Adding Influencing Agents to a Flock

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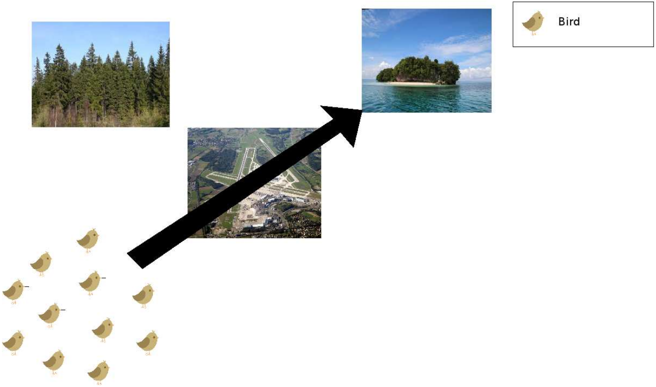
Motivating Example



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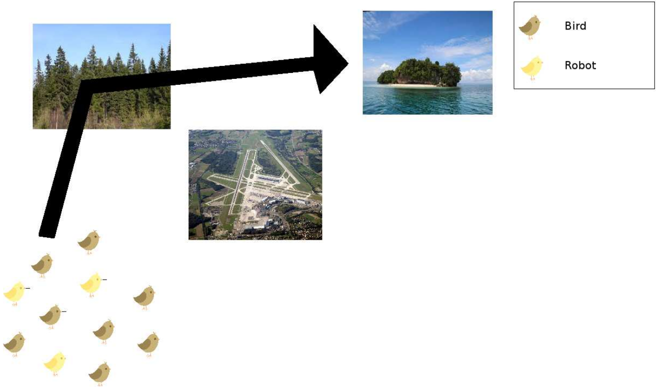
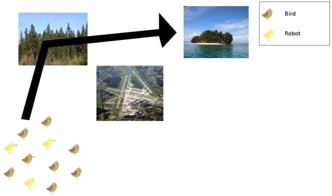


Ad Hoc Teamwork

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

Scientific question: How to design an agent to productively join a pre-existing team while requiring no pre-coordination?



Flocking

- Emergent behavior found in nature
  - Birds, fish, insects
- Simple local behaviors & interactions
- Group behavior appears well organized and stable

Research Question

Research Question:

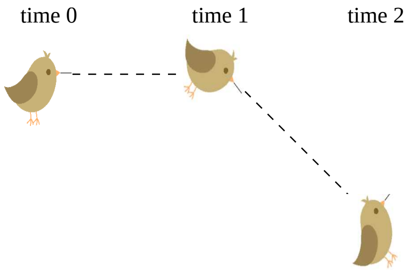
How can robots be utilized in various types of flocks in order to influence these flocks towards a particular behavior?

Outline

Problem Definition

Both robots and birds have:

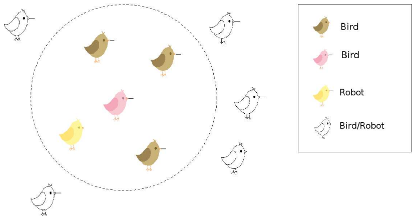
- Constant, equal velocity
- 2D Position
- Global orientation



Problem Definition - Neighborhood

Each bird reacts only to birds and robots within a certain neighborhood around itself.

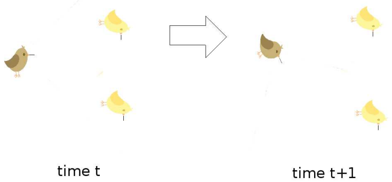
- Characterized by a sphere of influence in this work



Problem Definition - Orientation Update

A birds' orientation at the next time step is set to be the average global orientation of all birds and robots currently within the bird's neighborhood.

- Birds follow a simplified Reynolds flocking model



Problem Definition - Performance Metrics

Two metrics used in this work:

- Number of birds ‘lost’
- Number of trials in which any birds are ‘lost’

Research Question

Previously we considered how robots should behave and where they should be located within a flock in order to best influence the flock (Genter and Stone, ANTS 2014 & Genter, Zhang and Stone, AAMAS 2015).

