Universidade de Aveiro
Departamento de Electrónica, Telecomunicações e Informática

**Robótica Móvel e Inteligente / Intelligent Mobile Robotics**
**(Academic year of 2021-2022)**

# Assignment 1

## Robotic challenge solver using the CiberRato simulation environment

October, 2021

## 1 Objectives

In this assignment each group should develop a robotic agent to command a simulated mobile robot in order to overcome a set of robotic challenges, involving different navigation skills.

The list of challenges is the following:

1. Control: The objective of this challenge is to control the movement of a robot through an unknown closed circuit as fast as possible and without colliding with the surrounding walls.
2. Mapping: The objective of this challenge is to explore an unknown maze in order to extract its map. (No penalties for collisions.)
3. Planning: The objective of this challenge is to explore an unknown maze in order to locate two target spots and compute a best closed path that allows to visit both target spots starting and ending in the starting spot. (No penalties for collisions.)

Each of the challenges will be detailed below.

## 2 The CiberRato environment

The CiberRato simulation environment will be used to assess the agent developed to overcome the different challenges. The simulated robot (see figure 1) is equipped with 2 motors (left and right) and 3 leds (visiting, returning and finish). In terms of sensors, it include a GPS, a compass, four obstacle sensors, a beacon sensor, a ground sensor, and a collision sensor. The available sensors depend on the challenge to be solved. The simulated robot navigates in a delimited rectangular arena that can be seen as a bi-dimensional array of fixed size cells. Each cell is a square with side length equal to twice the diameter of the robot. The maximum size of the arena is 7-cells tall and 14-cells wide. Cells may be referenced by their position in the labyrinth where cell (0,0) is located at the bottom left corner and cell (13,6) is located at the top right corner.

A maze is defined by putting thin walls between adjacent cells. The target cells are detectable by the ground sensor.

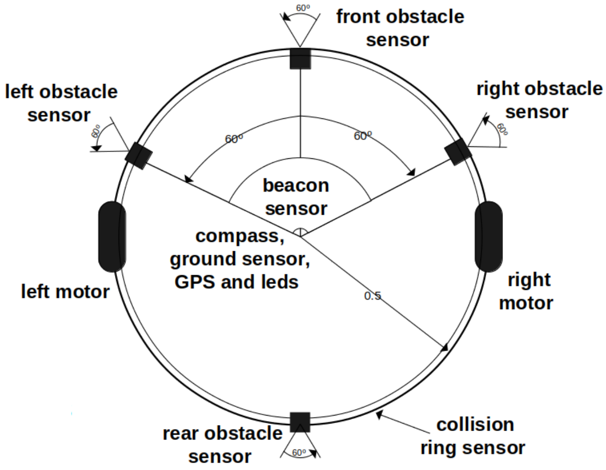


Figure 1: The simulated robot.

# 3 Challenges' description

This section presents a more detailed description of the different challenges.

## 3.1 C1 – Control challenge

As stated before, the objective of this challenge is to develop an agent suitable to control the movement of a robot through an unknown closed circuit as fast as possible and without colliding with the surrounding walls. Figure 2 shows an example of a maze suitable for this challenge, which will be available during development. On start, the robot will be facing North (XX axis). GPS sensor and compass will not be available. The idea behind this challenge is to use the obstacle sensors to control the movement of the robot in the maze. There are checkpoints along the closed path, in order to ensure the robot fulfills the challenge correctly. These checkpoints are sensed by the ground sensor, and therefore they can be verified by the agent.

The robot should complete 10 laps to the circuit. Scoring (and so grading) will be based on the number of completed cells along the closed loop and the number of collisions with the walls.

