CMRoboBits:
Creating an Intelligent AIBO Robot
Multi-Robot Systems II

Manuela Veloso

15-491, Fall 2007

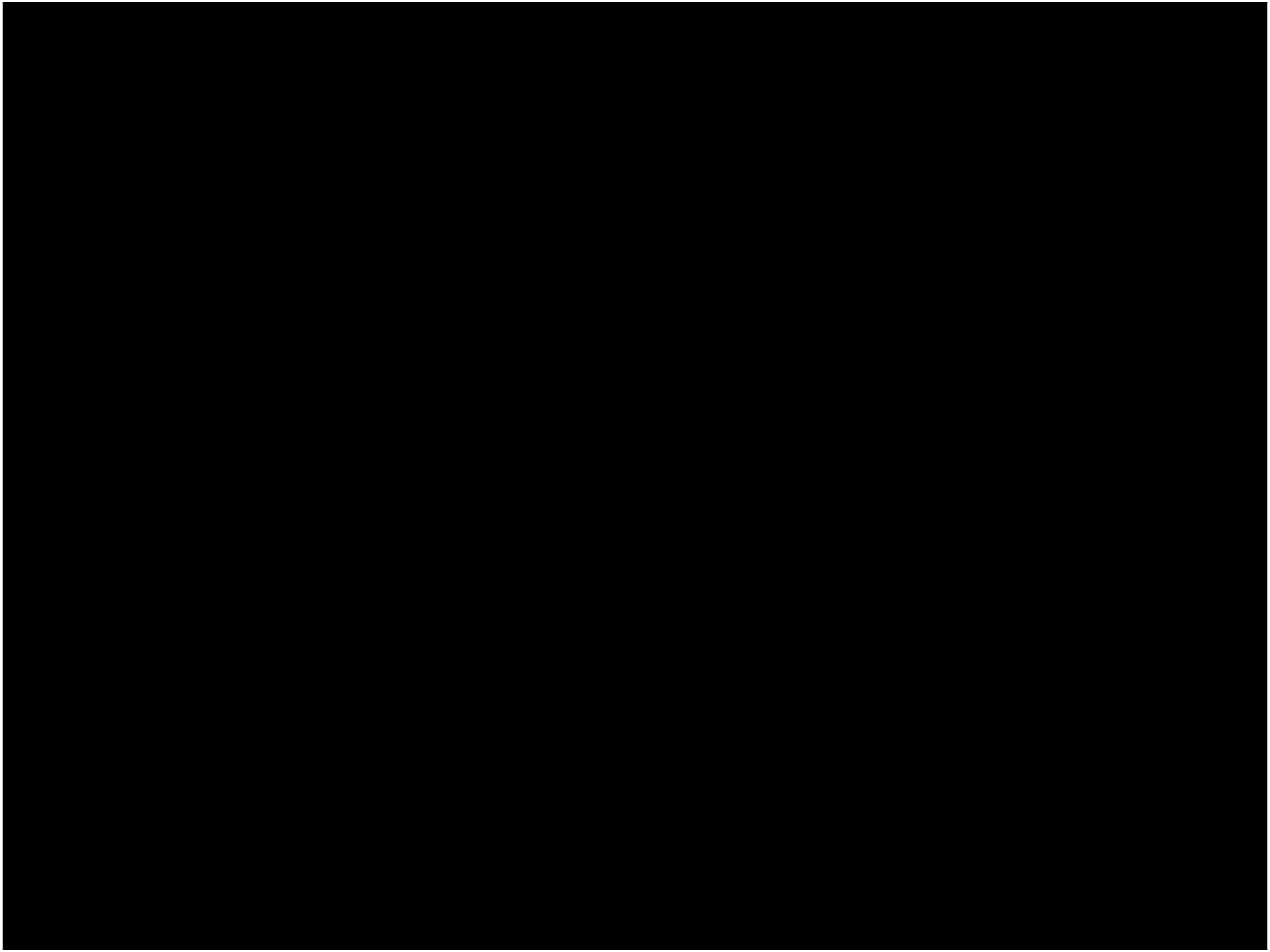
http://www.andrew.cmu.edu/course/15-491

Computer Science Department

Carnegie Mellon

Four-Legged (AIBO) Robot Soccer

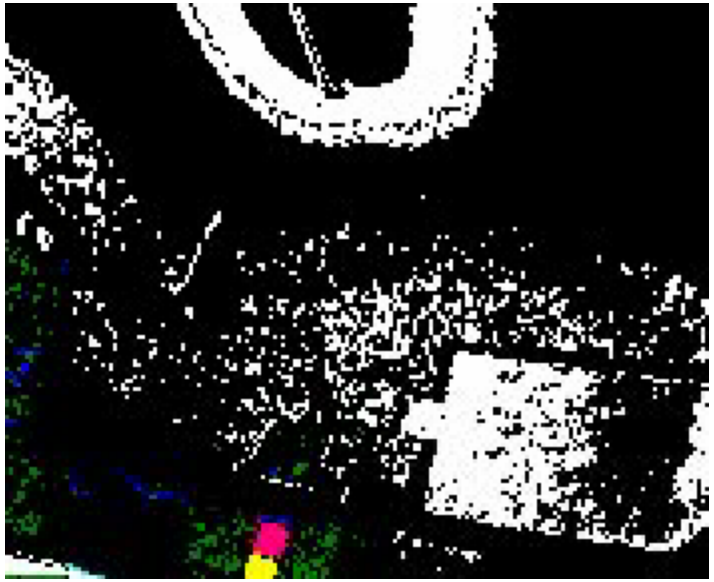
- Teams of 4 robots (initially 3 robots)
- Remarkable hardware - SONY AIBO robots
- Sensing, computing, and communication onboard



Teamwork

- Teamwork without communication
  - Team is set of individual robots
  - View of the world from own sensors
  - Teamwork achieved through *roles*
