University of Amsterdam

Faculty of Science

Exam

Probabilistic Robotics

Master Artifical Intelligence

Retake Final Exam
Date: January 10, 2018
Time: 18.00-21.00

Number of pages: 4 (including front page)
Number of questions: 6
Maximum number of points to earn: 10

BEFORE YOU START

- Please **wait** until you are instructed to open the booklet.
- Check if your version of the exam is complete.
- Write down **your name, student ID number**, and if applicable the **version number** on **each sheet** that you hand in. Also **number the pages**.
- Your **mobile phone** has to be switched off and in the coat or bag. Your **computer or e-reader** has to be in flight-mode. Your **coat and bag** must be under your table.
- **Tools allowed**: scrap paper, calculator, notes, (electronic) book.

PRACTICAL MATTERS

- The first 30 minutes and the last 15 minutes you are not allowed to leave the room, not even to visit the toilet.
- You are obliged to identify yourself at the request of the examiner (or his representative) with a proof of your enrollment or a valid ID.
- During the examination it is not permitted to visit the toilet, unless the proctor gives permission to do so.
- 15 minutes before the end, you will be warned that the time to hand in is approaching.
- Please fill out the evaluation form at the end of the exam.

Good luck!

Probabilistic Robotics, PRR06, Fall 2017

Retake Exam, Wednesday January 10, 18:00 - 21:00, room A1.14

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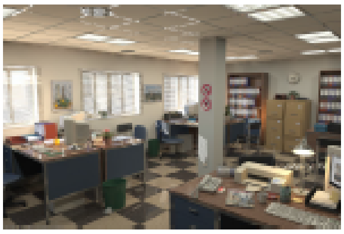
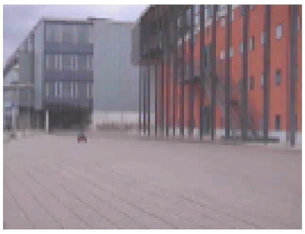
Question 1

Assume you have a robot equipped with a sensor capable of measuring the distance and bearings to landmarks. The sensor furthermore provides you with the identity of the observed landmarks. A sensor measurement $z = (z_r, z_\theta)^T$ is composed of the measured distance z_r and the measured bearing z_θ to the landmark with signature l. Both the range and the bearing measurements are subject to zero-mean Gaussian noise with variances σ_r^2 and σ_θ^2. The range and the bearing measurements are independent from each other. A sensor model models the probability of a measurement z of landmark l observed by the robot from pose x. Design a sensor model $p(z|x, l)$ for this type of sensor.

Question 2

Robots operate in many different environments. In each environment different types of landmarks may be useful. For each of the following three environments: office, outdoor and underwater think of five different types of landmarks that might be well suited.


How useful are your landmarks in combination with the following sensors: sonar, laser, monocular vision, and stereo vision? Please submit your ratings[1] (”++” very useful, ”+” useful, ”-” not useful, ”–” not possible) in tabular form with short explanations for not-obvious ratings.

Question 3

Suppose we have an existing (and working!) EKF implementation of feature-based localization for a mobile robot operating on a paved surface. Now suppose we like to operate the robot in outdoor terrain where the robot can face four very distinct surfaces: pavement (where the existing EKF implementation works well), ice (where the wheels slip at random), water (where the robot floats), and mud (where the wheels frequently become stuck). To do this, we se set up a Rao-Blackwellized EKF with extends the state of the existing EKF with a discrete surface variable.

Note: a simple yes/no is insufficient. Please explain your answers. And please keep things simple! This question is not about the dynamics of floating robots!

[1] Please note, that different ratings can be possible under different assumptions (e.g. lighting conditions). Yet, you may assume the ’typical’ conditions for each environment.

(a) In the Rao-Blackwellized EKF, what elements of the state would be implemented by particle filters, what elements by Kalman filters?

(b) What modification would one have to apply to the EKF itself?

(c) How would you compute the weight for resampling? (No equations please, just an intuitive explanation.)

(d) Can the filter figure out the surface type? Will it?

(e) Someone proposes to replace the particle filter by a histogram filter. Is this possible? Is this a good idea? Argue why / why not.

(f) Obviously we can re-implement the EKF using FastSLAM. What would the mean for the basic filter? What variable would be represented by particles, what variables by Gaussians?

Question 4

Suppose an indoor robot uses sonar sensors with a 15 degree opening cone, mounted on a fixed height so that they point out horizontally and parallel to the ground. This is a common configuration for an indoor robot. Discuss what happens when the robot faces an obstacle whose height is just below the height of the sensor (for example, 15 cm below). Specially, answer the following questions:

(a) Under what conditions will the robot detect the obstacle? Under what conditions will it fail to detect it? Be concise.

(b) What implications does this all have for the binary Bayes filter and the underlying Markov assumption? How can you make the occupancy grid algorithm fail?

(c) Based on your answer to the previous question, can you provide an improved occupancy grid mapping algorithm that will detect the obstacle more reliably than the plain occupancy grid mapping algorithm?

Question 5

FastSLAM generates many different maps, one for each particle. The textbook didn't specify how to combine these maps into a single posterior estimate. Suggest two such methods, one for FastSLAM with known correspondence and one for FastSLAM with per-particle data association.

Question 6

Imagine you are modelling the location of a robot with linear Kalman filters. Due to a circuit error, sometimes the measurement variance is a few orders of magnitude larger than expected. This happens with a small failure rate p_f.

(a) Explain what happens to your estimates.

(b) Improve the filter, such that it fixes the above mentioned problem.

(c) Consider that p_f goes to 1, suggest an alternative improvement to the filter.

Success!

Acknowledgements

The first question is originating from Jana Košecká course ”Autonomous Robots”. The second question is based on an assignment from the Albert-Ludwigs-Universität Freiburg, written by Wolfram Burgard. The third question is from the Sebastian Thrun’s ”Statistical Techniques in Robotics” course. The fourth and fifth question is directly from the ”Probabilistic Robotics” book [2]. The last question is from the textbook ”Computational Principles of Mobile Robots” [1].

References

[1] G. Dudek and M. Jenkin, *Computational Principles of Mobile Robotics*, Cambridge University Press, 2nd edition, 2010.

[2] S. Thrun, W. Burgard and D. Fox, *Probabilistic Robotics (Intelligent Robotics and Autonomous Agents)*, The MIT Press, September 2005, ISBN 0-262-20162-3.