EE631 Cooperating Autonomous Mobile Robots

Lecture 2: Introduction to Multi-Robot Systems

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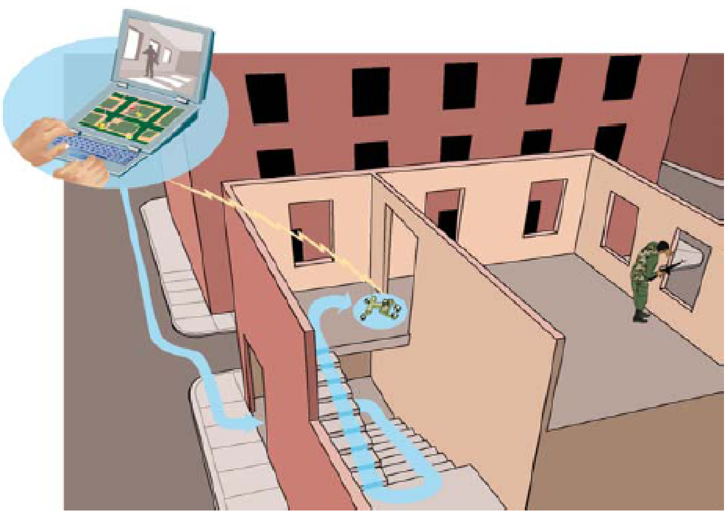
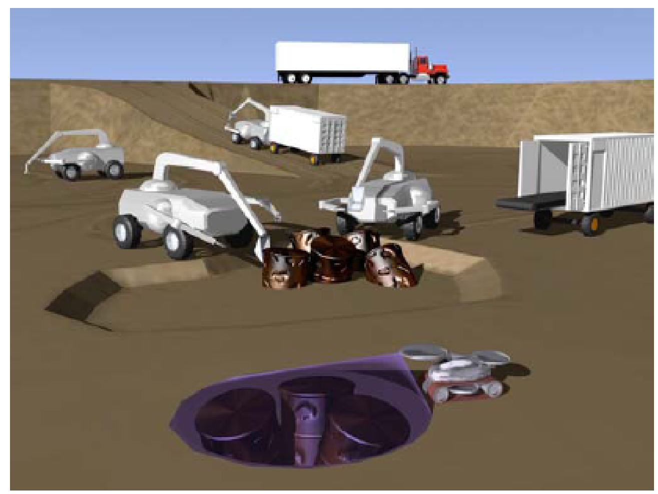
Application Domains of Muti-Robot Teams

