Agent Behaviors for Joining and Leaving a Flock (Extended Abstract)

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ABSTRACT

Each individual bird in a flock of birds updates its behavior based on the behaviors of its neighbors. Previous work has considered how a small set of algorithmically controlled influencing agents, or robot birds, can influence the flock to behave in a particular way — such as to avoid airports or wind farms. These robot birds are assumed to be seen by the flock as ordinary birds, and hence are able to influence their neighbors. However, we are aware of no previous work that has considered the issues related to robot birds joining and leaving flocks of natural birds. Due to the influence the robot birds have on the flock as soon as members of the flock become neighbors, joining and leaving are not straightforward. In this abstract, we discuss simple approaches for robot birds to use when joining and leaving flocks of natural birds.

Keywords

Flocking; Emergent Behavior; Swarms and Collective Behavior; Joining a Flock; Leaving a Flock; Ad Hoc Teamwork

1. INTRODUCTION

Imagine that a flock of birds is flying towards an airport. Although this flock will be harmless in most cases, it could cause a costly and potentially dangerous bird strike if the flock collides with a plane. With this motivating example in mind, this abstract introduces approaches that robot birds could use to join a flock, influence the flock away from an airport, and then leave the flock.

Our work follows a well-recognized flocking model [6] when we assume that each bird in the flock updates its heading at each time step based on the headings of its neighbors. Since there is no way to directly control the flock's flight path, we must instead alter the environment so as to encourage the flock to alter their flight path as desired. Specifically, we assume the possibility of deploying *robot birds* to influence the flock. Once these robot birds are part of the flock, they influence the flock by orienting according to the 1-Step Lookahead algorithm [1]. These robot birds follow our algorithms but are perceived by the rest of the flock to be one of their own.

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Previous work [4] assumed that influencing agents could either (1) start within the flock or (2) teleport into the flock. Neither of these assumptions would hold though if robot birds were deployed to influence flocks in nature. Hence, in this abstract we consider how robot birds could join a flock in motion. There are two different scenarios for joining — *hover* in which the robot birds are able to hover with a particular orientation at a set position and *join together* in which the robot birds maintain the same velocity as the birds in the flock. Due to space limitations, we only consider the easier *hover* scenario in this abstract. Likewise, we point the reader to our previous work [4] for a problem definition that describes the flock dynamics assumed in this abstract.

2. JOINING A FLOCK

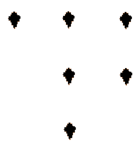
The *hover* approach for joining a flock features the robot birds reaching their desired positions along the flock's flight path ahead of the flock. Once at their desired positions, the robot birds adopt a particular heading and hover at their desired positions. In this section we consider methods for selecting desired positions and orienting before the flock arrives.

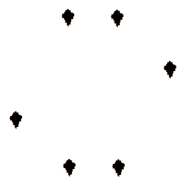
2.1 Desired Positions

Selecting positions for k robot birds is often a trade-off between effective high computation cost methods and less effective low computation cost methods. Since selection of desired positions needs to occur in real-time and be scalable to large flocks, we consider successful computationally efficient methods from previous work [3] as well as a new method. The three methods we consider are depicted in Figure 1.

The *grid* and *border* position selection methods are adapted from previous work [3]. Specifically, the *grid* position selection method selects k well-spaced, gridded positions within the dimensions that will eventually be occupied by the natural birds. The *border* position selection method selects k well-spaced positions along the borders of the area that will be occupied by the natural birds. At most $\lceil \frac{k}{4} \rceil$ robot birds are placed on any particular side of the flock — the edges that receive an additional robot bird are chosen randomly.

The *K-Means* desired position selection method utilizes the open-source Weka implementation [5] of the K-Means clustering algorithm. First, the algorithm uses the Farthest First clustering algorithm to choose k natural birds as cluster centers. Then, all m natural birds are assigned to their nearest cluster center and the centroid is calculated for each cluster. These centroids are then set as the new cluster centers. Then, all natural birds are assigned to their nearest cluster center. This process repeats until convergence, at which point the robot birds are each assigned a position at a cluster center.


(a) Grid


(b) Border

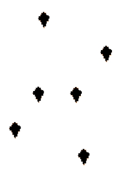

(c) K-Means

Figure 1: The three *hover* position selection methods for $k = 6$ influencing agents.

2.2 Arrival Behavior

Once the k robot birds are positioned at their desired positions ahead of the approaching flock, their orientation becomes important because the orientation of the robot birds will influence the flock as it arrives. In this abstract we consider four different arrival behaviors. Examples of each of these arrival behaviors are shown in Figure 2.

The *face initial* and *face goal* arrival behaviors behave as would be expected from their names. Robot birds employing the *face initial* behavior have no influence over an arriving flock, as the flock is already facing the same direction as the robot birds. On the other hand, the *face goal* behavior begins influencing the natural birds to orient towards θ^* before the flock has even finished arriving.

The *influence* arrival behavior influences natural birds towards θ^* using the 1-Step Lookahead algorithm [2]. We expected this approach would perform similarly to the *face goal* behavior, since both approaches influence the natural birds towards θ^* before they finish arriving.

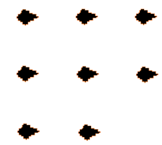
Finally, the *condense* arrival behavior orients each robot bird at a 45° angle towards the mean axis parallel to the natural flock's initial heading. Although this behavior influences the natural birds before they finish arriving, it also condenses the natural birds. Our hypothesis was that a more condensed flock would be easier to influence.

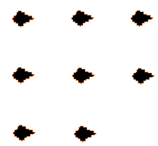
3. LEAVING A FLOCK

Once the robot birds have joined the flock and influenced the flock to face a new orientation using the 1-Step Lookahead algorithm [2], they should then leave the flock. To the best of our knowledge, no previous work has considered how robot birds should leave a flock after influencing it. Given short battery life, exiting a flock quickly without negatively influencing the flock will be important if joining and influencing approaches are to be used with real flocks of birds.

The *hover* approach for leaving a flock is similar to the *hover* approach for joining a flock. In this case, all of the robot birds hover in place facing θ^* when it is time to leave. Leaving a flock under the *join together* scenario is much more complicated.


(a) Face Initial


(b) Face Goal


(c) Influence

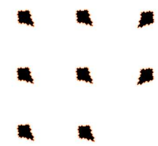

(d) Condense

Figure 2: The four *hover* arrival behaviors when $k = 8$, the *grid* position selection method is used, the flock is approaching from the north, and we want to turn the flock to the east. Each agent is facing in the direction of its narrow triangular tip — hence, in (a) all of the influencing agents are facing south.

4. DISCUSSION

Due to space constraints, rather than presenting extensive experimental results, we briefly summarize our main initial findings. In general, the *K-Means* position selection method and either the *face goal* or *influence* arrival behavior methods should be used. However, if it is most important to maximize the number of natural birds oriented within 10° of θ^*, then the *grid* position selection method and the *face initial* arrival behavior method should be used.

5. SUMMARY

The main drawback of the *hover* approach for joining and leaving is that it requires the robot birds to hover in place. Hovering could be problematic if robot birds that would be recognized by birds as 'one of their own' are unable to hover. For this reason, in future work we will consider the *join together* scenario in which the robot birds maintain the same velocity as the birds in the flock. Additionally, future work will present complete experimental analysis of the *hover* approaches for joining and leaving.

6. ACKNOWLEDGEMENT

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