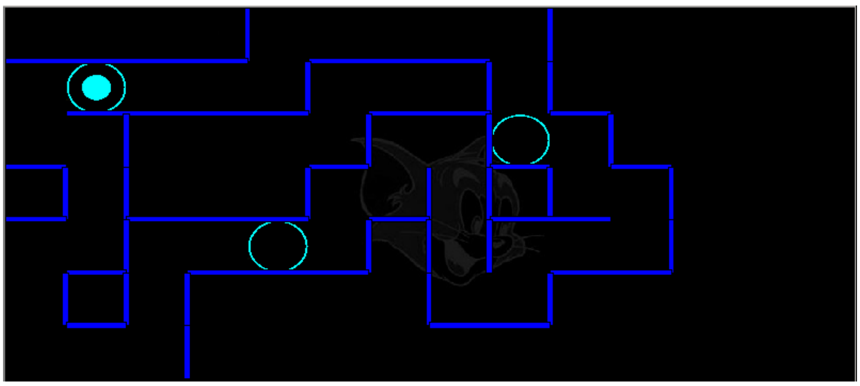

Figure 2: Example of a maze for challenge C1.

### 3.2 C2 – Mapping challenge

As stated before, the objective of this challenge is to explore an unknown maze in order to extract its map. Figure 3 shows an example of a maze suitable for this challenge, which will be available during development. On start, the robot will be aligned with the X (horizontal) axis. GPS sensor and compass will be available, without noise. By using these sensors, the agent can know, at every cycle, where the robot is positioned and oriented on the maze. Hence, localization on the maze will not be a problem. Navigation can be done using the approach followed in challenge C1, but it is easier to do it using the noiseless GPS and compass. Collision with walls will not be penalized.

The idea behind this challenge is to use the obstacle sensors to determine where are the walls throughout the entire maze. A strategy should be followed in order to ensure the entire maze is explored.

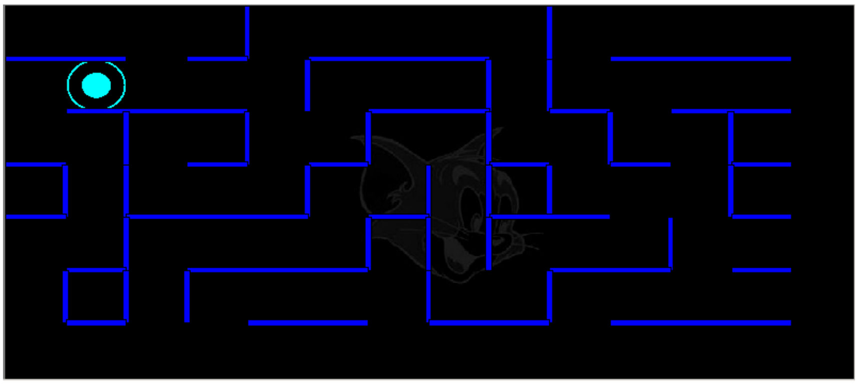

Figure 3: Example of a maze for challenge C2.

### 3.3 Planning challenge

As stated before, the objective of this challenge is to explore an unknown maze in order to locate a number of target spots and compute a best closed path that allows to visit those target spots starting and ending in the starting spot. Figure 4 shows an example of a maze suitable for this challenge, which will be available during development. On start, the robot will be aligned with the X (horizontal) axis. GPS sensor and compass will be available, without noise. By using these sensors, the agent can know, at every cycle, where the robot is positioned and oriented on the maze. Hence, localization on the maze will not be a problem. Navigation can be done using the approach followed in challenge C1, but it is easier to do it using the noiseless GPS and

