Development of intelligent systems (RInS)

Introductory information

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Academic year: 2025/26

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 Wednesdays 14:15 – 17:00 (in P22)
- Tutorials, 4 groups, in R2.38:
  - Mondays 11:15 - 13:00
  - Tuesdays 11:15 - 13:00
  - Tuesdays 14:15 - 16:00
  - Wednesdays 9:15 – 11:00
- 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: Thursdays, 14:00-15:00 (or at other times, send an email)

ViCoS
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ystemslab

Teching assistants

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

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

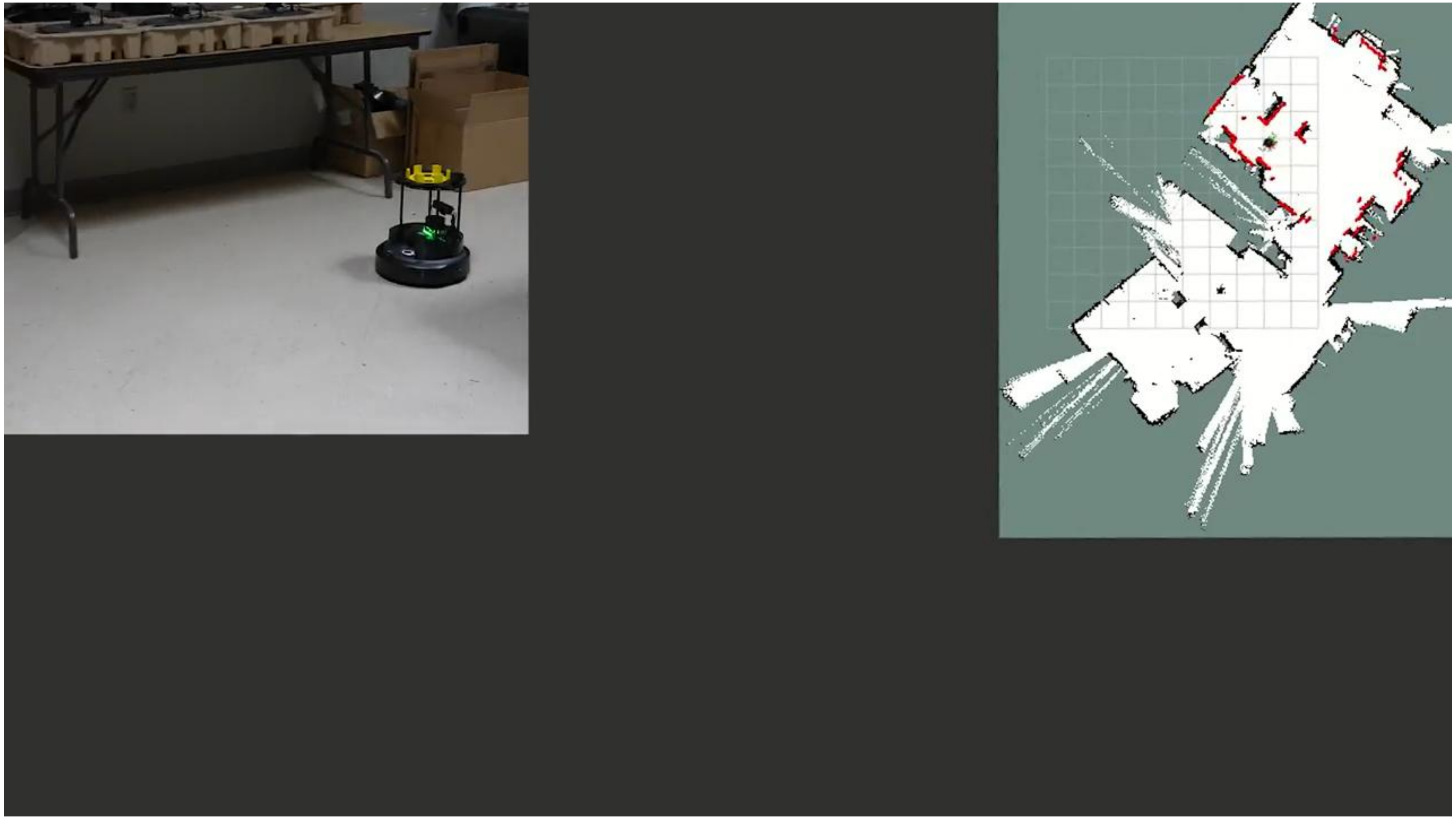
- Robot platform: Clearpath Robotics TurtleBot 4 Standard
- Software platform: ROS 2, Robot Operating System

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	Gemini 335L
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

