Collaborative Authoring based on Physics Simulation

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Abstract This research studies the Virtual Reality simulation of Newton's physics law on rigid body type of objects for physics learning. With network support, collaborative interaction is enabled so that people from different places can interact with the same set of objects in Collaborative Virtual Environment. The taxonomy of the interaction in different levels of collaboration is described as: distinct objects and same object, in which there are same object - sequentially, same object - concurrently - same attribute, and same object - concurrently - distinct attributes. The case studies are the interaction of users in two cases: destroying and creating a set of arranged rigid bodies. We identify a specific type of application for contents authoring with modeling systems integrated with real-time physics and implemented in VR system. In our application called Virtual Dollhouse, users can observe physics law while constructing a dollhouse using existing building blocks, under gravity effects.

Keywords: VR, Simulation, Collaborative Virtual Environment, Collaborative Authoring, E-Learning

1. Introduction

In educational science, there is a concept called constructivism[1], which means that a human being responds to his/her environment, and using it to construct and to organize his own knowledge. By this principle, a student who participates in planning and design phase can experience simulation based on what he/she has designed or configured, not just experiencing simulations with a pre-designed set of parameters. A reconfigurable simulation is needed for educational purpose.

Several Virtual Reality (VR) systems have included easy configurability with XML-based description. However, it lacks naturalness of the Virtual Experience (VE). Despite the recent technologies that enable various interaction techniques, animation and simulation quality is limited due to lack of physics-based simulation.

Meanwhile, Computer Graphics (CG) techniques have come to enable precise modeling and simulation for 3D objects, such as physics-based simulation engines. However, CG techniques are not sufficient in describing interactivity and not configurable easily by users.

By integrating CG techniques and VR technologies, we identify a specific type of application that can be developed. It is a system for contents authoring with modeling systems integrated with real-time physics and implemented in VR system. Our focus is to implement the system on a collaborative support so that we can involve users in a Collaborative Virtual Experience (CVE) for authoring system.

Virtual Dollhouse is our developed application so that users can author 3D contents in physics-based CVE, so that physics-based simulation can also be experienced during authoring process. In this system, users learn by building a certain arrangement of rigid bodies of several shapes in order to build a Dollhouse.

In this type of simulation, teachers only act as mediator, so that there is no intervention to students learning. Thus, cooperative work between students is the result of the student-centered learning. With the development of Internet, a Collaborative Virtual Environment (CVE) can be developed for "learning by doing" activities by students from different physical places.

Several studies about interaction between users and objects in CVE have been done based on the type of interaction. Categorization based on objects handling i.e. which object to interact with, is described by this cooperative object manipulation research[2].

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Categorization based on attributes handling i.e. interaction on the same attribute both sequentially and concurrently, is described by a research[3] on event traffics during shared manipulation of objects.

2. Design

2.1 Taxonomy

Based on several related works[2],[3], we would like to propose a taxonomy for collaboration types in CVE. First of all, we focus on object manipulation, because interaction between users and objects describes much of what users must do in the CVE.

Our taxonomy, as in Figure 1, starts with a category of objects: manipulation of distinct objects and same object. In many CVE applications, users collaborate by manipulating distinct objects. Each user interacts with own set of objects. For manipulating the same object, sequential manipulation also exists in many CVE applications. For example, in a CVE scene, each user move one object, and then they take turn in moving the other objects.

Concurrent manipulation of objects has been demonstrated in related works[2] by moving a heavy object together. In concurrent manipulation of objects, users can manipulate in category of attributes: same attribute or distinct attributes.

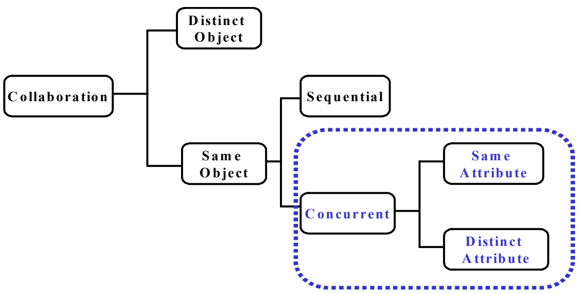

Figure 1: Taxonomy of Collaboration on Objects

2.2 Scenario

Same object manipulation can be described using the Virtual Dollhouse application. The users are presented with several building blocks, a hammer, and several nails. Simple interactions like putting nails on a building block and then hammer them down are the key of this simulation. During the building, user may want to lift a block together with the other user, because it may be too heavy.