Space Exploration

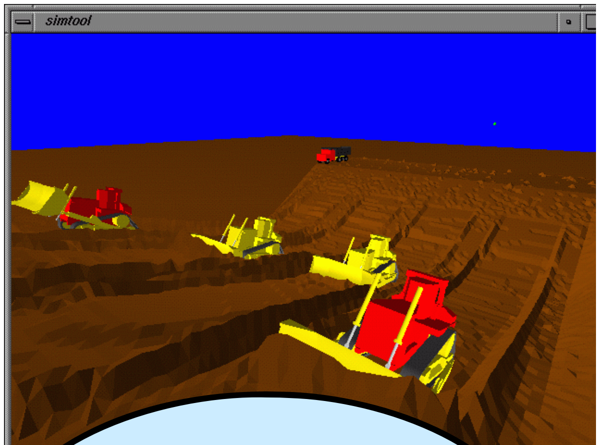
Mining



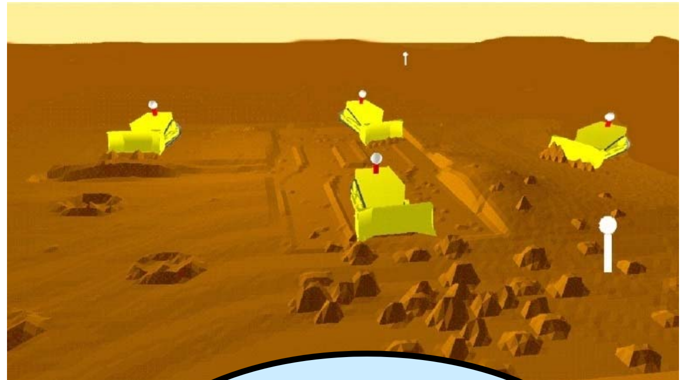
Surveillance and Reconnaissance



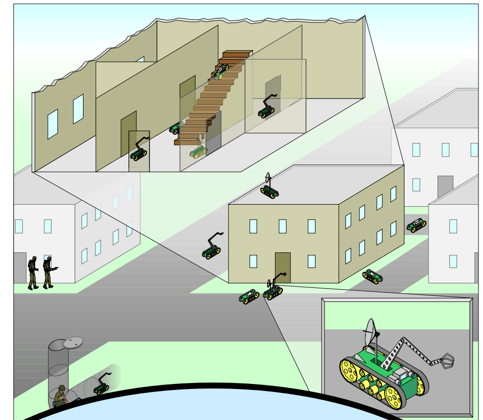
Hazardous Waste Cleanup



Intelligent Systems
in Industry
Caterpillar



Planetary Exploration
NASA/JPL



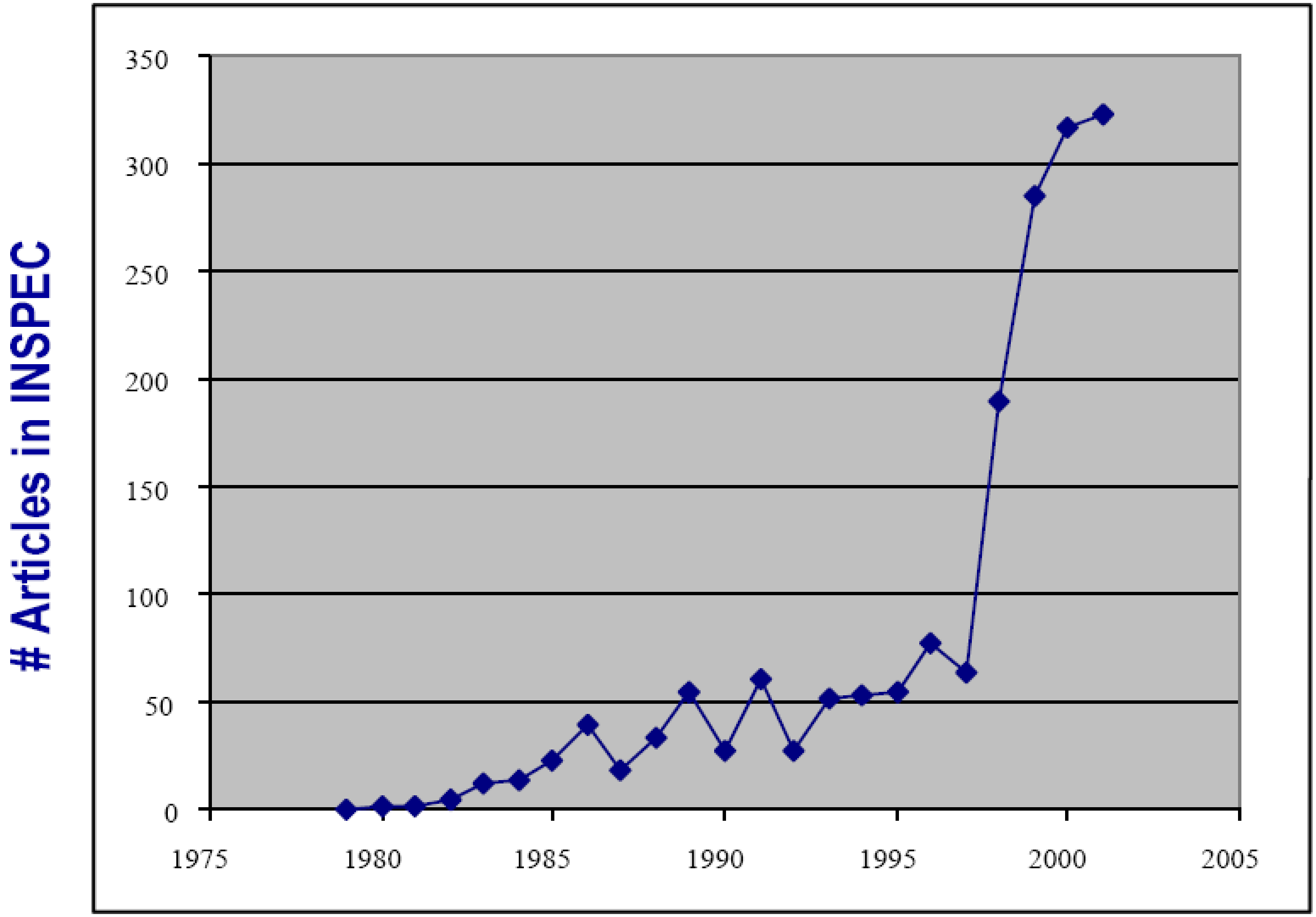
Military Operations
DARPA
(TTO/ATO, ITO)

