This question paper consists of 7 printed pages each of which is identified by the Code Number (COMP363101)

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School of Computing

January 2018

COMP363101

Intelligent Systems and Robotics

Answer ALL 3 questions

Time allowed: 2 hours

Question 1

(a) Suppose you have a large collection of photos from your vacation and you wish to develop an automatic algorithm to find the location, orientation and scale of a bounding box containing any frontal image of your face in the collection. The simplest brute-force method is to construct a template that consists of a small image of your face together with the 2D coordinates for the centre of your eyes, tip of your nose, and ears that can be applied at multiple locations, scales and orientations to the image and to compute a matching score.

(i) Explain how Histogram Back Projection might be used to identify possible regions that contain a face. **[3 marks]**

(ii) Explain how an Image Pyramid containing downsampled versions of the image could reduce the complexity of the search for the location of the bounding box and state any limitations of this approach. **[2 marks]**

(iii) Describe how you could use SIFT features to find the orientation of the bounding box located in (ii). **[4 marks]**

(b) To perform face recognition, a student creates a vector of features (pixel values) as the representation for each of the images in a training set. In order to compute the eigenfaces, they concatenate each of these vectors together into a matrix, and then find the eigenvectors of this matrix.

State, justifying your answer whether or not this is the correct method. **[2 marks]**

(c) If a robot, driving straight ahead, takes two successive pictures of the environment in front of it, explain with the aid of a diagram the configuration of the epipole and epipolar lines in the first (earlier) image. **[2 marks]**

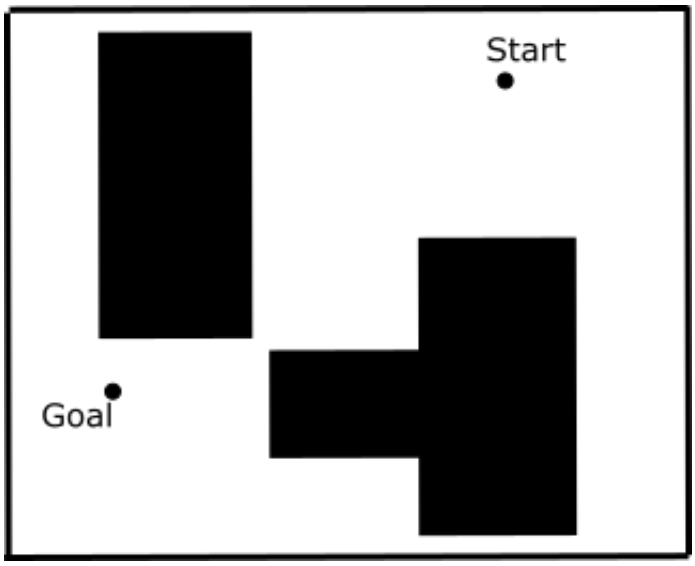
(d) Two cameras are related by the fundamental matrix $\begin{bmatrix} -1 & 0 & 2 \\ 0 & -1 & 3 \\ -3 & 2 & 0 \end{bmatrix}$.

By constructing epipolar lines corresponding to the points (1,0) and (0,1), compute the coordinates of the epipole in the image-plane of one of the cameras. Show your working. **[7 marks]**

[Question 1 total: 20 marks]

Question 2

(a) You are given the configuration space below, along with a start and a goal configuration for your robot.



i. Apply the Visibility Graph method and show the resulting graph. A copy of the map is provided in Appendix 1. Please show your result on the map in Appendix 1 and **attach the Appendix 1 page to your answer book**.

[2 marks]

ii. In such an environment with narrow passages, would you prefer to use the Fixed-Size Cell Decomposition method or the Visibility Graph method? Why?

[2 marks]

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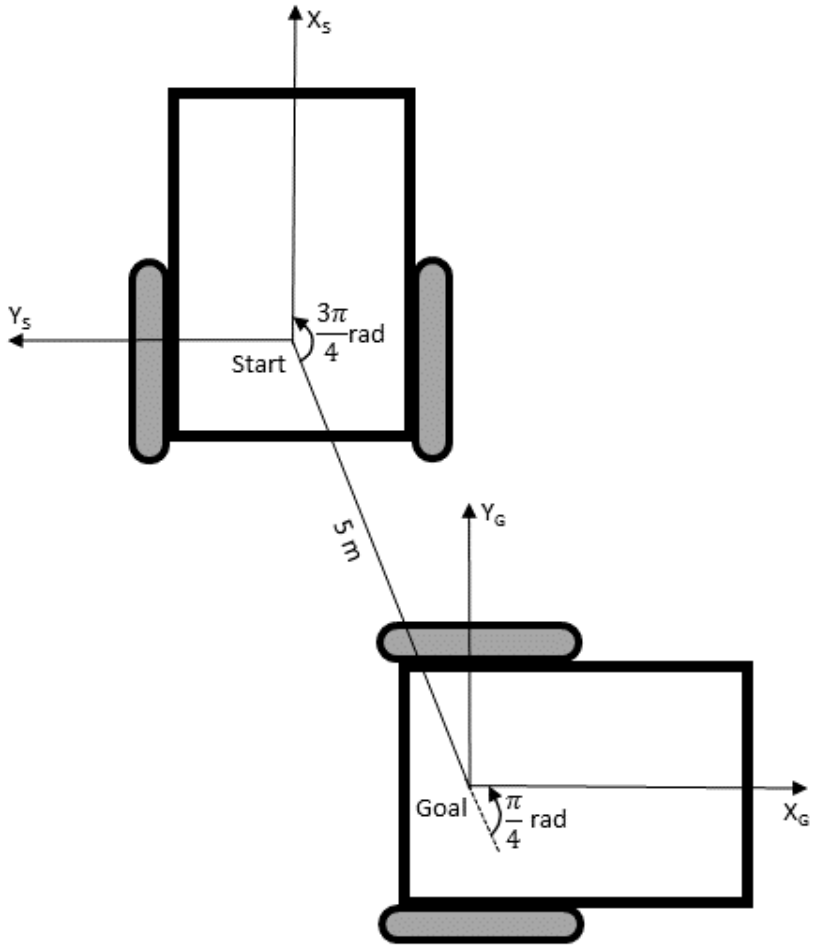
(b) Suppose you are controlling the differential-drive robot below to move from the Start pose to the Goal pose. The X-axis gives the heading direction of the robot.

