Exam in
DD2425 Robotics and Autonomous Systems

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You are allowed to use a calculator but will not need one I think. 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 40 points to pass. The mapping from exam score to 0-10 which is averaged with your score from the project, is such that 40 points on the exam gives you 0 and max points (100) gives you score 10.

Do not forget to turn the page!

WRITE ONLY ON ONE SIDE OF THE PAPERS. Put your name and the page number on each page and note how many pages are handed in on the cover page!

GOOD LUCK!

Short questions, short answers

1. What does IMU stand for? (2p)

   Inertial measurement unit

2. If you want to implement a crash detection system (i.e. detect when it has happened) for a robot with a complicated shape moving inside a maze like in this year's project, which sensor would probably be simplest to use; a micro switch, 2-axis accelerometer, IR-sensor, sonar, PrimeSense or a compass? (2p)

   2-axis accelerometer (mounted so that it detects high accelerations in the horizontal plane)

3. At what distance are you likely to get the worst measurement of distance from a PrimseSense RGB-D camera as used in the course; 0.2m, 1.2m or 2.2m? (2p)

   0.2m as it is below the detectable range. Otherwise it would be 2.2m because the farther away you are the higher the noise level.

4. How can you tell how much time it should take to move from the start to the end of a trajectory without knowing what robot will be used (assuming it can follow the trajectory)? (2p)

   The trajectory assigns time to the path, i.e. look at the time at the end of the trajectory.

5. Mention a problem that you might face when you use the inverse kinematics for an arm? (2p)

   There might not be a solution or there might be more than one and I need to pick one.

6. Mention one major challenge for using a robot arm in a domestic environment safely? (2p)

   Need a 3D model of the environment. Need to be able to detect or deal with collisions for the entire arm.

7. Mention a problem when a phase shift laser? (2p)

   Ambiguous distance measurements which depends on modulation wavelength.

8. Mention a limitation when using Doppler radar to detect speed? (2p)

   We detect radial motion with respect to the sensor, i.e. motion that generates a Doppler shift in the received signal because the target moves away/towards the sensor.

9. When using a camera for detecting the position of an object, mention a problem if the focal length in your camera model is wrong? (2p)

   The distances to objects will not be correctly estimated and thus not the position.

10. How can you use the stereo effect with only one camera? (2p)

    You move the camera to take the two images.

11. Mention an environment type where GPS is unlikely to be available? (2p)

    Indoors or other environments where the sky / satellites is not visible.

12. Mention a setting in which a passive sensor is to be preferred and why? (2p)

    A setting where you do not want to give away your position by sending out a signal as you do with an active sensor. An active sensor uses more energy so a setting where this is an issue it might be better with an passive sensor.

13. Mention a potential problem with a low resolution encoder for speed control of a motor? (2p)

    Low speeds are hard to estimate and thus to control.

14. Mention a potential problem with a high resolution encoder? (2p)

    You need hardware / software that is able to count the pulses fast enough.

15. Mention two advantages with a quadrature encoder compared to a standard one? (4p)

    Higher resolution. Can detect direction of motion.

16. Mention a problem when using a visibility graph for path planning? (2p)

    Paths will be touching obstacles. Very many vertices/edges unless the environment is simplified.

17. Mention a challenge when using a feature based representation and an EKF for SLAM? (2p)

    Need to determine what features to use. Computation complexity. Decisions are irrevocable.

Longer questions, longer answers. Make sure to motivate your answers. State any assumptions you make explicitly. ANSWERS MUST BE ON SEPARATE PAGES!!!!!

18. a) What type of components are part of an IMU? (3p)
    b) Describe how it is used to track the pose in 3D (no need for formulas). (7p)
    c) Discuss two limitations / problems. (4p)

    a) At a minimum accelerometers and gyros but also typically a compass all of 3-axis type if you want to track motion in 3D. b) The accelerometer gives us information about the translation. For this to work we need to keep track of the orientation which we do using the gyros. Given the orientation we can rotate acceleration measurement into the world frame and subtract the gravity vector and integrate what remains twice to update the position. We use the accelerometer to update the orientation under low acceleration conditions to reduce drift. The compass, if available, can also be used to update the orientation.
    c) The position will drift and will do so very quickly unless we are able to very accurately estimate the vertical direction to subtract the gravity vector. The compass is sensitive to magnetic disturbances and can lead to errors in the orientation estimate. The orientation will drift unless we can get measurements from compass or accelerometer. The accelerometer cannot give us information about the orientation around the vertical direction.

