Name: ___________________________ ITU ID: _____________________ Signature: ____________

İSTANBUL TECHNICAL UNIVERSITY

Department of Computer Engineering

BLG456E – Robotics – Fall 2015

Final exam.

BLG456E FINAL

Duration: 120 minutes. **There are <u>17 questions</u>.**

Rules: - <u>Not</u> open-book. No extra notes or books are allowed.
- Cellphones must be put away. Basic calculators are allowed.
- Answers must be in English. Put your name or ID on all pages.
- **<u>Show your working.</u>** Extra paper can be requested. Indicate if the back sheet is used.
- Do **not** talk to invigilators about exam contents – <u>not even definitions of common words</u>.
- If you write in the margins, indicate under the relevant question.

Reinforcement Learning

Question 1 (3 pts): In SARSA learning what do the letters in the acronym stand for?

Question 2 (5 pts): Why is "bootstrapping", used in reinforcement learning methods like SARSA, good to do?

Question 3 (13 pts): You will apply SARSA learning to a robot learning to follow a wall on its left. The robot has a range sensor on its left side, running at a frequency of 10 Hz, that is sufficient to determine whether the robot state is NEAR, FAR or UNDEF. The robot has two possible actions that it can take each time it gets a reading: LEFT or RIGHT. The robot gets a punishment if it hits the wall or gets too far away, otherwise no reward. Initialising the value function Q to zero, write the three tables representing the value function after each update below (use a learning rate 0.5 and temporal discount 0.5).

(t=0.0) Initial Value Function:

(t=0.1) Begin State: NEAR. Action: LEFT. Reward: -16. Next State: UNDEF. Action: RIGHT.

(t=0.2) Begin State: UNDEF. Action: RIGHT. Reward: 0. Next State: NEAR. Action: LEFT.

Question 4 (5 pts): In terms of information available to the learner, why is reinforcement learning more difficult than supervised learning?

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Spatial Transforms

*The camera of car-like Robot A sees another of the same kind of robot, Robot B, and determines the transform from Robot A to Robot B, which is expressed by matrix N below. The transform from the World frame of reference to Robot A is expressed by matrix M. In this problem, we model only **two dimensions** but are using **homogeneous coordinates.***

$$M=\begin{bmatrix}-1 & 0 & 0\\ 0 & -1 & 4\\ 0 & 0 & 1\end{bmatrix} \qquad N=\begin{bmatrix}0 & -1 & 2\\ 1 & 0 & -1\\ 0 & 0 & 1\end{bmatrix}$$

Question 5 (10 pts): Draw this situation below, ensuring to show all 3 frames of reference, labelling their x and y axes, and labelling the angles and distances of transforms.

Question 6 (8 pts): What is the matrix representing the transform from the World frame of reference to the frame of reference of Robot B? *Show your working.*

Question 7 (8 pts): Robot B is travelling, in its own frame of reference, 5 ms^{-1} forwards (in the positive x direction). Using matrix algebra, determine its velocity relative to Robot A (partial marks for determining this without matrix algebra). *Show your working.*

Question 8 (4 pts): What is the name of the general robot problem that must be solved *first* in order to acquire matrix M above?

Sensors & localisation

Question 9 (4 pts): Give examples of plausible (i.e. reasonable) latency and sensitivity of a photo sensor.

Question 10 (4 pts): What might cause errors with the results returned by an encoder?

Question 11 (2 pts): What is the name of the kind of control used when a robot does not attempt to localise?

Question 12 (2 pts): What is the name of the kind of control used when a robot uses only encoders to localise?

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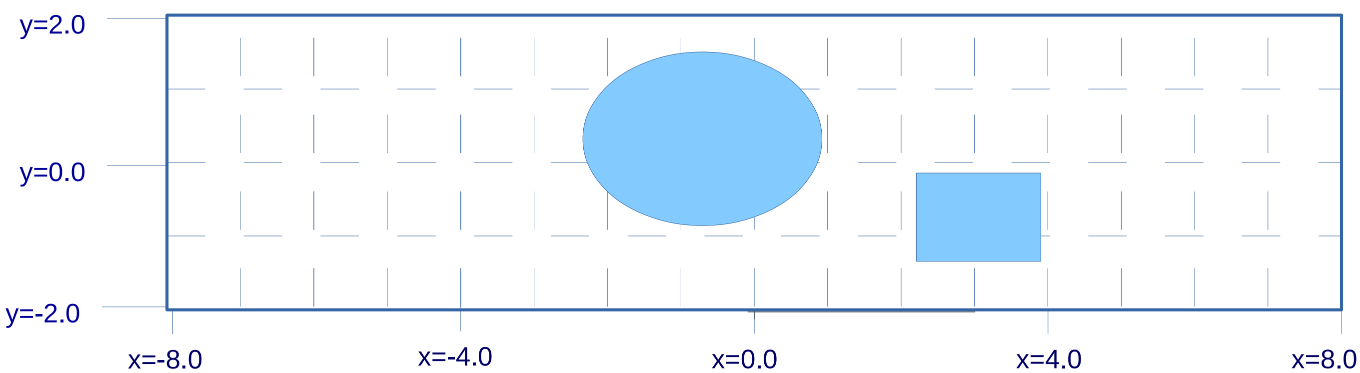
Question 13 (7 pts): Your robot is using wireless signal strength to localise. It has determined that it is 5m away from a hotspot at coordinates [0,2] and 5m away from a hotspot at coordinates [5,2]. What are your robot's coordinates? *Show your working & use general methods.*

Motion Planning

Question 14 (5 pts): What is meant by a motion planner that is **probabilistically complete**? How does this differ from **resolution completeness**?

Question 15 (10 pts): Draw a **probabilistic roadmap** over the below map. Each node should attempt 3 neighbours. Use the following random (x,y) points to build the roadmap: (-6.0,0.0), (8.0,2.0), (5.0,-1.0), (3.0, 1.0), (0.0,0.0), (-5.0,1.0), (-4.0,-1.0), (0.0,-2.0), (0.0,2.0), (-2.0,2.0), (3.0,-2.0), (1.0,1.0).

Take note of the scale of the map. Grid lines are provided.



Question 16 (4 pts): Augment the above roadmap with the start (-6.0,1.0) and goal (7.0,1.0) points, clearly labelling them with S and G and illustrate the shortest path S to G. What is the name of an algorithm that you can use to calculate such a shortest path from the augmented roadmap?

Question 17 (5 pts): What is the main difference between the Probabilistic Roadmap (PRM) algorithm and Rapidly-Exploring Random Trees (RRT)?

Trignometry Table

deg	**0**	**30**	**45**	**60**	**90**	**180**	**270**	**360**
rad	π	$\pi/6$	$\pi/4$	$\pi/3$	$\pi/2$	π	$3\pi/2$	2π
sin	0	$1/2$	$\sqrt{2}/2$	$\sqrt{3}/2$	1	0	-1	0
cos	1	$\sqrt{3}/2$	$\sqrt{2}/2$	$1/2$	0	-1	0	1
tan	0	$\sqrt{3}/3$	1	$\sqrt{3}$	*NA*	0	*NA*	0