

CPE 482 - Autonomous Mobile Robots

Final Exam

March 19, 2009

Name:

Signature:

Total Marks: 70

Open Book

Due: 7:00pm Thursday, March 19, 2009, by handin, just logon to Vogon.
From the directory that has your exam file My482exam.pdf type:

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>handin cmclark CPE482_FinalExam My482exam.pdf
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Multiple-Choice – 2 marks awarded for each correct answer, 1 mark deducted for each incorrect answer, 0 marks if no answer. Circle the answer that BEST completes the sentence.

1. Different types of robot locomotion include
 - a) Sliding.
 - b) Rolling.
 - c) Flying.
 - d) All of the above.

2. In Proportional feedback control, adjusting the gain K
 - a) Will always reduce the error.
 - b) Can lead to unstable behavior in the system being controlled.
 - c) By decreasing it will always decrease the error more quickly.
 - d) All of the above.

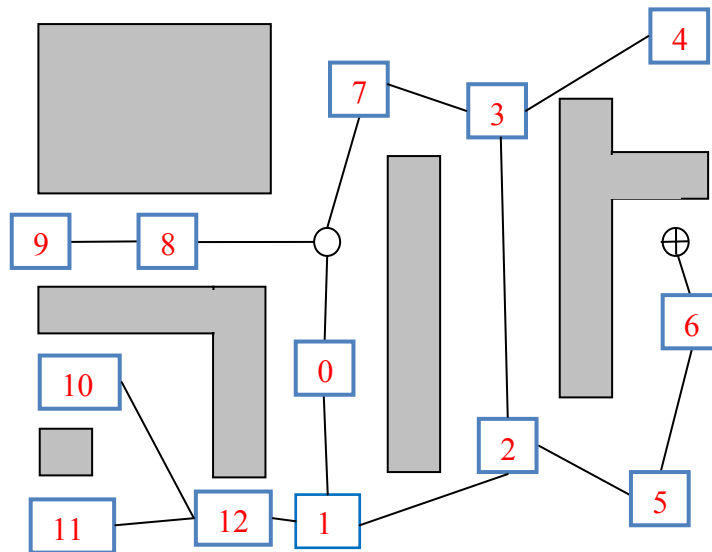
3. Markov localization, the Markovian assumption is made which assumes that
 - a) The probability that a robot's state estimate equals the actual robot state is maximized.
 - b) The current state is only dependent on the previous state, and not the entire history of states.
 - c) Only current sensor measurements are required for accurate localization.
 - d) None of the above.

4. Particle Filtering should be used instead of Kalman Filtering
 - a) When 100000 particles minimum are needed.
 - b) When the initial robot position is unknown.
 - c) When the robot is operating in an environment without any locations that produce identical sensor measurements.
 - d) None of the above
5. A motion planning algorithm will be good for many applications if
 - a) The algorithm is slow and a sub-optimal.
 - b) It is not complete.
 - c) It might not create a feasible trajectory.
 - d) None of the above
6. A robot will have better localization capabilities if it uses encoder measurements instead of control inputs in the prediction step because:
 - a) Encoders have no errors.
 - b) Encoders do not model slipping.
 - c) The model that takes the control inputs and converts them to real wheel motion is not perfect.
 - d) All of the above
7. Markov Localization can be used instead of Particle Filter localization when:
 - a) The environment is large enough.
 - b) There are only 10 possible values for each of the 3 degrees of freedom of the state vector.
 - c) The sensor model is unknown.
 - d) All of the above
8. If a robot localized itself using a particle filter with 5 particles, but had no knowledge of its start location,
 - a) The localization algorithm could run slowly because it uses so many particles.
 - b) The localization algorithm would perform extremely well because it has 5 particles and therefore 5 estimates of the state instead of one.
 - c) All 5 particles would go through a prediction step.
 - d) None of the above.
9. The X80 is equipped with:
 - a) No active sensors
 - b) No passive sensors.
 - c) All active sensors.
 - d) None of the above.
10. If automobiles were build with 4 swedish wheels,
 - a) The automobile would be able to move sideways.
 - b) Parallel parking would be much easier.
 - c) We would have trouble driving quickly on curved roads.
 - d) All of the above

Question 11: (10 marks)

The A* algorithm is being used to plan a path through a building hallway system. Given the map below, show the first 5 iterations of the A* algorithm by numbering the cells in the order that they are explored. The start location is \bigcirc and the goal location is \oplus . Provide details of the iterations (including the first). Details should include the fringe set and their path cost breakdowns ($f(n)$, $g(n)$, $h(n)$). That is, fill in the first 5 rows of the table below. Finally, draw the final path on the figure.

You can assume that the admissible heuristic used to calculate $h(n)$ is the Euclidean distance to the goal. The Euclidean distance is $= \text{sqrt}(\Delta x^2 + \Delta y^2)$, where $\Delta x = x(\text{goal}) - x(n)$ and $\Delta y = y(\text{goal}) - y(n)$. A ruler will help with this problem.



Node Selected	Fringe	f(n)	g(n)	h(n)
(○)	Node(0) Node(8) Node(7)	f(0) = ... f(8) = ... f(7) = ...	g(0) = ... g(8) = ... g(7) = ...	h(0) = ... h(8) = ... h(7) = ...

