Simulation of Honey Bees Navigation using OpenGL

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ABSTRACT

We have developed a mechanical navigation of honeybees (Apis-mellifera) using OpenGL. This simulation consists of a 3D scene in which the bees, the hive and the nectar source (flowers) are included. The behavior of bees is based in leader bees and follower bees. Simulation begins on leader bees coming out of the hive in random walk movement in search of flower nectar. When a flower is found, the leader goes back to the hive to alert the follower bees the position of this source through a dance [6]. This is when follower bees (informed by the leader) fly directly to the location where the flower is. We will present some OpenGL scenes showing the steps of this process.

1. INTRODUCTION

Computer models of the behavior of groups of social insects, like honey bees, have attracted a lot of attention in the last decade [1]. This is due to the intrinsic complexities involved in the parallel movement of a very large amount of individuals each with specific rules of behavior. From the point of view of the field ecologist computer models provides a mechanism for testing, in controlled conditions, hypothesis based in data obtained in the field work. From the point of view of the computer scientist the interest goes from the development of realistic computer graphics animations to more recent developments of optimization algorithms based on insects. Besides the challenges confronted in this type of modeling one attractive feature is that in many cases the observed global complexity can be reduced to a set of simple local rules of behavior.

At a first approximation honey bees can be characterized by a simple behavior goal, they search for food (nectar) and take it to the hive. A more detailed characterization recognizes a hierarchy where the hive contains the queen, the bees that search the nectar (leader), and the bees that follow the leaders (followers). So, any computer model should start by recognizing this hierarchy and use it as the foundation of a computer model.

In this paper we present an implementation of a three-dimensional (3D) simulation and visualization of the navigation mechanism of honey bees moving back and forth between the hive and the nectar sources. The model is based in simple local rules of behavior based on the individuals. In the next section we present the methods and algorithms that we applied in the implementation of the model. Then we present some of the scenes at different stages in the simulation and finally the conclusions.

2. METHODS

The 3D environment contains several objects: the bee, the flower and the hive. All the objects were constructed from scratch using the basic graphic primitives available from the OpenGL and GLUT libraries.

The physical objects of the simulation were constructed using simple three-dimensional geometric figures. We created individual sections and used them as building blocks for more complicated objects. For example, the bee is a yellow sphere with wire wings (Figure 1). Other objects derived from spheres were the flowers, the hive and the petals (half spheres). Also, we used cylinders to build the hive's tree and the flower's stem.

For each object in the scene we defined texture maps based on standard GIF image files [8]. Then, we put them in a matrix. This is like an invisible cube that let us manipulate the object. This matrix is collocated in the three-dimensional field and we move it by translations of its coordinates.

For obvious reasons the most active object in our simulation is the bee. There are two main types of movements involved in its dynamics: random walk motion and direct motion. These movements are carried out depending on the hierarchy to what they belong and they are basically defined as: random motion and direct motion. During random motion the bee search for food in the surroundings of the hive and the movement can be approximated with a random walk motion. This basic motivation is based on the fact that the honey bee is looking for a source of nectar that is not clearly defined during the first trip [7]. During direct motion the honey bee already found a source of nectar, knows the

location, and moves back to the hive to report the location to the follower bees.

2.1. Bees and Basic Behavior

The bees were divided in two categories: bee leaders and bee followers. Some of the functions were used by both types of bees.

2.1.1 Bee Leader

This is the bee that leaves the hive in search of nectar sources. If the search is successful comes back to the hive to communicate to the bees in the hive the approximate localization of the food.

Functions defined for the bee leader

Create leader

By using a function call Bee (that creates the body of the bee) the bee leader is created and its behavior defined by the following functions.

Activate Random movement

This function switches the movement of a particular object from direct motion to a random walk motion**.**

Detect the source of food

Each flower is associated with an "attraction barrier" with defined the distance where the bee can "see" the flower. Once, the bee go trough the barrier, it means that the bee has successfully seen it.

Activate direct movement to the flower

After detecting the flower, the random movement is deactivated and the direct movement takes place. This will take the bee to the exact coordinate of the flower.

Activate direct movement to the hive

After having successfully reached the flower, it means that the bee has the food. The next task is to go straight back to the hive to transfer the information. Therefore, direct movement is activated again, but this time the goal is the hive.

