CORC 3303 Exploring Robotics

Lecture F

Robot Teams

- **Topics:**
  1) Teamwork and Its Challenges
  2) Coordination, Communication and Control
  3) RoboCup

Why Teams?

- It takes two (or more)
  - Such as cooperative transportation: Pushing a box, fragile objects
- Better, faster, cheaper
  - Such as *foraging*, more robots can cover a larger area, but too many could get in each other's way
- Being everywhere at once
  - Sensor-actuator networks (for intruder, emergency monitoring), habitat monitoring
- Having nine lives
  - Increased robustness because of redundancy (robots share the same structure and capabilities)

Challenges of Teamwork

- Get out of my way!
  - Interference among robots, goal conflicting (one robot could undo the work of another)
- It's my turn to talk!
  - Wireless radio is the preferred way of communication, has to avoid collisions
- What's going on?
  - More robots, more uncertainty
- Two for the price of one?
  - More robots, more cost (hardware or maintenance)

Types of Groups and Teams

- How do you program robots to play soccer?
- We need teamwork and *division of labor* or *role assignment*
- Homogeneous Teams
  - Identical (in form and/or function), interchangeable members
  - Could be coordinated with simple mechanisms, may require no intentional cooperation to achieve effective group behavior (such as emergent flocking)
- Heterogeneous Teams
  - Different, non-interchangeable members
  - Typically requires active cooperation in order to produce coordinated behavior

Coordination Strategy

- Merely coexisting
  - no communication or even recognition of each other (seen as obstacles).
  - Interference increases with the # of members.
  - Well-suited for foraging, construction, etc
- Loosely coupled
  - group recognition, simple coordination,
  - don't depend on each other, robust,
  - difficult to do precise tasks
  - Well-suited for foraging, herding, distributed mapping, etc
- Tightly coupled
  - Cooperate on a precise task using communication, turn-taking.
  - Dependent on each other, with improved group performance
  - Less redundancy and less robustness
  - e.g. soccer playing, moving in formation, transporting objects, etc

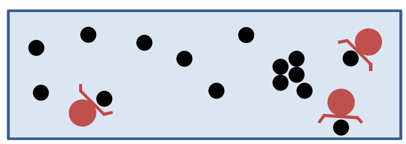
Communication

- The need for communication in a team
  - Improving perception
  - Synchronizing action
  - Enabling coordination and negotiation
- Examples of what could be communicated in foraging
  - Nothing (could still work well in merely coexisting)
  - Task-related state: locations of objects, # of recently seen robots, etc
  - Individual state: ID #, energy level, # of objects collected, etc
  - Environment state: blocked paths, dangerous conditions, new-found shortcuts, etc
  - Goal(s): direction to the nearest object, etc
  - Intentions: I'm going that way because …

How to Communicate?

- As humans, we
  - Gesticulate, shout/whisper, post signs/email/phone messages, write letters/cards/papers/books, and so on.
- As robots, they use
  - Explicit communication
    - Broadcast, peer-to-peer, publish-subscribe
    - Intentional, has cost (HW and SW)
    - Has to consider performance issue, what if message is lost?
  - Implicit communication
    - Individual robot leaving information in the environment
    - *Stigmergy* – information is conveyed through changing the environment, such as ant trails (*pheromone* left by ants).
    - Positive feedback: amplifying effects, in contrast to the regulatory feature of the negative feedback control

Example: Puck-Collecting Robots (R. Beckers *et al* 1994)



- A team of robots that
  - can't detect each other, no communication.
  - With a scoop that can detect collisions . Soft contact: <6~8 pucks, Hard contact: >6~8 pucks or fellow robots head-on.
  - The wall is made of flexible fabric and counts as soft contact.
- Controller:

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When hard contact detected
    stop and back up, then turn and go
When soft contact detected
    turn and keep going
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- That was it!
  - What happens when robot runs into the wall?
  - What happens when robot run into another robot?

Kin Recognition

- Being able to recognize "others like me" could be very beneficial
- In group robotics, kin recognition refers to
  - Distinguishing another robot from other objects
  - Recognizing one's team members
  - Typically worth the sensory and computational cost
- Robots can establish a *dominance hierarchy* to
  - help give structure and order to a group to avoid interference
  - Two types of hierarchies exist:
    - Fixed (static) hierarchy: determined once and does not change
    - Dynamic hierarchy: formed based on some quality (e.g. strength)

Control of a Group of Robots

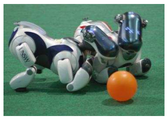
- I'm the Boss: **Centralized Control**
  - Single, centralized controller takes information from all other robots, thinks, sends commands to all
  - Is slow and gets slower when the team size increases
  - Not robust and the centralized controller is a bottleneck of the whole system
  - Advantage: optimal solution to a given problem
- Work It Out as a Team: **Distributed Control**
  - Control is spread over multiple/all members of the team
  - Each robot uses its own controller to decide what to do
  - No central information gathering, no bottlenecks
  - Works well with large teams, doesn't slow down with size
  - Disadvantage: issue of coordination,
    - hard to design individual behavior so that they will work well in their interactions to produce the designed group behavior (see competitive soccer playing).
    - Statistics tools can be used when there are many components and they are simple.
    - In robotics, we have small number of complicated components. Thus we have to solve the "*inverse problem*" – going from the global behavior to the local rules.

Architectures for Multi-Robot Control

- Apply to both centralized or distributed control
- Deliberative control
  - well suited for centralized control
- Reactive control
  - Well suited for implementing the distributed control
- Hybrid control
  - Good for both the centralized and distributed control
  - The centralized controller performs the SPA (sense-plan-act) loop, individual robots monitor their sensors and update the planner.
- Behavior-based control (BBC)
  - Good for implementing the distributed control
  - Each robot behaves according to its own local BBC controller

RoboCup

- The Robot World Cup Initiative (RoboCup) is an attempt to foster AI and intelligent robotics research
- Provides a standard problem where a wide range of technologies can be integrated and examined.
- RoboCup aims at providing a standard task for research on
  - fast-moving, multiple robots
  - with collaboration to solve dynamic problems
- RoboCup meets the need of handling real world complexities
  - Realistic, in a limited way
  - Affordable problem size
  - Manageable research cost
  - Tasks: real-time sensor fusion, reactive behavior, strategy acquisition, learning, vision, motor control, etc.
- First RoboCup was held in Nagoya, Japan, during IJCAI-97. Last year it was held in Singapore. Turkey is the host country for 2011.



Leagues of RoboCup

- RoboCup Soccer
  - Ultimate goal: a fully autonomous humanoid robotic soccer team to beat human World Cup Champions by the year 2050.
  - Leagues:
    - Standard Platform league (Sony's Aibo -> Aldebaran Robotics' Nao)
    - Small size league (5 robots of <18cm diameter and <15cm height)
    - Middle size league (5 robots, each fits a 50x50x80cm^3 box)
    - Simulation league (software)
    - Humanoid League
- RoboCup Rescue: urban search and rescue missions
- RoboCup @Home: started in 2006, autonomous robots in home society
- RoboCupJunior: introduction of RoboCup to kids younger than 18-yr. Its sub-leagues include soccer, rescue, dance and general.