



Robot Teams

CISC1003
Exploring Robotics

<https://cacm.acm.org/magazines/2013/3/161193-exploration-and-mapping-with-autonomous-robot-teams/fulltext?mobile=false>

Robot Teams



- **Topics:**
 - Teamwork and Its Challenges
 - Coordination, Communication and Control
 - RoboCup



<https://courses.lumenlearning.com/boundless-management/chapter/defining-teams-and-teamwork/>

<https://cosmosmagazine.com/technology/robocup-2017-wrap-up-highs-lows-plenty-of-falls>

Why Teams?

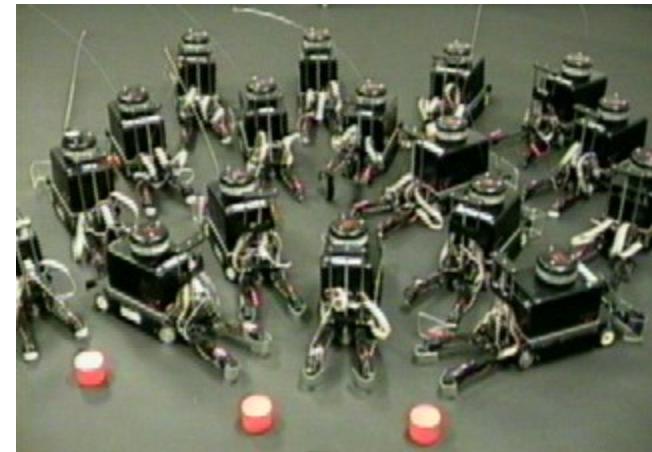
- It takes two (or more)
 - Example: cooperative transportation
 - Pushing a box, fragile objects



<https://www.youtube.com/watch?v=wmslQEyR-N8>

Why Teams?

- Better, faster, cheaper
 - Such as *foraging*, more robots can cover a larger area
 - but too many could get in each other's way



Why Teams?

- Being everywhere at once
 - Sensor-actuator networks (for intruder, emergency monitoring), habitat monitoring



<https://blog.csiro.au/may-the-fourth-be-with-our-bots/>

<https://inews.co.uk/news/technology/analysis-ces-demonstrates-how-majority-of-robots-still-have-far-to-go/>

Why Teams?

- Having nine lives
 - Increased robustness because of redundancy
 - Robustness:
 - ability to resist failure
 - Redundancy:
 - replication of abilities on the team
 - Robots share the same structure and capabilities
 - Provides redundancy
 - Not all teams are redundant
 - Some teams made of specialist robots
 - Reduces robustness



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



<https://newsela.com/read/soccer-robots>

<https://spectrum.ieee.org/automaton/robotics/home-robots/mayfield-robotics-announces-kuri-a-700-mobile-home-robot>

Challenges of Teamwork

- What's going on?
 - More robots, more uncertainty
 - Uncertainty about myself
 - Uncertainty about you
 - Your uncertainty about yourself

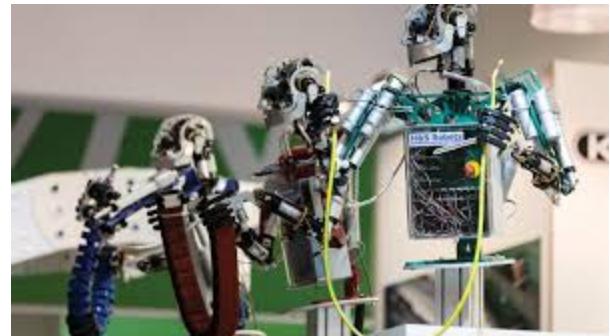


<https://drawception.com/panel/drawing/BurF6336/melting-robot-has-no-clue-whats-going-on/>

<https://www.cnbc.com/2017/04/05/president-trump-election-trade-robotics.html>

Challenges of Teamwork

- Two for the price of one?
 - More robots, more cost
 - hardware or maintenance



<https://adrdaily.com/robots-create-uncertainty-workers/>

<https://www.cnbc.com/2017/04/05/president-trump-election-trade-robotics.html>

Controlling Multiple Robots

- Different considerations for multiple robots
 - Inherently dynamic environment
- Need for coordination
 - Identity, intention, communication, plans
 - Working as a “team”

Team Work

- Coordination:
 - Arranging things in some kind of order
- Cooperation:
 - Joint actions with a mutual benefit
- Area of active research: group robotics, team robotics, multi-robot systems, etc.

