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DIFFERENT SIMULATIONS OF A BILLIARDS GAME

Lucio T. DE PAOLIS[1]
Assistant Professor, Department of Innovation Engineering,
Salento University, Lecce, Italy

E-mail: lucio.depaolis@unile.it

Marco PULIMENO[2]
BSc, ISUFI - Salento University, Lecce, Italy

E-mail: marco.pulimeno@unile.it

Giovanni ALOISIO[3]
PhD, University Professor, Department of Innovation Engineering,
Salento University, Lecce, Italy

E-mail: giovanni.aloisio@unile.it

Abstract: *Performance improvements in graphics hardware have made it possible to visualize complex virtual environments and provided opportunities to interact with these in a more realistic way. In this paper two different types of Virtual Reality applications for simulating a billiards game are presented. In one application a commercial haptic interface is used to provide a force feedback, thus rendering the interaction realistic and exciting to the user. However, there are limitations due to the use of a commercial haptic device which has not been specifically designed for this game and thus limits the workspace. Also, in the commercial device, it is not possible to use the left hand when aiming and striking the ball, as you can in a real game of billiards. In order to overcome these limitations another type of simulation has been developed using a real billiard cue; its movements are reproduced in the virtual environment using a visual marker detection system. No force feedback is provided to the player.*

In the game simulations the virtual environments have been built using the development environment XVR in the first simulator and OpenSceneGraph in the second; rigid body dynamics have been simulated utilizing the ODE and PhysX physics engines. ARToolkit was the visual marker-based detection system utilized to replicate the movements of the real cue used by the player in the virtual environment of the second simulator.

Key words: *simulations; billiards game; virtual environments*

In the field of computer entertainment new technologies have made it possible to generate new forms of human-computer interaction where some bodily feedback is provided, be it vibration or other, which is popular with players.

Haptic feedback in virtual environments makes it possible to increase the overall realism of a simulation by improving the user's experience and providing a deeper sense of being in control of the game and of participation.

In this paper two different types of Virtual Reality simulations of the billiards game are presented. The first uses a haptic device, in order to provide the user with an interactive and realistic interaction. The force feedback is provided by means of a commercial haptic interface and in this way it is possible to strike the billiard ball and to feel the contact between cue and ball. [4]

The second, in order to overcome the limitations due to the use of a commercial haptic device which has not been specifically designed for the billiards game, uses a different type of simulation which has been developed using a real billiard cue.

By means of a visual maker detection system the cue movements are replicated in the virtual environment, but no force feedback is provided to the player.

Billiards game simulations have been developed both with and without the force feedback sensation.

Gourishankar presents the HAPSTICK, a high fidelity haptic simulation of a billiards game.[5] 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 with haptic feedback along the translation.

Takamura et al. present a billiards game simulation and the method used in this research contributes to making the game extremely realistic.[6]

Visual markers are widely used in Augmented Reality (AR) applications. Currently there are several different types of based marker tracking systems.

Zhang et al. compare several marker systems all using planar square coded visual markers. They present the evaluation results, both qualitatively and quantitatively, in terms of usability, efficiency, accuracy, and reliability.[7]

Wilczynski et al. describe internal structure and potential applications of a newly constructed system for rapid game development in augmented environments. A description of separating marker recognition and display engine of behaviour is provided.[8]

Ohshima, et al. present AR2 Hockey where two users wear see-through head mounted displays to play an AR version of the classic game of air hockey and share a physical game field, hockey sticks and a virtual puck to play in simultaneously shared physical and virtual space.[9]

The Billiards Game Simulation Based on Force Feedback

In the first type of simulation of the billiards game, in order to make the game as interactive and realistic as possible for the user, a force feedback is provided and it is possible to strike the billiard ball and to feel the contact between cue and ball. By means of a commercial haptic interface (PHANTOM Omni) a force feedback is provided, thus rendering the interaction realistic and exciting to the user.

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

The graphical modelling consists of a set of 3D objects built using 3D Studio and imported into the XVR development environment where they are managed using the XVR scenegraph. An example of billiards with five skittles has been implemented.

Since in the real game it is possible to use your 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 amplification with which the ball is hit.

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 ODE library is used to carry out the physical modelling definition and to define the dynamics for simulating the billiards game.

Regarding the haptic modelling of the objects that are present in the virtual scene, the utilization of the OpenHaptics library makes it possible to exercise 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 haptic interface stylus.