Sequential manipulation case can be viewed when a user moves a building block to the other side of the space, and the other user moves it to another side. Concurrent manipulation is when more than one user wants to manipulate the object together, e.g. lifting a block together. In concurrent manipulation of an object, the manipulation can be done either on same attribute or distinct attributes.

We can consider two kinds of concurrent manipulation: same attribute manipulation and distinct attributes manipulation. Example of same attribute manipulation is when two users want to move a building block together, so that both of them need to manipulate the “position” attribute of the block. Example of distinct attributes manipulation is when one user is holding a building block (keep the "position" attribute to be constant) and the other is fixing the block to another block (set the "set fixed" or "release from gravity" attribute to be true).

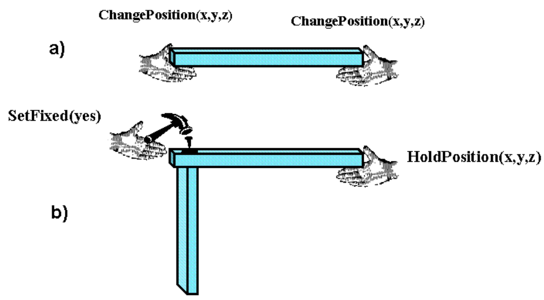

Figure 2: Scenario of Collaboration on Same Object

3. Implementation and Results

3.1 Implementation

SGI OpenGL Performer[4] is used in implementing this application. The application is programmed in C/C++ language in Microsoft Windows environment. A joystick is attached to each collaborating computer. The joysticks were configured to support 4 degrees of freedom (DOF), which includes front-back, left-right, up-down movements and rotation. VRPN server[5] is executed to provide management of networked joysticks to work with the VR application.

We use NAVERLib[6], a middleware used for managing several VR tasks such as device and network connections, events management, specific modeling, shared state management, etc. We use nvmDisplayManager to enable same display views in more than one computer. The module nvmDeviceManager is used for managing communications to VRPN servers attached by input devices. nvmEventManager is used to enable events sending from devices to system, and vice versa. nvmDSSM (dynamic shared state management) is used to implement shared-state management used in networked physics engine.

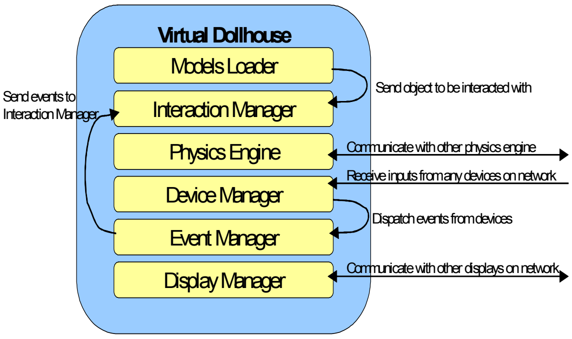

Figure 3: Modules of NAVERLib in Virtual Dollhouse

Our implementation consists of interaction manager and physics engine. The interaction system manages color feedbacks so that user can interact with the system more easily. In this case, each object's frame can change color according to what user has done to the object. The feedback system is described in Figure 6. This interaction system is useful in a space where the user is not immersed into the 3D space, so that user can have a clue on object's positions in 3D space that are viewed from 2D display.

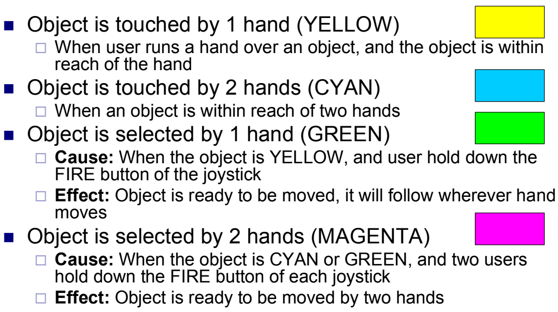

Figure 4: Color scheme for user feedbacks

The physics engine is an adaptation of AGEIA PhysX SDK[7] to work with SGI OpenGL Performer's space and coordinate systems. This physics engine has a shared-state management so that two collaborating computers can have identical physics simulation states.

