A 3-D Serious Game to Simulate a Living of a Beehive

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Abstract. Computational tools are increasingly supporting the learning process in several areas. They open new opportunities for teachers to teach contents and interact with their students. This group of tools includes simulations based on multi-agent systems. This work aims to present a simulation game to study the population growth of a beehive. System variables can be changed in order to analyze different results. Aspects such as duration and time of flowering can be manipulated by the student. The multi-agent approach in Distributed Artificial Intelligence has been chosen to automatically control the activities of the application. Virtual Reality is used to illustrate the behavior of the bees that in general, are not able to be seen in the real world or through mathematical simulation.

Keywords: Simulation, Virtual Reality, Multi-Agents Systems, Serious Games.

1 Introduction

Computer simulations are used to recreate real-life processes in computing environments. They allow us to check how the modeled system works under certain conditions and assess the consequences for the overall behavior of the system [1].

The biology area has many phenomena that can be simulated, which include the process of cell division [2] and predator-prey relationship [3]. Another possibility to simulate the real world in a digital system is to reproduce the activities of social insects. In this case, several agents, the insects, act as their experience and interact with other agents, making decisions in order to maintain the unity of the group. This group is a swarm [4].

This paper aims to present a 3-D game based on a simulation environment which supports the study of the population growth of a society of bees. One of the aspects involved in the beehive growth is the need to collect and produce nectar to ensure energy supply for the entire hive. The solution adopted was based on the areas of Distributed Artificial Intelligence and Swarm, exploring Multi Agents Systems

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concepts. The simulation environment allows the configuration of different variables involved in the hive development process, such as intensity of rain, humidity, wind speed and floral resources (nectar and pollen). The game manages the performance of bees in the collecting tasks. The virtual game offers some aspects of this process that cannot be visualized by mathematical simulation.

To reach these targets, the paper discusses some general related concepts as the use of simulations in the educational process; the Virtual Reality technology and the Distributed Artificial Intelligence. Next, we describe the game characteristics and the results of an experiment to analyse the software usability. Finally we present the conclusions and the reference list.

2 General Related Concepts

2.1 Education and Simulations

The construction of artificial worlds allows students and teachers to experiment environments with high power to support the teaching-learning process [3]. However, in the current model of education the teacher takes the role of the content host. Thus, students are not given the chance to make discoveries, test hypotheses, discuss results, using their own experiences in order to build their knowledge [5].

The simulation of a biological phenomenon in computers motivates learning, since the graphical interface and the ability to explore the environment variables serve to stimulate student. Hence, in this context, the simulations open new horizons in teaching practice as they allow experiments to be reproduced and repeated as often as needed by students [6].

In addition to the simulations, the animations and more recently, the Virtual Reality technology, have the ability to give information in different formats, where the evolution of various phenomena can be seen over time [7].

2.2 Virtual Reality and Games

The Virtual Reality (VR) is an "advanced interface" to access computational applications, with some features: the visualization of three-dimensional (3-D) environments in real time and the interaction with their elements. [8].

Thus, it can be considered as an important resource in facilitating learning. It turns the virtual experiments more realistic. There are 3 features that make VR environments attractive to students: interaction, immersion and presence. The integration of these features creates a sense of reality, captivating the attention of the student, and interfering positively, motivating him to learn [9].

The educational tools must present characteristics that offer the possibility of the students to build their own knowledge, and so enable the teacher to conduct this teaching-learning process in the context of knowledge construction. Among their key features, we can mention: Interactivity, simulation of real aspects; and representation of information in various ways, such as text, graphics, and animations [10].

In this sense, some initiatives have been developed to explore the potential of simulations in the educational context. The PhET is a web environment that has multiple simulations for the areas of Physic and Chemistry. The simulations have graphical interface, good usability and they do not use VR or Artificial Intelligence technologies. It is an initiative of researchers from the University of Colorado [11]. The Cell Biology Animation has several animations that simulate contents of Cell Biology. The animations have ambiance and low graphical interactivity with the user [12]. The NetLogo Hares & Lynx Model [13] consists of a simulation of the predator-prey relationship between lynxes and hares. It offers a graphical environment where we can choose some initial values and we can see a simple animation of these populations' evolution.

