Determining Placements of Influencing Agents in a Flock

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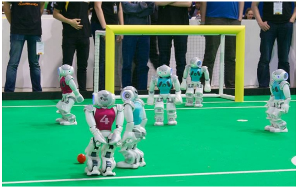
Background

- Artificial intelligence
  - Multi-agent systems
    - Teamwork
      - Ad hoc teamwork
    - Swarm behavior
      - Flocking



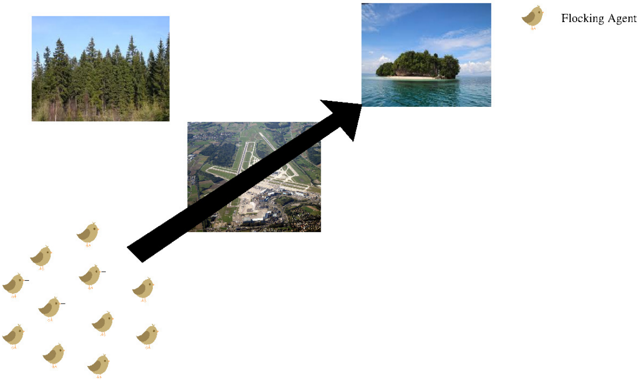
Ad Hoc Teamwork

- Only in control of a single agent or subset of agents
- Shared goals
- No pre-coordination
- No explicit communication

Flocking

- Emergent behavior found in nature
  - Birds, fish, insects
- Animals follow a simple local behavior rule
- Group behavior is cohesive

Example — Leading Teammates in Ad Hoc Settings



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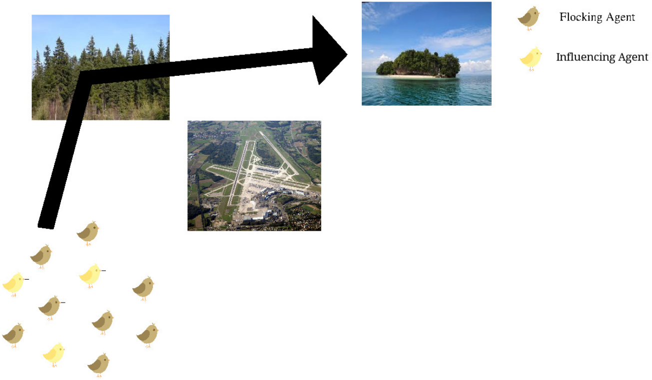


Differences from Related Work

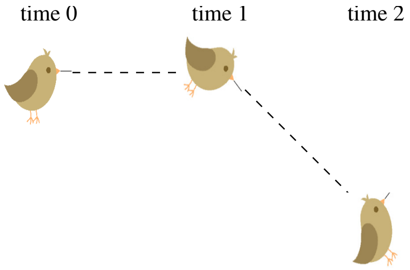
- Our work considers how to:
  - Influence the flock to quickly adopt a particular behavior by introducing agents into the flock
  - Control agents by considering and accounting for how the other agents will react

Outline

Problem Definition

Each agent has:

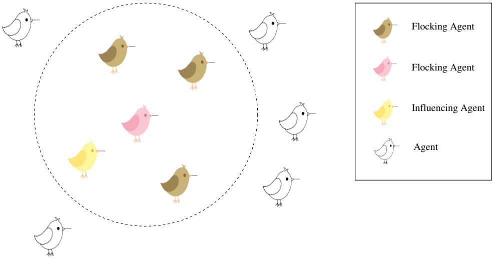
- Constant, non-zero velocity
- 2D Position
- Global heading



Problem Definition - Neighborhood

Each flocking agent reacts only to agents within a certain *neighborhood* around itself.

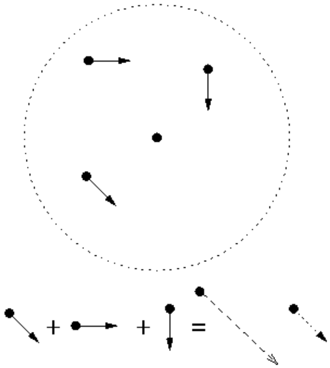
- Characterized by a radius in this work



Problem Definition - Heading Update

A flocking agent's heading at the next time step is set to be the *average global heading* of all agents currently within the agent's neighborhood.

