A 3D SIMULATION OF A GAME OF BILLIARDS USING A HAPTIC DEVICE

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Abstract: Performance improvements in graphics hardware and the diffusion of the low cost haptic interfaces have made it possible to visualize complex virtual environments and provided opportunities to interact with these in a more realistic way. In this paper a Virtual Reality application of a game of billiards is presented. By means of a commercial haptic interface a force feedback is provided, thus rendering the interaction realistic and exciting to the user; the introduction of the force feedback allows the user to actually feel the contact between cue and ball. The virtual environment has been built using the development environment XVR and rigid body dynamics have been simulated utilizing the ODE library. Since in the real game it is possible to use the left hand when aiming and striking the ball, in the play modality it is possible to fix the cue movement in the desired direction in order to allow a more careful aim and a more stable interaction in the virtual environment. In addition it is possible to choose the force with which the ball is hit.

1 INTRODUCTION

The field of computer entertainment technology has aroused a great deal of interest recently among researchers and developers in both academic and industrial fields as it is recognized as showing promise in terms of generating exciting new forms of human computer interaction.

Techniques used in computer entertainment are also seen to translate into advances in research work ranging from industrial training, collaborative work, novel interfaces, novel multimedia, network computing and ubiquitous computing.

At the same time, performance improvements in graphics hardware and the diffusion of the low cost haptic interfaces have made the visualization of complex virtual environments possible and provided us with the opportunity to interact with these in a more realistic way.

Haptic feedback in virtual environments makes it possible to increase the overall realism of a simulation by improving the user experience.

Haptic interfaces in virtual environments have been intensively studied in the past decade. Different types of haptic interface are used in virtual games which provide multimodal feedback creating a deeper sense of being in control of the game, of participation.

Players like to get some bodily feedback, be it vibration, movement or other. Vibration is a practical and important way of providing users with haptic feedback. It requires a minimal interface design and is low both in terms of complexity and cost. Vibration feedback joysticks are widely used input devices in current games.

Lindeman and al. investigated how vibro-tactile feedback improves task performance (Lindeman, Sibert, Mendez, Patil and Phifer, 2005).

Walters described the technical background of haptics and games and shows the first steps of integrating haptics in PC based games. He concludes by stating that the force feedback devices are now readily available to consumers looking for good force response in their games (Walters, 1997).

Haptic Battle Pong is a pong clone with haptic

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control through the SensAble Phantom device. Force feedback is used to haptically render the contact between the ball and the paddle. Although it provides force to the user it does not allow free bodily action because of the device's restrictions (Morris and Joshi, 2004).

Jiang et al. modified Half-Life and added force and vibration feedback. Their aim was to find out the effectiveness of feedback in a virtual reality training environment. The study concluded that haptic feedback plays an important role as it reduced the error rates of the players (Jiang, Girotra, Cutkosky and Ullrich, 2005).

Snibbe et al. described a set of techniques for manipulating digital media with force feedback (Snibbe, MacLean, Shaw, Roderick, Verplank and Scheef, 2001).

Hayward et al. provided an introduction to haptic interfaces and a summary of devices (Hayward, Astley, Cruz-Hernandez and Grant, Robles-De-La-Torre, 2004).

Salisbury et al. provided a survey of some haptic systems and discussed some haptic rendering algorithms (Salisbury, Conti and Barbagli, 2004).

Some virtual simulations of a billiards game have been developed with and without the force feedback sensation.

Gourishankar presented the HAPSTICK, a high fidelity haptic simulation of billiards game. The system incorporates a low cost interface designed and constructed for the haptic simulation of the billiards game; the device allows motion in three degrees of freedom (two rotations: pitch and yaw, and one translation) with haptic feedback along the translation. The game also includes an auditory feedback (Gourishanker, 2006).

Takamura et al. presented a billiards game simulation and the method used in this research contributes to build a game with high reality. The synchronization among visual, auditory and haptic sensations are attained by SCRAME Net, a fast network system (Takamura, Abe, Tanaka, Taki and He, 2006).

Ciger et al. presented a virtual billiard where ODE has been used to manage the collisions between the billiard balls and the table; for the collisions between the cue and any ball an own collision detector has been created. No force feedback is provided to the user (Ciger and Yersin, 2004).

2 DESCRIPTION OF THE TECHNOLOGIES USED

2.1 Phantom Omni Haptic Interface

The haptic interface used in this simulation is the PHANTOM Omni of SensAble Technologies, Inc.; the device offers 6 degrees of freedom output capabilities. The device specifications are reported in Table 1.

Table 1: Specifications of Phantom Omni Haptic Interface.

