84.5 p

Robot Design Lab
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Group: 09

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Worksheet 02

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15%

1 Quiz: Sensing on Europa

1.1 Name 2 interoceptive sensors, 2 proprioceptive sensors and 2 exteroceptive sensors that you would choose for such a mission.

1.2 Specify for which tasks they will be used.

1.3 Explain why they are important for the mission.

- **Interoceptive sensors:**

  Battery voltage sensor:

  - To measure the battery voltage to make sure it still has autonomy.

  - The robot has to act on his own in space and to assure that you need to observe the battery voltage.

  - Temperature of motors and electronics sensor:

  - Measuring the temperature of motors and electronics in order to avoid hardware damage.

  - The best way to provide long-term autonomy is to prevent hardware damage from occurring to begin with.

- **Proprioceptive sensors:**

  - Inertial Measurement Unit (IMU):

  - Measures the velocity and acceleration for localization.

  - This sensor is important for the mission because it's components allows to us to measure 3-axis angular velocities, 3-axis linear accelerations and the 3-axis magnetic field, which is needed for robot localization.

  - Optical Rotary Wheel Encoder:

  - To track the turning of the motor shaft to generate a digital position and motion information.

  - The optical encoder is reliable and can still be used in applications where a strong magnetic field is generated. In addition having multiple sensors that can ensure odometry is beneficial in case one sensor is malfunctioning.

- **Exteroceptive sensors:**

  - Camera:

  - Provides detailed information about the environment like object detection, navigation, mapping and localization.

  - The Camera is a crucial part of the mission, because with photos for the public you are more likely to get sponsors to contribute more money for future research. Also the detailed environment provided an accurate picture for object detection, navigation, mapping and localization.

  - Laser scanner (Light Detection And Ranging sensor (LiDAR)):

  - This active sensor will be used to measure distances to obstacles.

  - With this sensor in addition with the camera will grant very accurate measurement distances to obstacles to avoid possible physical damage to the robot. Furthermore for this mission it's important to increase robustness, so multiple sensors are used to monitor the environment.

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2 Quiz: Wheel Encoders

2.1 What is the working principle of an optical rotary wheel encoder? What does it measure?

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Every motor has it's own wheel encoder which in the case of the optical rotary wheel encoder, converts the angular position of the motor shaft to a digital code with the assistance of an emitting light source. Secured on a housing assembly (the encoder is manufactured by a stacking method), a light source passes through a code disk and the passed light will be detected by a photodetector and processed by the electronics board, which is on top.

It tracks the turning of the motor shaft to generate a digital position and motion information. To be exact: rotary encoders measure the rotational angle, number of rotations and the rotational position, therefore the position of an object.

2.2 How would you classify an optical rotary wheel encoder? Is it an active or a passive sensor? Is it an interoceptive, a proprioceptive, or an exteroceptive sensor? Justify your answers.

3%

It is a active sesor and an proprioceptive sensor, because it generates stimuli to perceive the environment (in this case a light source) and measures stimuli within the body which describes the robot state in the environment (refer to 2.1).

2.3 Provide a formula to convert the angular resolution Ra of an optical wheel encoder into on-ground distance resolution Rd (i.e. how many meters has the robot moved on the ground per tick).

1%

$$\frac{2\pi}{N} \cdot \frac{r}{1} = R_d$$

You should express Rd as a function of Ra: Rd = Ra * r

3%

2.4 Compute the angular resolution Ra and the on-ground distance resolution Rd of an optical encoder disc with N = 256 ticks and a robot wheel radius of r = 3.3 cm. If the disc has turned n = 2048 ticks, how much on-ground distance d (in meters) did the robot wheel move?

$$\frac{2\pi \cdot r}{N} \cdot n = d$$

You should compute Ra and Rd as well.

$$\frac{2\pi \cdot 3,3}{256} \cdot 2048 = 1,65876m$$

The robot wheel moved approximately 1,66 meters.

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2.5 What is quadrature shaft encoding? How can we determine the direction of rotation from it?

Quadrature shaft encoding is an incremental rotary encoding with 2 out-of-phase output channels. It measures the speed and direction of a rotating shaft.

We can identify the direction of rotation by using two encoders. The senors must be aligned 90 degrees out of phase in order to compare both outputs of the sensors at each time step with the previous time step. Only one sensor value (0/1) changes at each time step, based on the direction of the shaft rotation, hence it determines the direction of rotation.

11.5p

3 Quiz: Odometry

1. *What is odometry and why is it important for autonomous robot navigation?*

   Odometry is the measurement of change in position over time through motion sensors which is important for the avoidance of obstacles and arriving at the destination.

2. *Name three types of odometry models and state the main differences between them.*

   Odometry cannot directly contribute in obstacle avoidance, unless the robot knows it's position in a map. (-0.5p)

   - Differential drive
   - Ackermann steering
   - Omnidirectional

   Please state the main characteristics of the three odometry models. (-3p)

3. *What is the non-holonomic robot constraint?*

   The non-holonomic constraint is a limitation on the velocity of a robot, for example a lack of sideways velocity.

