EPiC Series in Engineering
Volume 1, 2018, Pages 1–6
ReVo 2017: Laval Virtual ReVolution 2017
"Transhumanism++"

MitsuDomoe: Ecosystem Simulation of Virtual Creatures in Mixed Reality Petri Dish

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Abstract

In this study, we propose the use of mixed reality (MR) for the purposes of biological education. Our objective is to create an interactive edutainment MR framework for users to learn about nature and human beings. MitsuDomoe, an interactive ecosystem simulator of virtual creatures in a petri dish, comprises three species of primitive artificial creatures. MitsuDomoe simulates the predation chain of the virtual creatures in the petri dish, and users can interact with this ecosystem via the petri dish interface. Users can also experience immersive observation by wearing HMD. By combining the MR petri dish and immersive virtual reality (VR) interfaces, we synergistically improve user understanding of the experience.

1 Introduction

In this study, we propose the use of mixed reality (MR) for biological education. Our objective is to create an interactive edutainment MR framework for users to learn about nature and human beings. As shown in Fig. 1, MitsuDomoe is an interactive ecosystem simulator of virtual creatures in a petri dish. This virtual ecosystem consists of three species of primitive artificial creatures and simulates the predation cycle of these virtual species in the petri dish, as illustrated in Fig. 2.

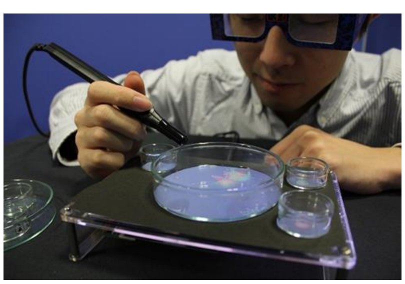


Figure 1: MitsuDomoe system

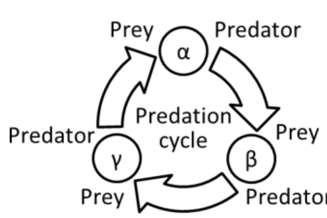


Figure 2: Predation cycle

Figure 3: Mitsudomoe symbol

"Mitsudomoe," the name of a Japanese abstract symbol depicting a swirl with three elements, refers to the cyclical, and typically eternal, relation among these three elements. Figure 3 shows the traditional mitsudomoe symbol.

In related studies, Ishii and Shinoki developed a "simple eco-ball" as an educational tool for a study unit on "nature and the human" for junior high school students in Japan [2]. The eco-ball is an experimental fish tank in a closed sphere, which simulates a miniature ecosystem. They placed small fish, crayfish, and aquatic plants in the simple eco-ball, which is filled with air, fresh water, and sand. With this tool, students are taught that environmental balance is important for all organisms. Our MitsuDomoe project introduces new interactive MR tools for science education.

2 Ecosystem Simulation Models

The cellular automata model computes the autonomous behavior of patterns on a grid space [6]. Conway's "Game of Life," which is based on cellular automata, shows the complex dynamics of cells whereby each cell expresses a primitive artificial life according to a simple rule [1]. More recently, Kamimura et al. developed an improved chase and escape model for modeling the behavior of two groups that are chasers and their targets [3].

In the computer graphics context, Reynolds developed a behavioral animation model for flocks of birds and/or schools of fish, known as "boids (bird-oids)" [5].

A number of predator–prey models have been proposed for simulating population dynamics in a system. Of these, Lotka-Volterra equations describe the competition between two species that are predator and prey [7].

Both the predator–prey and chaser–escapee models treat the relations between the two different species as asymmetric, with opposite functions.

In contrast, our proposed model assumes a symmetric and cyclical relation between three species that have essentially the same functions, as shown in Fig. 2. In this scheme, the species have a predator–prey relation, but each species can behave as both predator and prey. Based on this cyclical competition scheme, the simulated ecosystem establishes a fair rule for all species.

We define a behavior model for these virtual creatures in the ecosystem by two state-transition layers. The first layer represents the internal states, as shown in the life cycle in Fig. 4. The other represents the external states, which comprise the action states during alive, shown in Fig. 5. These layers work together.

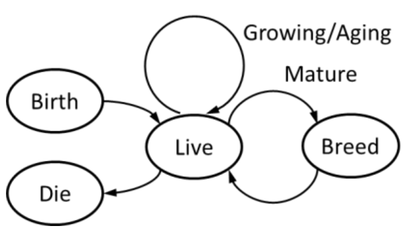


Figure 4: Life cycle

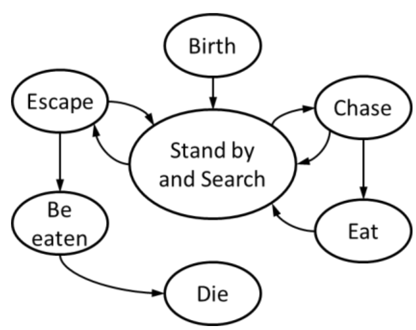


Figure 5: Action states

Users can interact by changing five groups of parameters with respect to each state and transition, as shown below:

1) Life-cycle-related parameters

2) Mobility parameters
3) Searching action parameters
4) Perception range
5) Initial number and distribution of creatures

To create a wide variety of dynamics, we change the parameters of a single simple behavior model applied to each species. Different parameter sets characterize different species, such that some behave like carnivorous creatures, others are herbivorous, and others are found in mass groups of small creatures such as insects or microorganisms.

