Development of intelligent systems (RInS)

Task 2: Industry 5.0

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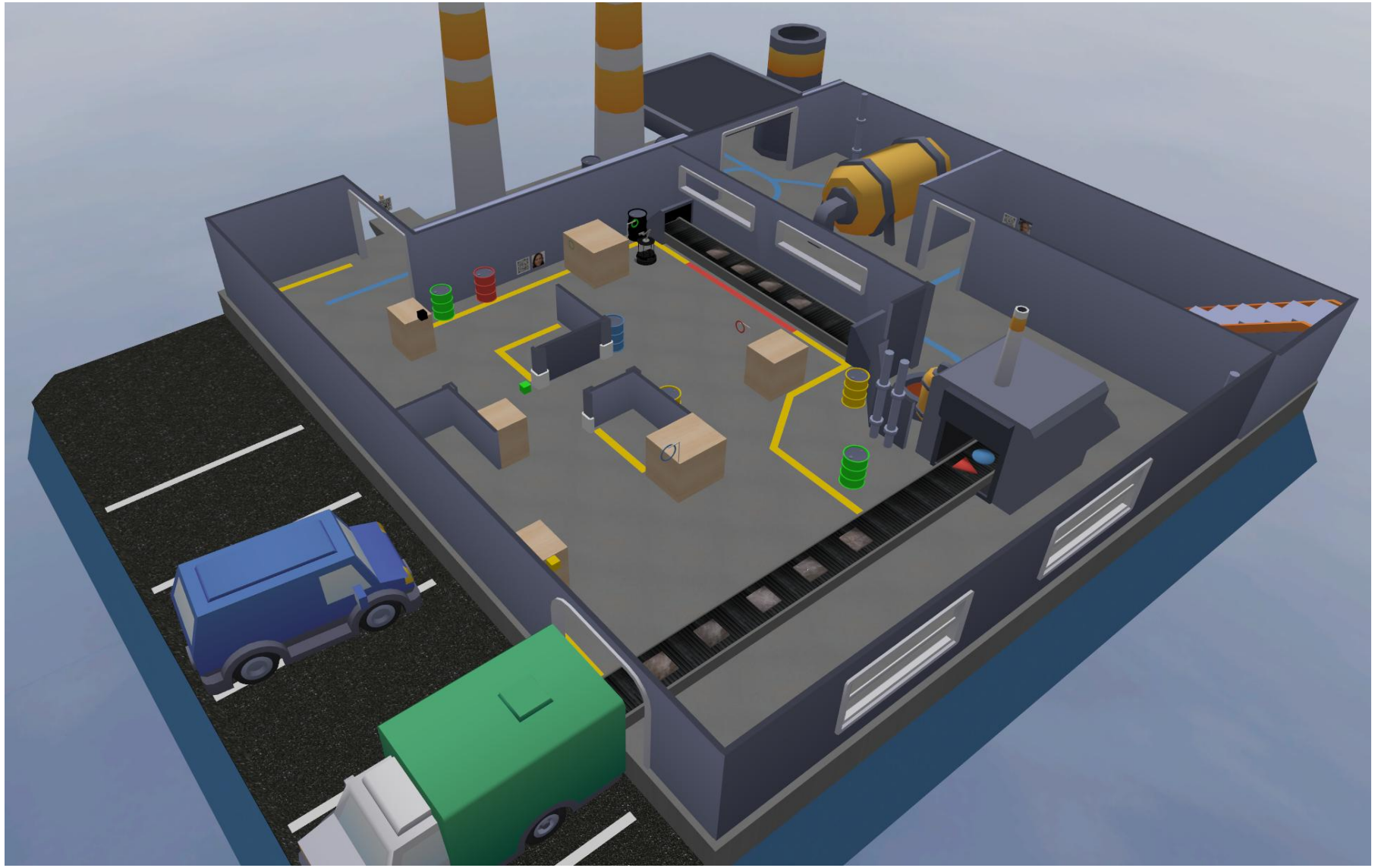
INDUSTRY 5.0