Figure 1 shows the interactions with the virtual environment using a haptic interface.

Figure 1. Haptic interaction

The limitations of the simulation are due to the use of a commercial haptic device which has not been specifically designed for the billiards game. 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 stroke, as would happen in a real game of billiards. For this reason some modifications have been introduced in the simulation; in particular it is possible to fix the chosen direction of the cue during the strike and also to decide on the force amplification with which to hit the billiard ball.

The Billiards Game Simulation Based on Marker Detection

In the second simulator of the billiards game, the player is not provided with a force feedback because a real cue is used instead of a haptic interface.

By means of a marker detection system the movements of the real cue are replicated onto the virtual one and this is able to interact with the other objects on the virtual billiards table.

In this way, although players cannot feel the contact with the virtual ball, they can carry out all the game procedures with a real cue and, as in the real game, they can use their left hand in order to stabilize the cue and to obtain a more precise stroke.

Figure 2 shows a game phase using the developed billiards game simulator.

Figure 2. A billiards game phase

Regarding the construction of the virtual environment, the same models utilized in the first simulator have been imported in OpenSceneGraph, the 3D graphics toolkit used in this simulation.

OpenSceneGraph is an open source high performance and cross platform 3D graphics toolkit written in Standard C++ and OpenGL; it is used in many flight simulators, games and virtual reality visualization systems. It includes a wide range of features among which there is a complete scene graph, support for a wide range of image and 3D model formats.[10]

OpenSceneGraph is more compatible with ARToolkit, the software utilized to manage the interactions in the virtual environment, and for this reason it has been chosen over XVR.

To implement the dynamics of the rigid bodies that make up the virtual game environment PhysX was the preferred choice.

The NVIDIA PhysX SDK is a physics engine used in a wide variety of console games and game engines.[11] Like ODE it allows rigid body dynamics simulation and collision detection; in addition it offers a wide range of other features such as simulation of deformable objects, advanced character control, articulated vehicle dynamics, cloth and clothing authoring and playback, advanced fluid simulation.

PhysX is free for non-commercial and commercial use on PC platforms, but it is not open source like ODE.

The visual marker-based detection system which was utilized in order to replicate the movements of the real cue used by the player in the virtual environment is ARToolkit.

ARToolkit is a software library for building Augmented Reality applications and uses square markers each carrying a unique pattern which is a planar bitmap enclosed by a black border.[12]

Pattern recognition proceeds in two stages: recognition of the pattern boundaries and correlation of the interior pattern with the patterns stored in a database.

These markers are observed by a single camera and the tracking software uses computer vision techniques to calculate the marker position and orientation from the captured image.

Markers can be used as a tangible interface to handle virtual artefacts or as user interface elements. Tracking is impeded whenever the marker to be tracked is not fully and clearly visible within the camera image; chances of full visibility can be improved by using several markers fixed to a rigid object.

The offsets between the markers must be well-known and there must be some components in the application which are able to calculate the final position of the object from the valid tracking input.

The accuracy of tracking depends on many parameters in the processing chain: the quality of the camera images, calibration of the camera, lighting, size and visibility of the reference marker, the size of the marker to be tracked. If only one of these factors is not optimally set, the results of tracking may be inaccurate or even unusable.

In the developed simulation of the billiards game it is possible, by means of a webcam, to detect a marker grid used to define the position of the reference system with respect which the movements of the real cue are calculated; these movements are detected by means of a marker placed on the cue.

Figure 3 shows the interactions with the virtual environment using a marker-based detection system.

