Purple Crayon – From Sketches to Interactive Environment

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ABSTRACT
Abstract controls often required for gameplay hinder the potential for social interaction, especially in domestic settings. *Purple Crayon*, an interactive electronic entertainment environment for children, attempts to reclaim the sociable qualities of traditional entertainment occurring in the physical world by replacing abstract controls with intuitive interaction. *Purple Crayon* allows children to sketch virtual entities and interact with them in a physical manner. The sketched entities become animated and playful and afford interaction within their physical locality or between several localities. Various techniques for physical interaction are explored, demonstrating the feasibility and promise of the approach.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – Interaction Styles

General Terms
Design, Human Factors

Keywords
Sketch-based Interfaces, Tangible Interfaces, Physical Interaction, Social Interaction, Electronic Entertainment, Mixed Reality

1. INTRODUCTION
The electronic entertainment industry has seen tremendous growth in recent years. With innovations in graphics, physics, and animation, an increasing number of people are drawn to the rich multimedia content and flexible gameplay that electronic entertainment can provide. Despite the advancements, there is still room to improve the human interfaces required for gameplay and the ways in which players can interact within games. Control devices such as the keyboard, mouse, or game controllers have persisted through decades, and most forms of electronic entertainment still require players to interact using these abstract controls while focused on a single computer monitor or TV. Not only are these control devices difficult to understand for novice users, but the limited interaction associated with them have also changed entertainment from a social to a more individual activity.

In contrast, gameplay in the physical world is innate, based on movement, touch, application and sensing of force on top of the visual and aural senses. Traditional physical entertainment differs from most electronic entertainment because the tangible physical interaction involved are transparent and understandable to both the players themselves and others in the immediate physical environment. This interpersonal understanding of the interaction required for gameplay is essential in allowing entertainment to easily become social events. Having transparent and understandable physical interaction makes gameplay easier for novices to learn and retain and invites others to comment on and participate in the activity. In contrast, electronic entertainment often requires the use of abstract control devices, and the corresponding interaction is difficult for novices to comprehend and cannot be easily interpreted and understood by others.

With online games, electronic entertainment has become increasingly social in certain aspects. However, the potential for social interaction through gameplay in the physical environment is still lacking. Such social interaction can be important especially in domestic settings where traditional entertainment occurring in the physical world often becomes family social events. As more and more people turn to electronic entertainment where games are frequently played in private, social interaction between family members are reduced. This paper explores the potential for enhancing social interaction through electronic entertainment within the domestic environment by using intuitive physical interaction for gameplay. Techniques and challenges of this approach are described using, *Purple Crayon*, an electronic entertainment environment for children in the home. Social interaction is encouraged by firmly grounding gameplay within the physical environment and focusing on supporting tangible actions which can be easily understood, inviting others to actively participate in the game.

2. PURPLE CRAYON
Children have untamed imaginations. They often play in their own make believe world with imaginary characters and objects that they have constructed and conceptualized. This form of pretend play helps children nurture their creativity as they mentally augment physical settings and props. In the children's story, *Harold and the*

Figure 1. Harold draws his blanket (figure is inspired by [1] and redrawn)

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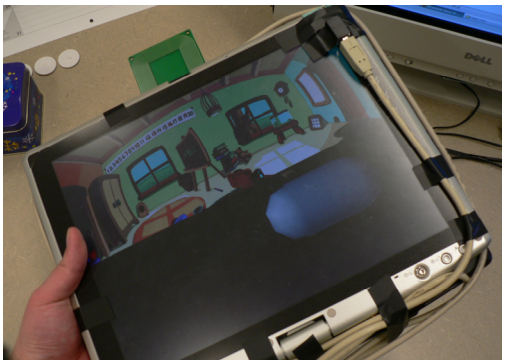

Figure 2. Tablet PC sketch pad with accelerometer and RFID reader

Purple Crayon [1], Harold uses a simple crayon to augment his world (Figure 1). He is able to draw entities which instantly become real and can be interacted with as physical objects. This manifestation of pretend play is the inspiration behind our *Purple Crayon*. By combining virtual entities and tangible interaction, children can draw desired objects and immediately play with them in a physical manner. In this electronic entertainment environment, the approach of replacing abstract controls with intuitive physical interaction is demonstrated. The goal is to provide an entertainment environment in a domestic setting where social interaction is encouraged. Children are ideal participants in this exploration because abstract controls are often difficult for them to learn and retain, and it is important for them to participate in social interaction which benefits their development.

3. RELATED WORK

The following section outlines relevant work in the two main areas of research explored in *Purple Crayon*: interacting with virtual entities and sketch-based input.