Nominal Position Resolution	~0.055 mm
Workspace	> 160 w x 120 h x 70 d mm
Friction	< 0.26 N
Maximum Exactable Force	3.3 N
Continuous Exactable Force	> 0.88 N
Stiffness	X axis > 1.26 N/ mm Y axis > 2.31 N/mm Z axis > 1.02 N/mm
Inertia (apparent mass at tip)	~ 45 g
Footprint	~ 168 w x 203 d mm
Weight	~1.47 kg
Force Feedback	3 degrees of freedom (x, y, z)
Position Sensing	x, y, z (digital encoders) pitch, roll, yaw (± 5% linearity potentiometers)
Interface	IEEE-1394 FireWire port

2.2 eXtreme Virtual Reality (XVR)

XVR is an integrated development environment for the rapid development of Virtual Reality applications. Using a modular architecture and a VR-oriented scripting language, XVR content can be embedded in a variety of container applications making it suitable for writing content ranging from web-oriented presentations to more complex VR installations.

The execution environment, the web browser plug-in and the virtual machine for this system have been developed by PERCRO Laboratory of Scuola S. Anna in Pisa, Italy and the XVR platform has been used in many virtual reality projects (Carrozzino, Tecchia, Bacinelli and Bergamasco, 2005).

Originally created for the development of web-enabled virtual reality applications, XVR has evolved in recent years into an all-around technology for interactive applications. Beside web3D content management, XVR now supports a wide range of VR devices (such as trackers, 3D mice, motion capture devices, stereo projection systems and HMDs) and uses a state-of-the-art graphics engine for the real-time visualization of complex three-dimensional models, which is perfectly adequate even for advanced off-line VR installations.

XVR applications are developed using a dedicated scripting language whose constructs and commands are targeted to VR, and provide developers with the opportunity to deal with 3D animation, positional sounds effects, audio and video streaming and user interaction.

In its current form XVR is an ActiveX component running on various Windows platforms and can be embedded in several container applications including the web browser Internet Explorer.

It is possible to load additional modules which offer advanced functionalities, such as support to VR devices, as a decision was made to keep them separate so that web applications, which do not usually need any of these advanced features, are not afflicted by additional downloading times.

2.3 Open Dynamics Engine (ODE)

The Open Dynamics Engine is an open source, high performance library for simulating rigid body dynamics. It is a fully featured, stable, mature and independent platform with an easy to use C/C++ API. It has advanced joint types and integrated collision detection with friction.

ODE is useful for simulating vehicles, objects in virtual reality environments and virtual creatures. It is currently used in many computer games, 3D authoring tools and simulation tools.

ODE is a free, industrial quality library for simulating articulated rigid body dynamics. It is good for simulating ground vehicles, legged creatures, and moving objects in VR environments.

ODE is designed to be used in interactive or real-time simulations and is particularly good for simulating moving objects in changeable virtual reality environments.

The ODE collision system provides fast identification of potentially intersecting objects and a non-penetration constraint is used whenever two bodies collide; the current collision primitives are sphere, box, capped cylinder, plane, ray, and triangular mesh. However, it can be ignored and an alternative collision detection can be used (Open Dynamics Engine, http://www.ode.org).

2.4 OpenHaptics

The SensAble OpenHaptics toolkit enables software developers to add haptics and true 3D navigation to a broad range of applications, it can be used for design and for games and entertainment and also for simulation and visualization.

Using the OpenHaptics toolkit, developers can leverage the existing OpenGL code for specifying geometry, and supplement it with OpenHaptics commands to simulate haptic material properties such as friction and stiffness.

The architecture enables developers to add functionality to support new types of shapes and it is also designed to integrate third-party libraries such as physics/dynamics and collision detection engines (SensAble Technologies, http://www.sensable.com).

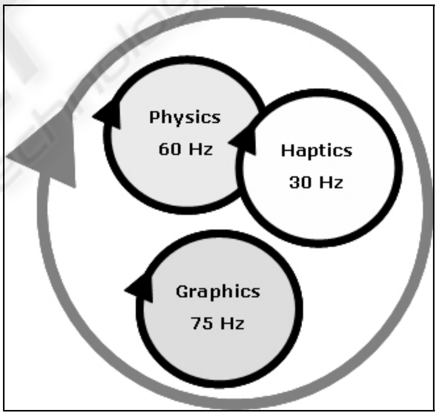

Figure 1: Loops of the simulation.

3 SIMULATION DESCRIPTION

The developed application is a simulation of a game of billiards. To make the game as interactive and realistic as possible for the user a force feedback is provided by means of a commercial haptic interface.

In the simulation it is possible to distinguish three different models: graphical modelling, physical modelling and haptic modelling.

Each type of modelling can be represented by a loop executed at a specific frequency; the XVR application combines all the loops. This is shown in Figure 1.

