Fission-fusion Multi-robot Systems

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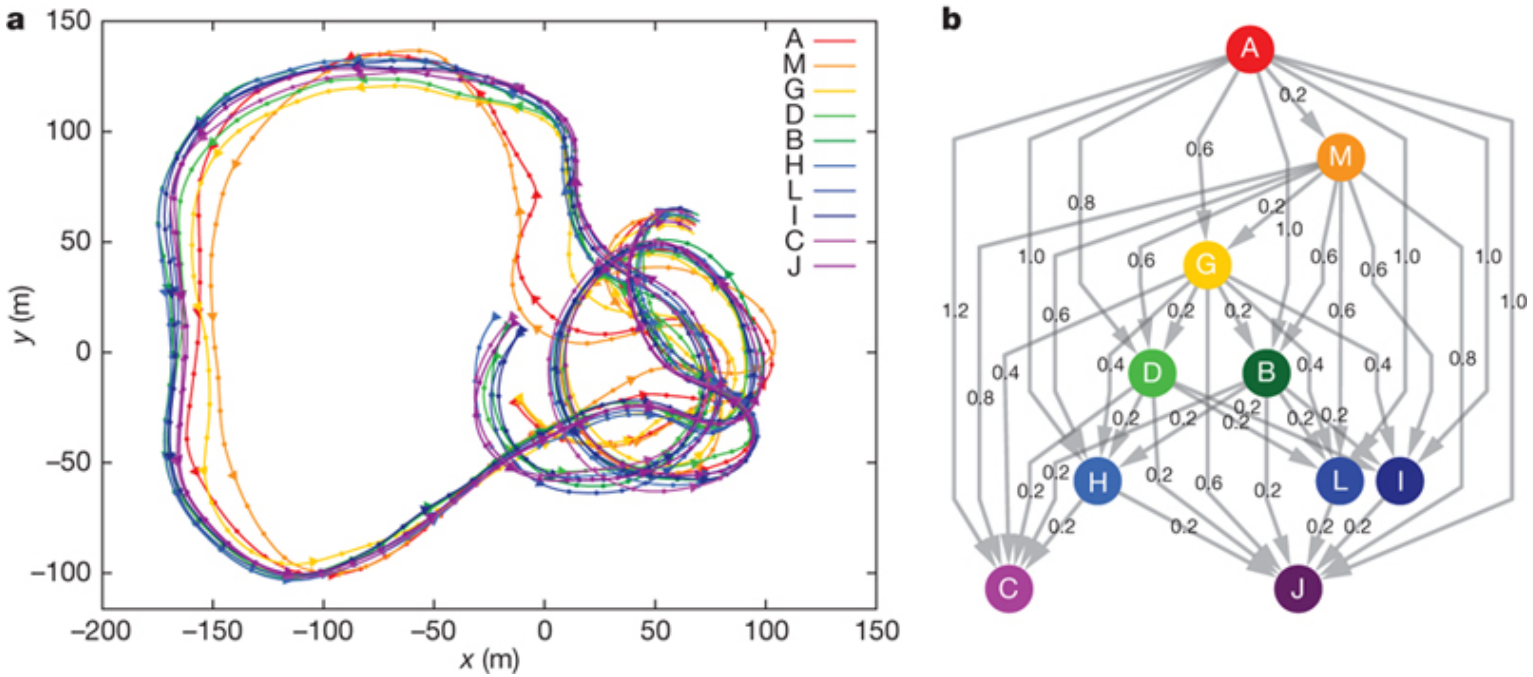
Warning!