In general, these systems have a low level of interaction; they do not explore intelligent strategies neither Virtual Reality technologies.

Currently, a 3-D computer game with the goal of education and/or construction of concepts can be considered as "Serious Games" [9]. In general, Serious Games allow the simulation of real-world situations, providing activities that stimulate the learning process.

2.3 Agents

The Distributed Artificial Intelligence (DAI) is an Artificial Intelligence area that addresses complex problems. It explores the idea of cooperation between software or hardware agents to perform a task. The DAI area includes the multi-agent approach, i.e., multi-agent systems (MAS). The MAS provide computational mechanisms using autonomous entities, the agents, which interact in a shared environment [14]. Unlike traditional approaches, the multi-agent approach has as its main focus the study of collectivity and not the individual entity. In this sense, the MAS approach can be used for the simulation of decentralized and collaborative environments. Agents are entities that can solve these minor problems to achieve an overall goal.

An agent can be considered an autonomous system seeking different ways to reach pre-established goals in a real or virtual environment [14]. Their behavior is the result of their knowledge about the environment and from the exchanged messages with other agents.

Agents have some important features: An environment of operation, a continuous cycle of life, sensors seeking changes in the environment, actuators acting on the environment and autonomy, that is, independent of user action. Agents have continuity over time and are continuously active. Among all these features, the ability to manage its internal state and its actions without human involvement is a consensus [14]. The agent model used in this work was the reactive one. Reactive Agents are simple agents based on simple event-response model, reacting to environmental changes. These agents have no memory and thus are unable to plan future actions [15]. The idea of this architecture is that a global intelligent behavior is achieved by the interaction of several simple behaviors.

In general, simulations with agents recreate an environment with autonomous entities that interact with each other. They evolve over time and undergo adaptations that depend on the conditions imposed by the changes in the environment.

Next, the game that integrates all these concepts is presented.

3 The Game

The 3-D game is composed by a scenario with some different plantations and a beehive. The goal of the game is to maintain the stock of honey in the beehive. A bee must go to some plantations to get nectar and take it back to the hive. There are some obstacles that can hinder the success of this action: a bird can eat the bee or the wind can take the bee out of its good way.

To start the game, the user must choose an option on the first screen: to play the game or to study the bee morphology.

If the game play is chosen, the player chooses the difficult level: beginner, intermediate and advanced; enter a name to register the scores; and chooses the climatic conditions: sunny day, cloudy day or evening. Next, the user receives information about his scores, the nectar and the honey stored in the hive, and the number of the bees that are in the hive. After that, a scene that shows a forest with a beehive opens up (Figure 1).

Then the user takes the position of the bee and flies in searching of flower fields. There are seven different plantations distributed in the environment. Each field has a flowering period.

Over time the player earns points but loses honey, due to consumption by the bees in the hive. When the bee collects nectar and takes to the hive to produce honey, the user gets points. Every 100 points he earns a lifetime. When the stored honey finishes, the player loses a life. If he has no more lives, the game ends.

The game has two cameras, one provides the vision that the bee has and another that shows the bee in flight (Figure 3).

On the other hand, if the user chooses to study the morphology of the bee, a screen containing the 3-D bee model is shown (Figure 2). In this case the parts of the bee can be viewed from different angles. The bee model can be rotated in various directions and if clicking on an area of its body, a brief description of their functionality is shown.

3.1 The Game Implementation

The simulation system and the game development process explored specific methodologies for agent modeling and implementation. They were modeled using a goal orientation method, the Multi-agent System Engineering-MaSE[16]. The JADE framework supported the agents' implementation. In order to integrate all particularities of these components we used the NetBeans platform [17].