3.1 Graphical Modelling

The graphical model consists of a set of 3D objects modelled using 3D Studio and imported into the XVR development environment where they are managed using the XVR scenegraph.

The modelled objects are: the billiard table, the cue, the billiard balls and the skittles. An example of billiards with five skittles has been implemented.

XVR provides classes for the lighting, shading and observation point (virtual camera) management; in addition it allows the user to superimpose 2D text onto the scene and this functionality is used in order to provide the user with messages about the system conditions, working modality and error states.

Three different working modalities are allowed:

- *camera modality* the ability to choose the desired position of the virtual camera (no force feedback is provided);
- *positioning modality* when a force feedback is provided for the user in order to allow the correct positioning of the billiard balls in case of necessity or so as to decide the starting state of the game.
- *play modality* when the end-effector is mapped onto the cue and a force feedback is provided to the user by means of the haptic interface;

Since in the real game it is possible to use the left hand when aiming and striking the ball, in the play modality it is possible to fix the cue movement in the desired direction in order to allow a more careful aim and a more stable interaction in the virtual environment. In addition it is possible to choose the force with which the ball is hit.

A game situation is shown in Figure 2.

3.2 Physical Modelling

Each object of the scenegraph is modelled from the physical point of view defining the geometry, the mass, the inertia, the stiffness and the contact friction with another one.

The physical modelling definition is carried out using the functions provided by the library of rigid bodies dynamic simulation (ODE); this library is also used to define the dynamics for simulating the billiard game.

The process of simulating a rigid body is called integration. Each integration step advances the current time by a given step size, adjusting the state of all rigid bodies for the new time value.

The ODE integrator is very stable, but not particularly accurate unless the step size is small. Between each integrator step the user can call functions to apply forces to the rigid body and the sum of these forces will be applied to the body when the next integrator step happens.

At each simulation step, ODE is used to check the collisions between objects and to calculate the forces of interaction and those applied by the user; in addition the speed, new orientation and positioning of the objects are computed. In this way the state of the system is updated and a new one is provided.

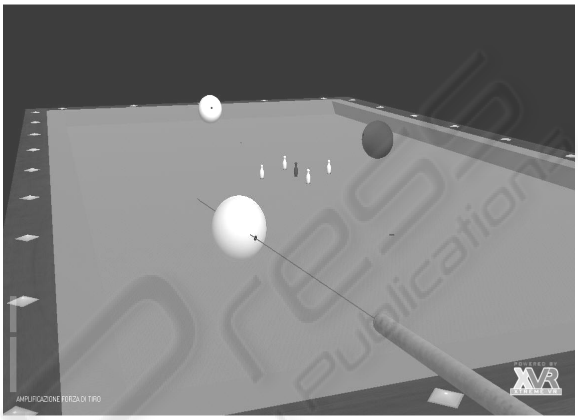

Fig. 2: A game situation.

3.3 Haptic Modelling

Regarding the haptic modelling of the objects that are present in the virtual scene, two different solutions have been considered:

- the utilization of the HapticWeb library of XVR;
- the utilization of the OpenHaptics library provided with the PHANTOM Omni haptic device.

The second solution has been chosen in this application because it permits control at a lower level of the haptic interface.

The cue is modelled as a rigid body and, in the play modality, its position and orientation are linked, using a spring-damper system, to the position and orientation of the stylus of the haptic interface.

At each step of the simulation the forces depending on the movement of the stylus are applied to the cue in order to replicate it as quickly as possible, while taking care to avoid stylus displacement. This model is shown in Figure 3.

The user is provided with a force feedback by means of the haptic interface and calculated applying the proxy method (Van den Bergen, 2004).

A virtual spring-damper system links the end-point position of the virtual cue (the proxy) to the end-effector position of the haptic device. When the cue is in a free space and no collision occurs, the

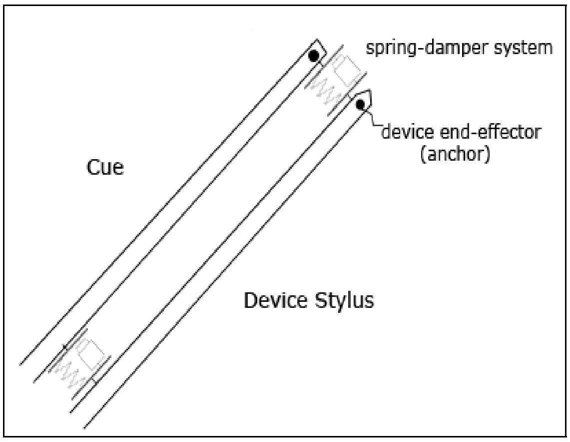

Figure: 3: Virtual coupling for the cue movement.

proxy and the end-effector position are the same, but when the virtual cue collides with an objects in the virtual scene, the proxy cannot enter the body and cannot follow the position of the haptic device; so the positions no longer match and a force is sent to the user.