19. Describe how topological mapping is done conceptually and how the robot would use the topological map for localization. (5p)

    The map is defined as a set of nodes and edges. The nodes represent places of interest which can be identified, at least locally, from our senses. The edges represents paths between such places. When we build the map we would add a new node to the map if we come to a new place. When we travel from one node to another (new or old) we connect the two nodes unless the are connected already. When we perform localization we keep track of our position in the graph and can limit the search for the next nodes to nodes connected to the previous one.

20. You have been tasked with building the vision system using a RGB-D camera (think PrimeSense) on a robot moving in a maze like the one in the course. You need to be able to detect and classify the objects. You can assume that the objects vary in color and shape like the ones used in the course project.
a) How would you mount your sensor and how would you pre-process the data? (5p)
b) How would you detect the objects? (5p)
c) How would you classify the objects? (5p)
d) Identify and discuss two problems with your solutions above? ("I did not answer b) and c) so I can neither detect nor classify objects" is not an OK answer, although that would clearly be a problem for your system) (5p)

All groups did this so you should be able to read your group's report for the answer.

21. Your robot is exploring an environment (can be thought of as 2D) of which only the dimensions are known. You are using an occupancy grid to represent the world. Explain:
a) How do you initialize (sizes (be explicit what sizes), initial values, etc) the grid? (5p)
b) How do you update (you do not need exact formulas) the occupancy grid? You do not need to worry about how and where the robot moves as this is taken care of by one of your team mates. All you need to explain is how the occupancy grid gets updated given that the robot moves. (5p)
c) How do you define unexplored space and good target locations to move to to explore space? (5p)
d) How do you find a path that the robot can travel from its current position to the target location defined in the previous question (you can call it P if you find that simpler or did not answer c)) when the robot has explored part of the environment? (5p)
e) Discuss how the way you update the map might influence the exploration behavior and problems that might occur in general (at least one). (5p)

Assumptions: The robot fits inside a circle with diameter D. The world is XxY. All openings that I need to represent as passable are at least D+2M. My sensors can sample the space on both sides of the robot using IR-sensors. The robot moves slow enough to detect all objects to the side that I need to find. I assume localization is solved, i.e. I know the pose of the robot. I know the pose of the sensors w.r.t. the robot.
a) Cellsize s=min(D,M)/2 and number of cells 3(max(X,Y)/s) in both x and y directions (to have some margins) and put the robot in the center of the grid. I initialize the values of the cells to 0.5.*
b) For every new sensor reading I calculate the pose of the sensor and ray trace through the grid and update the cells map using Bayes formula such that cells in free space (before the detected range) gets a lower value and cells close to the target gets a higher value. If the detected range is above a certain value R I only lower the occupancy grid values since the reading is too uncertain. I would put the value of all cells under the robot to a very small value (explored and free) but for sake of robustness I would avoid 0 because that would mean that this cell can never be anything but 0.
c) I define unexplored space as those cells that have values close to 0.5. I would look for borders between unexplored and explored space and define the target space to be at this border or slightly inside the unexplored space.
d) I would expand all occupancy cells to the size of the robot and put all values to the max of the previous value and the expanded cell. I would search from the current location to the target point, for example, using breadth first search with the cost to move from one cell to the next a function of the occupancy value. To start with I would try 0 for all cells with a value lower than T and infinity for all other cells.
e) The large the range our sensor has and we use in our update, the further away from the robot we will consider explored. In an environment without occlusions and large enough sensor range we could explore the environment by only turning. If we want the robot to move around we should use a smaller effective sensor range. We need to pay attention to target regions that are very small to aviod teh robot exploring for a very long time. Using a long range will also lead to updates that look like "spokes on a wheel" when the robot is turning unless we turn very slowly. This will generate long but very thin slices of space to explore. There are many things you could write here.