Types of Groups and Teams

- How do you program robots to play soccer?
- What if each robot is programmed to act as if it is alone?
 - Everyone tries to get to the ball and score
 - Is this a good idea?
 - We need *division of labor/role assignment*



http://www.slate.com/blogs/future_tense/2017/08/01/robot_soccer_tournament_displays_robots_mediocre_soccer_skills.html

Types of Groups and Teams

- 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



Types of Groups and Teams

- Heterogeneous Teams
 - Different, non-interchangeable members
 - Typically requires active cooperation in order to produce coordinated behavior

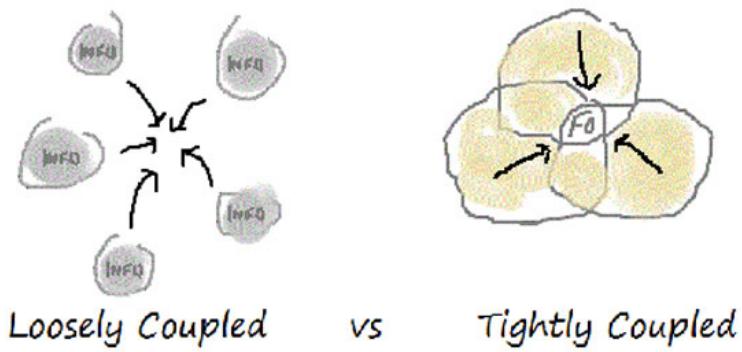


Coordination Strategy

- 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.

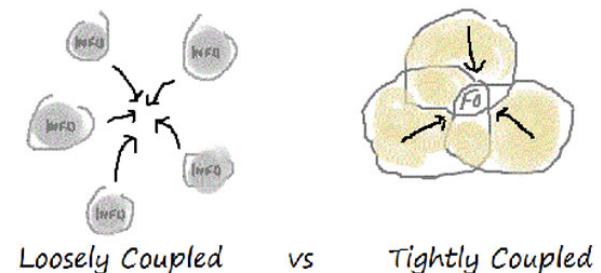
Coordination Strategy

- 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.



Coordination Strategy (cont.)

- 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



Communication (cont.)

- Examples of communicated info in foraging
 - Nothing:
 - could still work well in merely coexisting strategy
 - Task-related state:
 - locations of objects, # of recently seen robots, etc.
 - Individual state:
 - ID #, energy level, # of objects collected, etc.



Communication (cont.)

- Examples of communicated info in foraging
 - Environment state:
 - blocked paths, dangerous conditions, newfound shortcuts, etc.
 - Goal(s):
 - direction to the nearest object, etc.
 - Intentions:
 - I'm going that way because ...



Human Communication Methods

- Gesticulate, shout/whisper
- Post signs/email/phone messages
- Write letters/cards/papers/books
- etc.

Robot Communication

- Explicit communication
 - Broadcast, peer-to-peer, publish-subscribe
 - Intentional, has cost
 - HW and SW
 - Has to consider performance issue, what if message is lost?

Explicit Communication

- Broadcast communication:
 - Robotics can now rather easily use broadcast communication
 - sending a message to everyone on the communication channel
- Peer-to-peer communication:
 - sending a message to a selected recipient

Explicit Communication

- Publish-subscribe communication:
 - much like using an email list or a news group:
 - a select group of recipients interested in a particular topic signs up for the list
 - only those on the list receive messages

Robot Communication (cont.)

- 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,
 - The stronger the change (i.e., pheromones), the more it happens



https://en.wikipedia.org/wiki/Stigmergy#/media/File:Safari_ants.jpg

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

Kin Recognition

- 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

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
 - Slow and gets slower when team size increases
 - Not robust
 - Centralized controller is a bottleneck of the whole system
 - Advantage: optimal solution to a given problem

Control of a Group of Robots (cont.)

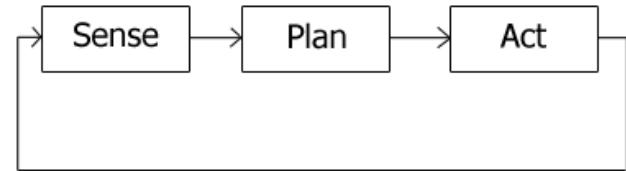
- Work It Out as a Team: **Distributed Control**
 - Control is spread
 - over multiple/all members of the team
 - Each robot uses its own controller
 - to decide what to do
 - No central information gathering, no bottlenecks
 - Works well with large teams
 - doesn't slow down with size

Control of a Group of Robots (cont.)

