CMPUT 631: Autonomous Robot Navigation
Fall 2019
Assignment No. 2
Due 23:59, October 14, 2019 (via email of a PDF file)

1. (**5 marks**) LiDAR's for robots commonly use the phase shift method to estimate depth using the time-of-flight (ToF) principle. The phase shift method relies on modulating the amplitude of the light emitted and measuring the phase difference (θ) between the emitted and the received light. Given the speed of light (c) and the modulating frequency (f), one can infer the distance to the object that reflected the light from θ.
   (a) Assume a modulating frequency of 250 KHz, what is θ caused by an object that lies at 20 meters from the LiDAR?
   (b) Since we know the largest phase shift is 2π without the problem of aliasing, what is the furthermost distance that this LiDAR can measure?
2. (**5 marks**) Assume a camera of known intrinsics. If the robot (camera) is at a 2D pose $x_i = (x, y, \theta)$, and if a 3D landmark l_j is at (a, b, c), the landmark is projected into the camera at $z_k = (u, v)$ in the image coordinate frame. Please answer the following questions about the corresponding factor graph:

   (a) What is the subset of unknown variables X_k associated with the observation z_k?
   (b) What is the likelihood function $p(z_k|X_k)$, assuming Gaussian noise, that relate the observation to the unknown variables in X_k?
   (c) What is the measurement function $h_k(X_k)$ for the camera?

3. (**20 marks**) In this problem, you will need to install either RTAB-Map or ORB-SLAM 2 on your laptop (not both), with or without ROS, i.e., you can run a SLAM software as a standalone system or install it from within ROS. Once the SLAM system is installed, run it on the freiburg1_xyz sequence of the TUM dataset. Record the resulting screen capture and submit the link to the video of your experiment.
4. (**10 marks**) The non-linear least square solver g2o is automatically installed when you install RTAB-Map or ORB-SLAM 2. You should be able to run g2o from command line on properly formatted input data files such the INTEL dataset in Homework Assignment No. 1. Run g2o on INTEL dataset and compare the two robot trajectories before and after optimization by (a) computing the average difference in the translational component of the robot pose, and (b) draw the robot trajectories before and after optimization to visualize the difference.
5. (**10 marks**) The pseudo code to convert a depth image from a Kinect camera to its equivalent point cloud is given at https://vision.in.tum.de/data/datasets/rgbd-dataset/file_formats. For Freiburg_1 sequence, please answer the following questions.
   (a) derive the two equations that compute X and Y.
   (b) determine point clouds depth images in Freiburg_1 dataset: 466046.png, 498096.png and 528267.png (ROS has a built-in nodelet in the package depth_image_proc to perform this conversion).
6. (**10 marks**) Install the point cloud library PCL on your laptop (if you have not installed it with ROS). Study this example on the iterative closet point (ICP) algorithm. Then modify the example so you can compute LiDAR odometry from two depth images as in Question 4. Use your program to estimate the two 3D transforms associated with the three depth images in Question 4.