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Abstract

Each one of birds flying in a flock seems to be flying based on its own will, and not thinking of the whole shape of the flock. But the entire shape of the flock looks as if all birds have discussed the flocking plan.

Based on the phenomenon, we have built a model of artificial creatures. In computer simulation, we observe their adaptive behavior and general shape of the flock under simple conditions and rules.

1. Introduction

Today, there are many kinds of artificial life with complex systems which make the dynamics of the whole system be complex with one or several simple changes. We focus on the behavior of a whole group when we define some simple conditions for individuals. In the artificial model it is assumed that the creatures decide their behavior based on a few conditions extracted from the Boids[1] behavior, which is a simulation of a flock of birds. Boids have simple rules, which are:

1) avoiding collision against neighbors,
2) matching and coordinating own moves with neighbors,
3) gathering together.

Though the flock's behavior is very complex, boids define rules only for each bird. The artificial model creatures also need to get feeds. Adding a simple feature of "searching for feeds," we see if the group can get feeds efficiently while each creature acts upon its own interest in feeds.

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2. Conditions

Next, we consider the conditions which are required for each creature. Each creature can only be aware of the movements of its neighbors. In our model we assume that each creature searches for feeds, so we add a condition on searching for feeds. The condition "searching for feeds" will make each creature act similar to its neighbors, and due to the condition there will be a general objective as a group.

We use the "searching for feeds" condition in place of the Boid's second rule of "matching and coordinating own moves with neighbors." Here are the three conditions we propose for the model:

1) searching for feeds,
2) keeping a distance from other creatures,
3) gathering together.

We will observe how the artificial creatures match their movements with the neighbors, guided only by the above three features. We also observe how the creatures flock, and how they move around the feeds, as well.

3. Territory

In search of feeds, we will adopt two rules. In the first rule, the creature's individual benefit is given priority over group benefit. This is done making *search-feed* energy higher than *keep-distance* energy, and hence, resulting in an *uncooperative* search.

In the second rule, the group benefit is given priority over the individual benefit by making *keep-distance* energy higher than *search-feed* energy, and thus, making a *cooperative* search.

Giving the creatures high *keep-energy* means encouraging them to make their own territory (Fig.1). This territorial behavior is essential for making use of the space in search of feeds. We examine which rule is more essential in resembling the real world under three conditions[2].

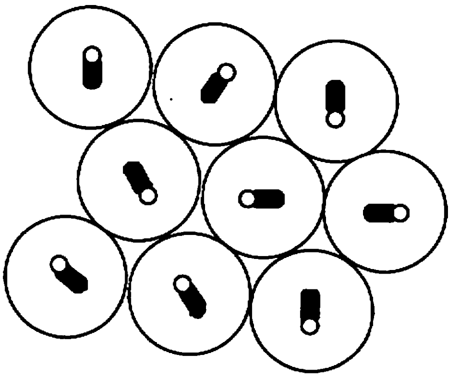

Fig.1 The creatures and territories

4. Vectorization

We treat each condition or rule expressed as a vector.

4.1 *Searching for feeds*
A creature can reach for a feed which is the nearest one in a limited space (neighborhood). It calculates a vector to the location of the feed. The creature has a vector for searching for feeds in the same direction of the vector and inversely proportional to the size of the vector.

4.2 *Keeping a distance from other creatures*
A creature obtains vectors to the locations of creature's neighborhood. The size of vectors corresponds to the distance to the other creatures in the neighborhood. When the size is smaller than minimum size allowed, the creature obtains a vector for keeping a distance from other creatures, in the opposite direction of the vector and inversely proportional to its size. The operation applies to all creatures in the neighborhood.

4.3 *Gathering together*
This feature works the same way as the feature *keeping a distance from other creatures*, in (4.2); the size of vectors corresponds to the distance to the other creatures in the neighborhood. When the size is more than a maximum size allowed, the creature obtains a vector for gathering together in the same direction of the vector and directly proportional to its size.

We sum the vectors mentioned in 4.1, 4.2, and 4.3 (Fig.2).