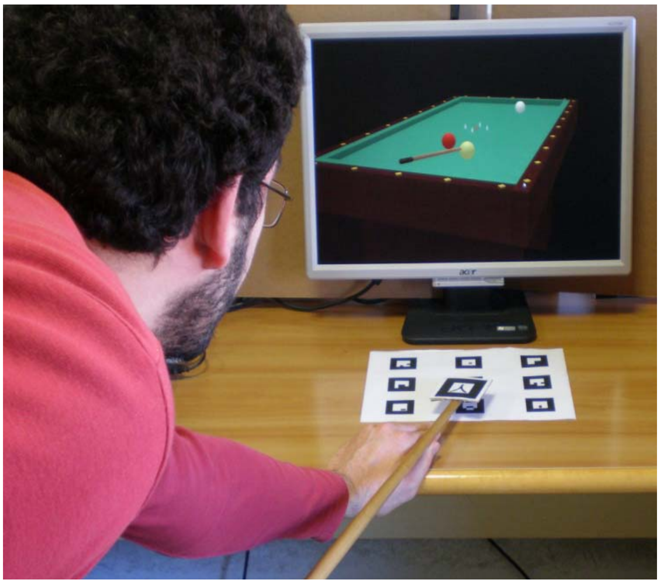

Figure 3. The marker-based detection system

The use of a second marker on the cue was not considered because it would have had to be placed in the visual field of the camera and thus close to the other one. This solution is not feasible because the second marker would impede the cue movement during the stroke.

The movements of the real cue are replicated on the virtual one that is modelled as a physical body provided with mass of its own. The force applied to the ball is calculated by a physic engine and is based on the speed of the real cue during the stroke.

The utilization of a physic engine as PhysX permits the modelling of the physical proprieties of the virtual objects and hence defines their dynamic behaviour by means of masses, frictions, etc.

Without the utilization of a haptic device, the force feedback due to the contact between cue and other objects of the billiard table is lost, but the use of a real billiard cue overcomes the limitations produced by the use of a commercial haptic interface which is not specific to the billiards game.

A marker-based detection system was preferred to another type of tracking system, such as an optical tracker, because it provides a solution which is both cheap and simple to build.

Evaluation Test

This marker-based simulator, based on a marker detection system, allows the player to handle a real billiard cue and thus to carry out all the strokes permitted in the real game, but no force feedback is provided to the player.

In order to validate the simulator, some tests have been carried out in order to check if the system is also able to detect the rapid strokes normally made in the real game.

To evaluate the performances of the tracking method based on marker detection, a test application has been developed able to store the following positions of the billiard cue detected by means of the tracking system during the stroke. This application makes it possible to draw the trajectory obtained from the following positions detected by the tracking system and to compare it with the linear path of the real cue during a stroke.

In this way it is possible to evaluate the ability of the system to detect the cue positions in the cases of slow and fast strokes and to estimate the validity of the chosen method. The data are also stored for future processing.

In the test phase ARToolKit Plus was chosen for use and just one marker to define the position of the reference system with respect to the movements of the real cue; in this way it was possible to achieve a higher degree of accuracy in marker detection and a reduction in processing time. These improvements could easily be transferred to the application.

The carried out tests highlight that the detection system is able to correctly register the billiard cue trajectory in the case of slow strokes; however, when a rapid stroke occurs, the number of detected cue positions decreases and the real trajectory departs slightly from the ideal one. Figures 4 and 5 show the following positions of the tip cue detected by the tracking system in the case of a slow stroke and the difference between the ideal (purple line) and real (yellow line) trajectories.

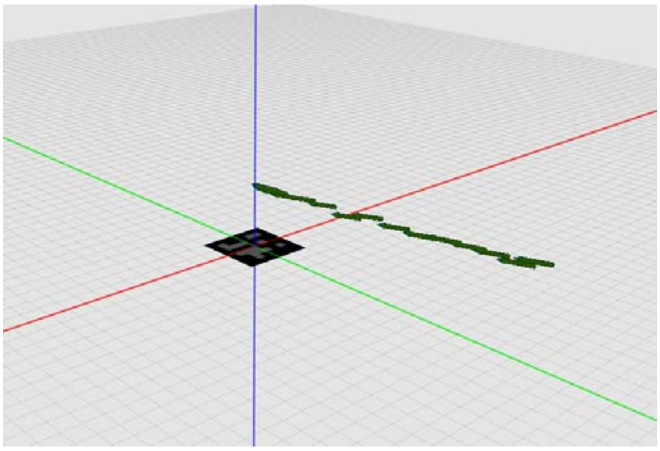

Figure 4. Following positions of the tip cue in the case of a slow stroke

Figure 5. Difference between the virtual and real trajectories in the case of a slow stroke

Figures 6 and 7 show the following positions of the tip cue detected by the tracking system in the case of a rapid stroke and the difference between the ideal (purple line) and real (yellow line) trajectories.