- Not your typical research presentation
- More biology than robotics
  - Agent-based modeling
- Some math, sociology, and psychology thrown in

Image available at http://www.clipartbest.com/warning-sign-template

Hierarchical group dynamics in pigeon flocks



https://www.youtube.com/watch?v=UFF74jWZmM4

Image available at http://www.nature.com/nature/journal/v464/n7290/fig_tab/nature08891_F2.html

NSF Grant 2011–2014

- Producing similar behavior in robots is difficult
  - Doesn't adapt well to changing conditions
  - Usually requires significant communication
  - Doesn't scale up
- How can we do it in Multi-Robot Systems (MRSs)?
- "Emergent Hierarchies of Leaders in Multi-Robot Systems"
  - NSF grant number BCS-1124837 ($159,552)

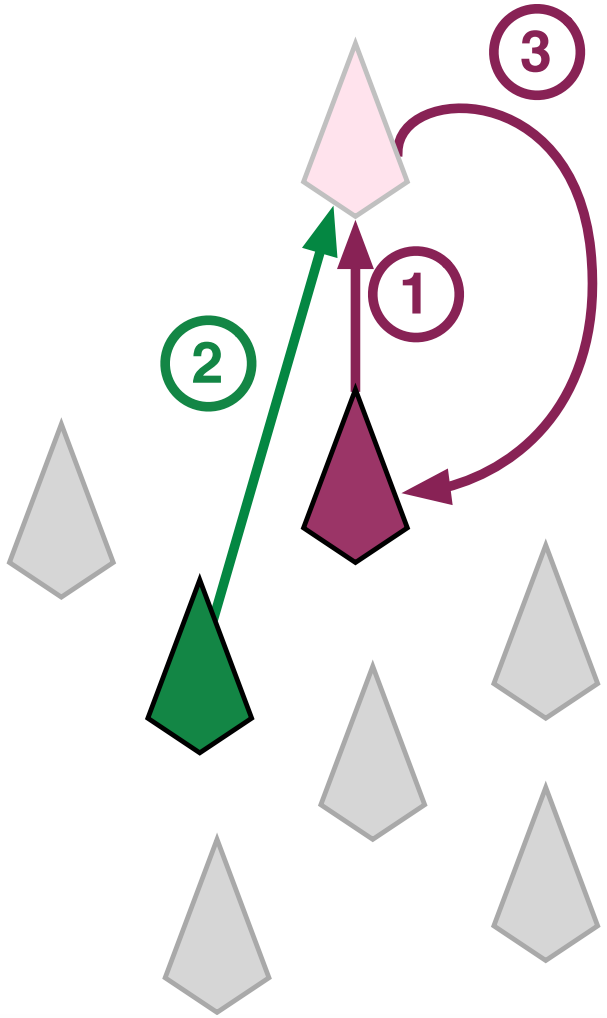
Research hypothesis

We hypothesize, using inspiration from biological systems, that a hierarchy of leaders can emerge in a multi-robot system without explicit communication.