    - Attacker*: "Can I see the ball? Go to Ball. Where am I and where is the goal? Kick ball to goal."*
    - Goalie: *"Can I see the ball? Is the ball next to me? Clear the ball. Where am I? Go back to defend goal."*
- Teamwork with communication?
  - Own sensors, communication, roles

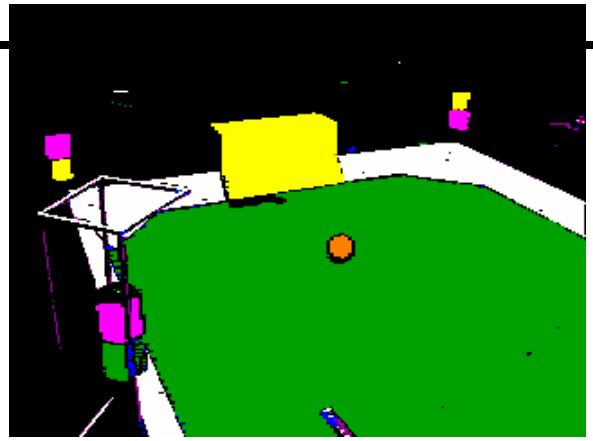
Vision



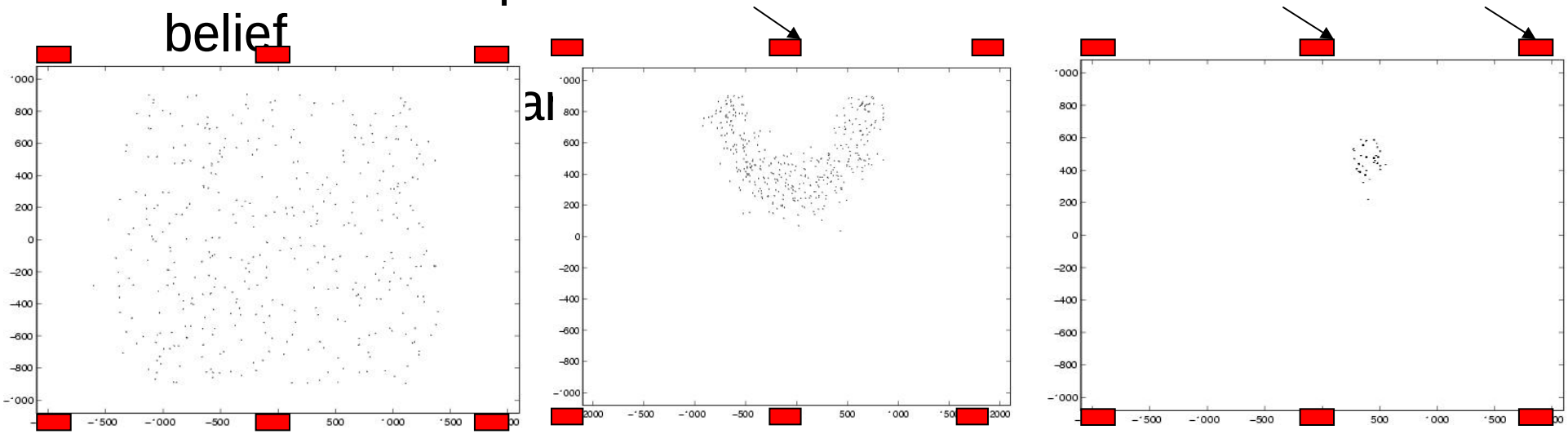
Sensor Processing

- Goal:
  - Estimate the *state* of the environment
  - Abstract from sensor *signals* to *symbols*
  - …orange ball in front… wall at 2m distance… door on the left… green light… person in front… personX entering the room…