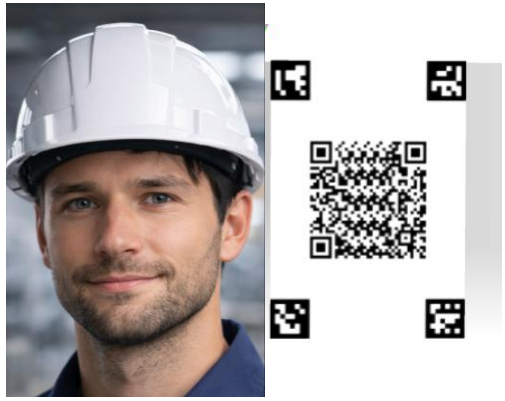
2026 Final task – Industry 5.0

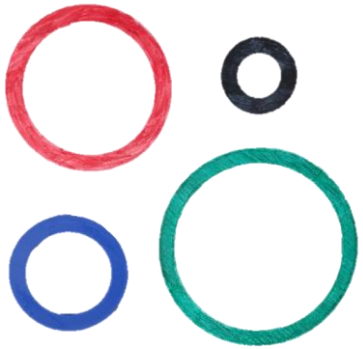
- Setup:
  - „A factory plant" scene. Paths, working cells, conveyor belts, obstacles.
  - Several working cells, containing objects to be inspected, barrels, rings.
  - Several workers, CTO.
- Goal:
  - Help human workers by executing visual inspection and counting tasks, while navigating safely and 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 cell.
  - Capture high-resolution images of the working cell and its objects.
  - Execute the prescribed tasks (defect detection, counting, inspection).
  - Generate an inspection report and present it to the CTO.

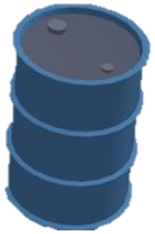
Simulated scene



Elements in the scene







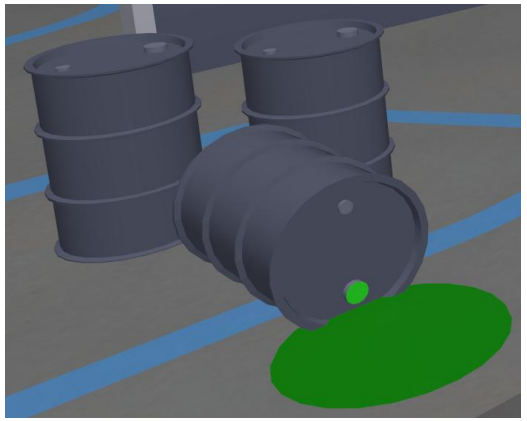
Navigation

- Explore the factory plant
  - Avoid all obstacles
- In the first room
  - Use standard (goal-based) navigation
    - by using a predetermined path or
    - preferably implement the autonomous exploration of space
  - Do not cross the yellow lines
  - You can use the range sensor
  - You can set the goal at the exit from this room
- In the second room
  - Follow the blue lines
  - Use visual survailence
  - Use the second camera pointed downwards to see what is there
  - Find CTO at the end of the blue line

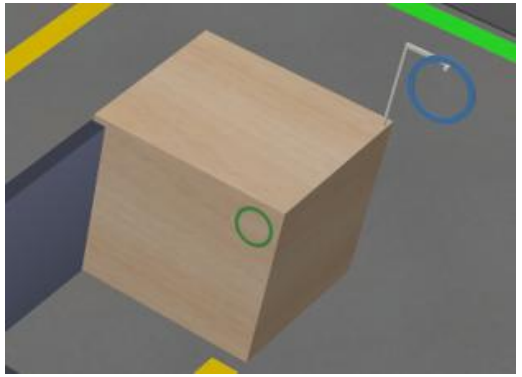
Perception

- Line detection
  - To detect forbidden zones
  - For line following
  - To determine the correct working cell

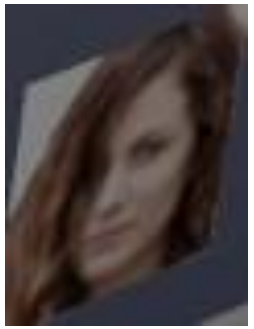
- Inspect the barrels
  - Locate all barrels (in the first room only)
  - Recognise barrel colour
  - Determine orientation (horisontal or vertical)
  - Check whether the horisontal barrel is leaking
  - Approach horisontal barrels and issue a warning if a spill is detected



- Count the rings
  - Detect all (3D) rings (discard 2D printed circles)
  - Recognise ring colour



- Find all persons
  - Recognise the person‘s name and gender
  - Approach and engage in dialogue



- The number of any element present is not known in advance
- Colours: red, green, blue, yellow, purple, orange, brown.
- Anomaly detection

