Collaborative Multirobot Localization

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- Chapter 6 in Robot Teams

Probabilistic Robot Localization

- The localization problem can be divided into two subproblems
  - Position tracking – initial position is known
  - Global self-localization – no prior information
- All previous work has been done with one robot
  - Since teams of robots can detect each other, there is an opportunity to do better.

Assumptions

- Detection models are probabilistic
  - Captures the reliability and accuracy of robot detection
- Color cameras and laser range-finders used for robot detection
- Robots are given a model of the environment
- Robots are given sensors that enable them to determine their position
- The environment is Markov
  - The robots' positions are the only measurable state

Multirobot Markov Localization

- Integrate measurements taken at different platforms
  - Each robot can benefit from data gathered by other robots
- The approach uses two rules to avoid problems from factorial distribution
  - The approach ignores events where a robot does not see another robot.
  - When a robot has been sighted, it can not be detected until the detecting robot has traveled a pre-specified distance

Data

- Odometry Measurements
  - Specify the relative change of position to the wheel encoders
- Environment Measurements
  - Robots query sensors in regular time intervals
  - These measurements establish the reference between the robot's local coordinate frame and the environment's frame of reference
- Detections
  - Robots query sensors for presence or absence of other robots.

Monte Carlo Localization

- A version of Markov localization that uses a different strategy for belief propagation

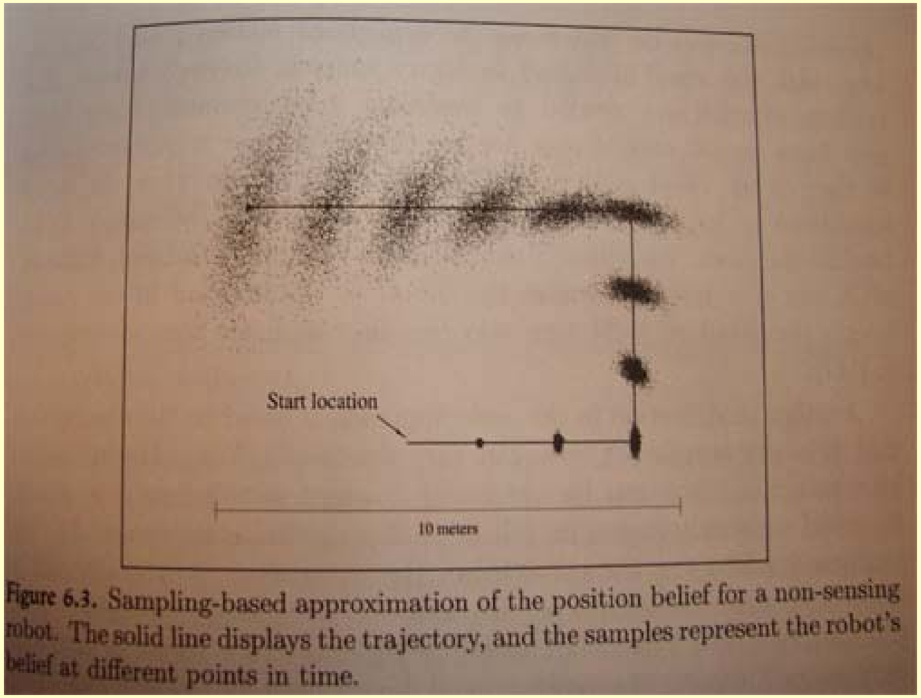
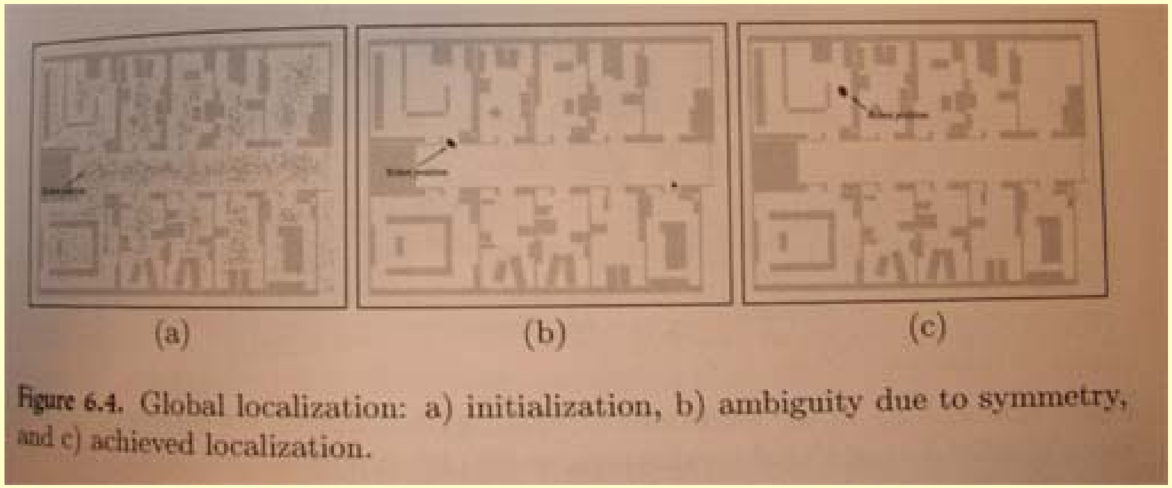


Figure 6.3. Sampling-based approximation of the position belief for a non-sensing robot. The solid line displays the trajectory, and the samples represent the robot's belief at different points in time.

