Name: _____ ITU ID: _____ Signature: _____

İSTANBUL TECHNICAL UNIVERSITY

Department of Computer Engineering

BLG456E – Robotics – Fall 2016

Final exam.

BLG456E FINAL

Duration: 120 minutes. **There are 17 questions.**

Rules:
- Not 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.
- **Show your working.** Extra paper can be requested. Indicate if the back sheet is used.
- Do **not** talk to invigilators about exam contents – not even definitions of common words.
- If you write in the margins, indicate under the relevant question.

General Robotics & Architectures

Question 1 (5 pts): Define the modern word "robot". Specify where your definition comes from. If it is your own definition, describe how it differs from another widely known definition.

Question 2 (4 pts): In the context of STRIPS, what is meant by a *precondition*? Give an example of a precondition.

Question 3 (4 pts): Many modern robots have sensors similar to Shakey's. Name 3 of Shakey's sensors for which similar sensors may be found on modern robots like the Turtlebot or PR2.

Question 4 (5 pts): What are the essential characteristics of a *behaviour* in behavioural robotics?

Mobile Robot Kinematics

Question 5 (7 pts): You have a differential-drive robot that you want to move with a forward velocity $\dot{x}$ of $1.0\,ms^{-1}$ and an (anticlockwise) angular velocity $\dot{\theta}$ of $2\ rad\,s^{-1}$. Calculate the radius of the circle through which this robot is turning. **Show your working.**

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Question 6 (7 pts): The wheel-base l of the robot is $l=0.1\,m$. In order to achieve the desired $\dot{x}$ and $\dot{\theta}$, at what velocities $\dot{x}_R$ and $\dot{x}_L$ should you drive the right and left wheels? **Show your working.**

Localisation & Mapping

Question 7 (8 pts): Our robot uses a grid-based map representation. The grid has 100×100 entries. The location of the centre of grid entry $\text{grid}[0][0]$ in the map frame of reference is $(-4.95,-4.95)$. The location of grid entry $\text{grid}[99][99]$ is $(4.95,4.95)$. The robot is currently at location $(-1.25,0.05)$ facing along the positive x axis. Its 5 laser range sensors at angles from front (expressed anticlockwise) of $90°,45°,0°,-45°,-90°$ report distances $6,\sqrt{2},1,-,3$,where - refers to lack of a reading. Assuming no objects are closer that the sensors' minimum range and that we choose to entirely believe the information reported by the laser range sensors, what are the indices of the grid entries that should be set to occupied? **Show your working.**

Spatial Transforms

Question 8 (9 pts): A hungry robot receives a message informing it that a particular location $L_W=[x_W,y_W]^T$ contains a nice lollipop. The location is with respect to a map (world) reference frame. The robot wants to move towards the lollipop.

The robot's location is $R=[X,Y]^T$ and its orientation with respect to the map is θ , the orientation of the robot's *X* axis anticlockwise from the map's *X* axis. The robot's reference frame's positive *X* axis corresponds corresponds to its forward direction and its positive *Y* axis corresponds to its left.

Give an expression for calculating the location $L_R=[x_R,y_R]^T$ of the lollipop with respect to the robot's own reference frame. **Show your working.**

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Question 9 (6 pts): The robot is a differential drive robot. Give a control rule for calculating the forward-back velocity and angular velocity components of a twist $(\dot{x}, \dot{\theta})$ that the differential drive robot could follow to get to the lollipop. What are the pros and cons of such a control rule? Give the conventional name for the rule or describe how it differs from a named rule.

Question 10 (6 pts): The lollipop is escaping! Its velocity in the world frame of reference is $\dot{L}_W = [\dot{x}_W, \dot{y}_W]^T$. Assuming the robot is currently stationary, give an expression for the lollipop's velocity in the robot's frame of reference $\dot{L}_R = [\dot{x}_R, \dot{y}_R]^T$. **Show your working.**

Question 11 (4 pts): If the robot also was able to specify the left-right $(\dot{y})$ component of the twist in additional to the forward-back component, its differentiable degrees of freedom would now match its degrees of freedom. What is the word used for robots whose differentiable degrees of freedom match their degrees of freedom?

Learning

Question 12 (6 pts): A robot is going to learn how to wall-follow using imitation learning. A user drives a differential-drive robot with a laser range scanner around a maze, following the walls and going through doors. The output of that activity is going to be provided to a supervised learning algorithm. Describe (i) what data will need to be recorded and provided to the supervised learning algorithm and what form it will need to take and (ii) the domain and the range of the function that is going to be learnt by the supervised learning algorithm.

Question 13 (5 pts): Instead of supervised learning, if we want to use reinforcement learning to learn wall-following, what would be the advantages and disadvantages?

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Question 14 (6 pts): What would we need to provide to the reinforcement learning algorithm and what would it provide us after learning?

Question 15 (5 pts): In reinforcement learning, what is the domain and the range of a Q function?

Motion Planning

Question 16 (9 pts): A holonomic robot is navigating towards a goal (G_x, G_y) in a 2D world with N obstacles with location (X_i, Y_i) for $0 \leq i < N$. It is going to use the Potential Fields method to navigate. Write down an example potential function that can be used for this purpose. What mathematical operation needs to be done to the potential function so that it can be used to generate robot velocities?

Question 17 (4 pts): Assume that a grid map that specifies whether each grid entry is occupied or free is given in the form of a 2D array. In the transform & search approach to path planning, what theoretical data structure would this map need to be interpreted as, or *transformed* into, to enable search? Name an algorithm that could then be used for the *search* phase?

Glossary

Stationary (adj.) – not moving, still. **Pioneer** (v.) - start, explore for the first time. **Lollipop** (n.) - a kind of sweet/treat.
Domain (of a function) (n.). - If a function is `y=f(x)` then the domain is the set of possible values of `x`.
Range (of a function) (n.). - If a function is `y=f(x)` then the domain is the set of possible values of `y`.
Clockwise (adj.) - the rotational direction in which clocks hands travel.
Anticlockwise (adj.) - the rotational direction opposite from that in which clocks hands travel.
Conventional (adj.) - typically accepted, usual.

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