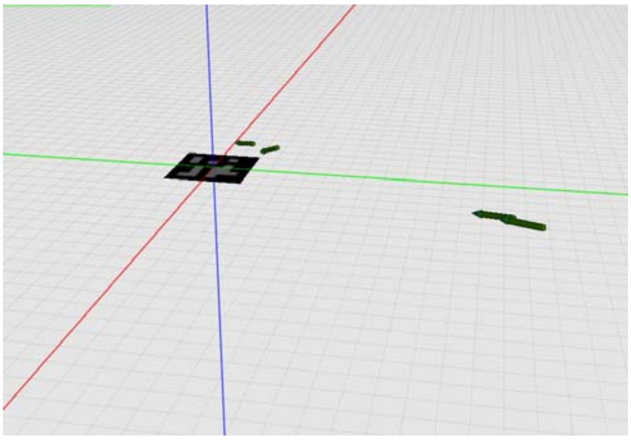

Figure 6. Following positions of the tip cue in the case of a fast stroke

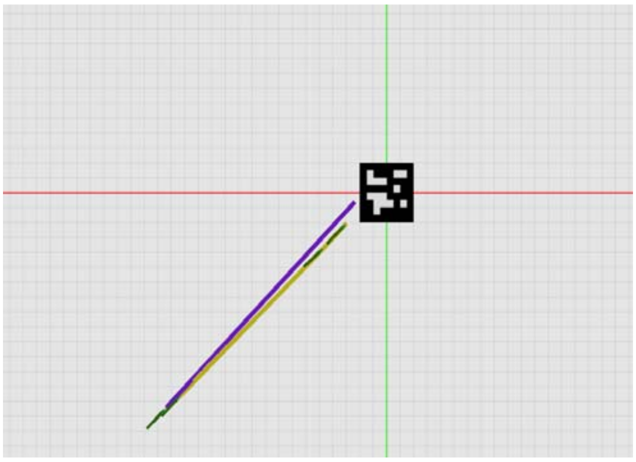

Figure 7. Difference between the virtual and real trajectories in the case of a fast stroke

Future Work

The analysis carried out to obtain a first validation of the marker-based billiards game simulation is qualitative and the test results highlight that the method used to detect the cue movements is not optimal.

It is probable that the use of a webcam provided with higher frame rate and resolution and a more appropriate lighting of the game area would be useful in obtaining better results.

An improvement in the simulation could be obtained by changing the modality of the stroke and splitting it into two different phases; in the first phase of the stroke only the movement of the billiard cue would be detected whereas in the second one the previously acquired data would be processed in order to obtain the correct force to apply to the ball.

In this way it would be possible to detect and to correct the errors due to the tracking system, but it is necessary to verify if the delay due to this processing remains enough short during the simulation.

In addition, a quantitative analysis could be obtained by means of a comparison with measurements obtained using a more accurate tracking system, such as an optical tracker, where the margin of error is well known.

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[1]**Lucio Tommaso De Paolis** is an Assistant Professor of Information Processing Systems at the Department of Innovation Engineering of the University of Salento (Italy).
He received a Degree in Electronic Engineering from the University of Pisa (Italy) and since 1994, first at the Scuola Superiore S.Anna of Pisa and then at the University of Salento, his research interest has concerned the study of the interactions in the virtual environments and the development of Virtual Reality and Augmented Reality applications in medicine and surgery.
He is a member of the Society for Medical Innovation and Technology (SMIT), member of the Southern Partnership for Advanced Computational Infrastructure Consortium (SPACI Consortium) and member of the Italian Movement of Modelling and Simulation (MIMOS).
He teaches Computer Science at the Faculty of Sciences of the Salento University.

[2]**Marco Pulimeno** is contract worker at the Salento University where he obtained a Bachelor Degree in Computer Science Engineering. His main interests include Augmented and Virtual Reality technologies applied to gaming and medicine.

[3]**Giovanni Aloisio** is Full Professor of Information Processing Systems at the Engineering Faculty of the University of Lecce. His research interests are in the area of High Performance Computing, Distributed and Grid Computing and are carried out at the Department of Innovation Engineering of the University of Lecce. He has been a co-founder of the European Grid Forum (Egrid) which then merged into the Global Grid Forum (GGF). He has founded SPACI (Southern Partnership for Advanced Computational Infrastructures), a consortium on ICT and grid computing among the University of Lecce, the University of Calabria and HP Italia. The Consortium is a follow-up of the SPACI project funded by the Italian Ministry of Education, University and Technological Research, to pursue excellence in the field of Computational Science and Engineering. He is the author of more than 100 papers in refereed journals on parallel & grid computing.

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