Vision-based Multi-Agent SLAM for Humanoid Robots

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Simultaneous Localization and Mapping

- SLAM answers the following questions
  - Where am I? (Pose)
  - What and where are the others?
- Performance criteria
  - Localization and map must be good enough to allow navigatiion
- Localization and mapping are tightly coupled
- Main challenge for humanoid robotic soccer
- FIRA HuroCup Obstacle Run

Multi-Agent SLAM

- Increase accuracy of the map
- Increase coverage of the map
- Speed up creation of the map
- Humanoid robots provide additional challenges
  - Small processing speed
  - Small memory

Algorithm

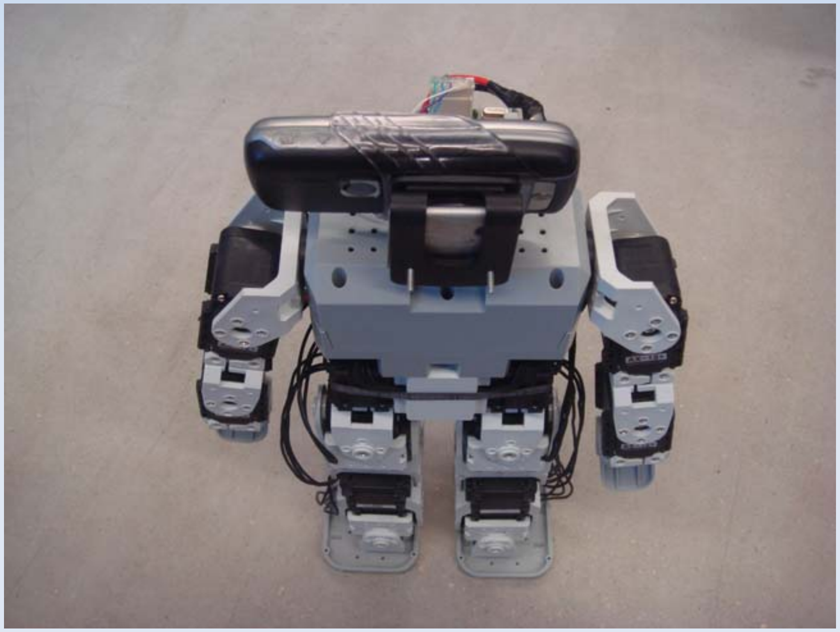
- Track each agent's pose over time using particle filters
- Map landmarks relative to best particle using an occupancy grid
- Each agent communicates
  - its pose
  - all landmarks in its map
  - Its target position