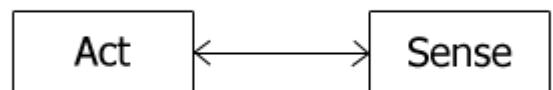
- Work It Out as a Team: **Distributed Control**
 - Disadvantage:
 - hard to design individual behavior
 - Robots need to work well in their interactions to produce the designed group behavior (see competitive soccer playing).
 - In robotics, small number of complicated components
 - Thus we have to solve the “*inverse problem*”
 - » going from the global behavior to the local rules.
 - Statistics tools harder to use
 - » Used typically when there are many simple elements

Architectures for Multi-Robot Control

- Deliberative control
 - Top-down control, heavy on planning
 - well suited for centralized control

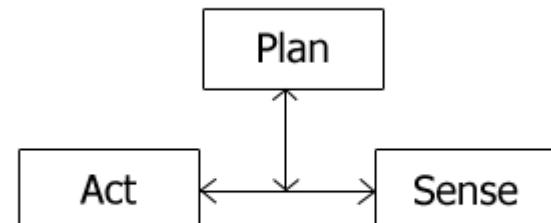


- Reactive control
 - Sense-act type of organization
 - Well suited for implementing the distributed control



Architectures for Multi-Robot Control

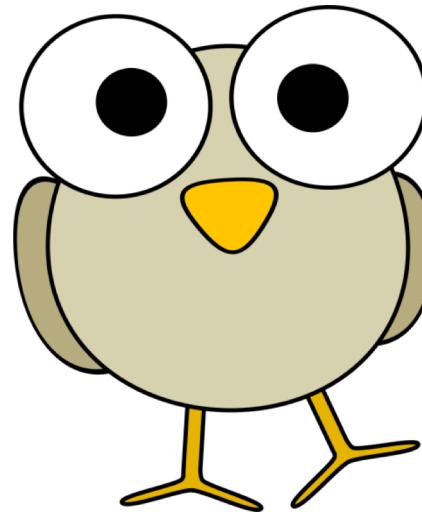
- Hybrid control
 - Robot first plans how to decompose a task into subtasks
 - => what are the suitable behaviors to accomplish each subtask
 - Good for both the centralized and distributed control
 - Centralized controller performs SPA (sense-plan-act) loop
 - individual robots monitor their sensors, update planner.



Architectures for Multi-Robot Control

- Behavior-based control (BBC)
 - Uses biological systems as a model
 - Robot exhibits complex-appearing behaviors
 - Can be implemented in both distributed or centralized control
 - Each robot behaves according to its own local BBC controller

- Questions?



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Crash Quiz

Why team work?

- A. Robots are prettier in a group
- B. Increased robustness because of redundancy
- C. Cheaper, faster
- D. Cooperative transporation

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Why use distributed control?

- A. Scales better for larger systems
- B. Easier to design individual behavior
- C. Solves bottleneck challenge
- D. Easier to use statistical tools

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How can robots communicate?

- A. Broadcast
- B. Peer-to-peer communication
- C. Leave information in the environment
- D. All of the above
- E. None of the above

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Robocup



RoboCup

- Reminder: 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 (cont.)

- 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.

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)
 - Small size league (5 robots of <18cm diameter,<15cm height)
 - Middle size league (5 robots, each fits a 50x50x80cm³ box)
 - Simulation league (software)
 - Humanoid League

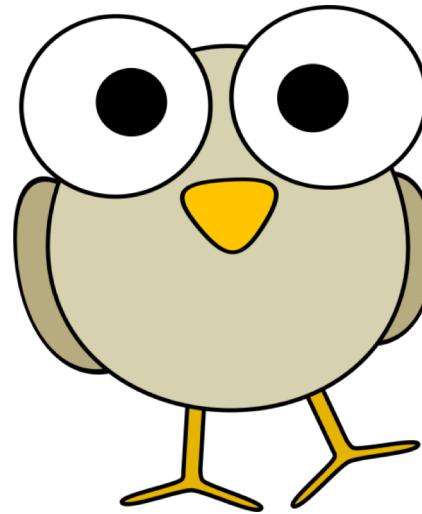
Leagues of RoboCup

- RoboCup Rescue: urban search and rescue missions
- RoboCup @Home: autonomous robots in home society
 - started in 2006
- RoboCupJunior: introduction of RoboCup to younger kids (< 18 yr)
 - Its sub-leagues include soccer, rescue, dance and general.

RoboCup Videos

- Soccer league
- Junior Rescue:
- Rescue league:
 - [https://www.youtube.com/watch?v=8AOID93y0n
w](https://www.youtube.com/watch?v=8AOID93y0nw)
 - [https://www.youtube.com/watch?v=IAAZwQVFYR
k](https://www.youtube.com/watch?v=IAAZwQVFYRk)

- Questions?



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