PhysicsBox: Playful Educational Tabletop Games

Ricardo Langner[1]*, John Brosz*[2]*, Raimund Dachselt*[1]*, Sheelagh Carpendale*[2]

[1] User Interface & Software Engineering Group
Department of Simulation and Graphics
University of Magdeburg, Germany
rlangner@st.ovgu.de, dachselt@ovgu.de

[2] InnoVis Group, Interactions Lab
Department of Computer Science
University of Calgary, Canada
{brosz,sheelagh}@ucalgary.ca

ABSTRACT

We present *PhysicsBox*, a collection of three multi-touch, physics-based, educational games. These games, based on concepts from elementary science have been designed to provide teachers with tools to enrich lessons and support experimentation. *PhysicsBox* combines two current trends, the introduction of multi-touch tabletops into classrooms and research on the use of simulated physics in tabletop applications. We also provide a Java library that supports hardware independent multi-touch event handling for several tabletops.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

General terms: Design, Human Factors

Keywords: Education, tabletop, physics engine, multi-touch.

INTRODUCTION

The goal of this work is to combine *(a)* the use of interactive multi-touch tabletops in supporting classroom learning and *(b)* development of appropriate interaction strategies based on the usage of physics simulations. We build upon recent research to create applications to support teachers and young students in educational scenarios, by creating *PhysicsBox*, a collection of three physics simulation based tabletop games to, in a playful manner, enable young students in their exploration of physics concepts.

Research regarding the introduction of technologies – interactive whiteboards, digitally augmented paper, and multi-touch tabletops – into classrooms has resulted in many positive comments: “may be of significant benefit to education by enabling, in particular, younger children to play with actual physical objects augmented with computing power” [3], “children were keen to contribute by moving objects”, and “children used all of the tabletop surface, but took more responsibility for the parts of the design closer to their relative position” [4]. In addition, recent research has introduced the use of physics simulations in tabletop applications [1, 5]. We combine these two directions to create physics-based multi-touch educational games.

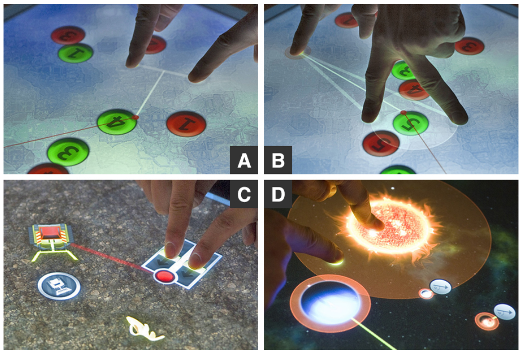

Figure 1: Billiards on Ice with (a) two-finger and (b) three-finger slingshot; (c) Bulldozers; (d) Planets.

THE PHYSICSBOX PROTOTYPE

Each game develops a science concept — inelastic collision (Billiards on Ice), recycling/vehicle control (Bulldozer), and gravity (Planets). These topics were selected based on their presence in elementary science curriculum and discussions with an elementary school teacher. In designing interactions within physics simulations one must be careful to create stable and predictable collision conditions. Wilson et al. [5] used direct force, virtual joints and springs, and proxy objects as strategies to modify the location and orientation of virtual objects. Alternatively, Hancock et al. [1] applied force by using virtual objects as virtual tools that influence other objects. PhysicsBox makes use of both of these interaction strategies.

Billiards on Ice This game combines billiards and curling (Fig. 1a+b). As in billiards, the goal is to shoot all balls into the pockets. As in curling, the balls physically behave like smooth objects on ice. The number of teams, balls and pockets are configurable. This game has two variations, *Direct* and *Strategy*, each with its own multi-touch interactions.

The *Direct* variation provides two methods of interacting with the balls. The first uses Proxy Objects [5] where each touch positions a proxy ball that follows the touch and can be used to move balls towards the pockets. Alternatively, players can touch the balls and flick them in the desired direction [6]. Both techniques allow many simultaneous points of interaction. While interacting, players can discover the fundamental physics upon which the game is constructed. The intention is to provide an easily discoverable, fast, and exciting game.

The *Strategy* variation offers a more challenging game for teachers who want to more thoroughly explain the princi-

ITS'10, November 7-10, 2010, Saarbrücken, Germany.

