Probabilistic Robotics
BAIPR6, Spring 2008
Examination: Mapping & SLAM & Exploration
Monday May 26th, 9:00 - 12:00, room P.017

Arnoud Visser

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Question 1

Before a mobile robot can perform a serious application, a solution has to be found on the following four tasks:

- Where am I?
- Where have I been?
- Where am I going?
- How can I reach that location?

Unfortunatelly, these problems cannot be solved independently from each other. Each is related to a field of robotics, described with at least a chapter in the textbook [2]. Figure 1 illustrates the overlap between of those robotics fields. The overlapping regions are tagged with Roman numerals.

Give a name to each of the overlapping regions, give a short description of that field of research and explain why an integrated solution is needed.

Give enough detail to demonstrate that you are comfortable with this subject. Keep it concise, because your description can be easily become fishy due a few incorrect associations.

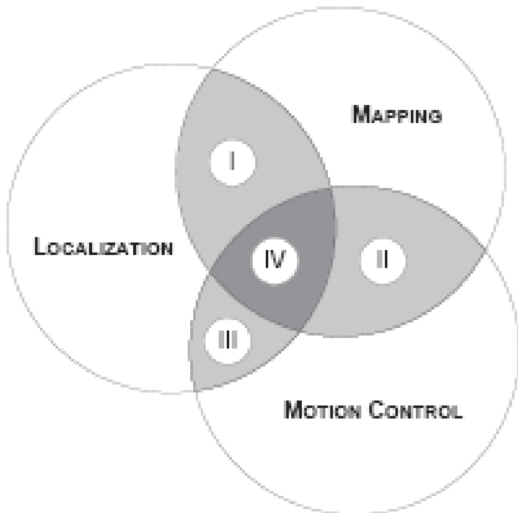

Figure 1: Tasks that need to be solved by a mobile robot. The overlapping regions represent combinations of mapping, localization and motion control. Courtesy of Makarenko *et. al.* [1]

Question 2

The *extended Kalman filter localization* algorithm in section 7.4 of the textbook depends on a multivariate Gaussian representation of uncertainty in the motion and measurement model. Noise enters the equations through the addition of (hopefully) small factor. It is important to understand that this is always an approximation: real systems never experience zero-mean white Gaussian noise. For an *extended Kalman filter* this approximation is made with an first-order Taylor expansion. For each of the noise sources below, briefly describe how the zero-mean white Gaussian noise assumption fails for a *classical Kalman filter*, and to what extend the EKF approximation solves this problem.

- odometry error in a differentially steered wheeled robot due to a mismatch in wheel size
- odometry error in a wheeled robot due to wheel slippage
- sonar errors due to multipath reflections
- temperature dependent drift in a rate gyro

Question 3

Suppose you have small LEGO-robot is moving in an indoor structured environment and needs to detect the distances to the walls around it (see Figure 2). For large robots usually time of flight sensors like laser range finders and ultrasonic detectors are used. On this LEGO-robot an omnidirectional camera will be used to measure the distance to the obstacles. To facilitate an easy detection of the obstacles, the environment is on purpose restricted to black walls and a white floor.

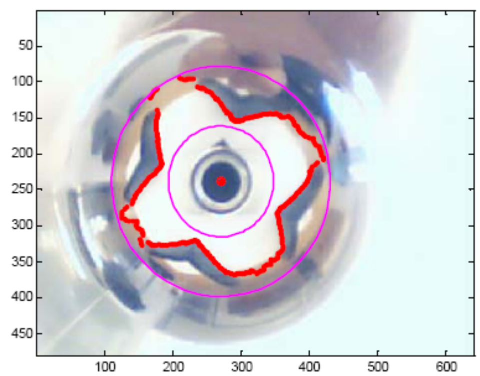

Figure 2: The view from an omnidirectional camera on the middle of crossing in a black and white world. The inner circle indicates a safe holonomic shape around the robot, the outer circle indicates the horizon (the edge of the table). Between the inner and outer circle obstacles can be found (indicated in red). Courtesy of Autonomous Systems Lab, ETH Zürich

You can now simulate a range sensor by defining a number of angular lines, and check for each line when a black wall is found. The outer circle can now be interpreted as the maximum range of the range sensor. Assume that you check 180 angular lines.

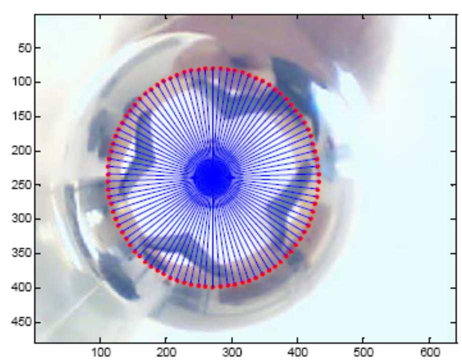

Figure 3: The view along a number of angular lines on an omnidirectional image. Courtesy of Autonomous Systems Lab, ETH Zürich

The small LEGO robot is now placed in a structured environment with the three rooms, according to the map of Figure 4. The robot can see nearly all black walls when it is in the middle of Place 1, as indicated with the circle. The robot does not know its initial orientation.

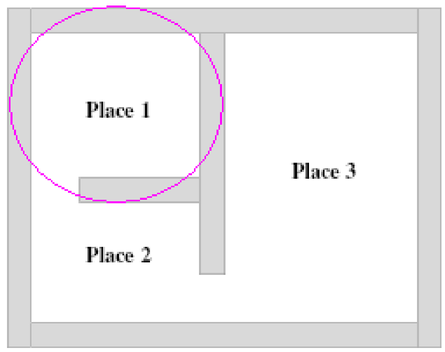

Figure 4: A small structured environment for a small LEGO robot. Courtesy of Autonomous Systems Lab, ETH Zürich

Design a localization algorithm which returns the probability that a robot is somewhere at place 1, 2 or 3. Hint: do not assume that the robot is precisely in the middle of a place. Do not use all 180 range measurements, but use as intermediate topological features (as for instance the probability that there is a gateway present).

References

[1] A. Makarenko, S. Williams, F. Bourgault and H. Durrant-Whyte, "An Experiment in Integrated Exploration", in "Proc. of the IEEE/RSJ Intl. Conf. on Intelligent Robots and Systems (IROS)", 2002.

[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.