Decision-making events

Three decision-making events

1. Initiate a movement
2. Follow an initiator
3. Cancel a movement

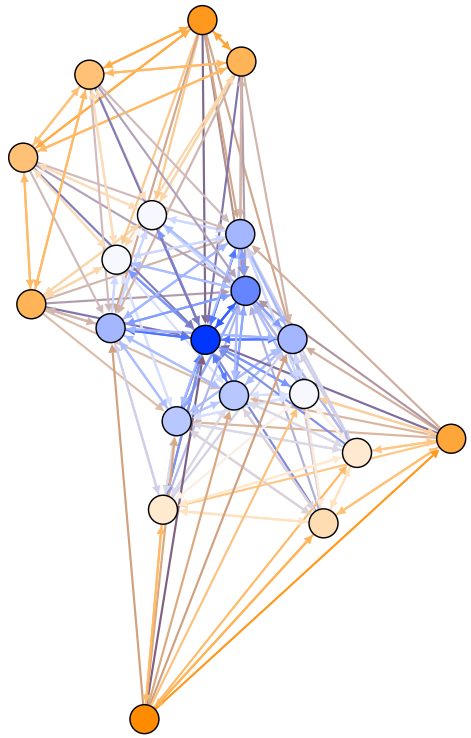


Leadership lessons from the dancing man

https://www.youtube.com/watch?v=V_qO7NFp4-s

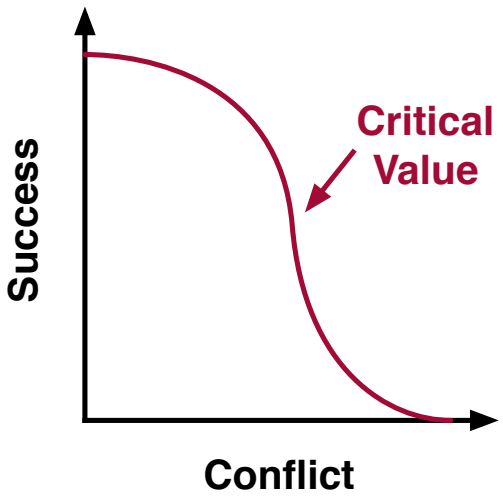
Leadership is affected by personality

- Bold individuals tend to lead more than shy
- Bold/shy is a single continuum
- Communication network is biased towards central individuals
  - But some information is only gathered at periphery
- Multiple personality traits can balance this bias somewhat



Conflict isn't necessarily bad

- Conflicts of interest are natural in groups
- Can be cause by:
  - Different decision-making
  - Different information/uncertainty
  - Different motivations/goals
- Sometimes beneficial



Student participants

Jeremy Acre	Math	Math project	■	★
Byron Crouch	CS	NASA SRE		
Cora Cummins	MC	Media		
Blake Jordan	CS	URA	■	★
Brenda Rivera	MC	Media		
Kyler Ross	Chemistry	NASA SRE		
Tim Solum	CS	URA	■	★
Elizabeth Valle	Biology	URA	■	★

■ Published a paper ★ Conference travel

Where now?

- Movement $\rightarrow$ dynamic communication network
- Allow explicit communication
- Investigate stable hierarchies
- Add social status
- Try more complex tasks
- Add more conflicts of interest
- Add hostile agents

Sample robot team scenario

- Consider an MRS engaging in a search & rescue task
- Group splits up to cover more ground
- Subgroup enters a building that requires a larger group
- Another subgroup decides to merge with the first to help
- All subgroups merge as they return home

Image available at http://d2rormqr1qwzpz.cloudfront.net/photos/2014/08/07/66095-swarm.jpg

Current state-of-the-art

- Existing approaches for artificial systems:
  - Tend to search for optimal sub-groups
  - Focus on multi-agent systems, not multi-robot systems
- Emergent coordination doesn't make these assumptions
  - Only focuses on the macro and not individual decision-making

