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tiİSTANBUL TECHNICAL UNIVERSITY

**Department of Computer Engineering**

***BLG456E – Robotics – Spring 2014***

***Statutory Makeup exam.***

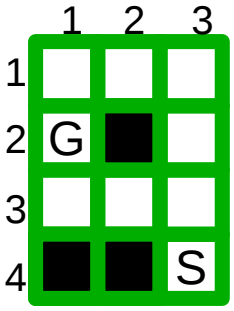
BLG456E FINAL 2

**Duration**: 120 minutes

**There are 16 questions.**

**Rules**: - Not open-book. No extra notes or papers are allowed.
- Cellphones must be put away. Basic calculators are allowed.
- Answers must be in English.
- **Show your working.**
- Put at least your name or ID on all pages.
- If you write in the margins (you should not need to), indicate under the relevant question.

*In the grid on the right, dark squares are obstacles. A robot intends to plan a path from S (at coordinates [3,4]) to G (at coordinates [1,2]).*




**Question 1 (20 pts)** Draw a graph derived from this grid for the purpose of path planning, labelling each node with the appropriate coordinates. Then use the **A*** (A-star) algorithm to solve the path planning problem. Show important quantities and node lists *for each step in the algorithm* (i.e. don't delete your working, and annotate it for the marker to check each step). Name the heuristic used.

**Question 2 (5 pts):** What are the specific challenges for state estimation (such as localisation) when considering a continuous state space (as compared to a discrete state space).

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**Question 3 (5 pts):** What is TD-learning and why might we need it for a robot arm to learn to hit a ball instead of supervised learning?

**Question 4 (5 pts):** In ROS, the ***tf*** library is the library responsible for publishing, collecting and composing transforms between frames. Referring to how the library works, explain how it can lead to a lot of network traffic.

**Question 5 (5 pts):** In HRI, what is a potential ethical problem that may occur in the context of robot football? Briefly give 2 different perspectives on this problem.

*A robot can be in one of 200 discrete states at any time-step and at each time-step can receive one of 10 observations. Assume* $P(X_t = x_t)$ *is known for every possible state* $x_t$ *at time-step t.*

**Question 6 (5 pts):** Give the appropriate expression for calculating the *prior* probability of a particular state $x_{t+1}$ at time *t+1*, from the known probability distribution $P(X_t = x_t)$ and a probabilistic dynamics model.

**Question 7 (5 pts):** Calculate how many times this expression will be needed to be calculated to get the prior probability distribution over the state at time *t+1*. Give working.

**Question 8 (5 pts):** Give the expression for calculating the *posterior* probability of a particular $x_{t+1}$ state at time *t+1*, from the probability distribution calculated in question 6 above (the prior probability distribution over the state at time *t+1*), an observation and a probabilistic observation model.

**Question 9 (5 pts):** Once an observation is received, calculate how many times this expression will need to be calculated to get the full posterior probability distribution over the state at time *t+1*..

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**Question 10 (5 pts):** Give one example each of a discriminative observation model and a generative observation model. Explain why they are discriminative/generative.

*An encoder using a breakbeam is placed on a robot's wheel at 5 centimetres from the centre of the wheel. The encoder has 20 holes. The wheel has a radius 10 centimetres.*

**Question 11 (5 pts)** If 100 signal edges are detected by the breakbeam in 2 seconds, work out the rotational and linear velocity of the wheel and how far it has travelled in 2 seconds. You can use constants like $\pi$ in your answer.

**Question 12 (5 pts)** If the ADC converting the signal from the breakbeam has a resolution of 25Hz (1/25s), how might this affect the output of the encoder and any distance estimates? Briefly describe 2 different scenarios.

*A transform **T** specifies the pose of a car and a point **p** specifies a destination way-point towards which the car is driving. You are developing a P-controller for driving the car to the way-point.*

**Question 13 (5 pts)** Specify a quantity to be used as an error measure for input into the P -controller. Justify your choice.

**Question 14 (5 pts)** Specify a quantity to be used as output of the P controller. Justify your choice.

**Question 15 (10 pts)** Give an expression for calculating the error quantity in terms of $\boldsymbol{T}$ and $\boldsymbol{p}$.

**Question 16 (5 pts)** Give the expression for calculating the output of the P controller in terms of the error input quantity you have selected.

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## Extra space for answers/working

- If you write answers here, indicate as such under the appropriate question.