Perception and dialogue

- Engage in a dialogue with people to determine which task to perform.
  - Approach a person
  - Recognise the person‘s name
    - The photos and names of all persons will be given in advance
  - Recognise the person‘s gender
  - Ask the person what task to perform
    - Barrels inspection (in the first room only)
    - Count the rings (in the first room only)
    - Anomaly detection in red|green working cell
    - Nothing
  - Men always tell the task directly
  - Women might reconsider their choice
    - The robot has to ask them twice or more
    - When the same task is named twice, this is the task you are looking for
    - The person can also confirm the selected task with „yes.“

Sample dialogues

- R: „Hi man, which task should I perform?“
- M1: „Detect anomalies in the green cell.“
- R: „OK. I will detect anomalies in the green cell.“

- R: „Hi man, which task should I perform?“
- M2: „Inspect the barrels.“
- R: „OK. I will inspect the barrels.“
- R: „Alert! Alert! This barrel is leaking!“

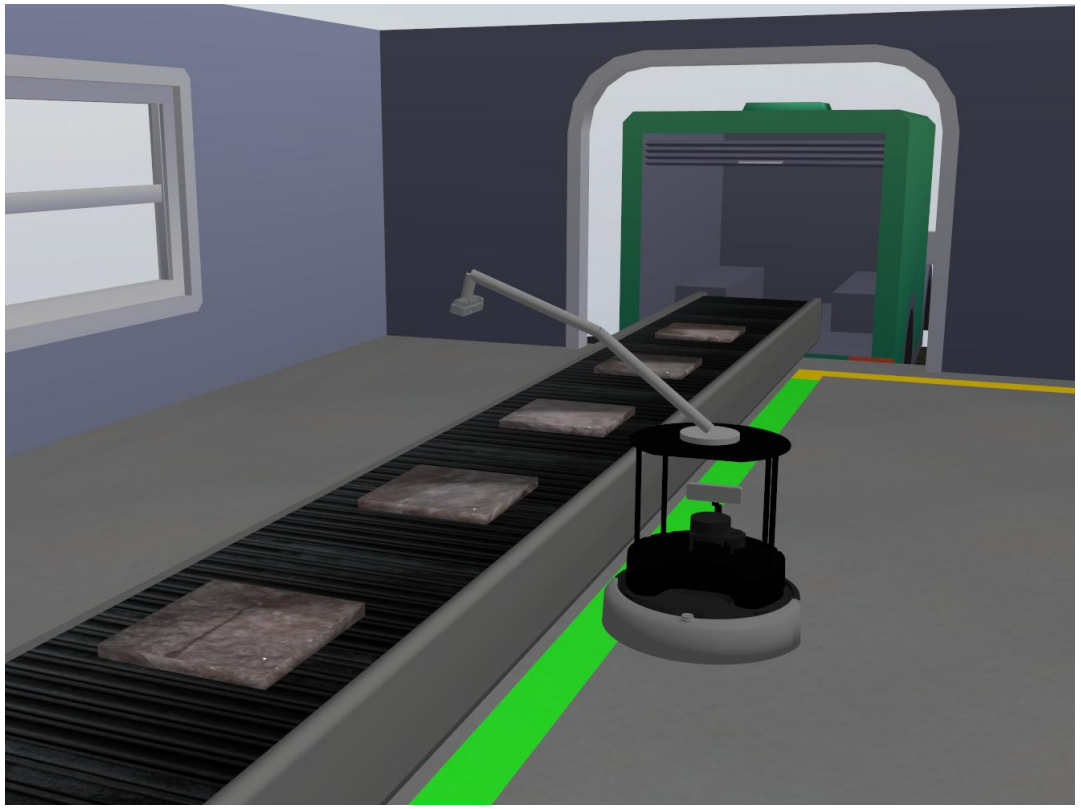
- R: „Hi woman, which task should I perform?“
- W1: „Count the rings.“
- R: „Are you sure?“
- W1: „Well, maybe you should inspect the barrels?“
- R: „OK, the barrels then. Are you sure?“
- W1: „Ah, not really. The count the rings.“
- R: „OK. I will count the rings.“