Hyena society

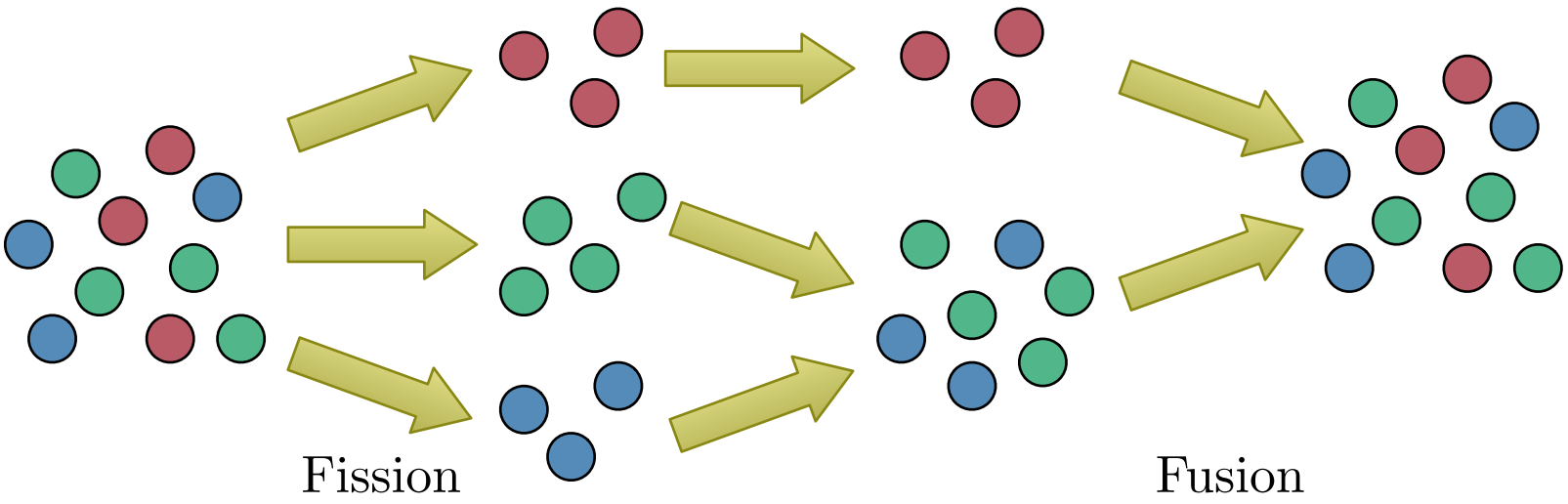
Fission-fusion society

Definition

“‘A society consisting of casual groups of variable size and composition, which form, break up and reform at frequent intervals.” [1]

- Group splits (fission) when costs $>$ benefits
- Groups merge (fusion) when costs $<$ benefits
- Dynamic process - size & composition change frequently
- Relieves tension caused by conflicts of interest

Fission-fusion society (*cont'd*)



Potential benefits for artificial systems

- Individuals are self-motivated
- Minimal communication required
- Scales to large group sizes
- Adapts to changing environments, tasks, & robot states
- Conflict resolution

NSF Grant 2016–2019

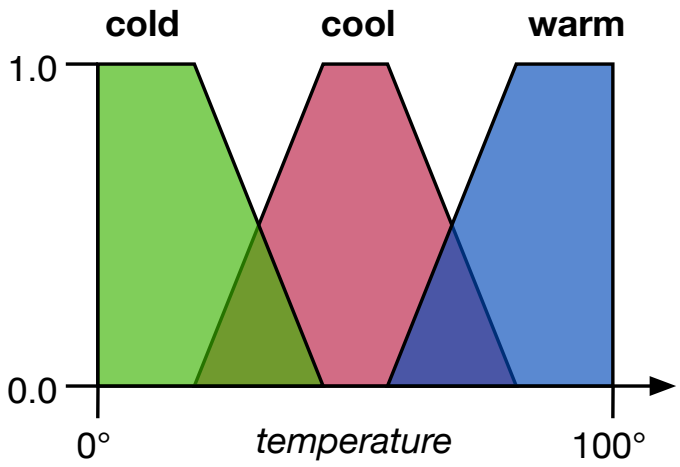
- Produce same behavior in artificial systems?
  - Specifically in Multi-Robot Systems (MRSs)
- "Fission-Fusion Multi-Robot Systems"
  - NSF grant number RI-1617838 ($192,557)

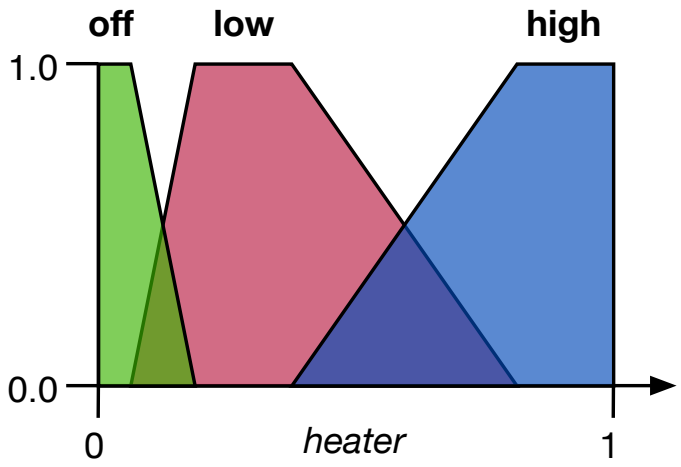
Research hypothesis

We hypothesize, using inspiration from biological systems, that MRSs can be designed to adapt subgroup size and number dynamically depending on the current task using artificial analogues of biological and environmental factors.