4. *Name two scenarios that can cause odometry drift. What would be a possible solution to compensate for the errors caused by odometry drift?*

   - Insufficient transfer of force to the surface (either through slip or a lack of contact)
     - *Possible solution:* Slip-detection by analysis of motor current
   - Change in important variables (i.e. change in tire diameter through depressurization)
     - *Possible solution:* Active observation of the environment in order to detect discrepancies between calculated and actual movement

   The possible solutions are not very well explained. (-1p)
   (e.g. sensor fusion with exteroceptive sensors such as laser scanner, camera or GPS)

12 p

4 Omnidirectional Robot

1. *Calculate the linear* $\left[\frac{m}{s}\right]$ *and angular* $\left[\frac{rad}{s}\right]$ *velocities of the robot, assuming that the robot was moving at uniform speed throughout its journey.*

```python
import numpy as np

# Initial values
# Start position with X, Y, theta
pos_0 = np.array([1, 0, np.deg2rad(0)])
# End position with X, Y, theta
pos_1 = np.array([2, 1, np.deg2rad(45)])
d_time = 10  # t in s

# Delta position with delta p = p_1 - p_0
d_pos = pos_1 - pos_0
# Calculating velocity with v = p / t
velocity = d_pos / d_time

print(f"X velocity {velocity[0]} m/s, \nY velocity {velocity
    [1]} m/s and \nRotational velocity {velocity[2]} rad/s")
```

Result:

X velocity 0.1 m/s, Y velocity 0.1 m/s and Rotational velocity 0.0785 rad/s

The linear velocity is computed based on the Euclidean distance over time, not separately for each axis.

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5 Differential Drive Model

Showcase Video: https://photos.app.goo.gl/NiWx5UEQEcJNtnPs6

```
currently:      speed 0.15222670638897523       turn 0.09266052860849927
currently:      speed 0.13700403575007772       turn 0.09266052860849927
currently:      speed 0.12330363217506995       turn 0.09266052860849927
currently:      speed 0.11097326895756296       turn 0.09266052860849927
currently:      speed 0.09987594206180667       turn 0.09266052860849927
```

Figure 1: Keyborad Teleopt Output

```
[INFO] [1668076969.443852669] [MoveBase]: send velocities: linear: 0.09987594206180667 angular: 0.0
[INFO] [1668076969.544206934] [MoveBase]: send velocities: linear: 0.09987594206180667 angular: 0.0
[INFO] [1668076969.646429880] [MoveBase]: send velocities: linear: 0.09987594206180667 angular: 0.0
[INFO] [1668076969.744483284] [MoveBase]: send velocities: linear: 0.09987594206180667 angular: 0.0
[INFO] [1668076969.846550344] [MoveBase]: send velocities: linear: 0.09987594206180667 angular: 0.0
[INFO] [1668076969.947170007] [MoveBase]: send velocities: linear: 0.09987594206180667 angular: 0.0
```

Figure 2: Move Base Output

The video does not show much. You have to show the robot being teleoperated.

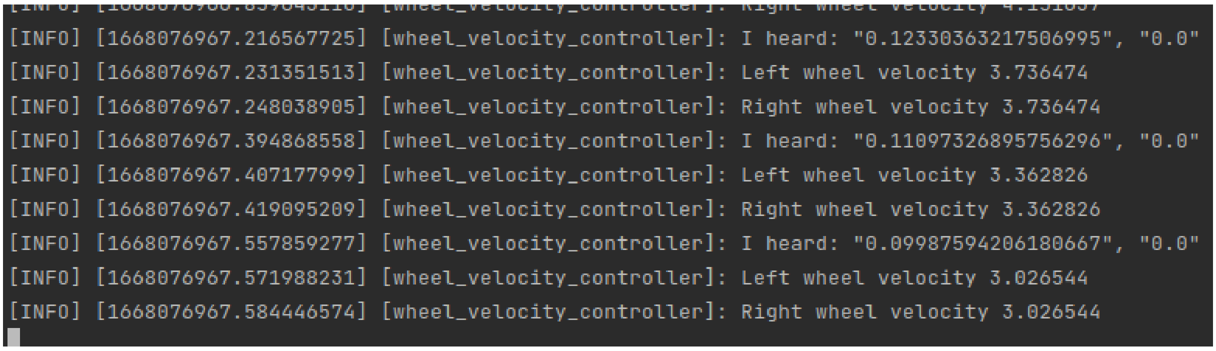

Figure 3: Wheel Velocity Controller

You should compare the absolute velocities as given below:
if abs(msg.linear.x) < 0.18 and abs(msg.angular.z) < 2.5

6 Feedback

1. How much time did you spend on doing this sheet per person?

   I spend the time in both tutoriums and about 3 extra hours on the worksheet.

   Roughly 8+ hours (in combination with studying as a whole).

2. Was it too easy, easy, ok, hard, too hard

   Correcting the code was quite easy but getting ROS to work was not. We had quit a lot of problems with ROS topics not working correctly.

   Too hard, because I am struggling with ROS.

3. Please tell us what you liked in this exercise sheet.

   I like that one is able to test the code on the real machine. And the topics of the lectures are quite interesting.

   I liked that some tasks have multiple correct options to choose from.

4. Did you face any difficulties? What should be improved?

   It was quite confusing that we had to have all those terminals running different nodes, just to test if our code worked.

   I think it would be nice, if there were more sources to study from.