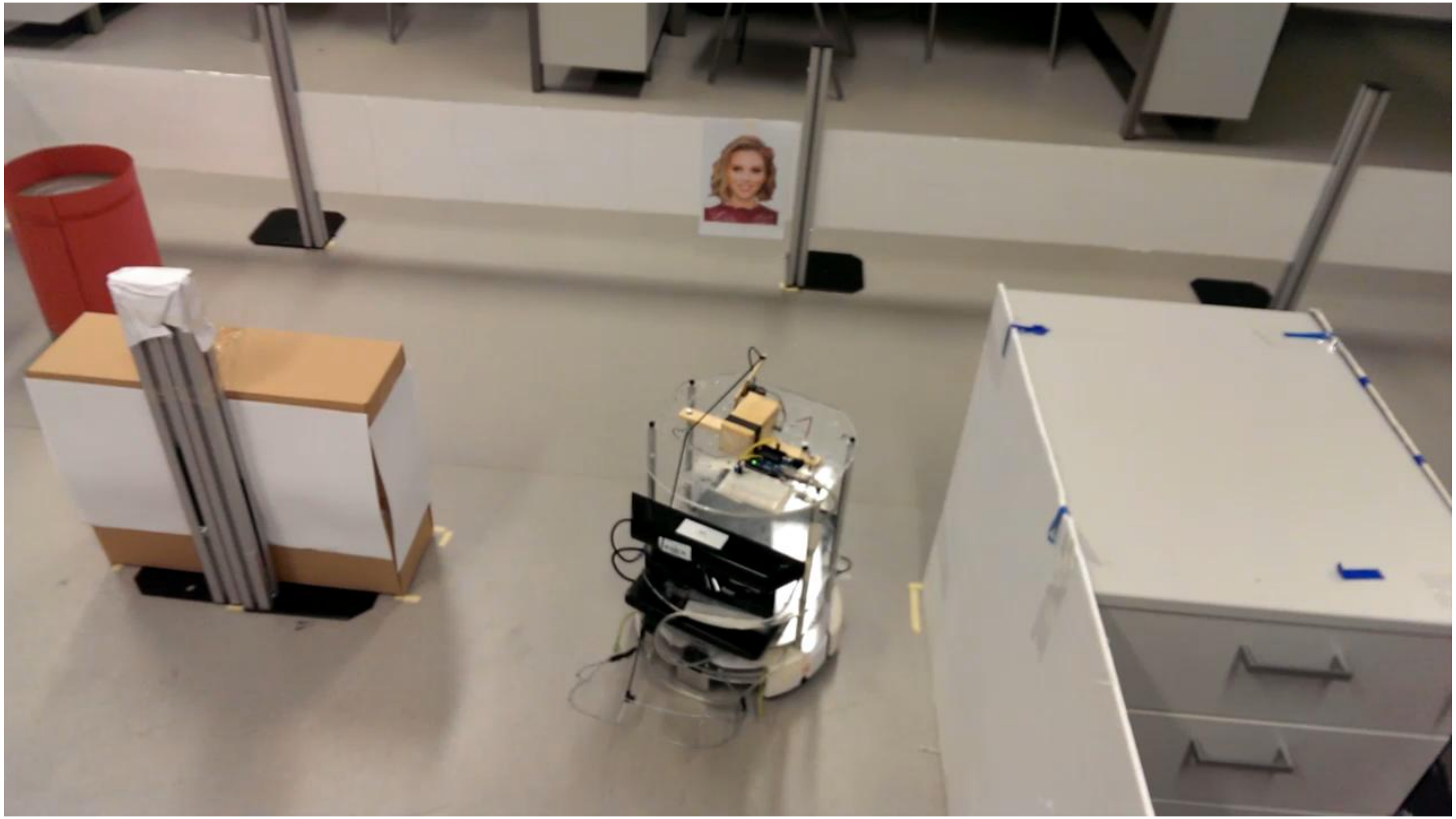
- Object search

RInS 2014

- Mini Cluedo

RInS 2015

- DeliveryBot



RInS 2016

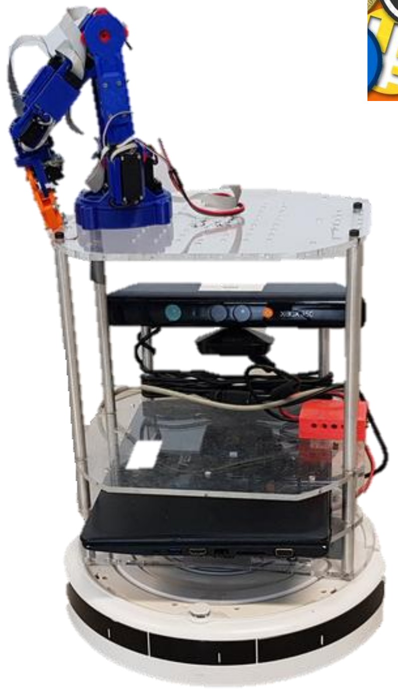
- TaxiBot

RInS 2017

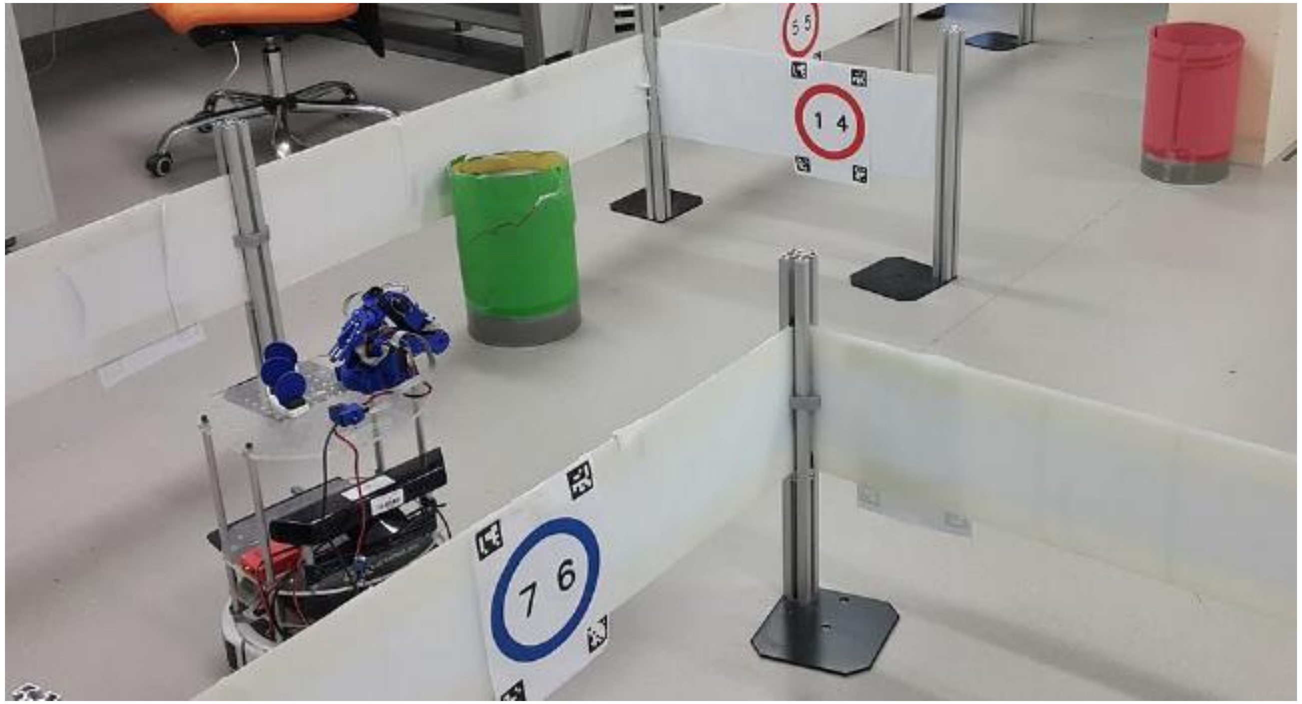