Global localization example



- Localization of a single robot
- Robot achieves success

Density Trees

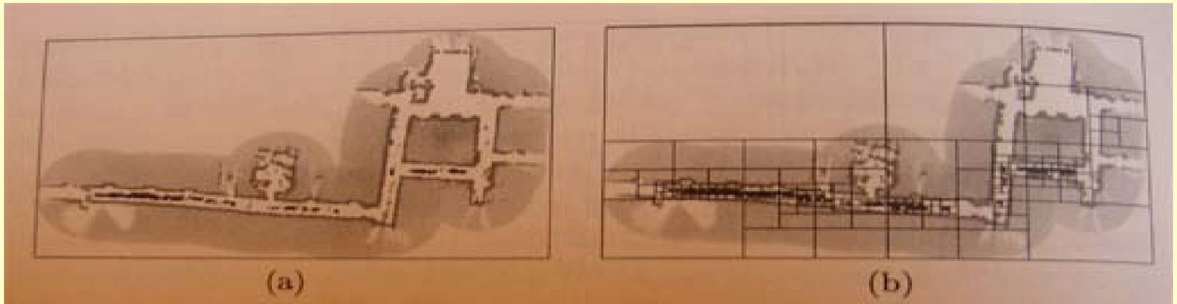


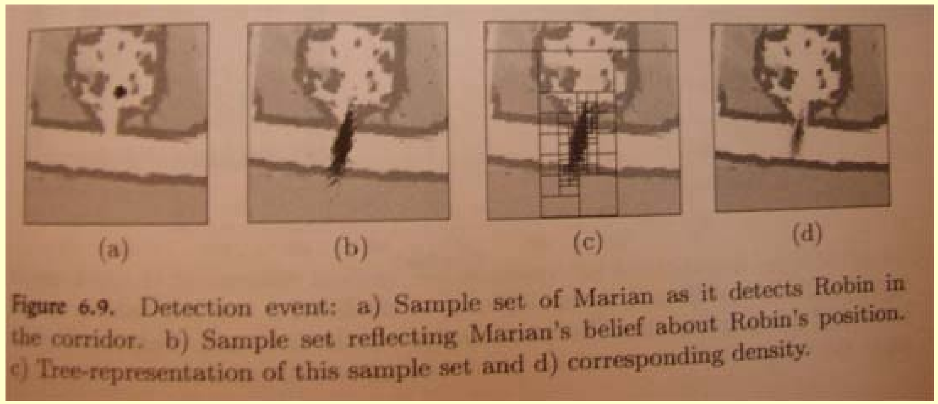
Figure 6.5. a) Map of the environment along with a sample set representing the robot's belief during global localization, and b) its approximation using a density tree. The tree transforms the discrete sample set into a continuous distribution, which is necessary to generate new importance factors for the individual sample points representing the belief of another robot.

- Approximate sample sets using piecewise constant density functions in a tree
- Each node is annotated with a hyper-rectangular sub-space of the state space of the robot
- The tree is grown by recursively splitting each node until a certain stopping goal is reached
  - When a node is split, its interval is divided equally into 2 nodes

Detection

- To determine the location of other robots
  - Onboard camera – to determine robot's ID
  - Laser range-finder – distance from current position
- To find robots in a camera image
  - The approach first filters the image by using local color histograms and decision trees tuned to the colors of the marker
  - The marker's characteristic color transition is then searched for
  - If this is found, a robot is present in the image.
  - The laser scan is then analyzed for the relative location of the robot in polar coordinates (distance and angle)

Multi-robot Example



- Robin moves through the corridor, and is detected by Marian
- Marian generates a sample set, which is converted into a density using density trees
- This density is transmitted to Robin

Multi-robot Example (2)

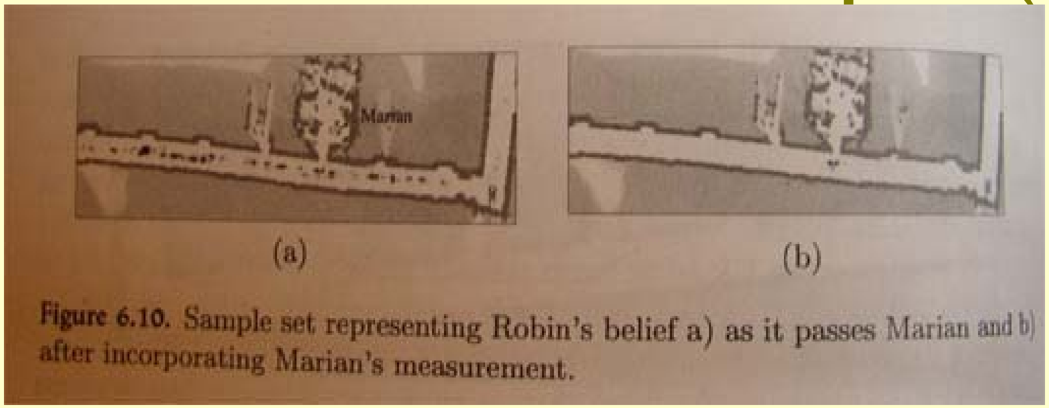


Figure 6.10. Sample set representing Robin's belief a) as it passes Marian and b) after incorporating Marian's measurement.

- Robin incorporates this density into its current belief
- As shown, the single detection completely resolves the uncertainty in Robin’s belief

Other Experiments and Data

- Environments designed to be symmetrical and challenging for the robots
  - i.e. Long identical hallways, polygons, etc.
- Involved heterogeneous and homogeneous teams of robots
  - Different types of sensors (sonar)
- In both types of simulations, an improvement was made by multi-robot localization over single robot localization.

Limits and Discussion

- Identification of robots
  - What to do when a robot is detected, but can not be identified
- False-positive detections
  - 3.5% chance of detecting a robot that is not there
  - Could be a problem in a scenario where robots see each other very rarely

Thank you!

- Questions?