorin	Gloin	Kili	Fili	Oin	Thorin	Gloin	Kili	Fili	Oin
	00:00 - 01:00										
	01:00 - 02:00										
	02:00 - 03:00										
	03:00 - 04:00										
	04:00 - 05:00										
	05:00 - 06:00										
	06:00 - 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:
  - Task T1s: Autonomous navigation and human search
    - Autonomous navigation around the competition area
    - Find and approach the faces
    - In simulation

- Milestone 2:
  - Task T1r:
    - On a real robot
  - Task T2: RoboBirder
    - Find and categorise birds
    - Computer vision, machine learning
    - Dialogue, mobile manipulation
    - Belief maintenance, reasoning, planning



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:
  - 15 points: T1s in simulator (system operation)
  - 15 points: T1r on real robot (system operation)
  - 35 points: T2 in simulator (concepts used, system operation, system performance)
  - 5 points: Homeworks (implementation)
  - 10 points: Final report (description of the methods used, experimental results, implementation, innovation)
  - 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 33 points (50%) for task completions
  - 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 (presentations of T1s, T1r, T2).
- 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