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

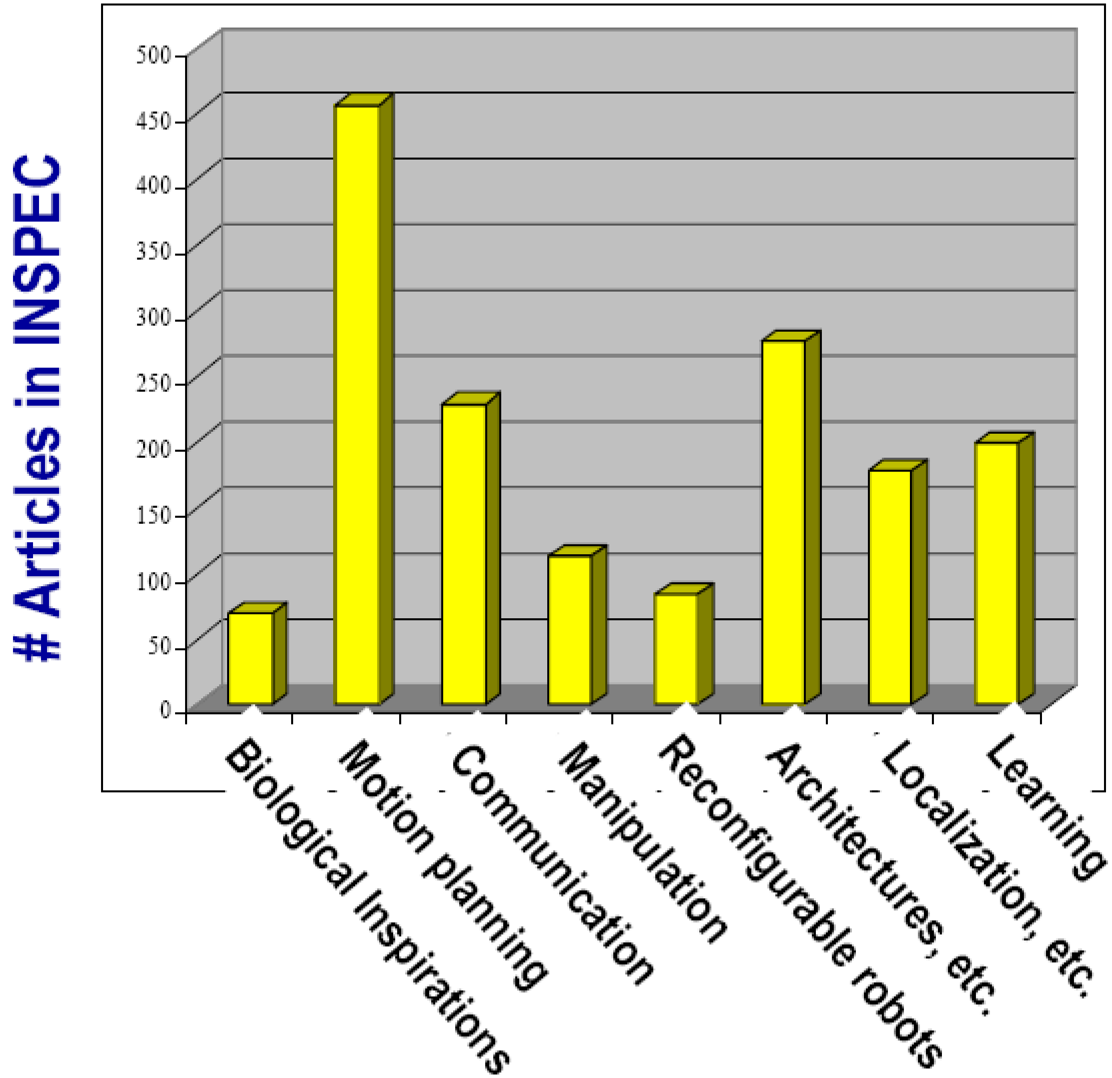


Articles in INSPEC
350
300
250
200
150
100
50
0
1975
1980
1985
1990
1995
2000
2005

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

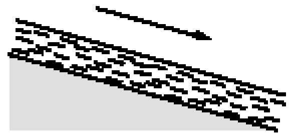
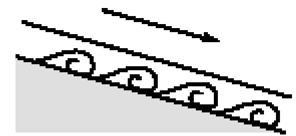
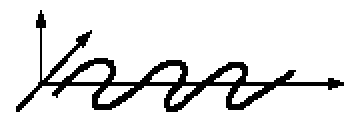
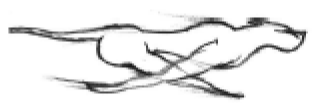
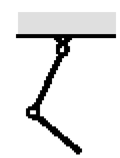
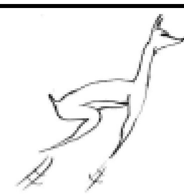
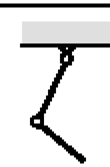
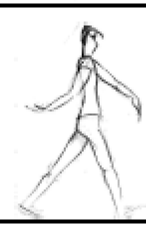
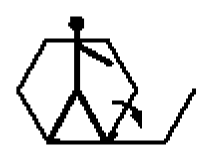


(Values based upon INSPEC search for years 1979 - 2001)

Parker'03

Biological Inspirations

- Locomotion Concepts: Principles Found in Nature