- Robot of the rings

RInS 2018

- CryptoBot

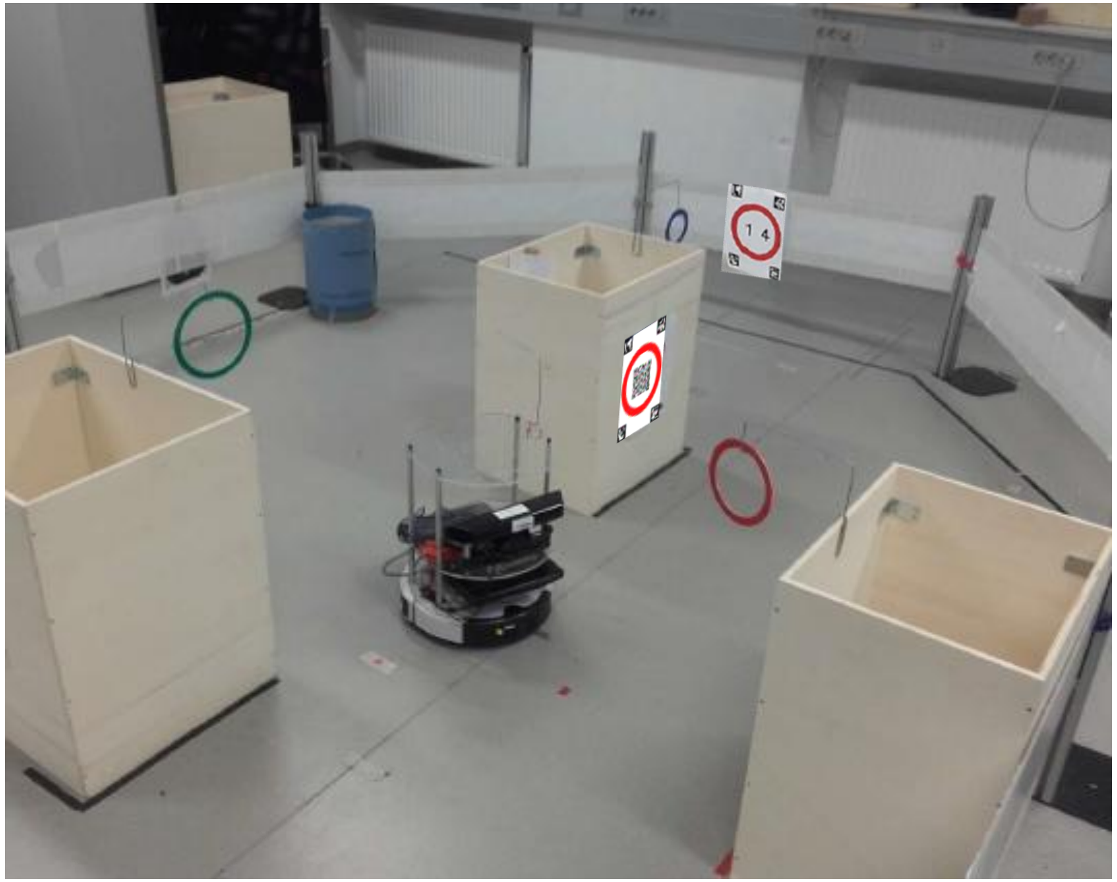


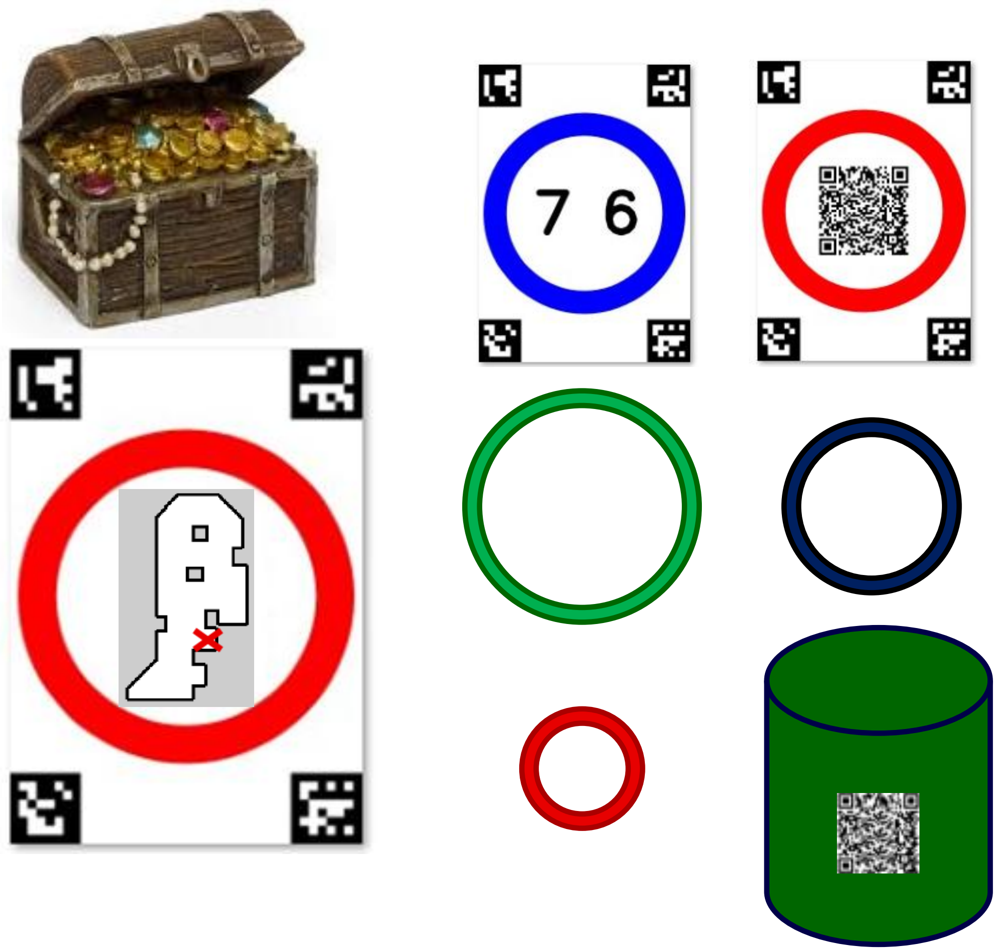
CryptoBot



- TreasureHunt

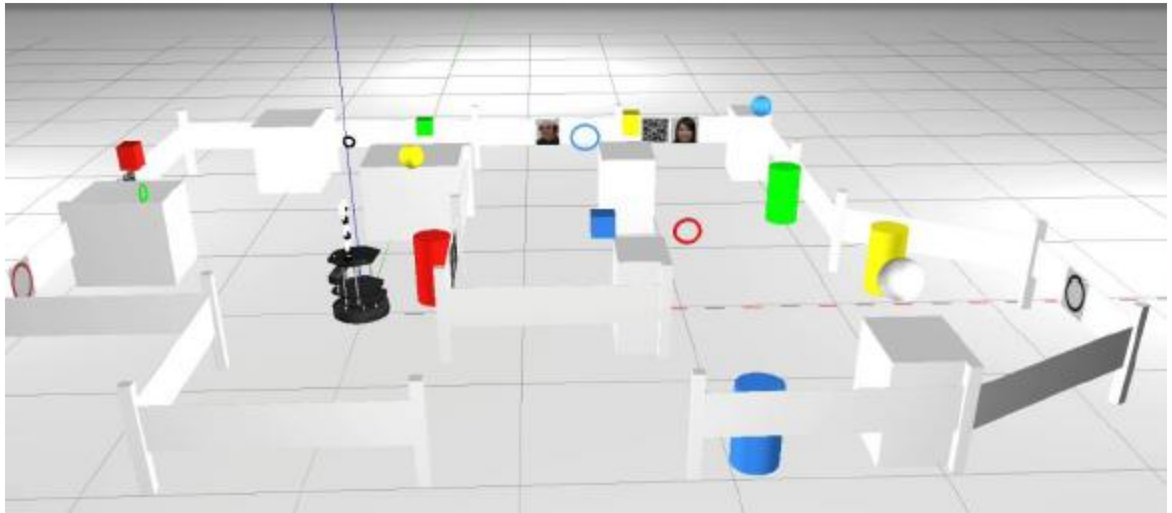