- Agent can turn any amount instantaneously (not fully realistic)



Research Question

Previously we considered on how the influencing agents should behave in order to best influence the flock (Genter and Stone, ANTS 2014).

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Research Problem:

Where should influencing agents be located within a flock to maximize their influence on the flock?

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Determining Desired Positions

- Two cases addressed in paper:
  - Initial position "dropped into the flock"
  - Desired position "entering from outside the flock"

Determining Desired Positions

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  - **Initial position "dropped into the flock"**
  - Desired position "entering from outside the flock"
- Talk focuses on *initial* position

Determining Desired Positions

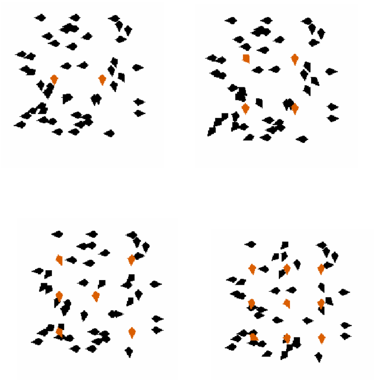
- Random Placement
- Grid Placement
- Border Approach
- Graph Approach

Determining Desired Positions

- Random Placement
  - Randomly place influencing agents within the dimensions of the flock.
- Grid Placement
- Border Approach
- Graph Approach

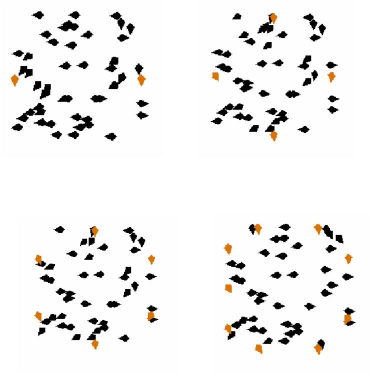
Grid Placement

Place influencing agents at predefined, well-spaced, gridded positions throughout flock.



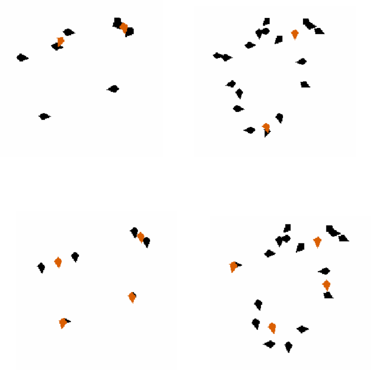
Border Approach

Place influencing agents as evenly as possible around the space covered by the flocking agents.



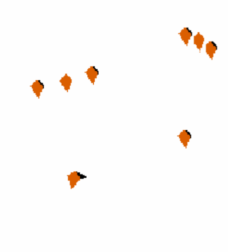
Graph Approach

Consider many possible sets of positions in which the influencing agents could be placed, and then evaluate how well each of these sets connects the flocking agents with the influencing agents.



Graph Approach - Steps (1)

- Create the graph of flocking agents
- Consider possible sets of influencing agent positions
  - Mid-points between flocking agents
    - Only for agents within 2 neighborhood radii
  - Near flocking agents



Graph Approach - Steps (2)

- Evaluate each set of influencing agent positions
  - minimize the number of flocking agents not *connected* to an influencing agent
  - maximize the number of *connections* between flocking agents and influencing agents
  - maximize the number of *direct connections* between flocking agents and influencing agents

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Random Placement

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Grid Placement

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Border Placement

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Graph Placement

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Outline

Possible Metrics

- steps for the flock to converge
- the number of trials in which any flocking agents were lost
- the average number of flocking agents lost
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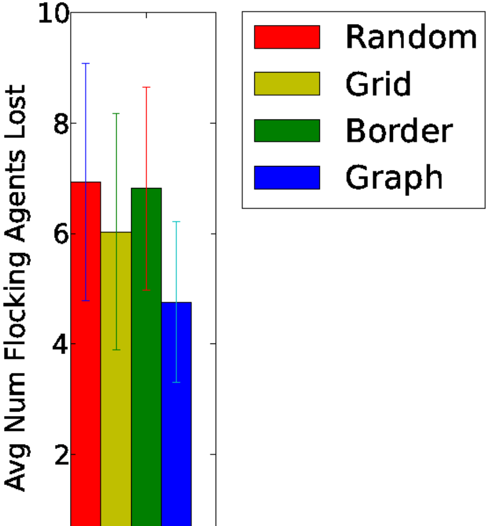
Experimental Results