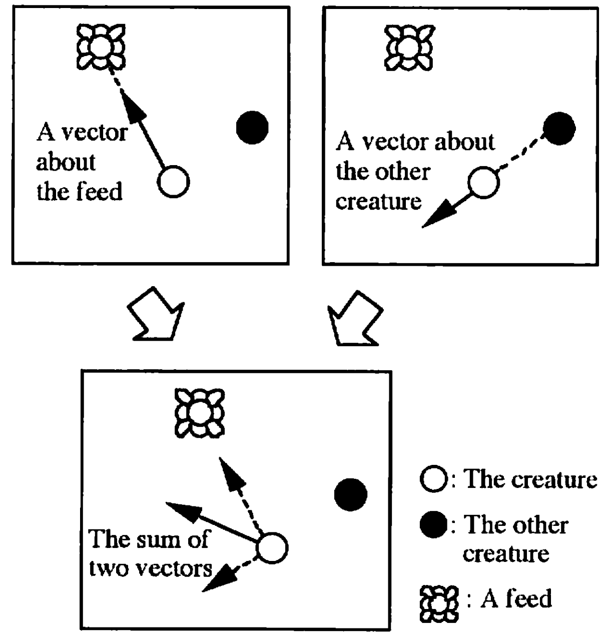

Fig.2 An example of the sum of two vectors

The resulting vector gives the direction and magnitude of the creature's next move.

5. Flow of the system

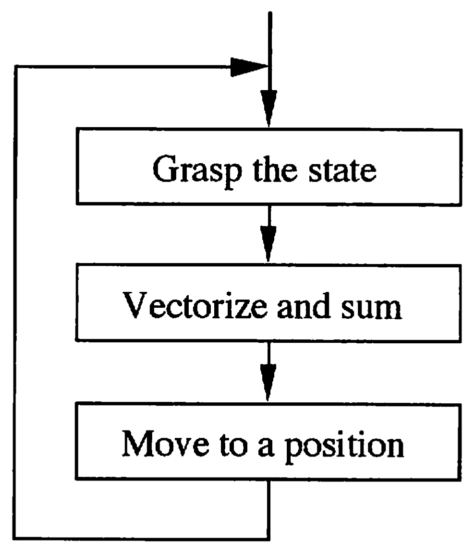

Fig.3 Flow chart of the system

We show a flow chart of the system (Fig.3). At first, we focus on a creature; we search for feeds and other creatures around the creature. Next, it vectorizes and sums these data and the creature decides the next action. Repeating the process, the artificial creatures can make a group like that of natural creatures.

6. The Experiments

6.1 Placing feeds

We need to determine methods for the creatures' feeds gathering. Here is a brief description of our artificial model: we assume that several artificial creatures and many feeds exist in a limited space. We assume two arrangements of feeds. In the first, we place feeds at random(Fig.4). In the other, feeds are in patches[3] scattered non-uniformly in the space (Fig.5). A patch is a set of feeds, similar to worms on a tree in nature.

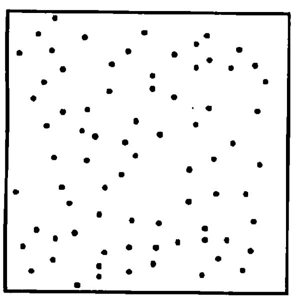

Fig.4 Feeds placed at random

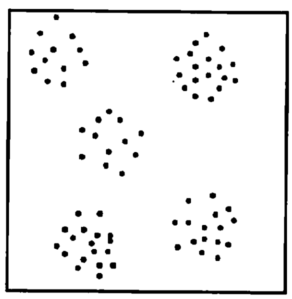

Fig.5 Feeds in patches

6.2 Placing creatures

We place creatures randomly within the space. We observe how the creatures gather together, and how long it takes for them to gather.

6.3 Priority

We must consider priority of the three features: *search-feed*, *keep-distance*, and *gather-together*. It is obvious that *search-feed* is searching for its own feed, *keep-distance* is keeping its own property, and *gather-together* is protecting individual/group interest, thus, we can set up the following basic priority levels:

Priority level	Feature
1	Search-feed
2	Keep-distance
3	Gather-together

The priority order may change depending on various situations. In general, if a creature is coming near other creature(s), then the highest priority is *keep-distance*, and so on.