TreasureHunt



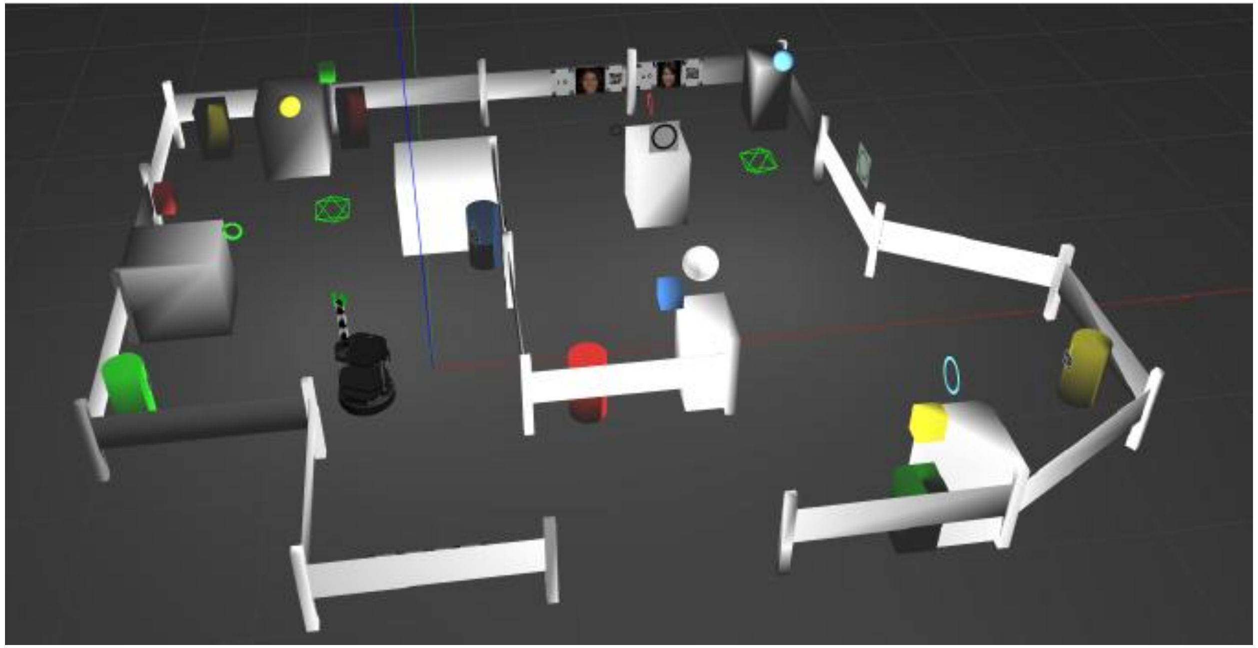


RInS 2020

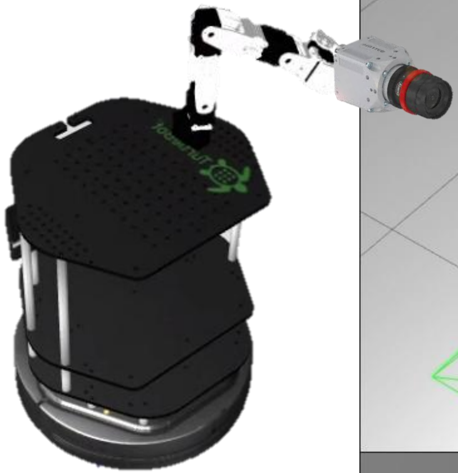
Matchmaker

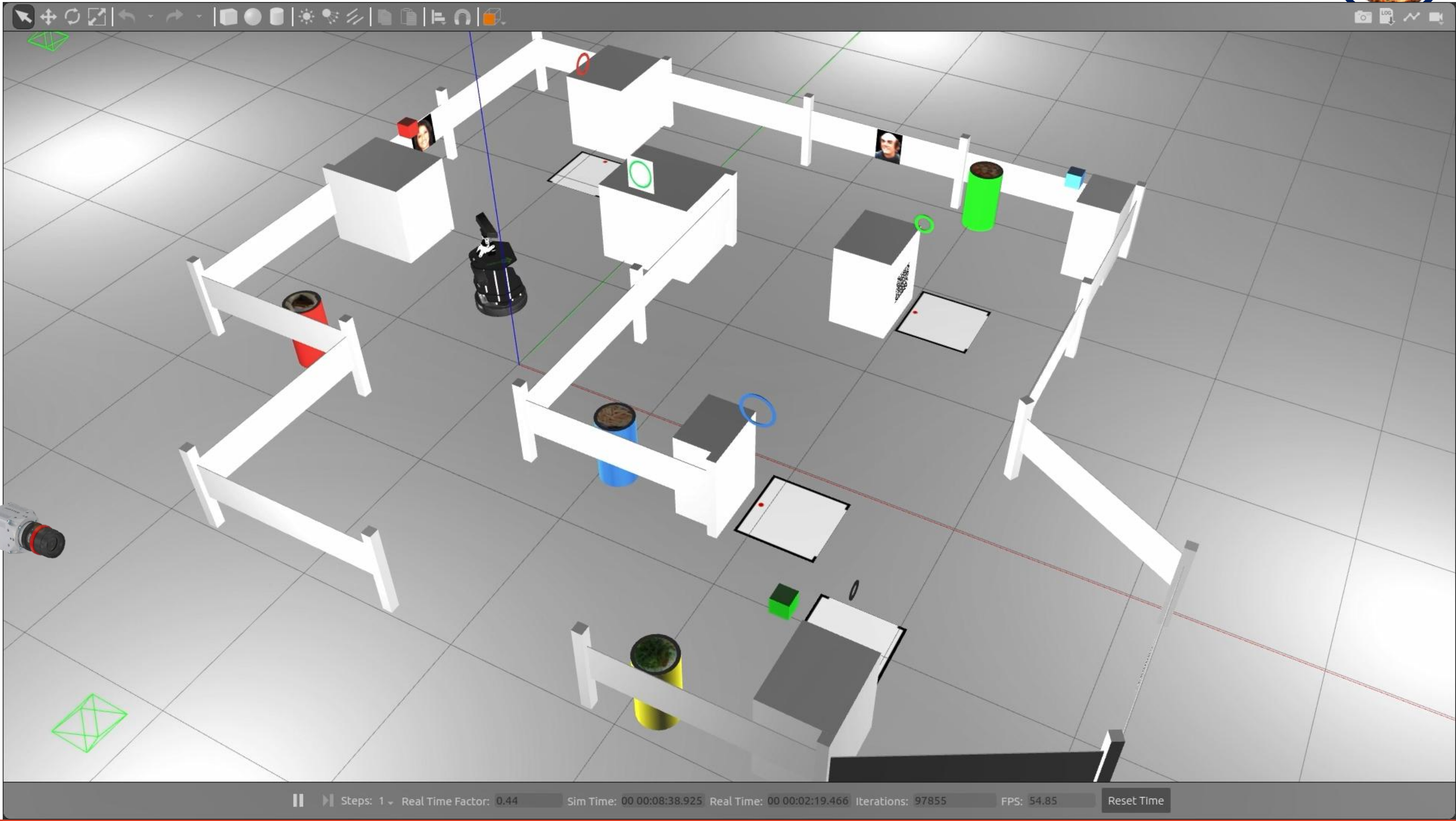


STOPCORONA

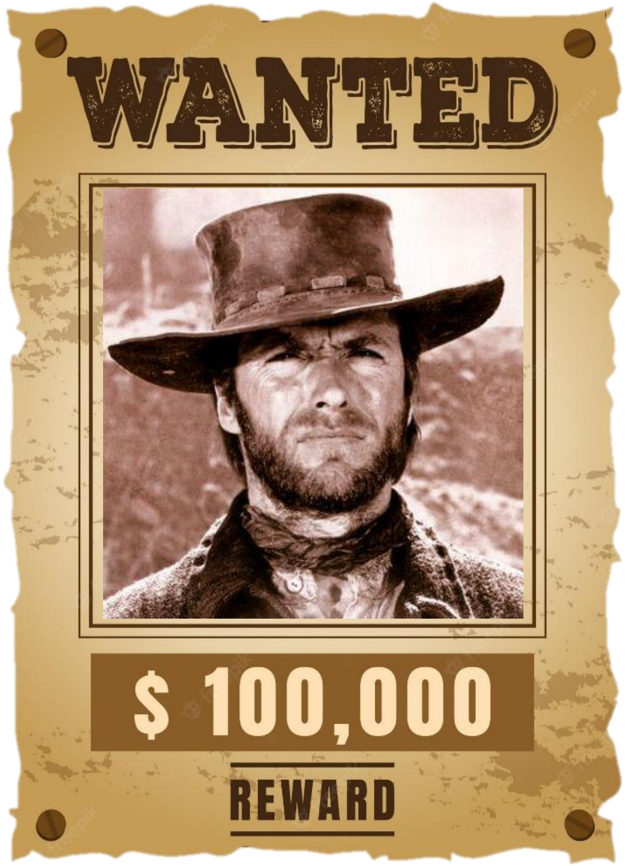


FooDeRo

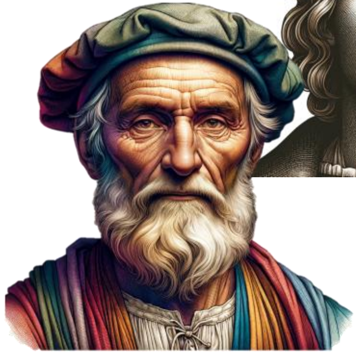


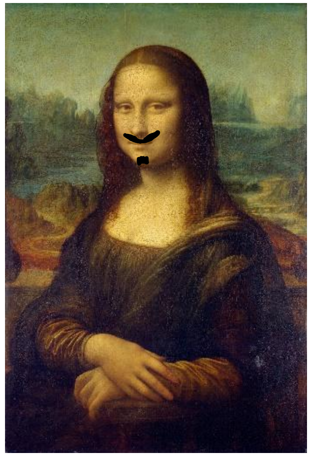

Steps: 1
Real Time Factor: 0.44
Sim Time: 00 00:08:38.925
Real Time: 00 00:02:19.466
Iterations: 97855
FPS: 54.85
Reset Time