Design and approach

- Decision-making is the same as the last project [3]
  - Probabilistic Finite State Machine (PFSM)
- Behaviors use Adaptive Fuzzy Behavior Hierarchies [2]
- Evolve neural networks to implement behaviors [4]
- Extract fuzzy rules from neural networks





Research goals

Goal 1: Relevant biological and environmental factors contributing to **fission** and **fusion**

Goal 2: Relevant biological and environmental factors contributing to **dynamic group sizes**

Goal 3: Implement the fission-fusion decision-making system in **physical robots**

Goal 1 plan

- Find relevant biological and environmental factors contributing to **fission** and **fusion**
- Which ones have artificial analogues that are relevant?
  - Time
  - Energy
  - Conflict
  - Social
  - Environmental (e.g., temporal and spatial variability of resources)
- Stability is key!
- Simulated MRSs to evaluate wide range of possibilities

Goal 2 plan

- Find biological and environmental factors contributing to **dynamic group sizes**
- Which ones have artificial analogues that are relevant?
- Generalized decision-making process capable of addressing transitions autonomously
- Simulated MRSs to evaluate wide range of possibilities

Goal 3 plan

- Implement the fission-fusion decision-making system in **physical robots**
- Constraints imposed by physical robots with limited capabilities
  - Limited sensor suites
  - Noise
  - Limited computational resources
- 12 e-Puck robots with Omnivision ($2,300/each)

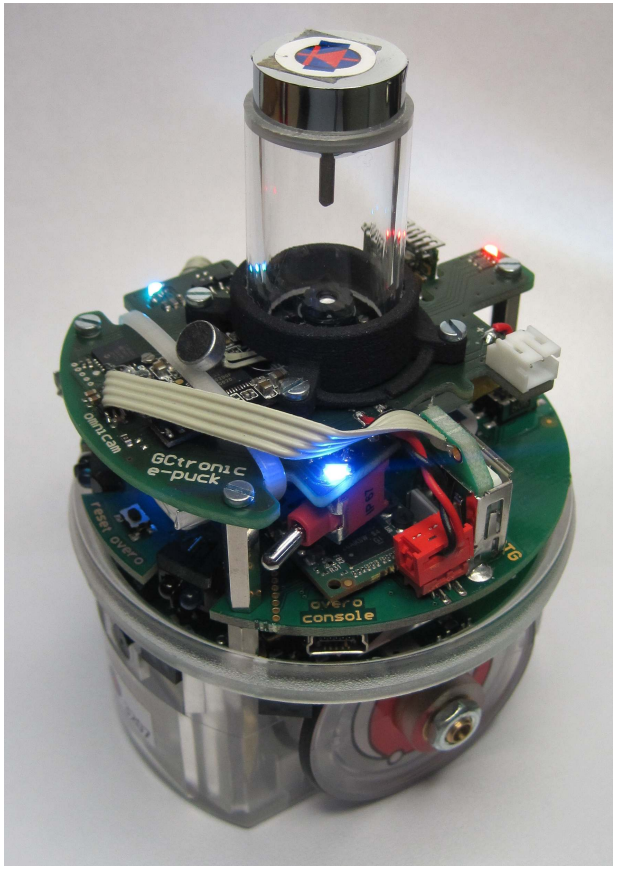


Image available at http://www.gctronic.com/img/omnivision-v2-epuck-1.jpg

Broader impacts

- Mentor Bethany HS First Robotics team
- Informational videos accessible to a wide audience
- Interdisciplinary research opportunity for SNU students

Image available at http://www.firstinmichigan.org/Images/2016game_image.jpg

Student Research Opportunities

- Two Undergraduate Research Assistants will:
  - Perform experiments
  - Analyze results
  - Write and prepare publications
  - If accepted, travel to a conference
- Year-round participation:
  - 10 hours/week during the school year
  - 40 hours/week for 10 weeks during the summer
- Annual stipend starting at $7,600

Student Media Opportunities

- Two Undergraduate Media Assistants will:
  - Communicate to a wider audience
  - Create videos
  - Communicate technical and non-technical benefits
- Academic year participation (starting year 2):
  - Estimate of 80 hours over academic year
  - No summer work
- Approximate stipend of $800

Acknowledgments

- Co-PI: Dr. Ingo Schlupp (OU)
- Southern Nazarene University
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Questions?

www.csne.snu.edu/research/apply

October 14 Deadline

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