3.1 Interacting with Virtual Entities

The typical method of interacting with virtual entities in electronic entertainment is through control devices such as keyboard, mouse, or game controllers. As indicated previously, interaction using these input devices tends to be abstract and difficult to comprehend. Following the goals of tangible user interfaces, many projects have developed means to interact with virtual entities in an intuitive physical manner. Kobito [2] visualizes virtual dwarfs pushing a physical tea caddy using a mixed reality viewing window. Users interact with these dwarfs by simply pushing back on the physical tea caddy and watching the effect of the action on the virtual characters. Virtual Raft [3] uses a land and water metaphor to define interaction with virtual characters. It involves several static computer monitors or "islands" where virtual characters can dwell and tablet PCs or "rafts" in which the virtual characters can be transported from one "island" to another. Similar in concept to our *Purple Crayon* is TSU.MI.KI [4] which also attempts to stimulate children's creativity by allowing them to model and interact with virtual entities using ActiveCubes, tangible blocks with embedded digital sensors, actuators and processing ability. Another similar effort is MIT's "The KidsRoom" [5] which guides children through an interactive adventure where they play with physical objects in the room, with each other, and with virtual creatures projected onto the room's walls. Along with the increasing number of tangible controls now marketed for electronic entertainment, these projects reflect the growing interests of exploring the benefits of intuitive physical interaction over conventional abstract controls.

3.2 Sketch-based Input

Drawing or sketching is an interaction technique which supports freeform and informal interaction, ideal for the social entertainment environment desired in *Purple Crayon*. However, these interaction techniques are often used for creating static 2D content. What is required in *Purple Crayon* is the creation of dynamic 3D entities. Several techniques use 2D drawings to infer 3D models. Teddy by Igarashi et al. [6] and the work of Cherlin et al. [7] allow users to intuitively draw freeform 3D models using only a few 2D strokes. A simpler approach to make 2D sketches come alive as 3D virtual entities is to use sketch recognition to instance predefined 3D models from a library of objects. Although Igarashi and Cherlin's approach supports pure freeform 3D model creation, the result is still static 3D models. Sketch recognition provides only a limited number of models for creation, but animated models can be used to better realize the idea of sketched entities coming to life. Naturally, these techniques can be used in conjunction to generate both animated and freeform 3D models.

4. DESIGN APPROACH

The general concept of *Purple Crayon* is to provide a rich interactive environment where children can nurture their creativity by intuitively creating virtual entities they wish to play with and freely interacting with them in a physical manner. This interactive environment is also expected to encourage social interaction within the domestic setting during gameplay. To realize the seamless unification of Harold's physical presence and his sketches, our system uses the metaphors of play stages and sketch pad. In *Purple Crayon*, a sketch pad is represented using a tablet PC which allows children to draw and create 3D virtual entities (Figure 2). Play stages are static displays distributed around the domestic setting (Figure 3). These displays are where virtual entities can dwell and "perform". Physical interaction is then achieved in two ways. Similar to the Virtual Raft, after virtual entities are created, they can be transported using the tablet PC from display to display. The analogy is like children taking their favorite toys to various spots around the house. These represent different imaginary locations in a make-believe world. Another way to physically interact with the created virtual entities is by a set of natural, tangible, and physical actions which affect their behaviour on the play stages. This design approach was chosen because it merges the physical and virtual

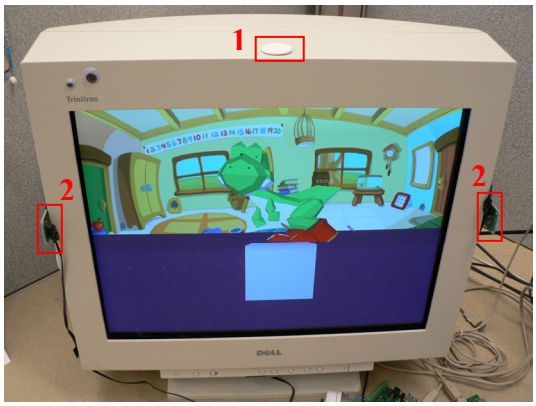

Figure 3. Play stage setup with RFID tags (1) and touch sensors (2)

environment. Although virtual entities can only dwell on displays, these displays are placed at different physical locations to give virtual entities a physical presence and to allow them to "live" in the various physical locations of the home. The act of transporting virtual entities is a direct physical interaction performed in the physical environment and can be easily noticed and understood by both players and observers of the interaction. Further more, social interaction between children can be easily achieved with multiple tablet PCs as each of them can create their own entities, play with them on their own play stage, but also bring their entities to other children's play stages, share, and play together. Parents can comfortably monitor and join their children's play activities, for instance noticing the various virtual entities they have created on the play stages.