RoboScheriff

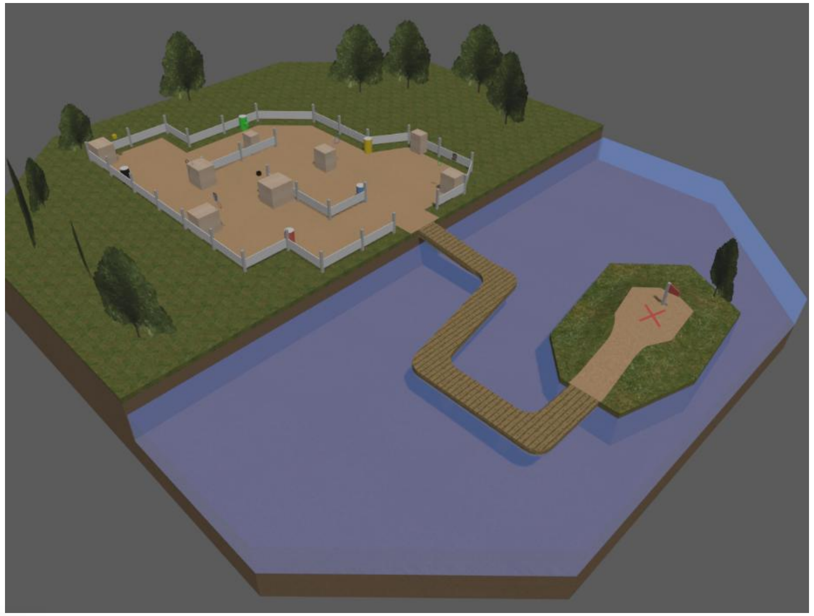


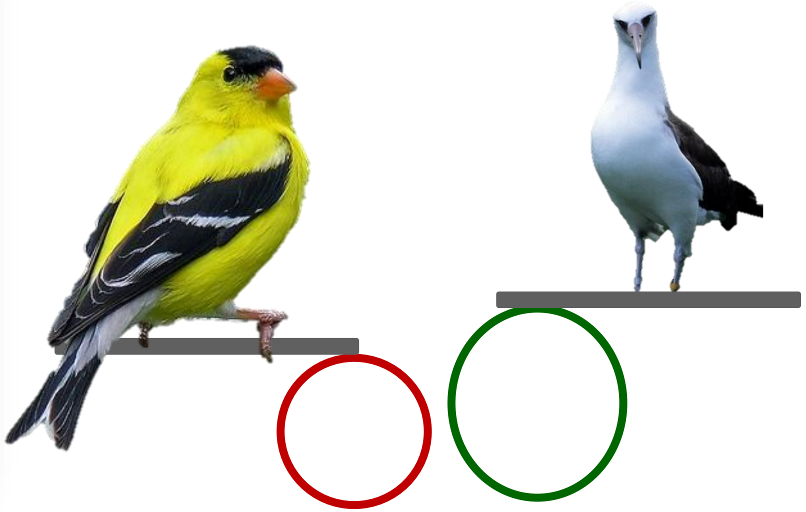
Robo da Vinci





RoboBirder





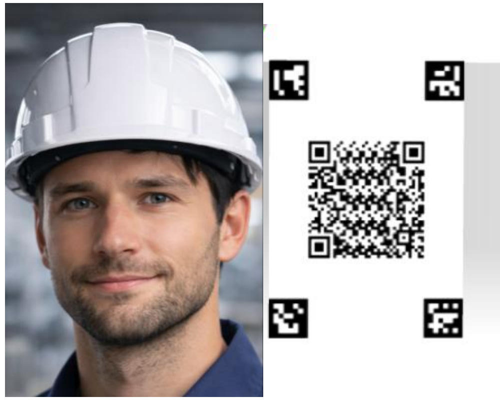

INDUSTRY 5.0

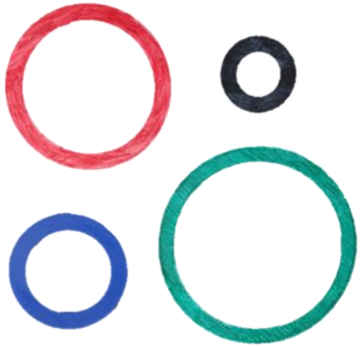
2026 Final task

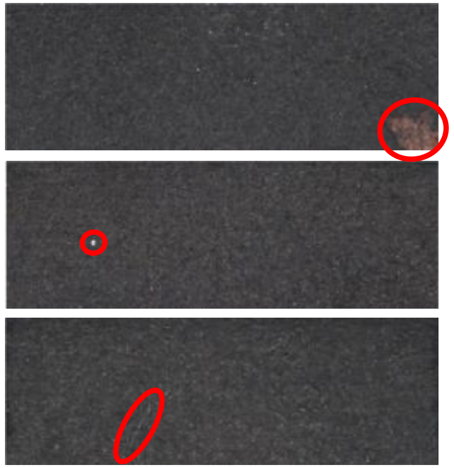
- Setup:
  - „A factory plant“ scene. Paths, working cells, conveyor belts, obstacles.
  - Several working cells, containing objects to be inspected or manipulated.
  - Several workers, CTO.
- Goal:
  - Help human workers by executing visual inspection and simple transport tasks, while navigating safely and communicating clearly.
- Task:
  - Navigate safely through the factory while staying on permitted paths.
  - Detect and approach workers to receive task instructions.
  - Identify and localise the requested working cells.
  - Capture a high-resolution image of the working cell and its objects.
  - Execute the prescribed task (e.g., defect detection, counting, …).
  - Transfer specified objects between locations as required.
  - Generate a report of actions and results and present it to the CTO.

2026 Final task

2026 Final task

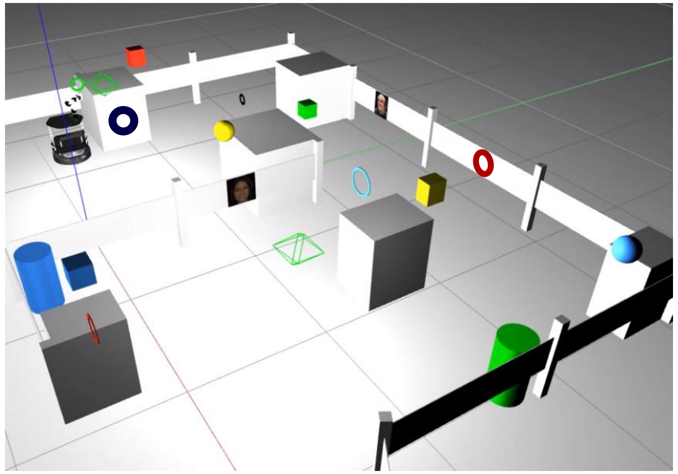


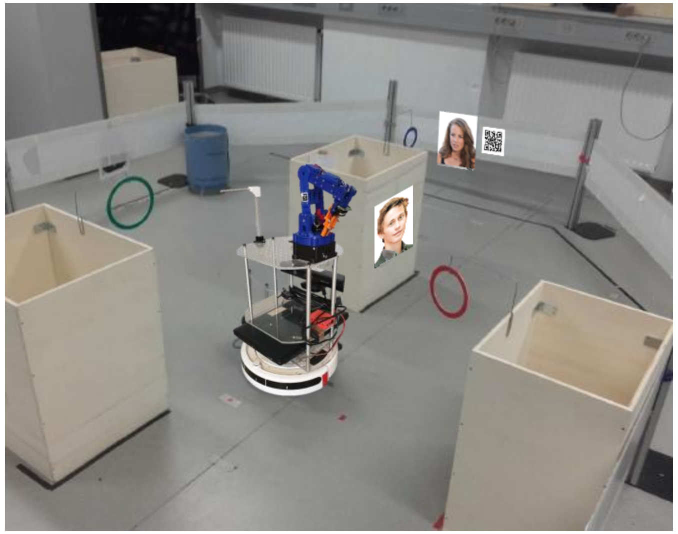




Intermediate tasks

- Task T1: Autonomous navigation and human search
  - The robot should autonomously navigate within the competition area.
  - It should search and detect faces.
  - It should approach each detected face.
  - It should greet each approached face.
  - It should detect 3D rings.
  - It should recognise the colours of the rings.
  - It should announce the recognised colour of each ring.





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

Practical implementation

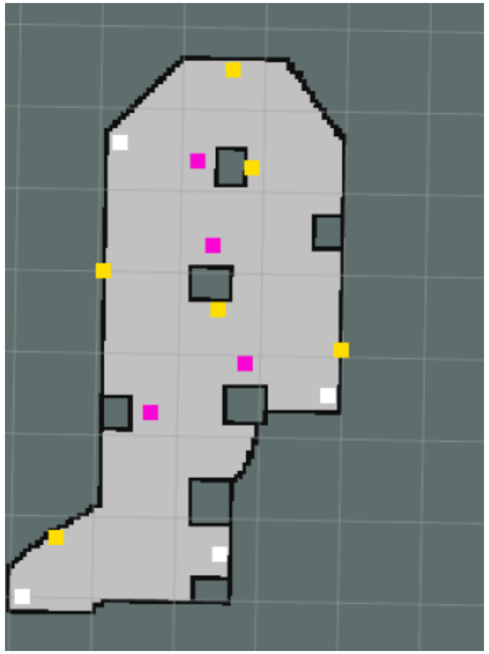
- Five robots are available
- Teams of three students
- Each team
  - there is at least one good Python/C++ programmer
  - there is at least one member who can work with Linux and robots/hardware
  - there is at least one member good in computer vision and machine learning
  - all the members are equivalent – 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
    - (Windows, MacOS)
- 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, cylinders, and objects
  - Recognition of faces and ring colours
  - Segmentation of the ground
  - Object detection and counting, defect detection
  - Speech synthesis, speech recognition, dialogue processing (reading QR codes)
  - Belief maintenance, reasoning, planning

