

CMPUT 631: Autonomous Robot Navigation
Fall 2019
Assignment No. 1
Due 23:59, October 2, 2019 (via email of a PDF file)

1. (5 marks) [Turtlebot2](#) robot uses a differential drive. Assume its wheel base to be 0.4 m.
 - For the robot to move at 0.5 m/s and rotate at 0.1 radian/s at the same time, what must be the linear velocities of the left and the right wheels?
 - If the robot starts at pose $(0, 0, 90^\circ)$, how do its left and right wheel velocities have to be controlled in order to reach $(1, 1, 45^\circ)$ in 5 seconds. You can assume perfect control, no limit on wheel velocities, and no vehicle dynamics. You can divide the motion into three segments.
2. (5 marks) [Tesla](#) and [Roomba 980](#) are both robots capable of autonomous navigation as you can see in these videos. Use any online resources you can find, with respect to how they achieve autonomous navigation, list three differences and three similarities between these two robots.
3. (10 marks) Assume that a robot moves from its initial pose x_1 through a sequence of poses till x_{10} . At each pose, the robot is able to observe two observations to two landmarks l_i and l_{i+1} , $i=1 \dots 10$. In addition, a loop closure is detected between x_3 and x_9 . Please answer the following questions.
 - (a) What is the corresponding factor graph for this SLAM problem (omit the node for the camera intrinsics K and assume initial condition for x_1 to be p)?
 - (b) What is m in Eq. (2) of [Cadena 2016]?
 - (c) What are z_1 through z_m ?
 - (d) What are X , and X_1 through X_m , respectively?
 - (e) What are h_1 through h_m ?
 - (f) Is the problem over-constrained or under-constrained and why?
4. (5 marks) Assume a 3D sensor such as a LiDAR capable of detecting and measuring distance to 3D point landmarks. If the robot is at a 2D pose $x_i = (x, y, \theta)$, and if a 3D landmark l_j is at (a, b, c) , a range value from the robot to the landmark is measured as z_k . Please answer the following questions:
 - (a) What is the corresponding subset of unknown variables X_k ?
 - (b) What is the corresponding likelihood function $p(z_k|X_k)$, assuming Gaussian noise?
 - (c) What is the measurement function $h_k(X_k)$?
5. (5 marks) A LiDAR on a robot detects a point l with respect to the LiDAR frame $\{\text{laser_link}\}$ at $(3, 4, 2)$. $\{\text{laser_link}\}$ shares the same orientation as the robot frame $\{\text{base_link}\}$ but its origin is offset at $(0.2, 0.0, 0.1)$ with respect to $\{\text{base_link}\}$. If the 2D robot pose in the map frame $\{\text{map}\}$ is at $(5, 10, -30^\circ)$, determine l in $\{\text{map}\}$. By default, the robot moves on the x-y plane.
6. (5 marks) Visit the [dataset page](#). First read the one-page note on how the non-linear least square solver called [g2o](#) formats its input. Second, download the dataset called INTEL, and understand its data. If we are to construct an equivalent factor graph for INTEL, (a) what is m and (b) among the measurements z_k , how many are odometric measurements (u_i) and how many are loop closure measurements (c_i)?
7. (5 marks) Find a laptop. Install [Ubuntu](#) (16.04 preferred) or install a virtual machine together Ubuntu (16.04 preferred). Special office hours will be arranged to help you if you are not able to complete this.