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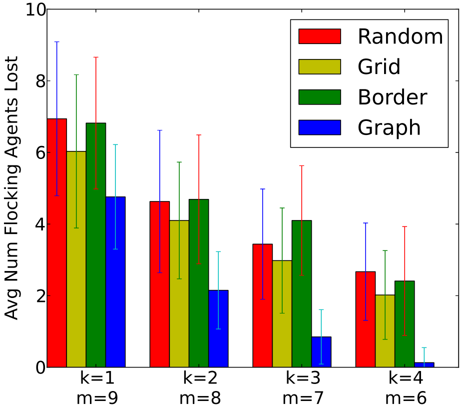

The average number of flocking agents lost when the flock contained 10 agents. These results are obtained over 100 runs. Error bars show sample standard deviation.

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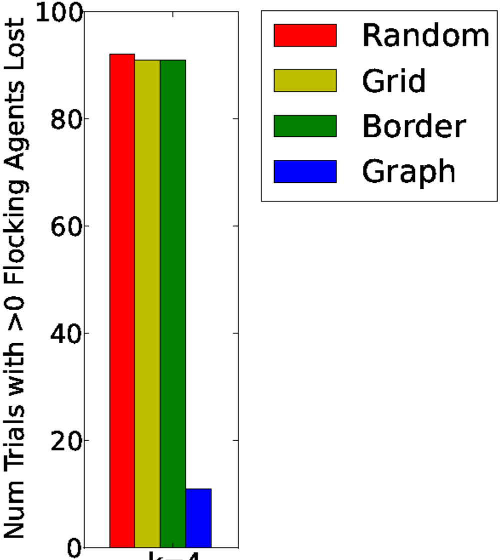
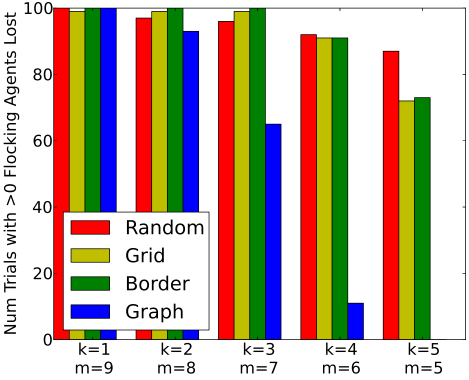


Learning Agents Research Group

Experimental Results



The number of trials (out of 100) in which any flocking agent was lost when the flock contained 10 agents.

Ongoing Research

- More efficient graph-based placement approach
  - Current placement selection is $O(n^3 \binom{m^2+m}{k})$
    - n is flock size
    - m is the number of flocking agents
    - k is the number of influencing agents
- Automatically determine ideal influencing agents formation
- Utilizing multiple stations from which agents can emerge to join the flock

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Summary

Research Problem:

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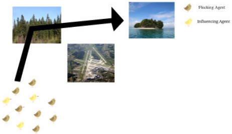

Related Work — Ad Hoc Teamwork

- Stone et al. 2010
  - Introduced the ad hoc teamwork problem
- Agmon and Stone 2012, Stone et al. 2010
  - Leading teammates in ad hoc settings from a game theoretic approach
- Jones et al. 2006
  - Empirically studied dynamically formed heterogeneous multi-agent teams
  - All agents know they are working as a team

Related Work — Flocking (1)

- Reynolds 1987, Vicsek et al. 1995
  - Concerned with simulating flock behavior
  - Not concerned with adding controllable agents to the flock
- Turgut et al. 2008
  - Considered the behavioral effects of providing different information to the flock
- Jadbabaie et al. 2003, Su et al. 2009, Celikkanat and Sahin 2010
  - Used controllable agents to influence the flock
  - Only concerned with making the flock converge to some heading eventually

Related Work — Flocking (2)

- Couzin et al. 2005
  - Considered how grouping animals make informed unanimous decisions
- Cucker and Huepe 2008, Ferrante et al. 2010, Yu et al. 2010
  - Used informed agents to influence flock
    - Behave in a fixed way that is predetermined on based on type
- Han et al. 2006
  - Studied how one agent can influence the direction in which a flock of agents is moving
  - Utilized one influencing agent with unlimited, non-constant velocity