Probabilistic Robotics Exam Sample
Dec 12 2019

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1 Question: Data Association

Illustrate the problem of data association, and present potential solutions in the Gaussian case. Discuss the heuristics that can be used to quickly compute an approximated solution.

2 Exercise: Indoor Localization

Scenario: An indoor GPS system consists of a set of beacons at known locations in the environment. These beacons transmit a data packet at periodic intervals. A packet set by the i^{th} beacon contains the following information:

- time when the packet was transmitted
- location $\mathbf{p}_i$ of the beacon

The clocks of the beacons are synchronized. A robot equipped with a receiver that can decode this packets, and timestamp their arrival. If the clocks of the beacons and of the robot would be synchronized, the travel time of the message is proportional to the distance between transmitter and receiver.

The clock on the robot is not synchronized with the one of the beacons. The robot has a differential drive kinematics, moves on a plane, and is controlled issuing a desired velocity to the left and the right wheels, but the parameters of the platform are unknown b, k_r, k_l. The control interval is ΔT. The receiver is assumed to be at the center of the robot.

2.1 Question 1

Model the dynamic system by identifying:

- State
- Measurements
- Transition Function
- Observation Function

2.2 Question 2

After having identified the system, approach the problem of estimating the robot position with a filter at your choice. Report the filter equations, for the specific problem and a sketch of filter implementation. If Jacobians are involved report the sizes.

2.3 Question 3

Exend the problem to other classes of filters.

3 Exercise: Map The Stars

Scenario: a robot moves on the surface of a planet that can be approximated by a sphere.

The robot is equipped with a (3D) odometer, that reports the relative motion between subsequent poses of the robot on the surface. The robot has a spherical camera pointed upwards, that observes the sky and sees the stars. In this scenario we assume that the camera can identify the stars.

The stars can be seen as infinitely far from the robot, thus we can observe only the azimuth and the elevation of each star.

3.1 Quesion 1

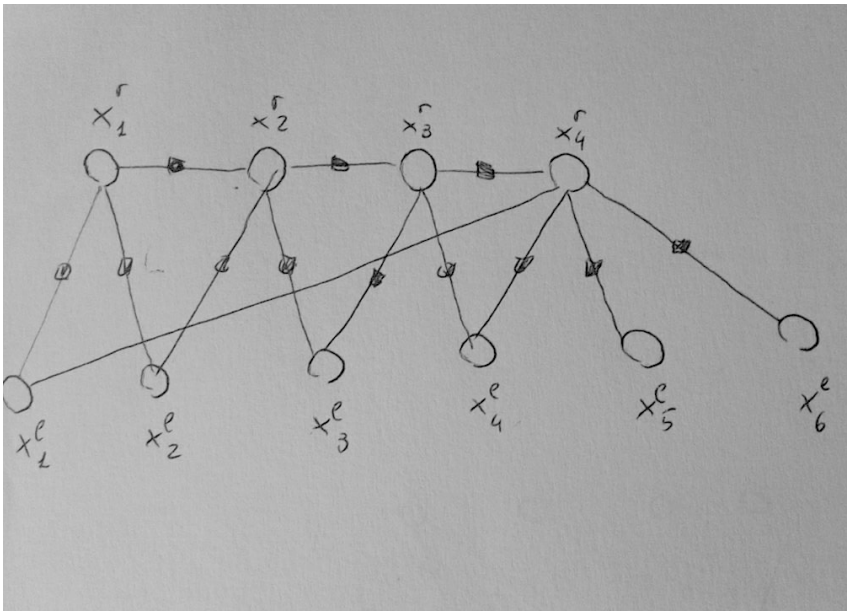
Formulate a least squares problem that, computes the trajecory of the robot and the position of the stars as azimuth and elevation with respect to the initial position of the robot.

Define:

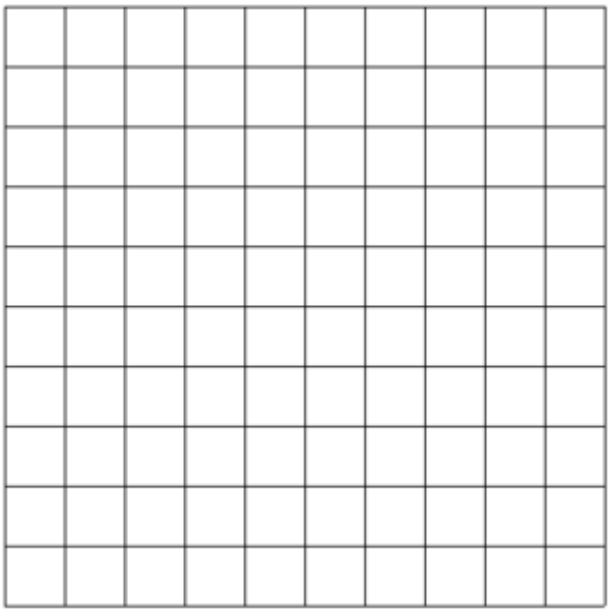
- State: Domains, parameterization of the increments, $\boxplus$ if needed.
- Measurements: Domains, $\boxminus$ if needed.
- Prediction function
- Error function
- The size of the Jacobians

3.2 Quesion 2

Consider the simple problem illustrated in the following factor graph:



where $\mathbf{x}^l$ denotes a star and $\mathbf{x}^r$ denotes a robot pose. Show the block structure of the H matrix, by filling the grid provided here:



3.3 Question 3

In case the data association would not be known how would you approach the problem?. Consider the case of sequential observations, and assume the stars are not too close to each other.