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> Given computational limitations, how should robots be placed within a flock?

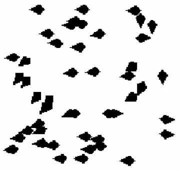
> How should robots join a flock in motion if they are able to arrive ahead of the flock?

Outline

Existing Placement Methods

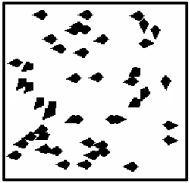
Initial position “dropped into the flock”

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



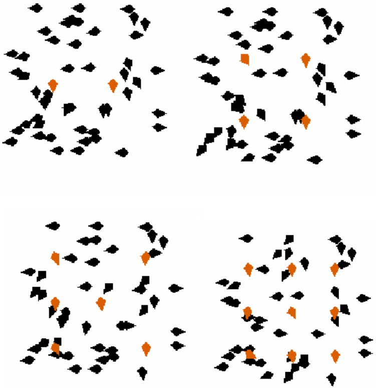
Existing Placement Methods

- Random Placement
  - Randomly place robots within the square in which birds might exist.
- Grid Placement
- Border Approach
- Graph Approach



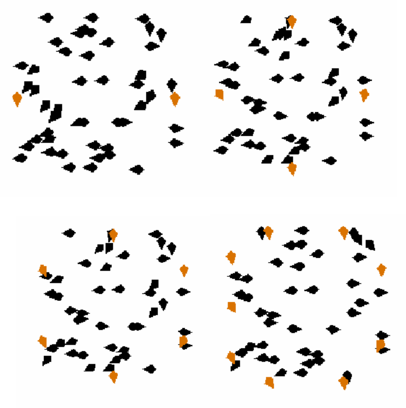
Grid Placement

Place robots at predefined, well-spaced, gridded positions throughout the square in which birds might exist.



Border Approach

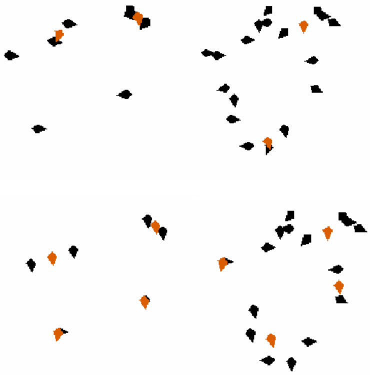
Place robots as evenly as possible around the square in which birds might exist.



Graph Approach

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

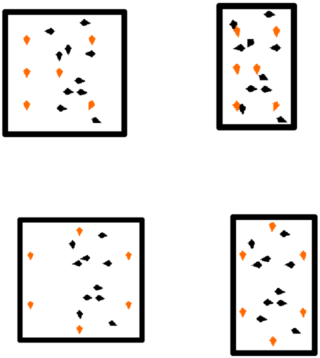
Complexity of placing robots:
$O((\text{robots}+\text{birds})^3 \binom{\text{birds}^2+\text{birds}}{\text{robots}})$



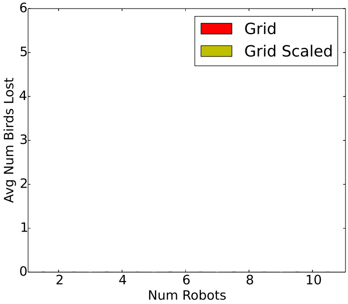
Outline

Scaled Placement

Fit the placement area for robots as a rectangle around the actual area covered by the flock.

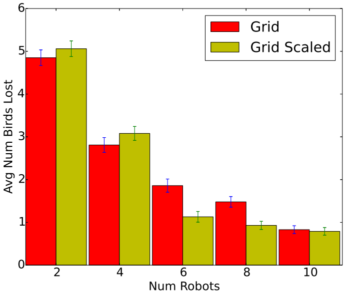


Scaled Placement Experimental Results



The average number of birds lost when the flock contained 10 birds and 2-10 robots. These results are obtained over 100 runs. Error bars show the standard error of the mean.