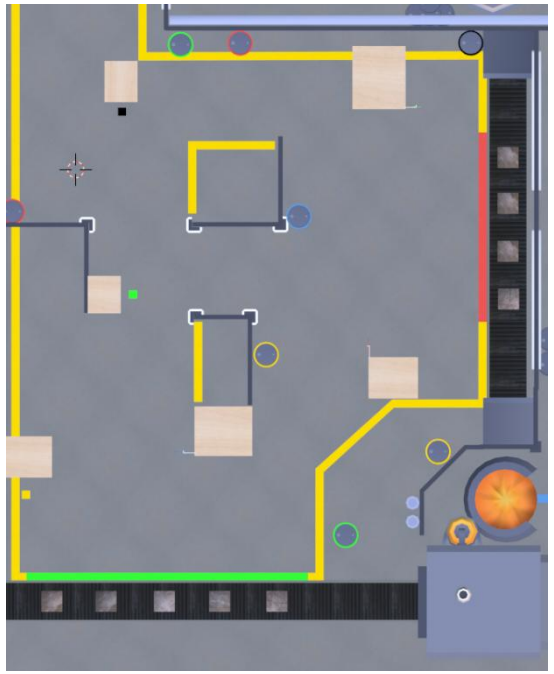
- R: „Hi woman, which task should I perform?“
- W2: „Detect anomalies in the red cell.“
- R: „Are you sure?“
- W2: „Yes, I‘m sure.“
- R: „OK. I will inspect anomalies in the red cell.“

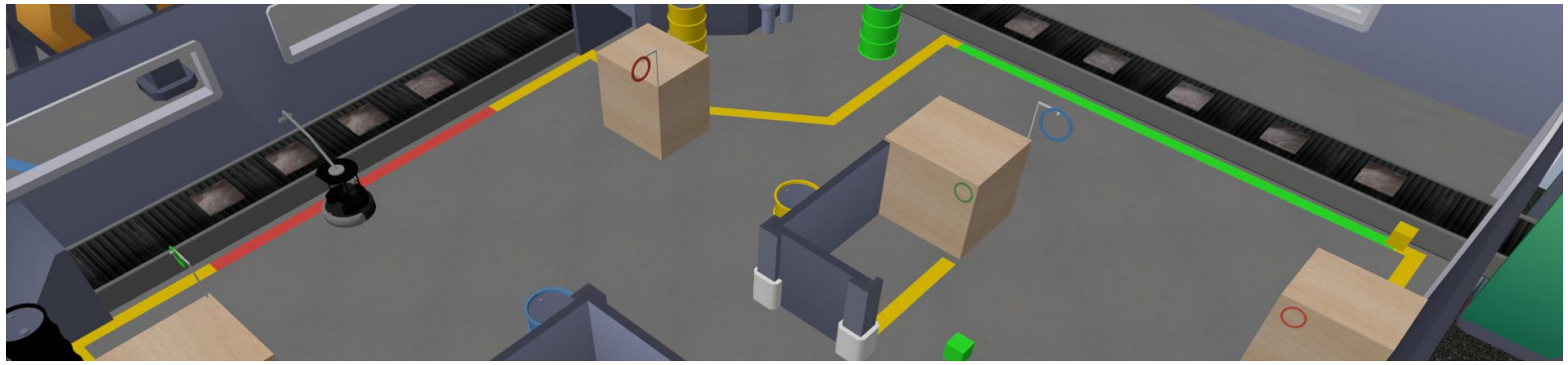
- R: „Hi woman, which task should I perform?“
- W3: „Inspect anomalies in the red cell.“
- R: „Are you sure?“
- W3: „Well, inspect anomalies in the green cell instead.“
- R: „OK, the green cell then. Are you sure?“
- W3: „Ah, not really. Just count the rings.“.
- R: „Are you sure now?“
- W3: „Yes.“
- R: „OK. I will count the rings.“

