Robot Perception, Cognition, and Navigation, 2022

Assignment description, v1.3

12.12.2022: updated groupwork part b description

Course coordinator:
Ville Lehtola, v.v.lehtola@utwente.nl

Course teaching assistants:
Bhanu Chidura, b.t.chidura@utwente.nl (Data acquisition and rosbags for the group work)
Bavantha Udugama Vithanage, b.udugama@utwente.nl (Theoretical and technical Q&A)

Lidar-inertial assignment

This assignment comprises both an individual part and a group work part. The student is expected to hand in an individually written report and a group work report. The group work report is submitted in three stages.

Individual assignment content:
(maximum length 1 page, including figures, min font size 10):

Content	Deadline	Assessment weight
IMU calibration report	16.12.2022 23:59	40%

IMU experiments are done in class on Thursday, 1 December 2022, 15:45. If you miss the class, no worries, you can download the data online for the report.

Groupwork assignment content:
(maximum length 2 pages for each stage, including figures, min font size 10):

Content	Deadline	Assessment weight
a) Pedestrian dead reckoning (IMU integration in 3D)	22.12.2022 23:59	20%
b) Lidar-inertial sensor fusion in 2D	13.01.2023 23:59	20%
c) Registration of lidar data and analysis of a 3D point cloud	20.01.2023 23:59	20%

BOOK THE DATA RECORDING TIMES ASAP! THE DATA ACQUISITION TA IS AVAILABLE ONLY BEFORE 8th DECEMBER. There will be a practical session Tuesday, 20 December 2022, 15:45 to introduce groupwork item (b) essentials.

Assessment

The assignment is a mandatory part of the course and needs to be passed with a minimum grade of 5. The assessment weights are shown in the tables above: the individual work is 40% of the grade and the group work is 60% of the grade. Reports exceeding page limits are not assessed.

See the following pages for details.

Individual assignment

Objective:

The objective of this practical is the rudimentary IMU calibration. We study accelerometers and gyroscopes and their bias and scale factor errors.

Preparation:

Download the IMU MT Software Suite from: https://www.xsens.com/mt-software-suite/ and install it.

Then go to the MT Manager folder and open and read MT Manager documentation.

Experiment:

The experiment shall be done together in the class as follows. Align the IMU in the way that one of its axes is aligned with gravity. Record the IMU acceleration and angular rate of this axis for few seconds. Average the acceleration and angular rate. Then turn the IMU upside down in the way that the gravity is in the opposite direction. Record another time series and average the acceleration and angular rate.

Repeat this procedure for two other axes (=up and down for all three axes).

Now turn off and turn on the IMU and repeat the whole procedure 3 times.

Report:

Reports are written individually but interaction between students is encouraged. Calculate **bias** and **scale factor** error of acceleration and angular rate from the following equations introduced at the first lecture:

$$\mathbf{f}_{up} = \mathbf{b}_a + (1 + \mathrm{S}_a)\mathbf{g}$$

$$\mathbf{f}_{down} = \mathbf{b}_a - (1 + \mathrm{S}_a)\mathbf{g}$$

$$\mathbf{b}_a = \frac{\mathbf{f}_{up} + \mathbf{f}_{down}}{2}$$

$$\mathrm{S}_a = \frac{\mathbf{f}_{up} - \mathbf{f}_{down} - 2g}{2g}$$

$$\omega_{up} = \mathbf{b}_g + (1 + \mathrm{S}_g)\omega_e \sin\phi$$

$$\omega_{down} = \mathbf{b}_g - (1 + \mathrm{S}_g)\omega_e \sin\phi$$

$$\mathbf{b}_g = \frac{\omega_{up} + \omega_{down}}{2}$$

$$\mathrm{S}_g = \frac{\omega_{up} - \omega_{down} - 2\omega_{\mathbf{e}} \sin\phi}{2\omega_{\mathbf{e}} \sin\phi}$$

Calculate bias offset and scale factor error for each run. In addition, estimate run-to-run bias and scale factor instability. Can we estimate other error sources? Is yes, please do so.

Please write a report where you document and explain the results. <u>Recommend calibration parameters for $\boldsymbol{b}_a, \boldsymbol{S}_a, \boldsymbol{b}_g, \boldsymbol{S}_g$ that should be used for the IMU (=bias offset and scale factor error)</u>. You will use these to initialize the IMU data for the group work.

Group assignment

Book a time with the course teaching assistant (TA) for your group, at the ITC building, Hengelosestraat 99. This is where the measurement test field is. The TA will guide you to the measurement site and help you to operate the lidar-inertial backpack sensor system to do data acquisition.

Objectives:

a) Pedestrian dead reckoning (IMU integration in 3D): Calculate a trajectory by integrating the IMU data over time. Plot the trajectory. Did the IMU arrive on the same place than it started from, according to the data? Estimate the magnitude of drift. Discuss the results. Remember to calibrate the IMU first with the bias and scale factor values you obtained from the individual assignments. Use only one set of values for the group's work. If different values were obtained by the group members, choose the best values.

b) Lidar-inertial sensor fusion in 2D. You need a linux OS for this, e.g. ubuntu, because you need to plug in the ros topics from the rosbag into the SLAM algorithm. Use the supplied docker file to build a ready virtual environment with all the needed libraries and packages. Documentation about scan matching 2D lidar data and using supplementing IMU data can be found at:
   - http://wiki.ros.org/cartographer
   - (http://wiki.ros.org/laser_scan_matcher)

   Discuss in your report:
   - What are the relation between keyframes (lidar lecture 1), landmark poses (rviz), and submaps (cartographer documentation)?
   - What are the conditions for creating submaps in cartographer?
   - How are the submaps used?
   - Is the density of submaps increasing during the 2nd and the 3rd loop? Why/ Why not?
   - What is the least number of landmark poses you can use to run the part B exercise successfully?
   - How is loop closing done?

   Plot the following trajectories in one figure and add to your report:

   - IMU integration trajectory (group work part a)
   - 2D lidar trajectory
   - Lidar-imu fusion trajectory (see the my_robot.lua file options to enable IMU data usage)

   Figure 2: Using the trajectory, register the horizontal lidar data together and take a snapshot of the 2D point cloud.

   Discuss the results briefly.

c) Registration of lidar data and analysis of a 3D point cloud. Use the trajectory computed from lidar-inertial fusion to register the data from the two non-horizontal lidars. The result is a 3D point cloud. Discuss how you could detect objects such as doors from the data (those are big objects). Convert the point cloud into a 3D occupancy grid. What is a suitable voxel size? Give approximate estimations of the dimensions of the test field. How high is the ceiling? Discuss briefly what robotic applications could benefit from lidar-inertial perception systems.

Preparation:

1. Book a time and meet with the TA. Book a time so that preferably all group members can attend. In case of a force majeure, one group member can be missing from the meeting.
2. Capture data from the indoor test field at the first floor of the ITC building. There is a short loop to be walked around **three times** with the backpack. Finally, make sure that the IMU starts and ends the data capture at the same location, but with opposite heading.
3. Download the data (rosbag format) and the supplementary files (Dockerfile etc) to your computer as instructed by the TA.
4. Install the supplied docker image (ubuntu) to playback the rosbag file to access the data (ROS has also experimental window support, http://wiki.ros.org/noetic/Installation)
    a. For the pedestrian dead reckoning, if you find it helpful, you can extract ascii data from the rostopic /imu/data, with e.g. rostopic echo /imu/data > imu_ascii_data.txt

For details, the backpack laptop has ubuntu 20.04, ROS noetic, and needed drivers. These are also in the supplied docker image.