Robot's Position – Localization



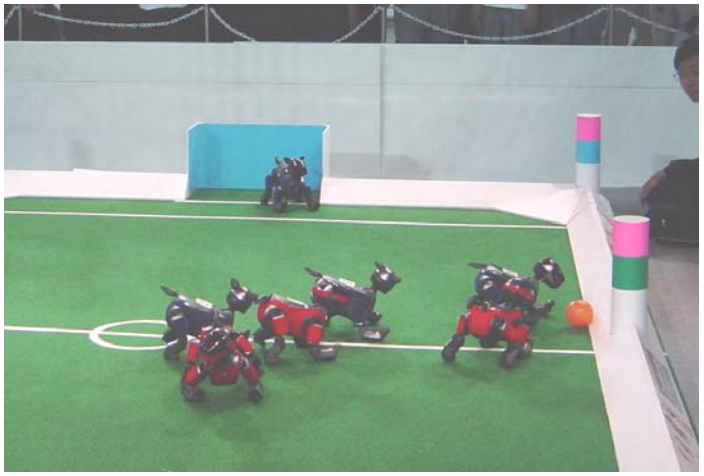
- *Apriori*: motion model, map
- *Given*: actual motion, sensing
- *Compute*: probabilistic distribution of position belief



State Information

- State - Localization
  - Position in *absolute* referential space
- State – further processed sensory data
  - “big” vector of task-relevant quantities:
  - *Relative* distance to task-relevant objects
    - Ball, goal, other robots, landmarks

Multi-Robot World Modeling



- Communication with latency
- Noise in perception/assessment
- Multiple (variable) teammates

Challenge: Combine local and communicated information to form a coherent world model

Common World Model

- Shared information:
  - Localization plus relative information produces *shared global* coordinates of objects
- Discussion
  - Impact of perceptual errors
  - Single versus multiple robots

Use of Shared Information

- Tracking
- Position of *seen* and *unseen* object
- Example:
  - Where is the ball?

Modeling from probabilistic effects of robot's own actions

Manuela Veloso, Paul E. Rybski,
Sonia Chernova, Colin McMillen

“Level 1” Prediction

- Robot predicts position of *temporally unseen/lost* object through:

  State MEMORY and MODEL

  of object motion and effect of actions

Action Models

- Actions are described in terms of
  - Preconditions
    - Position of the ball with respect to the robot
    - Position of the robot on the field
  - Probabilistic effects
    - Expected final position of the ball – mean, variance

Modeling from probabilistic effects of robot's own actions

Manuela Veloso, Paul E. Rybski,
Sonia Chernova, Colin McMillen

“Level 2” Prediction

- Robot predicts position of *temporally unseen/lost* object through:

  State MEMORY and MODEL of
  object motion and action,
  which includes probabilistic effects

- Effects are visited in order according to their probability

Modeling from teammate communicated observation

Manuela Veloso, Paul E. Rybski,
Sonia Chernova, Colin McMillen

“Level 3” Prediction

- Robot predicts position of *temporally unseen/lost* object through:

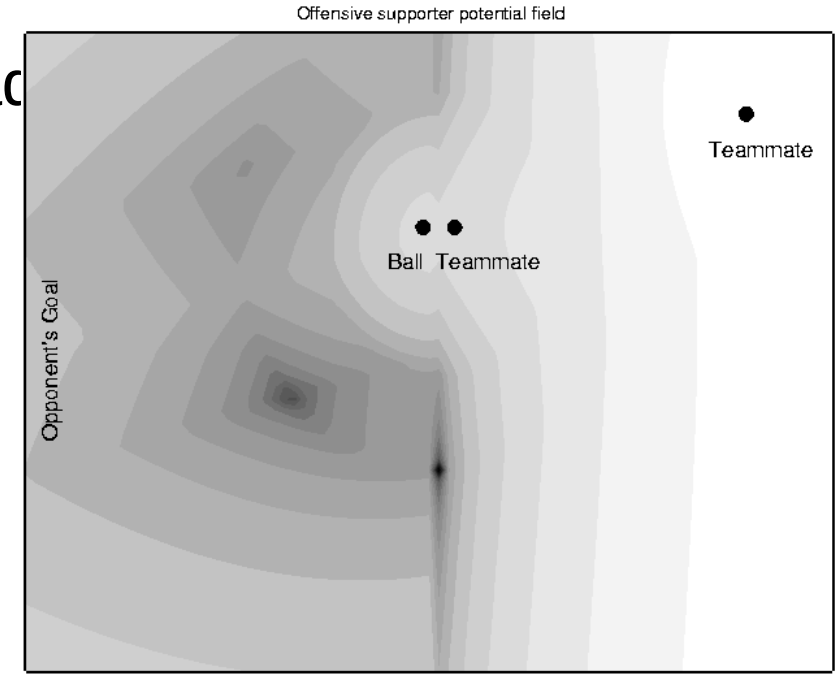
  State MEMORY and MODEL of
  object motion and action,
  which includes probabilistic effects,
  and **information from teammates**