Anomaly detection

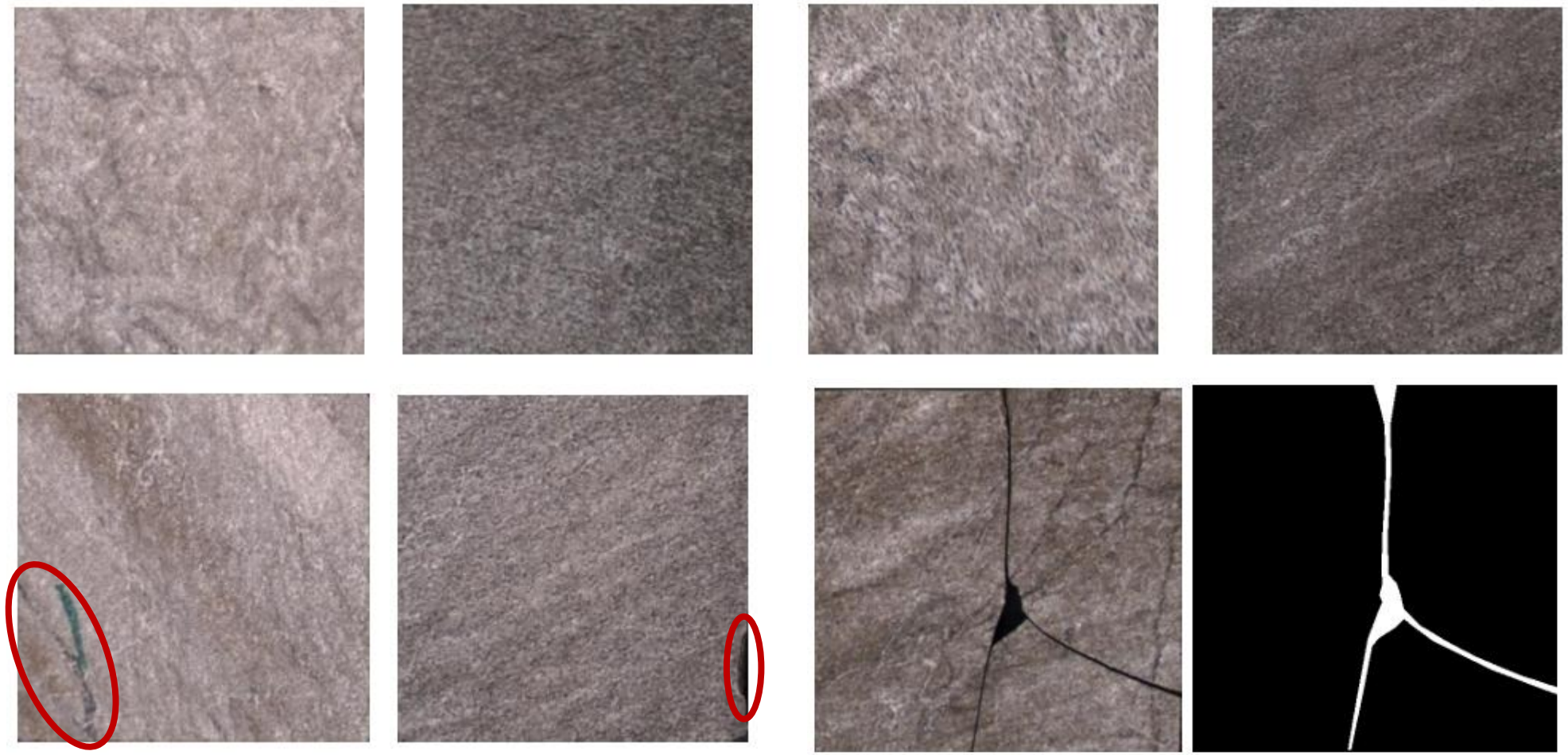
- Locate the correct working cell
  - Red or green
- Extend the camera above the objects
- Move along the working cell
- Take images of all objects (tiles)
- Detect anomalies (defects)







Anomaly detection



Anomaly detection

- Create/train a surface anomaly detector
  - Based on PCA, AE, VAE, normalising flow,difusion models, discriminative, reconstructive methods, etc.
  - Supervised or unsupervised learning
  - Training a couple of test images will be given in advance
  - Train an anomaly detection model
  - Two levels of difficulty:
    - Severe degradations (cracks, etc.)
    - Mild degradations (more difficult to detect)
  - Take a number of training images and augment them
    - In Gazebo, in simulation, as you want
    - Taken from the frontal view or from side views as well
    - Vary the illumination conditions etc.
  - Use or design a method for anomaly detection
  - Train the model
- Evaluate the anomaly detection model
  - Create also test images
  - Evaluate the model under different environments
- The robot shuld detect and segment the anomaly
- Can be done (almost) completely outside ROS and Gazebo

Inspection report in pdf file

Inspection report

Date: 22.4.2026

Robot: R2D2

Task: Ring Counting

Requested by: Tom

Results:

Total number of rings detected: 5

Detected colors:

Red: 2

Blue: 1

Green: 2

Task: Barrel inspection

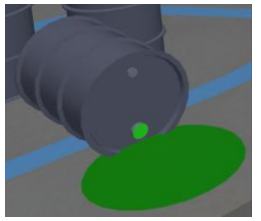
Requested by: Ana

Results:

Total number of barrels inspected: 3

Barrel ID	Colour	Orientation	Leak detected
1	Red	Vertical	No
2	Green	Horisontal	No
3	Blue	Horisontal	Yes

ID 3:



Task: Anomaly detection

Requested by: Janez

Results:

