Swarm Intelligence

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Introduction

- Swarm intelligence was originally used in the context of cellular robotic systems to describe the self-organization of simple mechanical agents through **nearest-neighbor interaction**
- It was later extended to include "any attempt to design algorithms or distributed problem-solving devices inspired by the **collective behavior** of social insect colonies and other animal societies"
- This includes the behaviors of certain ants, honeybees, wasps, cockroaches, beetles, caterpillars, and termites

Introduction 2

- Many aspects of the collective activities of social insects, such as ants, are **self-organizing**
  - Complex group behavior **emerges** from the interactions of individuals who exhibit simple behaviors by themselves: finding food and building a nest
  - Self-organization come about **from interactions based entirely on local information**

- **Local decisions, global coherence**
- **Emergent behaviors, self-organization**

Videos

- https://www.youtube.com/watch?v=dDsmbwOrHJs
- https://www.youtube.com/watch?v=QbUPfMXXQIY
- https://www.youtube.com/watch?v=M028vafB0I8

Why Not Centralized Approach?

- Requires that *each agent interacts with every other agent*
- Do *not* possess (environmental) obstacle avoidance capabilities
- Lead to *irregular* fragmentation and/or collapse
- *Unbounded* (externally predetermined) forces are used for collision avoidance
- Do *not* possess distributed tracking (or migration) capabilities for groups

Fundamental Questions 1

- How do we design scalable flocking algorithms and guarantee their convergence?
  - Computational efficiency and guarantee
- What does cohesion mean for groups and how is it achieved in a distributed way?
  - Global coherence yet locally driven (with distributed autonomy)
- What are the stability analysis problems related to flocking?
  - Emergence, Convergence
- What types of order exist in flocks?
  - Local interaction rules

Fundamental Questions 2

- How do agents in flocks perform obstacle avoidance?
  - Problem solving
- How do flocks perform split/rejoin maneuvers or pass through narrow spaces?
  - Problem solving
- How do flocks migrate from point A to B?
  - Problem solving
- Do they need any leaders?
  - Self-organization
- What is a flock? and what constitutes flocking?
  - Self-organization, emergent behaviors

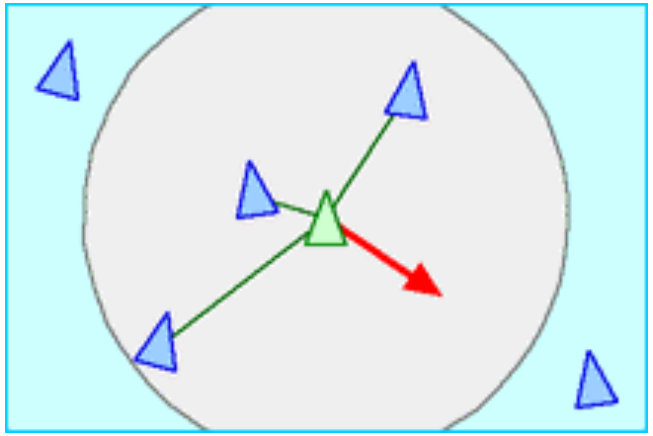
Flocking 1

C. W. Reynolds (1987). Flocks, Herds, and Schools: A Distributed Behavioral Model, *Computer Graphics*, **21**(4), July 1987, pp. 25-34.

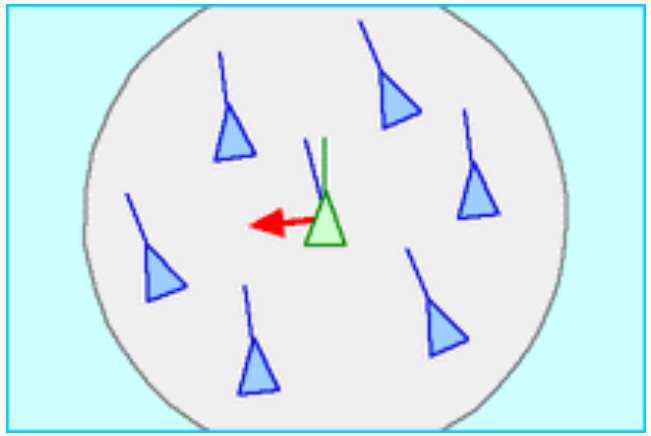
- Behaviors of *Boids* that lead to simulated flocking are:
  - **Collision Avoidance**: avoid collisions with nearby flockmates
  - **Velocity Matching**: attempt to match velocity with nearby flockmates (both speed and direction)
  - **Flock Centering**: attempt to stay close to nearby flockmates

Flocking 2

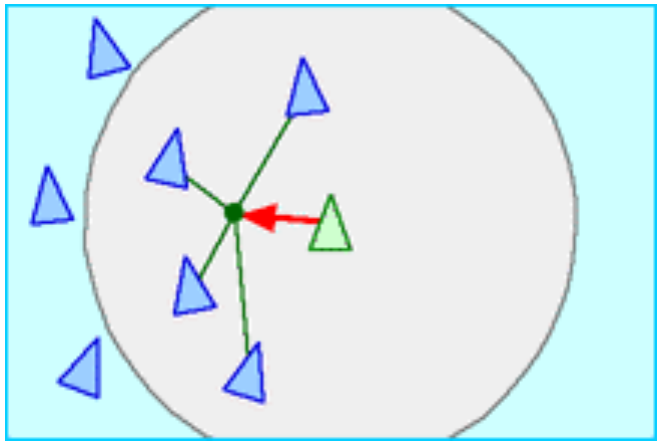
- Collision Avoidance
- Velocity Matching
- Flock Centering



separation



alignment



cohesion

http://www.red3d.com/cwr/boids/

https://www.youtube.com/watch?v=M028vafB0l8

Local Decisions vs. Global Coherence

- All computations are based on relatively simple observations and interactions with local neighbors: Collision Avoidance, Velocity Matching, Flock Centering
  - Distributed
  - Computationally efficient
  - Scalable
  - ***Dynamic, incomplete, uncertain, non-episodic, continuous environment***
- Emergent behaviors: Flocking or swarming behaviors
  - No collision, matched velocity, flock cohesion

www.swarm.org

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Agent- and Individual-based Modeling Resources

Resources for agent-based modeling. This area of the wiki is for information on agent-based modeling in general. **This area is no longer maintained and we refer interested people to more up-to-date sites such as www.OpenABM.org**

There is still information on:

- Agent-based modeling community resources
- Software (information on alternative platforms; learning materials; template models; integrated development environments)
- "How and why to do agent-based modeling": techniques and theory
- Resources specific to different scientific domains