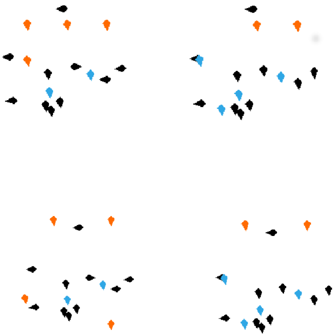
Scaled Placement Experimental Results



The average number of birds lost when the flock contained 10 birds and 2-10 robots. These results are obtained over 100 runs. Error bars show the standard error of the mean.

Hybrid Placement

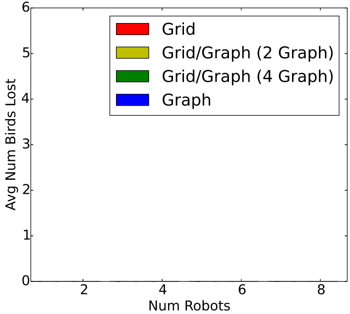
Use the Graph placement method to choose the first k_g robot placements. Then select the remaining $k - k_g$ placements using a constant time placement method.



Complexity of Graph placement:
$O((\text{robots}+\text{birds})^3 \binom{\text{birds}^2+\text{birds}}{\text{robots}})$

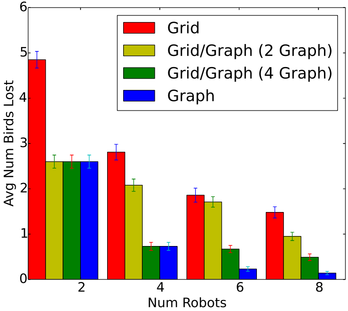
Complexity of Hybrid placement:
$O((\text{robots}+\text{birds})^3 \binom{\text{birds}^2+\text{birds}}{k_g})$

Hybrid Placement Experimental Results



The average number of birds lost when the flock contained 10 birds and 2-8 robots. These results are obtained over 100 runs. Error bars show the standard error of the mean.

Hybrid Placement Experimental Results



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Outline

Behavior as Flock Arrives

So far, we have assumed robots can be placed into a flock.
Now, we begin to consider joining a flock.

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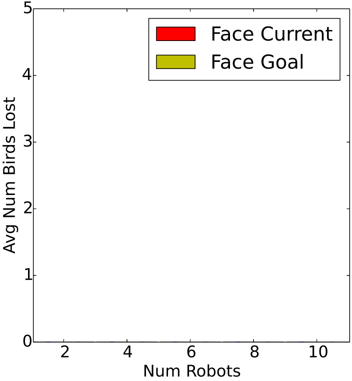
Now, we begin to consider joining a flock.

If robots are able to position themselves ahead of an approaching flock, how should these robots behave as the flock approaches?

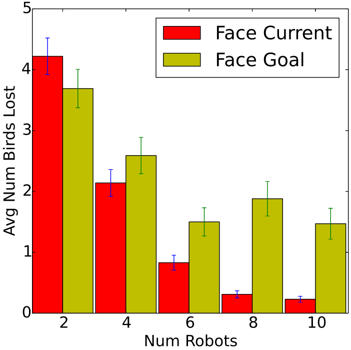
- Face Current
- Face Goal

Arrival Behavior Experimental Results



The average number of birds lost using the border placement approach when the flock contained 10 birds and 2-10 robots. These results are obtained over 100 runs. Error bars show the standard error of the mean.

Arrival Behavior Experimental Results



The average number of birds lost using the border placement approach when the flock contained 10 birds and 2-10 robots. These results are obtained over 100 runs. Error bars show the standard error of the mean.

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 robot with unlimited, non-constant velocity

Summary

- Scaled placement approach
- Hybrid placement approach
- Behavior when able to position ahead of flock

Research Problem:

Given computational limitations, how should influencing agents be placed within a flock? How should influencing agents join a flock in motion if they are able to arrive ahead of the flock?