The particular parameters are hidden from the users. Instead of the parameters, we present the users easily comprehensible factors to be controlled. The factors are fertility, mobility and sensing factors. By tuning these factors, species can be changed to exhibit offensive or defensive behaviors.

3 System and User Interface

Figure 6 shows the system configuration, in which there are two interface subsystems for participating in the experience—the MR petri dish and immersive virtual reality (VR) interfaces.

Users interact with the ecosystem via the interactive petri dish display. There are four petri dishes on an LCD module, and users can observe the ecosystems in these dishes. Figure 7 shows the petri dish display. The large dish at the center is the primary dish inhabited by the three species, and the three small surrounding dishes supply species samples. Users can transfer creatures from the small dishes to the primary dish using a pipette-like device.

User can control the factors by dropping virtual chemical from a factor control palette into the small dishes.

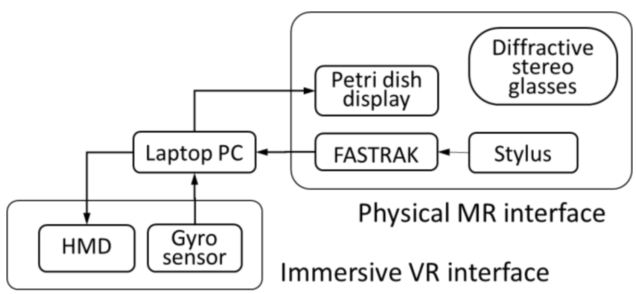


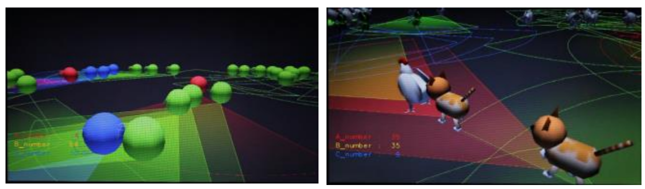
Figure 6: System configuration

Figure 7: Petri dish display and factor control palette

Because the petri dish interface enables users to experience an MR space, that is, virtual creatures in physical petri dishes, it can provide users with the sense and enjoyment of performing experiments in a laboratory.

Since there are many small creatures displayed in the petri dish, the stereoscopic feature serves to enhance user understanding of the ecosystem dynamics. We adopted a view-independent pseudo stereo scheme so that people observing the display can do so with a stereoscopic view. Users wear ChromaDepth 3D, diffractive holographic glasses by which longer wavelength colors, such as red, appear to be above shorter wavelength colors regardless of the observing position.

With the VR interface, users can also experience immersive observation. Figure 8(a) shows a first-person view of the system. In this prototype, creatures are depicted as simple colored spheres in order to avoid any user impression bias based on specific shapes. However, the use of appropriate models that match creature behaviors would enhance the reality of the simulated ecosystem, which is shown in Fig. 8(b).



(a) Sphere models (b) Creature models

Figure 8: First-person view of the system

By combining the MR and immersive VR interfaces, we synergistically improve user understanding of the experience, because the observation target can be seen simultaneously from both the outside and inside. The use of this interface in group learning will further enhance its benefits to students who can exchange ideas based on each viewpoint.

As shown in Fig. 9, from one to four people can participate simultaneously in the ecosystem simulator experience.

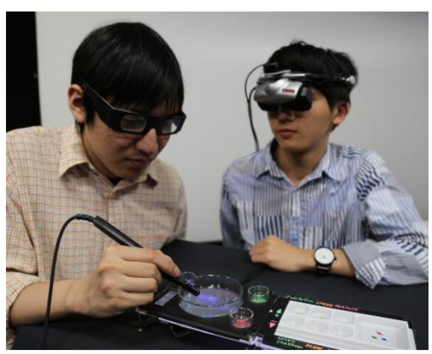


Figure 9: Multi-user experience

4 Conclusions and Future Plans

In this study, we developed a novel prototype system for the purposes of biological education, comprising a simulation model and MR and VR interfaces.

We have conducted user demonstration studies with professionals and the public to establish proof of concept of the project at Laval Virtual 2017 in March. There are about two hundred participants joined our demonstration. Figure 10 shows the scene. In general, we have confirmed this MitsuDomoe system prototype to serve as a new technical platform for augmenting the creative experience of users in science education.

In the next research phase, we will make detailed tests of the qualitative behaviors and quantitative descriptions in the model and develop it to a higher level of sophistication. And the validity and feasibility of this concept should be further determined with reference to issues in the target domain—science education. And we will also develop other variety of the system based on the same concept.

Figure 10: Demonstration for public users

Acknowledgements

We would like to thank the members of our laboratory for their help in preparing materials, developing the system, creating content, and performing the experimental demonstration.

This work was supported by the Japan Society for the Promotion of Science KAKENHI Grant Number 16K00288

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