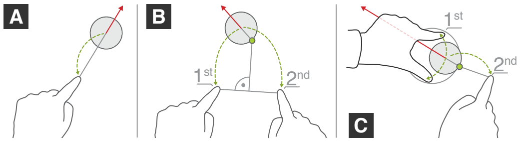

Figure 2: Slingshot technique; (a) one-finger [2], (b) two-fingers with an orthogonal virtual cue; (c) three-fingers using the other hand to adjust the force.

ples of inelastic collision. For this mode we have designed a precise set of interaction techniques, called Slingshot. Our Slingshot interactions extend Drag-and-Throw [2] by adding two and three-finger touch interactions that use touch order, similarly to sticky fingers and opposable thumbs [1]. Following the metaphor of a slingshot, the principle interaction is to pull objects back and then release them, like stones in a slingshot (Fig. 2). Players can manipulate point of impact (virtual cue and ball) and put spin on the ball using the two or three-finger technique. Visual feedback is given during the interaction by drawing the trajectory and indicating the point of impact. Two finger interaction is activated when two fingers are used to pull a ball back, creating an orthogonal force vector starting from the midpoint of the two contacts (Fig. 2b). The three finger interaction is triggered if two touch contacts occur on either side of the ball. These initial contacts act as the slinghot's arms while the third contact acts as the slingshot's pocket. The direction of the force applied to the ball is described by a vector from the third contact to the midpoint of the first two contacts (Fig. 2c). When the third contact is lifted the specified force is applied. This provides a precise technique for controlling the direction (line from game ball to third finger release point), magnitude (distance from game ball to release point), and point of impact for providing a force upon an object.

Bulldozers In this game (Fig. 1c) students learn about the control mechanisms and behaviour of a two-engine bulldozer. The advantage of tracked vehicles is the ability to turn on the spot by moving their tracks in opposite directions. The application's goal is to use the bulldozers to isolate and transport four types of waste and to push each type into its own container. In the game, bulldozers are controlled by a movable virtual remote control. A coloured line visualizes this connection. This control features two sliders that control the direction and speed of each engine/track.

Planets Planets (Fig. 1d), is a virtual planetarium. It provides an environment where students can learn about and experiment with orbits and gravity. While trying to bring different sized planets into orbit, students can observe gravitational effects between planets and the resulting elliptical shape of stable orbits. Touching empty space brings up a pallet of planets that can be placed in the planetarium. Once created the planet is provided with an initial direction and speed, indicated by an arrow. Players can adjust this velocity by dragging the head of this arrow. A tap on the planet toggles activation. Only activated planets are included in the system's gravity calculations. Deactivating planets provides opportunity to adjust their direction and speed.

IMPLEMENTATION

The prototype is written in Java using the physics engine JBox2D. *PhysicsBox* is fully operative and stable. Through this work we have developed a novel socket framework that allows *PhysicsBox* to be executed on the SMART Table, Microsoft Surface and TUIO based tabletops with code that is hardware-independent. This framework, called *Java Touch Library* (JTL), collects the system dependent touch data, generalizes it and broadcasts standardized touch data to the client application (*PhysicsBox*). This framework has been made freely available at *http://isg.cs.ovgu.de/uise/jtl*.

DISCUSSION

The elementary school teacher we worked with was extremely enthusiastic and confirmed the educational potential of the games. Our next step is to bring *PhysicsBox* to the classroom and collect feedback from students and teachers about the games' appearance, lesson integration, and the design and level of difficulty of the interaction techniques. Initial feedback from adult UI experts raised questions about the slingshot technique. The one-finger technique was preferred and the three-finger interaction was noted as time-consuming and difficult in terms of controlling the exact point of impact and managing hand interactions of more than two people on a small tabletop surface. They also noted that providing visual feedback for the scenario where the virtual cue will not strike the ball would be useful.

CONCLUSION

We have presented a physics simulation based tabletop application called *PhysicsBox*. This prototype is composed of three multi-touch educational games that can be used by a teacher to enrich lessons. We have made use of and in one case extended existing interaction techniques. With this extension we have introduced a novel set of techniques called Slingshot. As a part of the prototype we contributed a separate touch framework, the Java Touch Library, that allows developers to easily create hardware independent applications for tabletops.

ACKNOWLEDGMENTS

We would like to thank Mark Hancock for his assistance and initial source code that contributed to the *Java Touch Library* as well as to elementary teacher Heather Connollan for her insights and feedback on the games and their design.

REFERENCES

1. M. Hancock, T. ten Cate, and S. Carpendale. Sticky tools: full 6dof force-based interaction for multi-touch tables. In *Proc. of ITS '09*, pages 133–140, 2009.
2. M. Hascoët. Throwing models for large displays. In *Proc. of HCI'03*, pages 77–108, 2003.
3. C. O'Malley and D. Stanton-Fraser. Literature Review in Learning with Tangible Technologies. In *NestaFutureLab Series*, Report 12, 2004.
4. J. Rick, A. Harris, P. Marshall, R. Fleck, N. Yuill and Y. Rogers Children designing together on a multi-touch tabletop: an analysis of spatial orientation and user interactions In *Proc. of IDC '09*, pages 106–114, 2009.
5. A. D. Wilson, S. Izadi, O. Hilliges, A. Garcia-Mendoza, and D. Kirk. Bringing physics to the surface. In *Proc. of UIST '08*, pages 67–76, 2008.
6. M. Wu and R. Balakrishnan. Multi-finger and whole hand gestural interaction techniques for multi-user tabletop displays. In *Proc. of UIST '03*, pages 193–202, 2003.