Suppose you want to use a three-step control procedure, where you first rotate the robot so that it heads in the correct direction, then translate the robot to its goal position, and then rotate again to attain the goal heading direction. The relevant angles and distance are given in the figure. Assume the robot does not have any motion noise, i.e. your motion commands are executed perfectly by the robot. During rotations, use the side that gives the shorter angle of rotation.



i. Suppose you are using an open-loop controller with fixed speed to perform each of the three steps separately. For translational movements, use the fixed speed of 0.2 m/s or -0.2m/s. For rotational movements, use the fixed speed of 1 rad/s or -1 rad/s. Specify the time it will take to execute each step.

[3 marks]

ii. Find the actual spin speeds for left and right wheels that would move the robot in the desired way during each of the three-steps. Assume that the distance between the midpoint of the two wheels and each wheel is 1.6 m. Assume each wheel is a circle of radius 0.4 m. **[3 marks]**

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(c) Suppose you are using the Occupancy Grid Mapping method to build the map of an environment. You divide the environment into a 4-by-4 grid and initialize every grid with the counter value 0 (zero). After running the Occupancy Grid Mapping method for a while you end up with the counter values shown below.

0	0	2	-2
2	2	3	-3
-2	-2	-3	-3
0	-2	-2	-2

i. What is a good threshold value to use to determine the occupied grids in this map? Why? **[2 marks]**

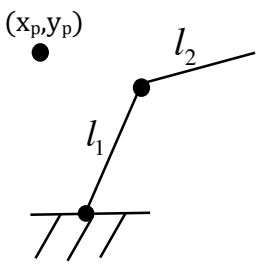
ii. With the threshold you have chosen above, which cells in this map should be marked as occupied? Re-draw the 4-by-4 grid (no need to include the counter values) and then show the occupied cells by putting a cross into them. **[2 marks]**

(d) Name two localisation algorithms. Compare their strengths and weaknesses.

[4 marks]

(e) Take the robot arm with two joints below. Let Θ_1 and Θ_2 represent joint angles, and l_1 and l_2 represent link lengths. Assume robot joints can rotate without any limits. Given the coordinates of a point, $p = (x_p, y_p)$, with respect to the robot base, how would you quickly check whether the robot's hand can or cannot reach p?

[2 marks]



[Question 2 total: 20 marks]

Question 3

At the School of Computing, we would like to have a robot that collects empty tea mugs from offices and puts them into the sink at the staff kitchen. How would you develop such a system? State key components of the system, in terms of hardware, software, and data. State the kind of sensors you would want on the robot. Suggest algorithms and techniques that will be used and explain how they fit together. You are not required to give details of how each individual algorithm works. You should state the reasons for your choice of design, its strengths and weaknesses and any assumptions.

Assume that the robot will work only on a given floor and a floor plan is available. The floor plan, however, does not include any movable objects, such as desks, chairs, and tables. You can also ignore the existence of doors; i.e. your robot does not need to open doors.

[20 marks]

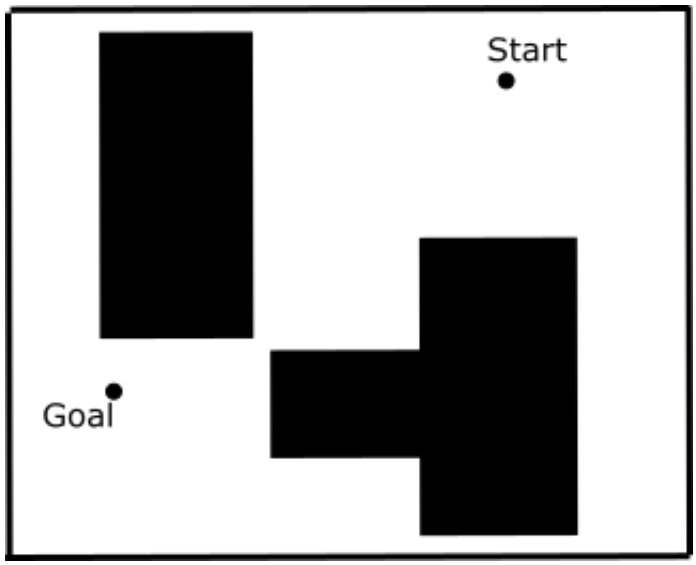
[Question 3 total: 20 marks]

Appendix 1

Student No:

Please write your student number above and **attach this Appendix page to your answer book.**

Below is an exact copy of the map shown in Question 2 (a). Please show the result of your work for Question 2 (a) on this map.



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