EE631 Cooperating Autonomous Mobile Robots

Lecture 2: Introduction to Multi-Robot Systems

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Application Domains of Multi-Robot Teams

- **Space Exploration**
- **Mining**
- **Surveillance and Reconnaissance**
- **Hazardous Waste Cleanup**
Intelligent Systems in Industry
Caterpillar

Planetary Exploration
NASA/JPL

Military Operations
DARPA (TTO/ATO, ITO)

Surveillance & Security
DHS
Research in multi-robotics growing rapidly

- Conducted an INSPEC* Search:
  - Yearly query, 1979 - 2001
  - Searched for articles including at least one of the following terms:
    - Multi-robot
    - Multirobot
    - Cooperative robot
    - Collaborative robot
    - Distributed robot

* Citation index for physics, electronics, and computing
Parker'03
Primary Research Areas in Distributed Robotics

- Biological Inspirations
- Motion Coordination
- Communication
- Object Transport and Manipulation
- Reconfigurable Robotics
- Architectures, Task Planning, and Control
- Localization, Mapping, and Exploration
- Learning
(Values based upon INSPEC search for years 1979 - 2001)
### Biological Inspirations

**Locomotion Concepts:** Principles Found in Nature

<table>
<thead>
<tr>
<th>Type of motion</th>
<th>Resistance to motion</th>
<th>Basic kinematics of motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow in a Channel</td>
<td>Hydrodynamic forces</td>
<td>Eddies</td>
</tr>
<tr>
<td>Crawl</td>
<td>Friction forces</td>
<td>Longitudinal vibration</td>
</tr>
<tr>
<td>Sliding</td>
<td>Friction forces</td>
<td>Transverse vibration</td>
</tr>
<tr>
<td>Running</td>
<td>Loss of kinetic energy</td>
<td>Oscillatory movement of a multi-link pendulum</td>
</tr>
<tr>
<td>Jumping</td>
<td>Loss of kinetic energy</td>
<td>Oscillatory movement of a multi-link pendulum</td>
</tr>
<tr>
<td>Walking</td>
<td>Gravitational forces</td>
<td>Rolling of a polygon (see figure 2.2)</td>
</tr>
</tbody>
</table>
- Communication
  - Auditory, chemical, tactile, visual, electrical
  - Direct, indirect, explicit, implicit
- Roles
  - Strict division vs. loose “assignments”
- Hierarchies
  - Absolute linear ordering, partial ordering, relative ordering
  - Purpose: reduction in fighting, efficiency
- Territoriality
  - Reduces fighting, disperses group, simplifies interactions
- Social facilitation/sympathetic induction
  - Allows for efficient use of resources
- Imitation
  - Complex mechanism for learning
Biological Inspirations

Objective: Study biological systems to achieve engineering goals
Motion Coordination

- Objective: enable robots to navigate collaboratively to achieve spatial positioning goals
- Issues studied:
  - Multi-robot path planning
  - Traffic control
  - Formation generation
  - Formation keeping
  - Target tracking
  - Target search
  - Multi-robot docking
Reconfigurable Robotics

Objective: Obtain function from shape, allowing modules to (re)connect to form shapes that achieve desired purpose

- Earliest research included reconfigurable/cellular robotics
- Several newer projects:
  - Various navigation configurations (rolling track, spider, snake, etc.)
  - Lattices, matrices (for stair climbing, object support, etc.)
Architectures, Task Planning, and Control

- **Objective**: Development of overall control approach enabling robot teams to effectively accomplish given tasks

- **Issues studied**:
  - Action selection
  - Delegation of authority and control
  - Communication structure
  - Heterogeneity versus homogeneity of robots
  - Achieving coherence amidst local actions
  - Resolution of conflicts
Localization, Mapping, and Exploration

- **Objective:** Enable robot teams to cooperatively build models of their environment, or to accomplish spatial tasks requiring knowledge of other robot positions.

- **Issues studied:**
  - Extension of single-robot mapping approach to multi-robot teams
  - Hardware, algorithms for robot positioning
  - Sonar vs. laser vs. stereo imagery vs. fusion of several sensors
  - Landmarks vs. scan-matching
Topics of Study This Semester

- Robot kinematics
- Path planning, motion planning
- Cooperative behaviors
- Formation control of robotic vehicles
- A case study: micro/nano-robots in biomedical applications