Exam in
DD2425 Robotics and Autonomous Systems

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You are allowed to use a calculator. Please read the entire exam before preparing the answers to make sure that you have a good view of the questions to be answered. You need at least 30 points to pass. The mapping from exam score to 0-10 which is averaged with your score from the project, is such that 30 points on the exam gives you 0 and max points (80) gives you score 10.

Do not forget to turn the page!

Write only on one side of the pages and make sure to put your name and page number on each page and note how many pages are handed in on the front page!

GOOD LUCK!

Short questions, short answers

1. You want your robot to move from one point to another in a cluttered room without sensor feedback but you have access to the robot's exact location all the time. Would you prefer to navigate based on an occupancy grid or a topological map? (2p)

2. Robot A has wheel base (distance between the wheels) 0.1m and robot B has wheel base 0.2m. Assuming the two robots have the same wheel radii which robot will rotate faster if we let the wheels spin with the same speed but different direction? (3p)

3. What happens to the field of view of a camera if you make the image sensor smaller but keep everything else the same? (2p)

4. Assume an object 1m away is visible in both left and right camera in a stereo pair. Does the accuracy in the estimated distance to the object typically improve or degrade with increased base line (ie when the distance between the cameras increases)? (3p)

5. Mention one advantage with having an omnidirectional drive system for a robot. (2p)

6. Assume a setup with a DC-motor that powers a wheel via a gearbox (with neglectable backlash) that makes the wheel rotate 1 revolution for every 50 revolutions of the motor. We want to equip this system with an encoder and we want to be able to detect as small movements of the wheel. Do we put it on the wheel axis or the motor axis? (2p)

Longer questions, longer answers

7. In object recognition, techniques based on keypoints / interest points are common. Describe roughly how this is done. (5p)

8. You have a simple phase shift based laser with a modulation wavelength of 10m and a reflecting target at 16m.

    a. What distance will the sensor report? (4p)

b. What wavelength do we need to make sure that the sensor will report distances correctly up to 20m? (4p)

9. You have implemented a SLAM system using landmarks in the form of points. The robot is in an area where there is only one landmarks which according to the map is expected to be 1.5m away. The robot makes a measurement that says that the landmark is 1m away. Assuming that we have a sensor with really small errors, what will happen (conceptually) with the robot's and the landmark's positions in the map in the following situations?

   a. The uncertainty in the robot position is huge and the uncertainty in the landmark is small. (4p)

   b. The uncertainty in the robot position is small and the uncertainty in the landmark is huge. (4p)

10. Assume that a differential drive robot with wheel base $B = 0.2m$ and wheel radii $r = 0.05m$ is at pose $(x_0, y_0, \theta_0) = (0, 0, 0)$ at time $t = 10s$ and that it travels with **constant** wheel speeds (but not necessarily the same for both wheels). What are the left and the right wheel speeds if the robot passes through the position $(x_1, y_1) = (0.3, 0.15)$ at $t = 12s$. (10p)

11. Given a sonar sensor with a very large beam width of 40°, ie the sound spreads 20° around the acoustic axis (we assume an idealized model of a sonar sensor such that the side lobes are ignored in the radiation pattern). Assume that the robot body can be approximated with a block with length $L = 0.3$, width $W = 0.2m$, height $H = 0.1m$ and that you tilt the sonar up 10°. Assume that all obstacles extend from the floor to the ceiling. You want to use the sonar to detect objects close to the robot in the front.

   a. Have far back should the sonar be placed for the beam to be as wide as the robot at the front the robot? (5p)

   b. At what height above the robot should the sonar be placed to avoid detecting the robot body? (5p)

   c. At what distance from the front of the robot does the sonar detect something at floor height? (5p)

12. Describe two advantages of using HSV rather than RGB in some cases. (5p)

13. You are building an occupancy grid with an IR-sensor. The size of the square grid cells is 2cm x 2cm. The IR sensor is placed in the center of rotation on a robot that is rotating around its own axis. Assuming that we can sample the IR-sensor at a rate of 5Hz, what is the maximum rotation speed if we want to make sure that the IR-sensor passes through some part of every cell in the grid up to a distance of 40cm. (5p)

14. You have no idea where the robot is, except that it is in a rectangular room with landmarks in the corners. The landmarks are indistinguishable, ie you can not tell them apart. You have access to some measurements of these landmarks. What can you say about the position of a robot. The sensor is in the center in the two following cases?

   a. The room is 10m by 5m. You measure the range to two of the landmarks as $\rho_1 = 10m$ and $\rho_2 = 10m$ and the robot has radius 0.2m. (4p)

   b. The room is 10m by 5m. You measure the bearing to two of the landmarks as $\alpha_1 = 42°$ and $\alpha_2 = 227°$ and the robot has radius 0.5m. (6p)