İSTANBUL TECHNICAL UNIVERSITY
Department of Computer Engineering
BLG456E – Robotics – Spring 2013
Practice questions for final exam.
The below questions encompass mostly the practical aspect of the final exam.
The final exam will include 10 questions like those below.
Conceptual questions related to the contents of the lectures may also be asked.

BLG456E PRACTICE

***** You should know your basic sines and cosines (0, π, π/2, 3π/2). *****

***** Calculators will be allowed, but using fractions will make your life easier. *****

Your autonomous car is following another car. You will install a control system whose aim will be to keep your car 2 seconds behind the other car. In other words, between the time the leading car passes a roadside landmark and the time that your car does, there should be only 2 seconds (in road traffic terminology this is called the "2 second rule").

Question 1: Write down the inputs and outputs of the *system being controlled* and the inputs and outputs of the *controller* you would install to control it.

Question 2: Write down the input-output equation for a P controller controlling this system. Using educated guesses for all constants, give three example input/output pairs (these will be numbers) of the **controller**.

Question 3: Determine whether a P controller would be a good controller for this system. If not, what are the problems, and how might they be remedied?

Question 4: Referring to the expected behaviour of the car, what would happen if the gain of the P controller was chosen:
a) too low.
b) too high.

Question 5: A robot on rails has a current orientation of one of 0 , $\frac{\pi}{2}$, π , or $-\frac{\pi}{2}$. It has no prior information about its current orientation. Write down the prior probability of each orientation and justify your answer.

Question 6: The probability of a visual face detector detecting a face if a human is in front of the robot is 0.8 [`P(FaceDetector=yes | NextToHuman(state)=yes)=0.8`]. The probability of it detecting a face if there is no human in front of the robot is 0.3 [`P(FaceDetector=yes | NextToHuman(state)=no)=0.3`]. The prior probability of there being a human in front of the robot is 0.1 [`P(NextToHuman(state)=yes)=0.1`].
a) What is the probability of the robot failing to detect a face if there is a human in front of the robot? *Write down both the expression and the number.*
b) What is the probability of the robot detecting the absence of a face if there is no human in front of the robot? *Write down both the expression and the number.*
c) What is the prior probability of there being no human in front of the robot? *Write down both the expression and the number.*
d) What is the Maximum Likelihood (ML) estimate as to whether there is a human in front of the robot if the robot detects a face? *Write down both the expressions and the numbers representing the appropriate likelihoods.*
e) What is the Maximum Likelihood (ML) estimate as to whether there is a human in front of the robot if the robot detects no face? *Write down both the expressions and the numbers representing the appropriate*

likelihoods.

f) What is the Maximum A Posteriori (MAP) estimate as to whether there is a human in front of the robot if the robot detects a face? *Write down both the expressions and the numbers representing the appropriate probabilities.*

g) What is the Maximum A Posteriori (MAP) estimate as to whether there is a human in front of the robot if the robot detects no face? *Write down both the expressions and the numbers representing the appropriate probabilities.*

Question 7: Name one path planning algorithm that is *complete.* Explain why it is complete.

Question 8: Name one path planning algorithm that is not *complete* but is *resolution complete* and explain why. Give a definition of resolution completeness in your answer.

Question 9: Name one path planning algorithm that is not *complete* but is *probabilistically complete* and explain why. Give a definition of probability completeness in your answer.

Question 10: Under what conditions would *iterative forward search* be a good path planning algorithm to choose? What are its faults?

Question 11: Suggest some pseudocode for the *iterative forward search* algorithm.

Question 12: Give an example of a set of *motion primitives* for a mobile robot (choose 3-6 primitives).

Question 13: What are the problems with *grid-based path planning* algorithms, and their strengths?

Question 14: A robot weather balloon is responsible for measuring its current altitude. Suggest a discrete probabilistic dynamics model governing the balloon's current height. Do not attempt to model the balloon's velocity, do not worry about incorporating an observation model, and do not worry about specific measurements; your only task is to suggest a discrete probabilistic dynamics model. Assume time step sizes of 10 seconds and discretise the height of the balloon into 5 categories:

- Grounded.
- 0.5-10m.
- 10-500m.
- 500m-20000m.
- 30,000m-80,000m.

Question 15: The pose of a mobile robot in the world coordinate frame is given by $_W T_R = \begin{bmatrix} 1 & 0 & -1 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \end{bmatrix}$.

Give the orientation and position of the robot with respect to the world coordinate frame. Use radians and metres for all units.

Question 16: The pose of a mobile robot in the world coordinate frame is given by $_W T_R = \begin{bmatrix} 0 & 1 & 9 \\ -1 & 0 & 2 \\ 0 & 0 & 1 \end{bmatrix}$.

