CISC 1003 - EXPLORING ROBOTICS

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

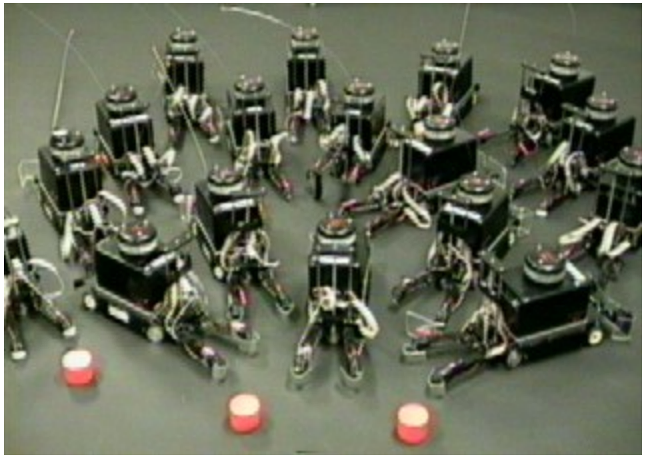
Why Teams?

- 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



http://robotics.usc.edu/?l=Robots:retired

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

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

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

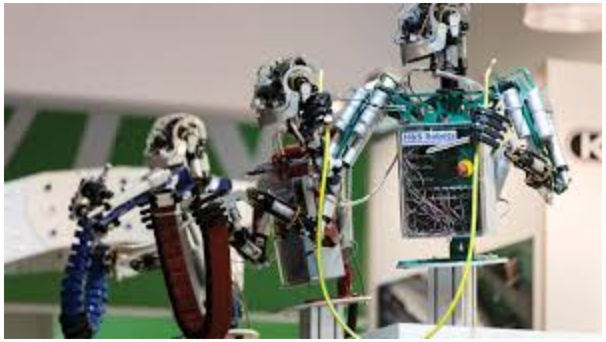
Challenges of Teamwork

- 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

https://www.slideshare.net/stevemitchinson16/building-an-effective-credit-management-team

Types of Groups and Teams

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

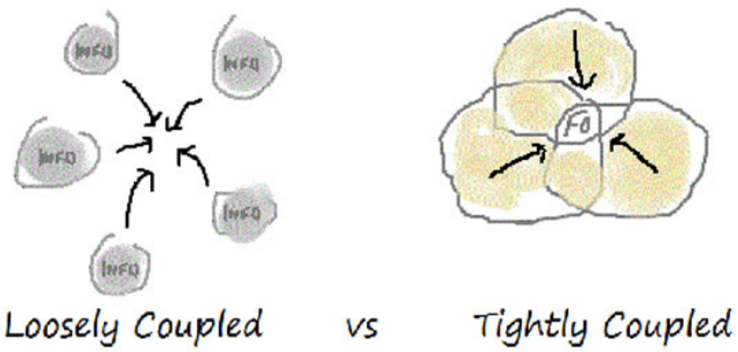
https://www.slideshare.net/stevemitchinson16/building-an-effective-credit-management-team

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.

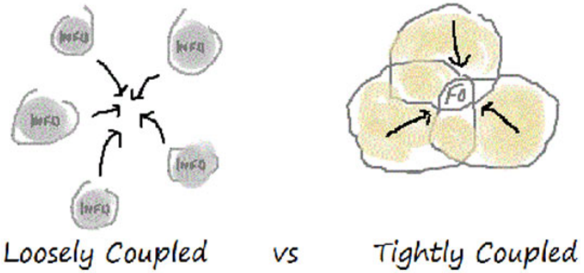


http://www.roger-wilco.net/flight-object-ion/

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.

http://www.roger-wilco.net/flight-object-ion/



Communication

- The need for communication in a team
  - Improving perception
  - Synchronizing action
  - Enabling coordination and negotiation

https://www.wired.com/2010/10/children-robots/

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.

http://robotglobe.org/e-stores/communication-product-stores/

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 …

http://www.sastrarobotics.com/products/webots/

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

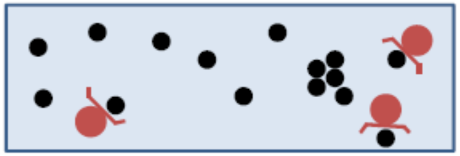
- Being able to recognize "others like me" could be very beneficial
- In group robotics, kin recognition refers to
  - Distinguishing another robot from other objects
  - Recognizing one's team members
  - Typically worth the sensory and computational cost

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)

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.