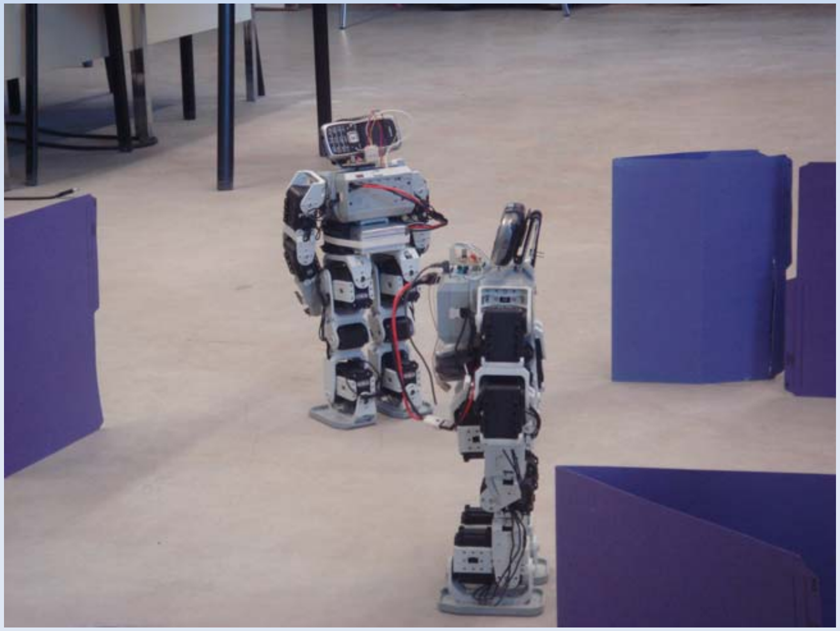
Algorithm

- Select new target pose based on
  - Coverage
  - Distance

Homogeneous Agents

- Rogue and Storm
- Bioloid Robot Kit
- Nokia Mobile Phone

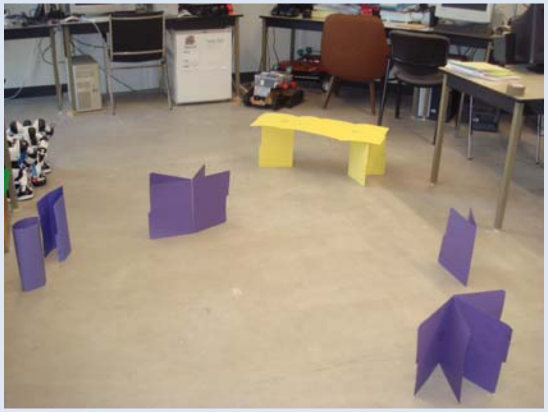




Environment

- Wall obstacles

- Gate obstacles



Particle Filters

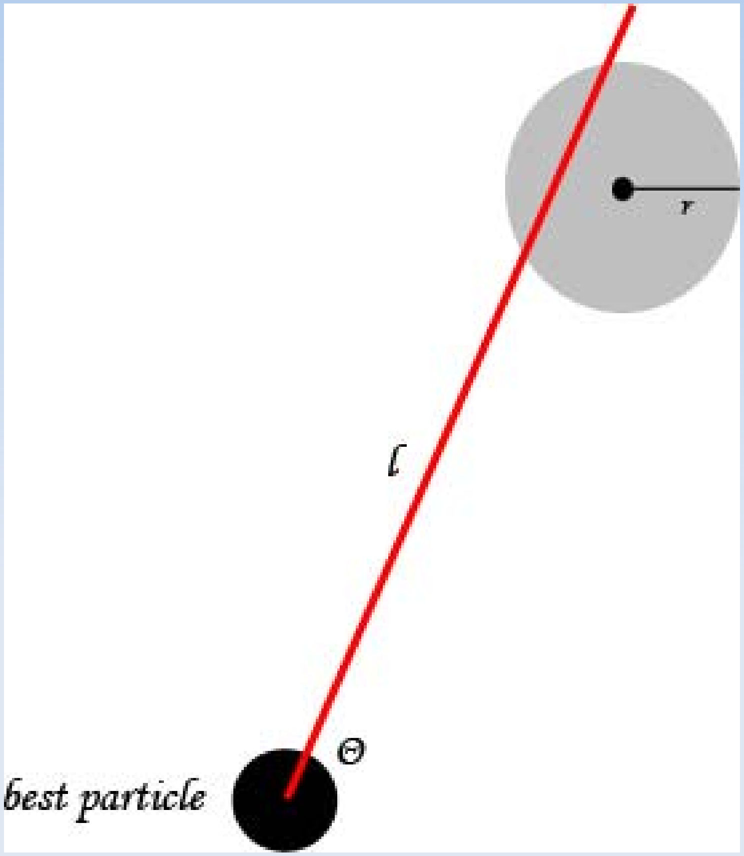
- Most popular algorithm for SLAM
- Bayesian approach
- Allows modelling of arbitrary probability distribution through weighted particles
- Particles are moved through motion model
- Sensor model is used to update weight of particles
- Resampling of particles based on weight
- Best position estimate: Weighted average

Map Representation

- Occupancy grid with 25cm x 25cm cells
  - Recency (0..255) value to handle dynamic objects
- Recency update
  - The sensor senses an object
    - If an object exists within the map relative to the best particle, its recency is increased
    - Otherwise it is initialized to 128
  - The sensor does not sense an object
    - If an object exists in the map relative to the best particle, the recency of the object is decreased

Map Representation

- Obstacle model



Communication

- Bluetooth L2CAP layer
- Decentralized, asynchronous approach
- A robot can join or leave a team at any time
- Agent sends:
  - Its estimated pose
  - Landmarks in its map
  - Minimize size of messages

Map Merging

- Sequential deployment strategy
  - Origin of world frame is known
- If a landmark send by another robot
  - If the landmark already exists in our map, then use the maximum recency value
  - If the landmark does not already exist in our map
- Store pose of nearest agent to select targets

Target Selection

- Constraints on target pose
  - Must be on the frontier
  - Euclidean distance from the target pose to the nearest agent is greater than maximum sensor range

Video

- Visualization using bluetooth communication
- Two agents use different colours
- Brightness indicates recency
- Arrows represent best particle

Conclusions

- Implementation of particle filters with
  - Motion model
  - Sensor model
- suitable for small embedded systems
- Decentralized, asynchronous communication model to support multi-agent SLAM
- Simple target selection method for frontier exploration