Blender modeling environment was chosen for the creation of 3-D models [18]. To create the game environment and the configuration of the system interactivity the Unity 3D engine was used [19].

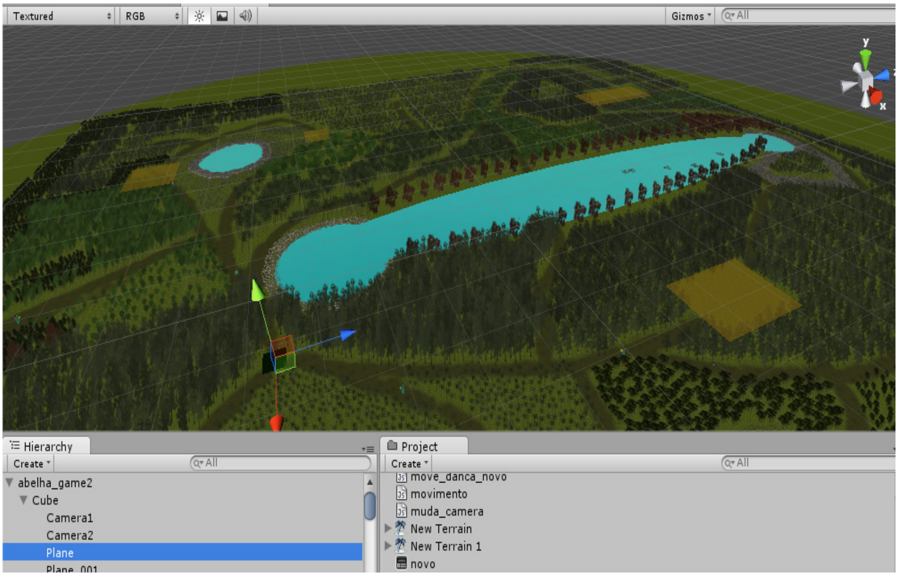

Fig. 1. The visualization of the game scene

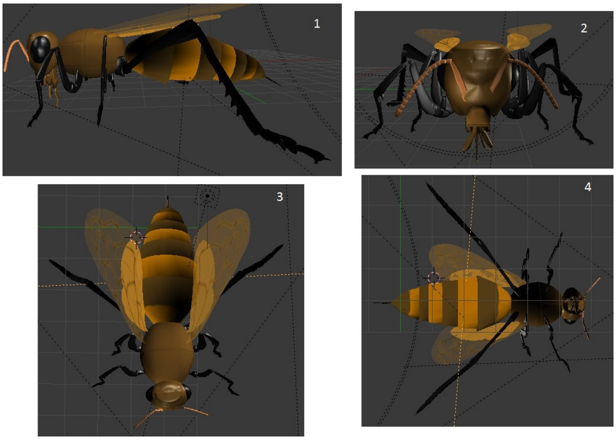

Fig. 2. The morphological study of a bee

Fig. 3. The two cameras vision

In the game, the behavior of bees and the hive are similar to real. To support that requirement we used mathematical models that simulate the hive's population growth, the hive's energy balance; climatic variations and flowering cycle of different plants. Next, these models are briefly described.

3.2 Simulation Models

A quantitative model of bees' population dynamics was applied to calculate the population growth curve of bees [20]. In this mathematical model the eggs originate larvae that become the young bees, which carry out tasks in the hive. Then they become forage bees that work for a period and die. The egg laying held by the queen is influenced by the beehive size. The lack of sufficient food for all beehive individuals can raise the mortality rate of bees causing in the long run, the collapse of the beehive.

The beehive energy balance was based on other work [21] that quantified the pollen and nectar collecting and the honey and beeswax production by bees from a beehive. A beehive with approximately 50,000 bees produces 125 kg of honey. And this requires about 250 kg per year of nectar. For the pollen they collect about 25kg per year. On average, the beehive consumes about 90% of the honey produced to run their activities. Thus, approximately 15 kg of honey are stored in a honeycomb unmanaged, i.e. in the wild.