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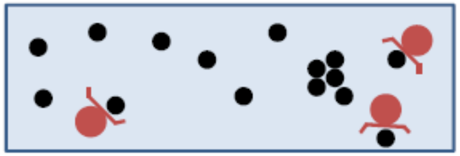


- Controller:

```
When hard contact detected
     stop and back up, then turn and go
When soft contact detected
     turn and keep going
```

- That was it!
  – What happens when robot runs into the wall?
  – What happens when robot run into another robot?

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

- Experiment in Stigmergy, Self-Organising and Collective Robotics
  - Demonstrates an implementation of the Beckers et. Al. using lego robots

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.)

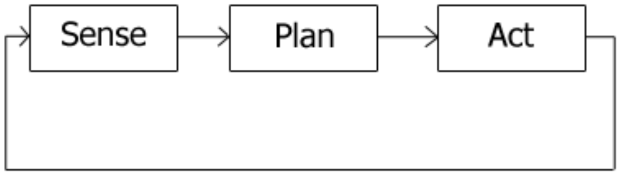
- Work It Out as a Team: **Distributed Control**
  - Control is spread
    - over multiple/all members of the team
  - Each robot uses its own controller
    - to decide what to do
  - No central information gathering, no bottlenecks
  - Works well with large teams
    - doesn’t slow down with size

Control of a Group of Robots (cont.)

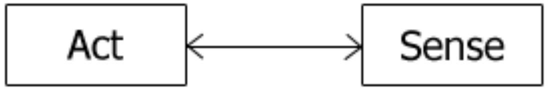
- Work It Out as a Team: **Distributed Control**
  - Disadvantage:
    - hard to design individual behavior
      - Robots need to work well in their interactions to produce the designed group behavior (see competitive soccer playing).
    - In robotics, small number of complicated components
      - 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



https://en.wikipedia.org/wiki/Robotic_paradigm

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.

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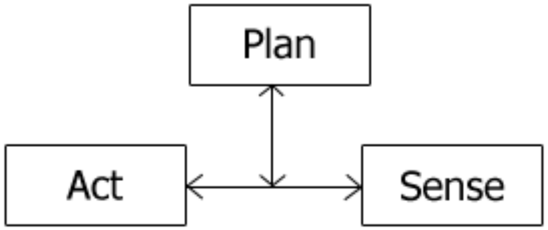
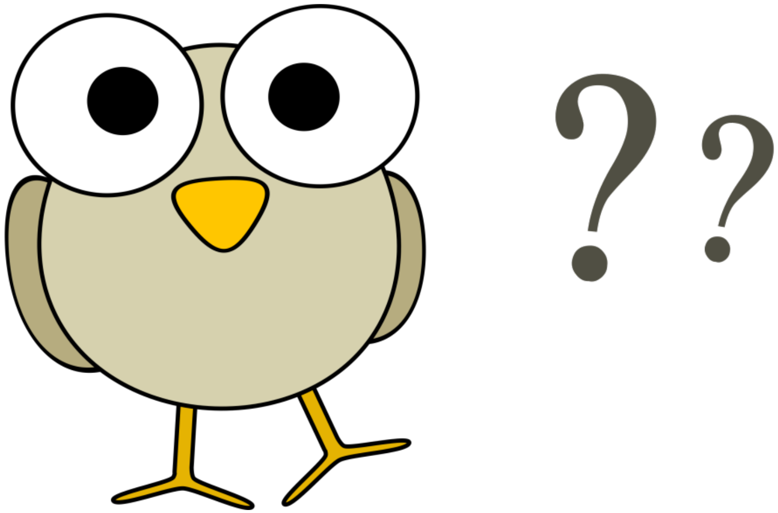


Architectures for Multi-Robot Control

- 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?



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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- B. Easier to design individual behavior
- C. Solves bottleneck challenge
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Robot Teams

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ROBOCUP

RoboCup

https://www.robocup2015.org/

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=8AOID93y0nw
  - https://www.youtube.com/watch?v=IAAZwQVFYRk

- Questions?