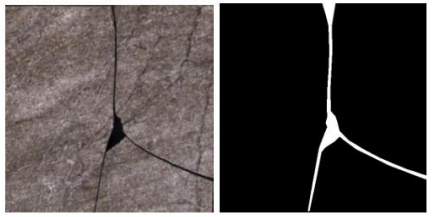
Total number of tiles inspected: 3

OK: 2

NOK: 1

Tile ID	Status
1	OK
2	OK
3	NOK

ID 3:



Shortcuts

- You may not implement all the functionalities (for a lower grade)
- You may not implement the autonomous exploration of space
  - And can use fixed goals instead
  - The first and the exit point in the first room can always be handcoded
- The robot can skip the dialogue with a person
  - And read the task requested in the QR code next to the person
- The robot does not need to classify the faces according to gender
  - You assume that all the persons answer the right answer right away
- The robot does not need to recognise persons
  - It just enumerates the persons
- The robot doe not need to avoid crossing yellow line
  - It can navigate cross the as well
- The robot does not need to follow the blue line
  - You can set a goal in front of the CTO in the second room
- The robot can skip one of the tasks
  - Either ring counting, barrel inspection or anomaly detection
- The robot can skip anomaly segmentation
  - It can report defects o the level of images only
- The robot does not need to create the inspection catalogue
  - It just reports the results during operation

Demonstration

- Demonstrate what is going on in the robot
- Visualize in RViz:
  - Locations of detected faces, rings, barrels, tiles
  - Recognised colours, faces
  - Navigation goals, path plans
  - Current sensor readings (images, Lidar)
  - Show live strem from both cameras
- Show the dialogue in a separate window
- Show the reasoning process
- Show also the current environment in Gazebo
- Information in the console does not suffice!
- Use also sound to demonstrate what is going on

R: „Hi woman, which task should I perform?“
W2: „Detect anomalies in the red cell.“
R: „Are you sure?“
W2: „Yes, I‘m sure.“
R: „OK. I will inspect anomalies in the red cell.“

Tasks

- 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 and 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 and cylinder colours
  - Line detection
  - Object detection and counting
  - Defect detection
  - Speech synthesis, speech recognition, dialogue processing (reading QR codes)
  - Belief maintenance, reasoning, planning

Task 1

Task 2

Evaluation protocol

- The evaluation course will be set up in advance
  - The main setup will not change
- The teams will be allowed to build the map in advance
  - The yellow lines will not be moved, they can be cosidered to alter the map
- The faces, rings, cylinders and tiles will be positioned on the day of the evaluation
  - The size and colours of the rings and cylinders are known in advance
- The robot has to operate completely autonomously
  - only the initial positioning is allowed
  - Also the exit from the first room can be hardcoded
  - (and the optional answering by typing the text)
- The robot starts at the starting position in th first room

- Every team will have allocated 15-20 minutes to show the performance of the robot
- Show the performance of your robot on the lab computer (not on a slow laptop)
- The evaluation will take place in the last week of the May

Tasks

- System setup
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For 6

For + max. 2

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Grading

- Must do:
  - Goal-based navigation (1 pt)
  - Face detection (2 pts)
  - Ring detection (2 pts)
  - Cylinder detection (2 pts)
  - Colour recognition (1 pt)
  - Approaching faces (1 pt)
  - Speech synthesis (1 pt)
- Should do:
  - Face recognition (1 pt)
  - Gender recognition (1 pt)
  - Auton. space exploration (1 pt)
  - Not crossing yellow line (2 pts)
  - Follow blue line (2 pts)
  - Correct cell detection (1 pt)
  - Tile detection (1 pt)
  - Defect detection (3 pt)
  - Dialogue with ASR (2 pts)
  - Creating the inspection report (1 pt)

- Performance evaluation
  - Navigation (1 pt)
  - Reasoning (1 pt)
  - Visualisation (1 pt)
  - Robustness (2 pts)
  - Relative speed (2 pts)
  - Overall impression (3 pts)

- Points:
  - Must do: 10
  - Should do: 15
  - Performance: 10
  - Total: 35

Task 2 goals

- The main goals of the third task and evaluation are:
  - to navigate the robot around
  - to detect faces in 2D
  - to detect and count objects (rings and cylinders) in 3D
  - to learn and recognize colours
  - to classify faces according to gender
  - to recognise faces
  - to detect and follow lines
  - to detect defects on the tiles
  - to do simple reasoning
  - to do simple dialogue processing
  - to plan adequate actions
  - to fine manoeuvre the robot
  - to do simple mobile manipulation
  - **to integrate all functionalities into a coherent system**