Give the orientation and position of the robot with respect to the world coordinate frame. Use radians and metres for all units.

Question 17: A mobile robot is oriented at an angle of $\frac{\pi}{4}$ radians and positioned at a location of (3,5) with respect to the world reference frame. Give the:

- pose vector
- transformation matrix

expressing the robot's pose in the world coordinate frame.

Question 18: A mobile robot is oriented at an angle of $\frac{\pi}{4}$ radians and positioned at a location of (3,5) with respect to the world reference frame. The front left wheel of the robot is oriented at an angle of 0 radians and a location of (2,1) in the robot reference frame. Give the:

- pose vector
- transformation matrix

expressing the wheel's pose in the world coordinate frame.
What is the position of the wheel in the world coordinate frame?

Question 19: A mobile robot is positioned at a location of (3,5) in the world reference frame. Give the robot position in the world reference frame in *homogeneous coordinates*.

Question 20: A differential-drive mobile robot has a wheel base of $10cm$. It has a wheel radius of $4cm$. An encoder is attached to each wheel. Holes in the encoder are at a radius of $1cm$ to the centre of the wheel and there are 10 of them on each wheel. The left encoder measures the passing of 10 holes (by measuring voltage transitions) and the right wheel measures the passing of 20 holes in the space of 10 seconds. Assuming the robot is moving with each wheel turning at a constant rate, and starts at coordinate (0,0) pointing along the positive x axis, calculate:
a) The angular velocity of left and right wheels (in radians per second).
b) The robot's forward velocity (in metres per second).
c) The robot's angular velocity (in radians per second).
d) The arc distance the robot has moved after 5 seconds (in metres).
e) The robot's new orientation after 5 seconds (in radians).
f) The new x,y location of the robot after 5 seconds (in metres).

You can use either decimals or fractions to express your working & answer and can include constants (like π) unevaluated.

Question 21: A mobile robot is initially located at $(x_w, y_w) = (5,5)$ in the world coordinate frame. It is oriented according to $\theta_w = -\frac{\pi}{2}$. This angle is expressed as an angle anticlockwise from the positive x axis. The robot moves with the following successive forward and angular velocities for the given amounts of time. For each, calculate the world position (x_w, y_w) the robot has moved to, and orientation θ_w . Draw the robot's trajectory.

Segment 1: $\dot{x}_r = 2 \quad \dot{y}_r = 0 \quad \dot{\theta} = 0 \quad \Delta t = 5$
Segment 2: $\dot{x}_r = \pi \quad \dot{y}_r = 0 \quad \dot{\theta} = \frac{\pi}{2} \quad \Delta t = 2$
Segment 1: $\dot{x}_r = 1 \quad \dot{y}_r = 0 \quad \dot{\theta} = -\frac{\pi}{4} \quad \Delta t = 12$

You can use either decimals or fractions to express your working & answer and can include constants (like π) unevaluated.

In this robot, $\dot{y}_r$ is constrained to be zero. What do we call this kind of constraint and this kind of robot?

Question 22: A 2-link robot arm is fixed in a 2 dimensional plane. The length of the links is 4cm and 3cm. The robot has its first link at 45 degrees ($\frac{\pi}{4}$ rad) anti-clockwise from the ground, and the second link is at 45 degrees ($\frac{\pi}{4}$ rad) anti-clockwise from the direction of the first. What is the position of the **end point** of the second link?

Question 23: What is the name for the calculation made in the previous question? Why is calculating its inverse (calculating joint angles from the end point position) calculation generally difficult to do?

You are trying to steer your autonomous car. It currently has the following dynamic state: $\begin{bmatrix} x_w \\ y_w \\ \theta_w \\ \dot{x}_r \\ \dot{y}_r \\ \dot{\theta}_r \end{bmatrix} = \begin{bmatrix} 3 \\ 5 \\ \pi/2 \\ 1 \\ 0 \\ \pi/2 \end{bmatrix}$

(all units are metres, radians, and seconds).

Question 24: Assuming there is no acceleration of the car, determine the dynamic state of the car after 5 seconds. Draw the path of motion, labelling the radius of curvature, distance travelled, and angle travelled around the centre of curvature.

Question 25 (3 pts): What is the difference between proprioceptive and extereoceptive sensing? Give an example of each.

Question 26 (3 pts): Give 3 robot learning scenarios, together with the algorithms used for learning, the data structures learnt, and how the data structures are put to use.

Question 27 (3 pts): Suggest a robot learning approach for a robot learning to hit a tennis ball.

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