Autonomous navigation

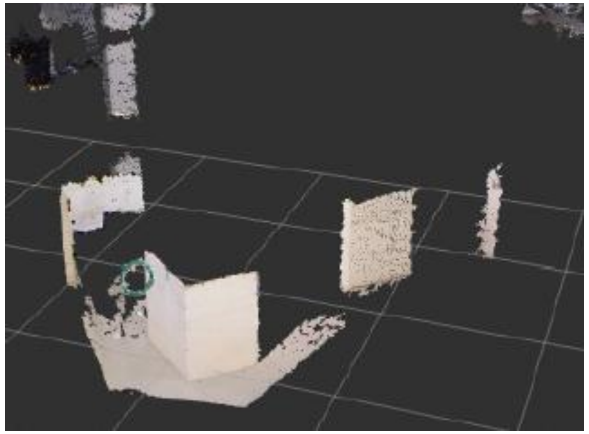
- Autonomous control of the mobile platform
  - components for controlling the robot
- Acquiring images and 3D information
  - using Gemini 355L
  - OpenCV for processing images
  - Point Cloud Library for processing 3D information
- Simultaneous mapping and localization (SLAM)
  - building the map of 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 and counting of objects
- Defect detection
- Segmentation of the ground
  - determining traversable area
- Colour learning and recognition
  - rings
- (QR code reading)

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

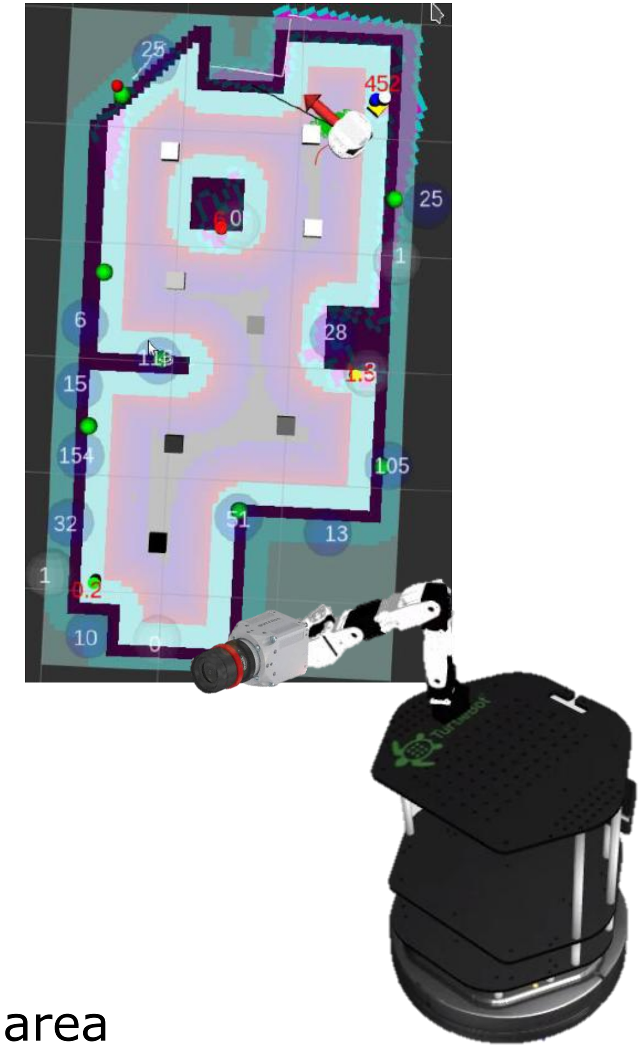


Advanced perception and cognition

- 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?

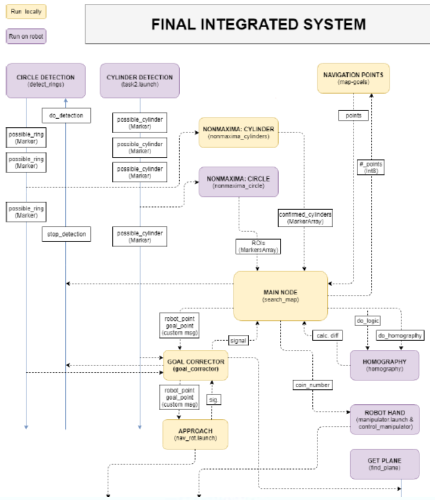
- Intelligent navigation
  - considering the map
  - optimize the exploration of space
  - optimize the distance travelled needed
  - Where to go next?

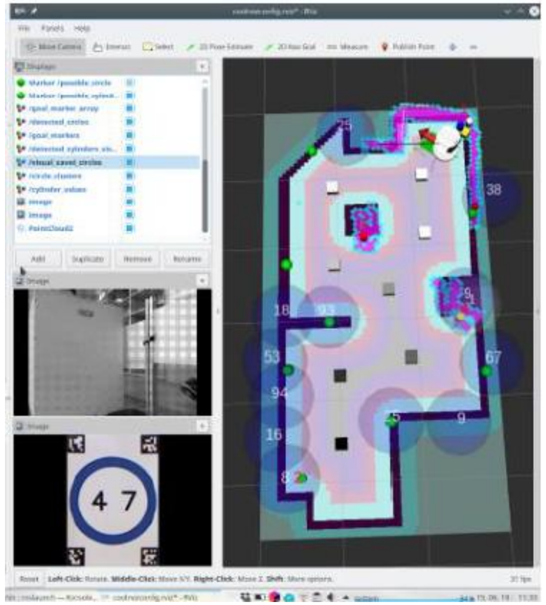
- Visual servoing
  - move the mobile camera to optimise perception
  - visual servoing to keep the robot inside the traversable area
  - Approach to specific points in the scene precisely



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





Competencies to be developed

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  - Running ROS
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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
  - Autonomous control of the mobile platform
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Mobile robotics

Computer vision, ML

Dialogue processing, AI

Requirements

- System setup
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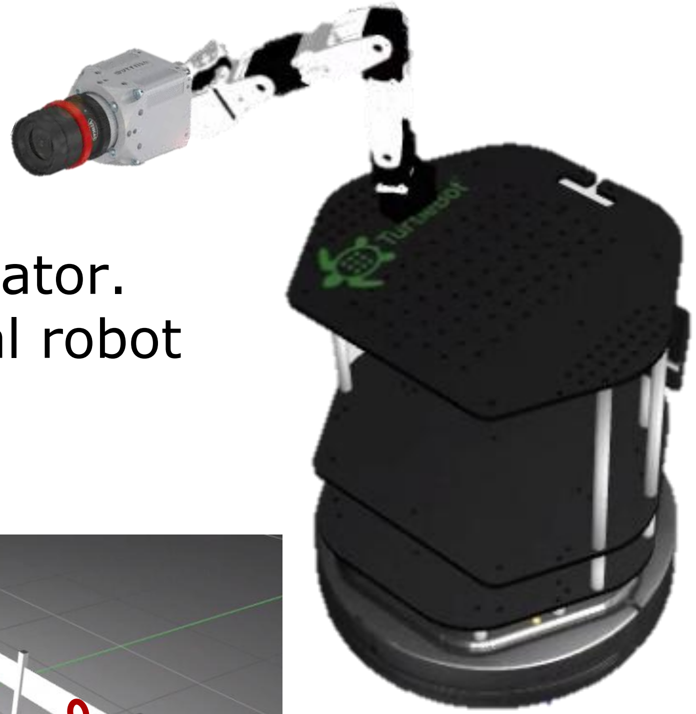
For 6