6.3.1 Uncooperative search

Uncooperative search means that the creature's individual benefit is given priority over group interest. This is done making *search-feed* energy higher than *keep-distance* energy. So the creatures are searching for feeds for the sake of their own individual benefit. Thus, when the creatures want to eat feeds, they consider their own territory less frequently, consequently, the priority of *keep-distance* becomes low; resulting in the following priority level:

Priority level	Feature
1	Search-feed
2	Gather-together
3	Keep-distance

6.3.2 Cooperative search

Cooperative search means that the group benefit is given higher priority over individual benefit, so it is the opposite of the uncooperative search. The creatures share a place to search feeds, and the search is expected to be an efficient move. In case of a cooperative search, *keep-distance* priority is maintained as the highest. The priority for *keep-distance* is to make each own territory, and for the *keep-distance* feature, we set up three levels: safe distance, recognition distance, and collision distance (Fig.6). These levels make the creatures' move flexible. Thus, we adopt the following priority levels for cooperative search below:

Priority level	Feature
1	Keep-distance
2 or 3	Search-feed
2 or 3	Gather-together

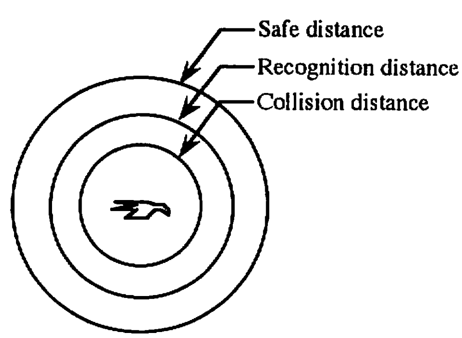

Fig.6 A creature's territory

6.4 Other environmental parameters

Here are other environmental parameters in the experiments:

Size of the space:	600 * 600
Population of the creatures:	50
Number of the patches:	5
Number of feeds:	50 in a patch

The behavior of creatures was observed, and performance of the artificial model was evaluated.

7. Results

Here are the results of the experiments.

7.1 Placing feeds

In the experiment, we watch how the creatures behave when we place feeds randomly, and when they are placed in patch(es).

7.1.1 At random

The creatures get feeds individually(Fig.7), and at the end of searching feeds action, the creatures gather.

7.1.2 In patches

The creatures get feeds, while they are gathering(Fig.8).

Fig.7 Behavior when feeds are placed at random

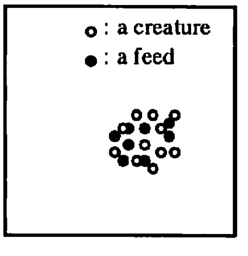

Fig.8 Behavior when feeds are placed in patches

7.2 Placing creatures randomly and placing no feeds

The creatures gather, but it is not always the case that all of creatures gather, due to their limited field of vision (Fig.9).

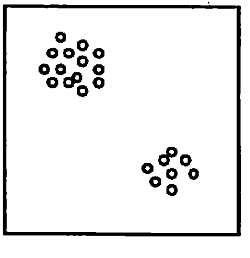

Fig. 9 No feeds are placed and creatures are placed randomly

7.3 Priority

In the experiments we change only the parameter of *keep-distance* vector, and we see the difference in *searching-feeds*.

7.3.1 Uncooperative search

The creatures gather very closely and get feeds while keeping a shape of flock(Fig.10). As a result they waste time for getting all feeds.

7.3.2 Cooperative search

Compared with the uncooperative search, the creatures break down flock to match appropriately with the size of the patch(Fig.11). As a result they get all feeds about twice as fast as in the uncooperative search.

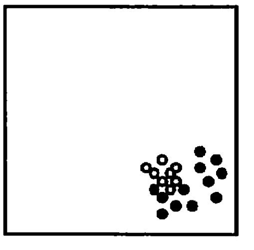

Fig.10 Uncooperate search

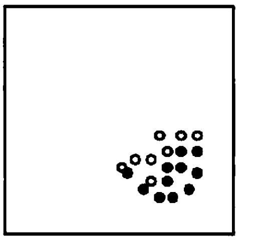

Fig.11 Cooperate search

8. Conclusion

From simulation results we conclude that we can create creatures whose performance is close to that of real creatures in the real natural world under some simple conditions.

In future work, we will create a more efficient system with more intelligent creatures that have short-memories to remember the previous movement. Also, we are considering applying the system to some real society problems.

9. References

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