In general, a bee carries a charge of about 40 mg of nectar. As for the pollen they carry about 20 mg [21]. Since the nectar and pollen loads carried by a bee are known, it becomes necessary to discover how many bees are foraging in a beehive per hour. From the knowledge of the average percentage of foraging bees that make the collection of pollen and nectar at a certain time, we can calculate the amount of nectar and pollen transported in a day.

All presented calculations on the energy balance do not consider the climatic influences and possible seasonality in bloom. Thus, we had to search for data that can be used to simulate these factors.

The Department of Ecology of the Biology Institute in the University of Sao Paulo (USP) has a bee Laboratory that provides a table with the timing of flowering plants visited by the *Apis melífera* bees [22].

Beyond flowering, that information provides the resources to ensure the beehive energy balance, and the climatic factors that affect the flight activity of bees, such as humidity, rainfall and wind speed.

4 Tests

Some usability tests were applied with elementary and secondary school students to observe some aspects of the game usability. According to Nielsen [23], there are five attributes that define usability: Ease of learning, Efficiency of use, Ease of use, Error Rate, and Satisfaction.

The usability test was conducted with five users. Nielsen [23] stresses that this number of users is sufficient to meet about 85% of the usability problems of a system. The test results are shown in Table 1.

Table 1. Usability tests results

Questions	Users					Average
	1	2	3	4	5	
1. The option “help” clarifies all doubts about playing.	5	5	4	5	5	4,8
2. The option “help” shows clearly the game goal.	5	5	4	4	5	4,6
3. The displacement in the environment is easily done.	4	4	4	4	4	4
4. The information on the screen help the player to achieve its goal.	5	5	5	5	5	5
5. It's easy to identify the scene elements.	5	5	5	5	5	5
6. The layout of the navigation keys facilitate its use.	5	4	5	5	5	4,8
7. The beginner level allows players to learn the game.	5	5	4	4	5	4,6
8. The colors of the scenes elements are adequate.	5	5	5	4	5	4,8
9. The game clearly displays the score and game time.	5	5	5	5	5	5
10. The game encourages the player to play at a higher level.	5	4	4	5	5	4,6
11. It's easy to pause the game and return without losing data.	5	5	5	5	1	4,2
12. The fact the game has a rating of record holders encourages the player to try again.	5	5	5	4	5	4,8
13. The information shown on the screen providing easy visualization.	5	4	4	5	5	4,6

This test had a great importance for the development of the system. It allowed us to detect problems in game control. From that, we changed some navigation controls and the format the information was presented to user. In general, we considered that the students had a high level of interest in the game activities.

Now we are starting a more formal experiment with a group of students to observe the gain in the learning processes.

5 Conclusions

In general, it is a hard task to teach some complex concepts that were not easily observed in the real world. The integration of three-dimensional visualization with simulation systems can facilitate the study of these topics.

Specifically, in the area of biology there are some software that offer diversified materials to support learning of complex concepts. However, they do not offer options for working with various learning strategies, because they address general topics.

Aiming to overcome these limitations, this paper presented some initial results of a project that has two objectives. The first one is associated with the technical and educational questions related to the development of a multi-agent simulation system to simulate the behaviour of a beehive, which is not exactly the focus of this paper. The other, aims at finding the combination of technologies to support the integration of intelligent agents within a 3-D serious game to open new possibilities for learning this theme in a more motivational way. The game depends on the simulation system because the bee behaviour in the game is based on the simulation models implemented in the first one.

The main contribution of this work in relation to others reported in the literature is the possibility to play a game to learn biology concepts associated to the bees' lives, supported by a simulation intelligent system. In this case, the game considers real situations and combines climatic variables and with the behavior of swarms. Another important issue is the innovative integration of specific technologies and languages for agents' modelling, development and their integration in a 3-D environment.

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