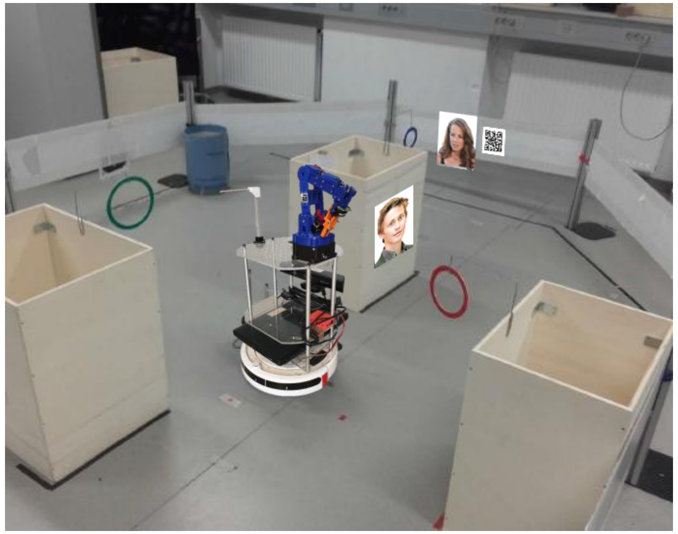
For + max. 2

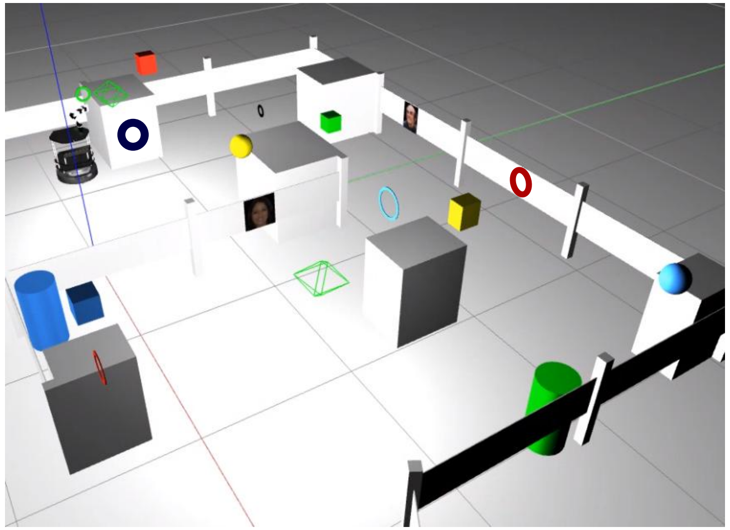
For + max. 2

Real-world robot vs. simulation

Task 2 has to be implemented only in simulator.
Task 1 has also to be implemented on a real robot (Task1r).







Tasks

- System setup
  - Running ROS
  - Tele-operating TurtleBot
- Autonomous navigation
  - Autonomous control of the mobile platform
  - Acquiring images and 3D information
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Task 1

Task 2

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
  - object detection and counting, defect detection
  - robot manipulation
  - artificial cognitive systems

Continuous integration

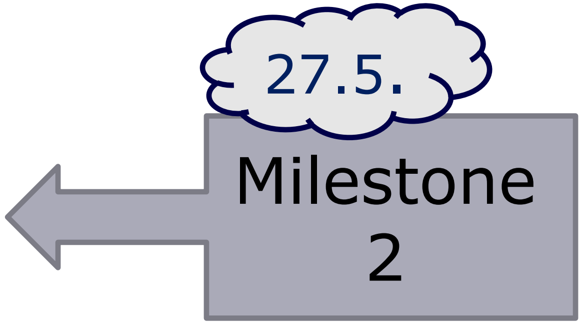
- It is essential to work during the entire semester
- Homeworks
- Time during the official classes does not suffice
- Book the robot and work at other times in RoboRoom R2.38

C2 | fx | Robot booking for the course Development of Intelligent Systems

	A	B	C	D	E	F	G	H	I	J	K	L
179			Monday					Tuesday				
180			29. 4. 2019					30. 4. 2019				
181		Timeslot | Robot	Thorin	Gloin	Kili	Fili	Oin	Thorin	Gloin	Kili	Fili	Oin
182		00:00 - 01:00										
183		01:00 - 02:00										
184		02:00 - 03:00										
185		03:00 - 04:00										
186		04:00 - 05:00										
187		05:00 - 06:00										
188		06:00 - 07:00										
189		07:00 - 08:00										
190		08:00 - 09:00										
191		09:00 - 10:00					gamma		pi	beta		
192		10:00 - 11:00	nu	pi	beta	omicron	gamma	zeta	pi	beta	ksi	gamma
193	29.04.2019 - 05.05.2019	11:00 - 12:00	nu	pi	beta	omicron	gamma	zeta	eta	beta	ksi	gamma
194		12:00 - 13:00	nu	pi	beta	omicron	gamma	zeta	eta	beta	ksi	gamma
195		13:00 - 14:00	nu	pi	beta	omicron	gamma	zeta	eta	beta	ksi	gamma
196		14:00 - 15:00	eta	pi		omicron	alpha	zeta	epsilon	theta	ksi	gamma
197		15:00 - 16:00	eta		kappa		alpha		epsilon	theta	nu	
198		16:00 - 17:00	eta		kappa		alpha		epsilon	theta	nu	
199		17:00 - 18:00			kappa		alpha		epsilon	theta	nu	
200		18:00 - 19:00			kappa		alpha		epsilon	theta	nu	
201		19:00 - 20:00			kappa						nu	
202		20:00 - 21:00										
203		21:00 - 22:00										
204		22:00 - 23:00										
205		23:00 - 24:00										
206												
207			Monday					Tuesday				
208			6. 5. 2019					7. 5. 2019				
209		Timeslot | Robot	Thorin	Gloin	Kili	Fili	Oin	Thorin	Gloin	Kili	Fili	Oin
210		00:00 - 01:00	zeta	beta	lambda	gamma	eta					
211		01:00 - 02:00	zeta	beta	epsilon	gamma	eta					
212		02:00 - 03:00	zeta	beta	theta	epsilon	eta					
213		03:00 - 04:00	zeta	beta	theta	epsilon	eta					
214		04:00 - 05:00	zeta	beta	lambda	epsilon	eta					
215		05:00 - 06:00	kappa	lambda	ksi							
216		06:00 - 07:00	kappa		ksi							
217		07:00 - 08:00	alpha	mu	ksi		kappa					
218		08:00 - 09:00	alpha	mu	omicron	delta	kappa					
219	2019	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
    - Find the rings and recognise their colour
    - In simulation
- Milestone 2:
  - Task T1r:
    - On a real robot
  - Task T2: Industry 5.0
    - Collaborate with humans in manifacturing tasks
    - Computer vision, machine learning
    - Dialogue, mobile manipulation
    - Belief maintenance, reasoning, planning
    - In simluation



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.

Conclusion

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