Type of motion	Resistance to motion	Basic kinematics of motion
Flow in a Channel 	Hydrodynamic forces	Eddies 
Crawl 	Friction forces	 Longitudinal vibration
Sliding 	Friction forces	 Transverse vibration
Running 	Loss of kinetic energy	Oscillatory movement of a multi-link pendulum 
Jumping 	Loss of kinetic energy	Oscillatory movement of a multi-link pendulum 
Walking 	Gravitational forces	Rolling of a polygon (see figure 2.2) 

- 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

Leaf cutter ants

Bees colony

Biological Inspirations

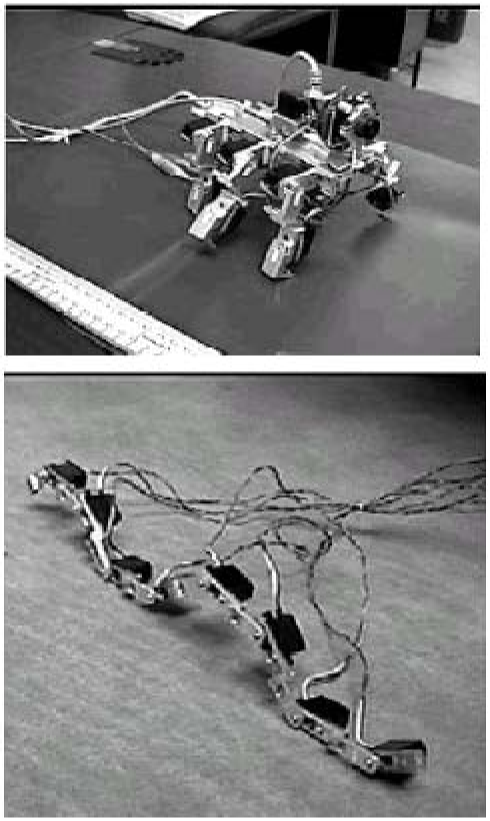
- *Objective: Study biological systems to achieve engineering goals*

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.)



Castano et. al.

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