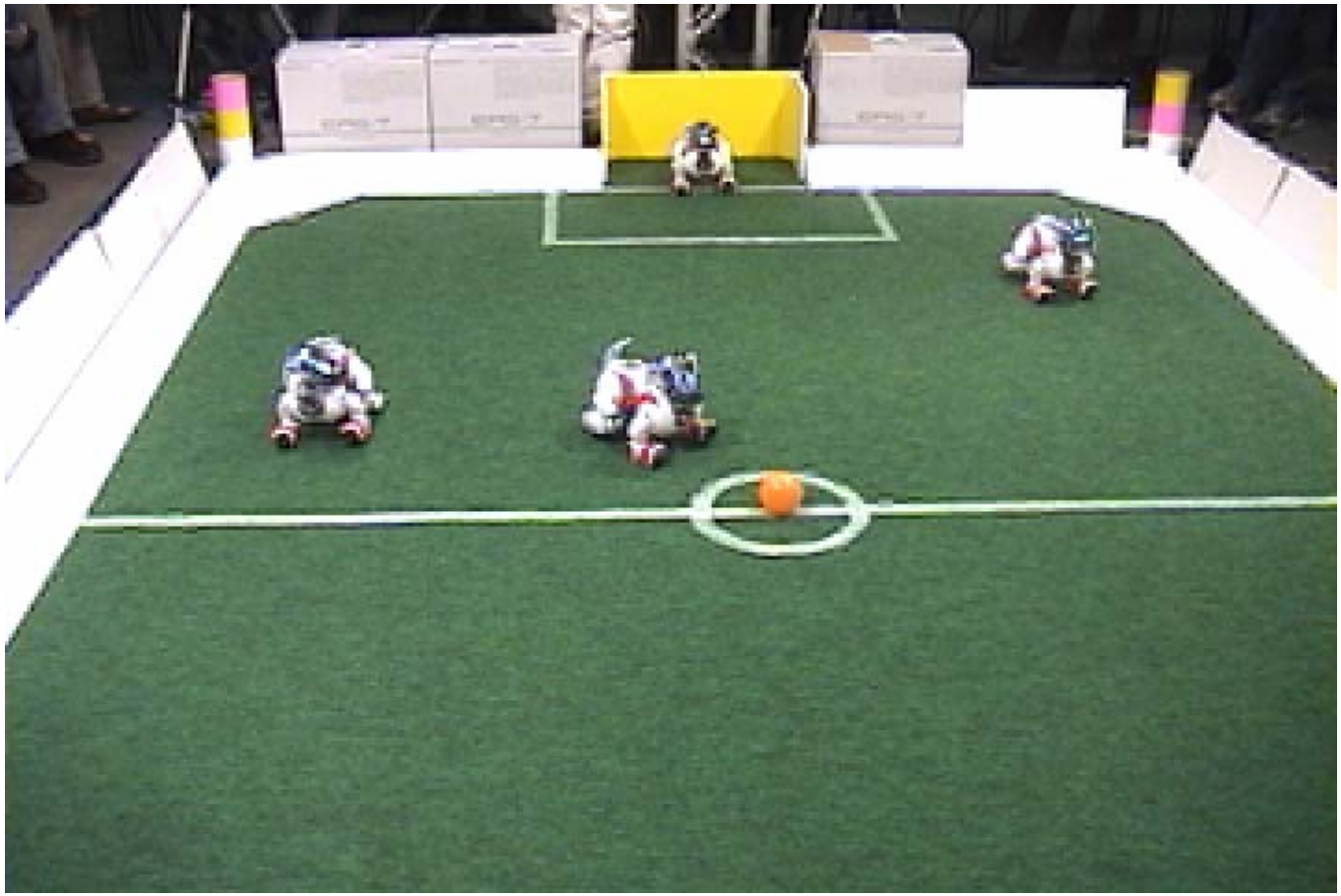
State Estimation
RMH: Ranked Multi-Hypothesis

- Use *own* perception
- If object not in own view:
  - Generate a probabilistic set of hypotheses
    - Nondeterministic models of own actions
    - Teammate shared sensory data
    - …
  - Rank the hypotheses according to a confidence and utility function
  - Visit in order the ranked hypotheses

Model, Multi-Robot Coordination

1. Role assignment
   - Primary attacker, offensive supporter, defensive supporter
2. Strategic positioning ac





Summary

- Teamwork
- Share and use of multi-source information
  - RMH State estimation
  - Ranked – probabilistic effects, possible errors in communicated information
- Use
  - Tracking
  - Team coordination