The force is calculated using (1), where x is the distance between the end-effector and the proxy positions, v is the velocity of the end-effector and k and b are respectively the spring and the damper constants (Van den Bergen, 2004).

$$F = -kx - bv \qquad (1)$$

The described model is shown in Figure 4.

In this way the forces exercised on the cue by the colliding objects are sent to the user by means of the virtual coupling cue-stylus providing the force feedback due to the impact between the cue and the other objects.

From the haptic point of view, the scene is rendered in two different ways: the play modality and the positioning modality.

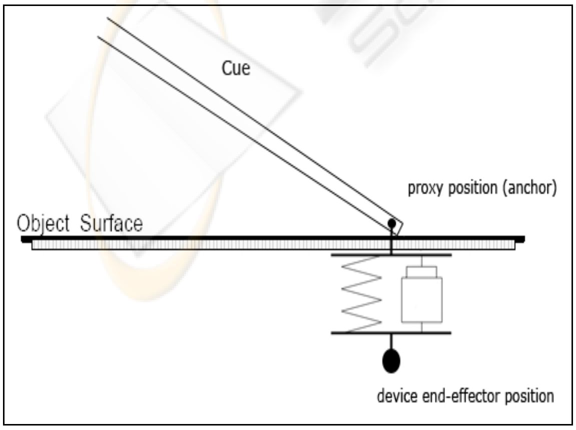

Figure 4: Virtual coupling for the force feedback.

In the play modality, the virtual coupling between the end-effector of the haptic device and the cue provides the force feedback to be sent to the user by means of the haptic device. Figure 5 shows a game phase using the Phantom haptic device.

In the positioning modality, used to allow the correct positioning of the balls in case of necessity or to decide the starting state of the game, the balls in the scene are attracted by the cursor (end-effector of the haptic device); in this way the selection of the ball is made very easy.

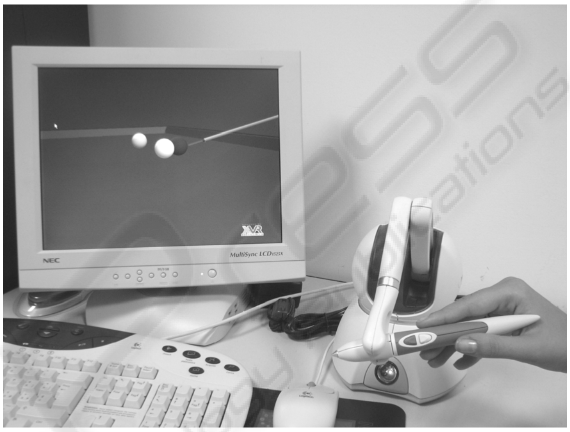

Figure 5: A game phase.

4 CONCLUSIONS AND FUTURE WORK

In this paper a Virtual Reality simulation of the game of billiards is presented. In order to provide the user with an interactive and realistic interaction a force feedback is provided by means of the Phantom Omni haptic interface.

The virtual environment has been built using the development environment XVR and the rigid body dynamics have been simulated utilizing the ODE library.

The introduction of the force feedback makes it possible to obtain a realistic simulation as it is possible to strike the billiard ball and to feel the contact between cue and ball.

The limitations of the simulation are due to the use of a commercial haptic device which has not been specifically designed for the game of billiards.

Because of the limited workspace of the haptic device used, it is not possible to perform some shots, which, in the real game, require wide movements in order to be carried out. In addition, it is not possible to use your left hand in order to stabilize the cue and to obtain a more precise strike, as would happen in the real game of billiards.

For this reason modifications have been made to the simulation: the possibility to fix a chosen direction to the cue during the strike has been introduced and also the ability to decide on the force with which to hit the billiard ball. In this way we have tried to reduce to a minimum the limitations that were present due to the use of a non specific haptic device.

In the present configuration of the simulator, a validation phase will be carried out.

In order to have a general opinion on the project and to obtain an objective response to the realism of the game simulator, billiard players will be asked to try the system out. These players will respond to a questionnaire with questions about the game's playability and the visual and haptic sensations; suggestions that could help improving the game simulation will be also asked. The results of this survey will be used to improve the performance of the simulator.

In order to obtain a more immersive virtual environment and to create the illusion of a stereoscopic image, the utilization of a pair of shutter glasses has been scheduled; these devices are able to display alternate frame sequencing for each eye, thus providing stereoscopic vision.

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