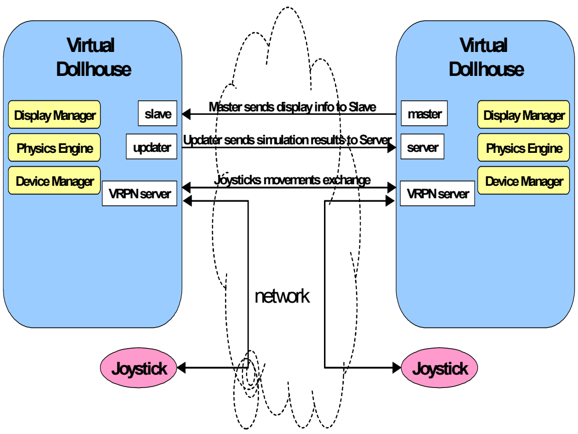

Figure 5: Networked Virtual Dollhouse

To enable easy XML configuration, the application is implemented in a modular way into separate DLL (Windows' dynamic library) files. Using pfvViewer, a module loader from SGI OpenGL Performer, the dynamic libraries are executed to work together into one single VR application. All configurations of the modules are written in an XML file (with .pfv extension). The modules can accept parameters from what are written in the XML file, such as described in Figure 8: the configuration for shared physics engine.

3.3 Results

A test-bed for this experiment consisted of two users. Each user used a computer with a joystick attached to it. The two computers are connected through LAN. First, the user tried to lift two objects together in order to build a dollhouse. The two users could lift two purple blocks together and then the yellow block as seen in Figure 6 (left) into a simple house (Figure 6 right).

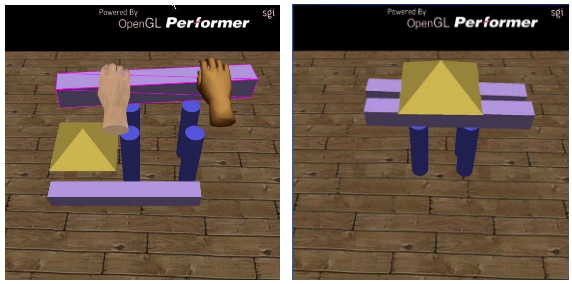

Figure 6: Two users lifting an object together to build a simple house

The Figure 6 above shows two persons with a hand each, lifting the blocks during building (left part), and the finished form of the house (right part). Then, the two users tried to manipulate different attributes of a block using a hammer object. User could hammer the object to release it from gravity so that the object can be released by hand and fixed on location.

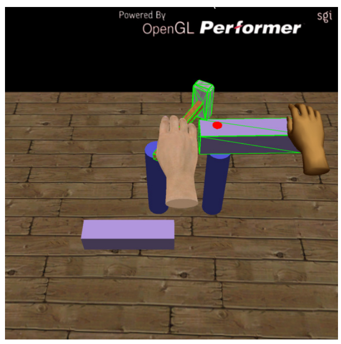

Figure 7: Two users working on same object but manipulating distinct attributes

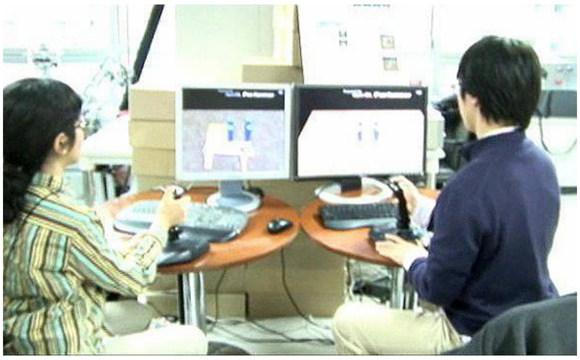

Figure 8: The test-bed system for collaboration over LAN where users each has a joystick and the two displays are identical

4. Conclusion and Future Work

We have implemented an application for simulation-based virtual experience, based on VR systems and simulation of physics law. The system allows reconfiguration of the simulation elements so that users can see the effects of the different configurations. The network support enables users to work together when interacting with the simulation, and see each other's simulation results.

This system supports collaborative authoring (building) of a house under physics law effects. Interactivity is enhanced by visual feedbacks so that two users can collaborate on 3D objects from 2D display views with the visual aid.

Our system has only been tested on LAN, so it is to be tested for collaboration over internet. Performance over internet will be tested accordingly.

The identification of collaboration cases are needed to decide the use of more appropriate haptic device, so that two hands can interact while lifting blocks and using virtual hammers. Using a 6DOF supporting device such as geOrb[8], the hand models can also be made more natural. In this case, each finger of a hand can be bent so that the grabbing movements are more intuitive for users.

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