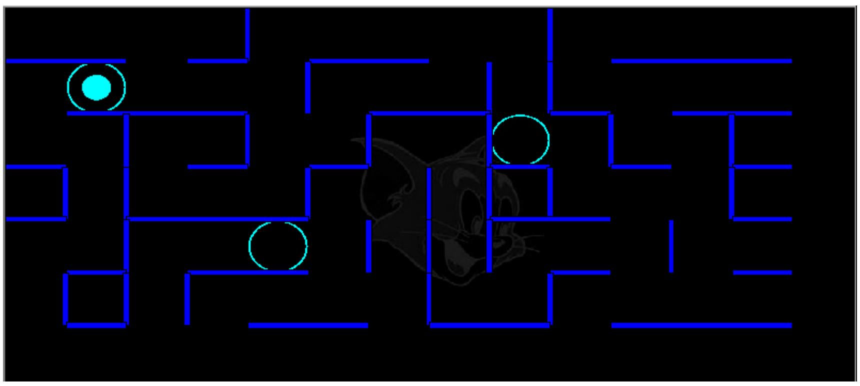

Figure 4: Example of a maze for challenge C3.

compass. Collision with walls will not be penalized.

The idea behind this challenge is to explore the maze just until the target spots are localized and a best closed path is identified. Therefore, the maze does not necessarily need to be explored in its entirety.

# 4 Movement model

Consider that the robot's pose is given by $(x, y, \theta)$, where $x$ and $y$ define the robot position and $\theta$ specifies the robot orientation. When the command sent to the simulator at step $t$ is `DriveMotors(`$in_t^l, in_t^r$`)`, then the following equations determine the new robot pose.

An IIR filter is applied to each of the powers provided by the agent ($in_t^l$ and $in_t^r$) that models the inertial characteristics of the motors and generates the effective powers that will be applied to the motors, corresponding to

$$out_t = (0.5\, in_i + 0.5\, out_{t-1}) * \mathcal{N}(1,\, \sigma^2) \tag{1}$$

where $out_t$ is the power applied at time $t$, $out_{t-1}$ the power applied at time $t-1$, and $\mathcal{N}(1,\, \sigma^2)$ Guassian noise with mean 1 and standard deviation $\sigma$.

Then, the movement is splitted in a translation of the robot position, considering its current orientation, followed by a the change of the orientation of the robot. For the translation one has

$$x_t = x_{t-1} + lin * cos(\theta_{t-1}) \tag{2}$$

$$y_t = y_{t-1} + lin * sin(\theta_{t-1}) \tag{3}$$

$$lin = \frac{out_t^l + out_t^r}{2} \tag{4}$$

and for the rotation

$$\theta_t = \theta_{t-1} + rot \tag{5}$$

$$rot = \frac{out_t^r - out_t^l}{D} \tag{6}$$

where $D$ is the robot diameter (1 in the CiberRato environment). This provides the new robot pose $(x_t, y_t, \theta_t)$ at the next step, in case no collisions occur. If the new pose involves a collision, the simulator only applies the rotational component.

# 5 Evaluation

The evaluation of this assignment will be composed of 3 components: an execution test of the agent, a report, a presentation.

- The agents will be tested and graded by teachers, in batch mode, in their own computers. Thus, the format specified for their execution is mandatory.
- The report must follow the Springer LNCS paper template and must contain the following sections:
  - the Introduction, describing the general approach followed to tackle the different challenges and summarizing the results achieved;
  - a section per challenge accomplished (entitled C1 challenge, ...), describing the approach taken in that challenge;

  - the Conclusion, drawing the main conclusions and pointing out future directions.

- Each group will make a presentation of its work, consisting of an oral presentation, based on powerpoint or similar (10 minutes, maximum), and a short discussion of the work.

## 6 Deliverables and deadline

- Source code of the developed agent.
- Report (in PDF format, according to Springer LNCS paper template).
- Presentation (in PDF format).

Source code and report must be available at the group repository by November, 21$^{\text{th}}$.

## 7 Bibliography


- "Principles of Robot Motion: Theory, Algorithms, and Implementations", Howie Choset et al., MIT Press, Boston, 2005.
- "Introduction to Autonomous Mobile Robots", Second Edition, Roland Siegwart et al., MIT Press, 2011.
- "Artificial Intelligence: A Modern Approach", 3rd edition, Russel and Norvig, Pearson, 2009.