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Create bee follower

Having reaching the hive, the bee leader indicates to its partners the location of the food. In this case, the information contains the coordinates of the flower. By this way, we create new bees whose only job is to collect the nectar from the flower that the bee leader found. We call these bees, the followers.

Activate random movement

Again, the random movement of the bee leader is activated to search for new flowers.

2.1.2 Bee Follower

These bees do no make decisions; they just receive information of where is the food and bring it.

Functions of Bee Follower

Create bee follower

By using a function call Bee (that creates the body of the bee) the bee leader is created and its behavior defined by the following functions

Create direct movement to the flower

There is an specific coordinate given by the bee leader to the be follower. Once this information is provided to the follower they only thing that it has to do is to activate the direct movement to the flower.

Activate direct movement to the hive

After having successfully reached the flower, it means that the bee has the food and the process repeats again.

Delete Bee Follower

Once the follower returns to the hive its main goal has been achieved. Subsequently a new bee leader will be reaching the hive with a new mission.

2.2. Pseudo Code

The entire mechanics of the simulation is described using the following pseudo-code:

```
BeeLeader()
{
```

```
    if( doesn't detect flower )
    {
      randomMovement()
    }

    else
    {
      directMovement( to the flower )
    }
}

directMovement( to the flower )
{
    if( doesn't reach flower )
    {
      translate( move a step to the flower )
    }

  else
  {
      directmovementHive( to the hive )
  }
}

directMovementHive( to the hive )
{
   if( doesn't reach hive )
   {
      translate( move a step to the hive )
   }

  else
  {
      createBeeFollower( with coordinate of flower )
  }
}
```

3. UNIQUENESS

Artificial intelligence was the most difficult task in this project, yet it was the most important. This means that bees can act and take decisions without the need of a user. Also, the movements of the bees are independent from each other. Each time a bee is made, an identification number is given to them. This allows uniqueness for the information for every bee. The data structures used to store this information were arrays.

4. SNAPSHOTS OF THE SIMULATION

Figure1: Here we show how a bee is represented in our simulation.

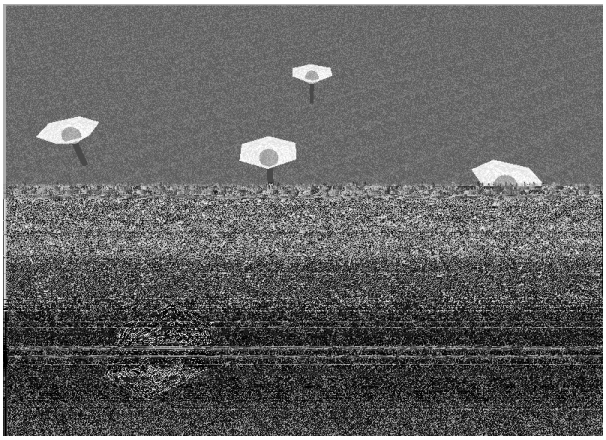

Figure 2: From a near point of view, here we can see the representations of flowers and field, both covered with individual texture.

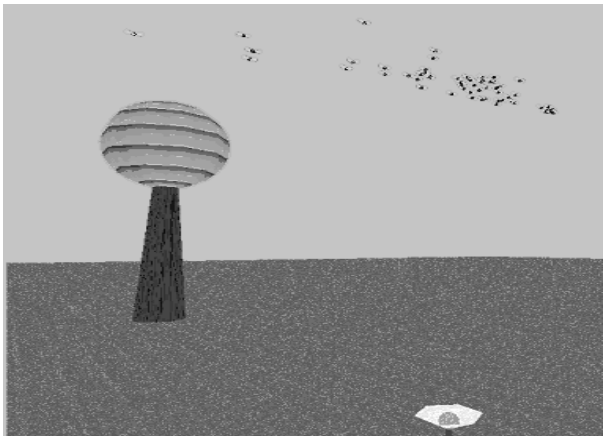

Figure 3: A group of bees flying over the hive, also covered with its own texture.

5. RESULTS AND CONCLUSIONS

We could make a simulation in 3D of the navigation of bees using simple rules and functions. The environment and the objects in it were made using

the graphic library OpenGL. The simulation consists in the behavior of the bees in search of food.

6. FUTURE WORK

There are several things yet to be done in our research. The simulation runs a simple case, just one bee at the same time. We need to make a generalization of this problem and it consists of several bees interacting with each other.

7. REFERENCES

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