Lab Course Mobile Robots

Exercise sheet 2, WiSe 2025

Protocols: *Please create a file* `protokoll_xx.pdf` *(*`xx` *number of the exercise) with your answers and experimental results for each exercise sheet with LaTeX and put it into the folder* `Protokolle` *. Please upload the file to* https://bitly.cx/LVepF *as well.*

Preparation: *Please carefully read the provided information about laser scanners and ultrasonic sensors, which you can find on* https://bitly.cx/LVepF, *in advance.*

Exercise 1 Laser scanner

(a) There are 3 types of laser distance sensors described in the provided text. Briefly describe ($2-3$ sentences) the functionality of each of them.

(b) What restrictions result from the functionality of the modulation range sensors? Are there comparable restrictions for time-of-flight sensors?

(c) Which type of sensor is the *Hokuyo URG-4LX* laser scanner we use in our robots?

(d) Create a new ROS package and write a ROS node that listens to the topic `/scan` and outputs following information:

- Number of distance measurements per scan,
- Angle difference between two subsequent rays,
- Orientation of the first and the last ray

The file name for the node should be `simple_scan.cpp` and the package should be called `simple_laser`. The associated `CMakeLists.txt` file has to be edited accordingly. Finally, perform the measurements with the robot. Record your findings.

(e) Derive how the distance measurements of the laser scanner can be calculated in 2D points with the help of these informations (A schematic is always useful for making the conventions and notations clear). Hint: The x-axis is oriented in driving direction of the robot, the y-axis to the left.

(f) Now extend your ROS node such that after each measurement the mean and standard deviation of all previous measurements are calculated. Consider only the ray that **points forward**. Write a reusable class `OnlineStatistics` that implements this statistic functionality. Use the formula provided in the appendix and create `online_statistics.h` and `online_statistics.cpp` files. Then, estimate the standard deviation you receive when putting an object at distances of $0.5\,\mathrm{m}$ and $1.5\,\mathrm{m}$ in front of the robot.

Hint: Restart your node for each measurement.

(g) Place one of the provided objects in front of the laser scanner at a distance of $1\,\mathrm{m}$, with its surface perpendicular to the robot. Rotate it in place and measure for different angles (in steps of about 10°) the measured distance. Explain your observations and specify possible causes.

Hint: Restart your node for each measurement.

(h) Now place a mirror at a distance of $1\,\mathrm{m}$ in front of the laser scanner and visualize the topic `scan` in RVIZ. What do you observe?

Exercise 2 Ultrasonic sensors

(a) Summarize in your own words the functionality of an ultrasonic range sensor.

(b) Which possible incorrect measurements have been mentioned in the text and what are their causes?

(c) Find the name and type of the ultrasonic topics. Hint: You can use some of the ROS commands mentioned. You can discover them with `ros2 -h`

(d) Determine the two dimensional area in which the ultrasonic sensors mounted on the robots can detect objects. You will have to read out the measurements with the right ROS command. Make a drawing with at least 10 measurements. What is the field of view of one of the ultrasonic range sensors? Use this information to determine the whole area.

Hint: Choose one sensor you want to analyze. Identify, which value in the measurement data of the topic belongs to this sensor. Choose your objects and their position in such a manner, that you are able to determine the limits of the measurement area.

(e) Now place a mirror at a distance of $1\,\mathrm{m}$ in front of the ultrasonic sensor. Justify your observation!

(f) Put the robot at a distance of $1.5\,\mathrm{m}$ in front of a wall, oriented perpendicular to the wall. Then, rotate the robot. Measure, up to which angle the wall is visible to the ultrasonic sensor.

Hints for ROS

- With `rviz2`, you can start the ROS visualization tool. You can find a user manual on `https://docs.ros.org/en/jazzy/Tutorials/Intermediate/RViz/RViz-User-Guide/RViz-User-Guide.html`.

Incremental calculation of mean and variance

You can incrementally calculate the mean and variance of one sequence x_k for example with the following method:[1]

- Mean M_k after k measurements x_k:

$$M_1 = x_1 \qquad M_k = M_{k-1} + (x_k - M_{(k-1)})/k$$

- Standard deviation σ or variance σ^2:

$$\sigma^2 = \frac{S_k}{k-1}$$

  where for the sequence S_k it is:

$$S_1 = 0 \qquad S_k = S_{(k-1)} + (x_k - M_{(k-1)})(x_k - M_k)$$

  Take care of the case $k = 1$.

[1] s. Donald E. Knuth (1998) *The Art of Computer Programming*, volume 2: *Seminumerical Algorithms*, 3rd edn., p.232