Question 12: (10 marks)

The ultrasound range sensors used on the X80 must be useful sensors but must be used with care. Answer the following questions regarding these sensors

- a) Explain the basic principles on how the sensor works in 4 sentences or less. Be sure to use a diagram, labeling variables on the diagram. Give the equation used to calculate range.
- b) Compare the use of sonars above water versus underwater. Provide 2 issues of comparison. For each issue, explain why the issue arises in 2 sentences or less.

Question 13: (10 marks)

An Autonomous Underwater Vehicle can surface to receive GPS measurements x , y and z with characteristics $(\sigma_x \sigma_y \sigma_z)$. The GPS sampling rate is 1 Hz. While underwater, the AUV uses accelerometers that measure accelerations d^2x/dt^2 , d^2y/dt^2 and d^2z/dt^2 with characteristics $(\sigma_{d^2x/dt^2} \sigma_{d^2y/dt^2} \sigma_{d^2z/dt^2})$ to estimate its state. A particle filter is used to fuse these two measurements to produce the state estimates of $[x \ y \ z \ \theta]$.

- a) What is a particle?
- b) Provide an outline of the PF algorithm
- c) Explain how the prediction step in the algorithm could use the accelerometer measurements. Assume the accelerometer measurements have a sampling rate of 30 Hz.
- d) Explain which step in the algorithm would use the GPS measurements. How would they be used? Assume the AUV will surface every 5 minutes.

Question 14: (10 marks)

A particle filter is used to localize a differential-drive robot within an indoor environment. The robot's state is defined by $[x \ y \ \theta]$.

- a) Consider the 3 particles below, determine the robot's position $[x \ y]$.

$x \ (m)$	$y \ (m)$	$\theta \ (rad)$	W
5.4	7.5	0.31	0.399
5.2	7.7	0.28	0.399
1.1	4.4	0.99	0.002

- b) Consider the 3 particles below, determine the robot's orientation $[\theta]$. You can assume that $\pi = 3.14$.

$x \ (m)$	$y \ (m)$	$\theta \ (rad)$	w
5.4	7.7	3.13	0.333
5.2	7.7	-3.10	0.333
5.5	7.6	3.11	0.333

- c) While conducting localization with the X80 in lab, comparing an actual measurement of 40cm with a particle's expected measurement of 41cm, could produce the same weight as when comparing an actual measurement of 70cm with a particle's expected measurement of 69cm.

Explain why this is a problem in 2 or fewer sentences.

- d) Why might it be a good idea to only resample particles when moving? Explain in 2 or fewer sentences.

Question 15: (10 marks)

In the file storage floor of a law firm, an autonomous robot is used to move boxes of files. For correct operation, the robot must be able to know within which of 4 rooms it is located.

To accomplish this, the robot is equipped with wheel encoders which measure the right and left wheel rotations (φ_r, φ_l), and a laser scanner that outputs a set of range measurements (z_t).

From experiments, the probability of being in a particular room has been determined, given it is known which room it was previously in, as well as the robot's odometry. More specifically, we know the probability functions:

$$\begin{aligned} p(l_t=1 \mid \varphi_r, \varphi_l, l_{t-1}=1) &= f_{11} \\ p(l_t=1 \mid \varphi_r, \varphi_l, l_{t-1}=2) &= f_{21} \\ p(l_t=1 \mid \varphi_r, \varphi_l, l_{t-1}=3) &= f_{31} \\ p(l_t=1 \mid \varphi_r, \varphi_l, l_{t-1}=4) &= f_{41} \\ p(l_t=2 \mid \varphi_r, \varphi_l, l_{t-1}=1) &= f_{12} \\ p(l_t=2 \mid \varphi_r, \varphi_l, l_{t-1}=2) &= f_{22} \\ p(l_t=2 \mid \varphi_r, \varphi_l, l_{t-1}=3) &= f_{32} \\ &\dots \\ p(l_t=4 \mid \varphi_r, \varphi_l, l_{t-1}=4) &= f_{44} \end{aligned}$$

Markov localization will be used determine which room the robot is residing in.

- a. Design a prediction step that determines the probability of being in each room. That is, give the equations for $p(l_t' = 1)$, $p(l_t' = 2)$, $p(l_t' = 3)$, and $p(l_t' = 4)$.
- b. Design a correction step for the algorithm. That is, give the equations for $p(l_t = 1)$, $p(l_t = 2)$, $p(l_t = 3)$, and $p(l_t = 4)$. State any assumptions necessary.

Some Equations that might be useful:

$$d = c t / 2$$

$$\lambda = c/f$$

$$D = fl/x$$

$$p(A \wedge B) = p(A | B) p(B)$$

$$E[X_1 X_2] = E[X_1] E[X_2]$$

$$\Delta\theta = (\Delta s_{right} - \Delta s_{left}) / b$$

$$\Delta s = (\Delta s_{right} + \Delta s_{left}) / 2$$

$$p(x_t | o_t) = \sum_{x'} p(x_t | x'_{t-1}, o_t) p(x'_{t-1})$$

$$p(x_t | z_t) = \frac{p(z_t | x_t) p(x_t)}{p(z_t)}$$

$$x = \frac{b(x_l + x_r)/2}{(x_l - x_r)}$$

$$y = \frac{b(y_l + y_r)/2}{(x_l - x_r)}$$

$$z = bf/(x_l - x_r)$$

$$p(x'_{i,t}) = \sum p(x_{i,t} | x_{j,t-1}, o_t) p(x_{j,t-1})$$