5. HARDWARE

The main hardware component of *Purple Crayon* is the sketch pad, implemented using a tablet PC (Figure 2). Along with the native pen-based interface, it is also equipped with a Phidget accelerometer and a Phidget RFID reader. Phidgets are a set of sensors, actuators, and physical controllers packaged as building blocks in an easy to use software library [8]. The accelerometer is mounted on the tablet PC to detect its orientation, and the RFID reader along with wireless network connections are used to transfer virtual entities to and from the static displays. Any display with a PC capable of connecting to the wireless network can be used as a play stage. In *Purple Crayon*, desktop PCs with monitors, large wall displays, and notebook computers are used. Each display must also have RFID tags attached to enable the transfer of virtual entities. Various Phidget sensors are also placed on or near displays to enable physical interaction including touch sensors, light sensors, motion sensors, and RFID readers. Some displays were setup with mixed reality capabilities, using a web cam and a set of mixed reality markers as additional interaction handles.

6. PLAY STAGE AND SKETCH PAD

A play stage or sketch pad display consists of two main areas of interest (Figure 3). The screen is divided approximately in half. The purple bottom half of the screen represents a ground plane. This is where the 3D virtual entities are situated. The colourful top half of the screen serves as an interesting background for the play stage or sketch pad. Virtual entities can be created at any play stage or on the sketch pad. Users simply draw their desired object on screen using a pen or a mouse, and a sketch recognition system is used to match the input drawing to a predefined 3D model in a library of objects. The recognition technique is based on the use of angular features of input strokes and works well for drawings of only a few strokes. In the current implementation of *Purple Crayon*, simple sketches such as cubes, spheres, and capsules are supported as well as more complicated entities such as apples and dinosaurs.

7. TRANSFERRING VIRTUAL ENTITIES

To enable the transfer of virtual entities to and from the sketch pad onto the play stages, an RFID reader, RFID tags, and the wireless network is used. The RFID reader and tags signal the initiation of transfer, and then data is sent from the tablet PC to the desktop PC attached to the display. Usually, three small circular RFID tags are placed on the left, top, and right of each display. Each tag represents the location of transfer, so if the tag on the left is read, the virtual entity will be transferred from the left of the display. When an RFID tag is read by the reader on the tablet PC, the ID of the tag is interpreted to determine the target for transfer. The direction of transfer is indicated using the physical tilt of the tablet PC detected by the accelerometer. To transfer a virtual entity from the tablet PC onto a display, the tablet PC is first tilted forward before the tag is read. This is an intuitive physical interaction since it resembles trying to slide an entity off the tablet. Conversely, to transfer a virtual entity from a display onto the tablet PC, the tablet PC is first tilted backward before the tag is read.

8. PHYSICAL INTERACTION

PhysX [9], a physics engine for games, provides physically realistic feedback of the virtual entities to the manipulations of the players. Interaction with virtual entities is achieved using a mix of various methods. To physically interact with virtual entities on the tablet PC immediately after they are created, children simply have to pick up the tablet PC and start walking with it. Since it is unlikely that the tablet PC is kept perfectly balanced, the created entities will start sliding around the screen in response to the way that the tablet PC is tilted. This creates a fun challenge for children as they attempt to carry the virtual entities to other displays and try to balance them on the screen at the same time. Interacting with virtual entities on the displays involves the use of Phidget sensors (Figure 3). One type of simple interaction is to tap the sides of the displays to apply a force to the virtual entities on screen and move them in the intended direction. This is accomplished using touch sensors positioned on the left, bottom, and right of the display. For example, by tapping on the bottom touch sensor, an upward force is applied to the physics simulation, and the virtual entities on the display appear to jump up from the ground plane. Similar effects are achieved for the other two touch sensors. By tapping two touch sensors together (e.g. left and bottom), lighter virtual entities can be made to jump over other heavier virtual entities. Another type of physical interaction is based on responses of the virtual entities or the virtual environment to changes or actions in the physical environment, creating a direct association between the two. In *Purple Crayon*, motion sensors and light sensors are used to detect these changes or actions. For example, when the motion sensor detects motion, the assumption that someone is approaching the play stage is made. This will then trigger a virtual entity such as an animated dinosaur to move closer to the front of the screen toward the detected person. The virtual entity will then attempt to grab that person's attention using exaggerate gestures such as jumping up and down. This type of reaction to the physical presence of people further enhances the liveliness of the virtual entities on the play stage and suggests that virtual entities are aware of what's occurring in the physical environment. A similar approach has been taken to establish a connection between the physical and virtual environment. The light sensor detects the brightness of the physical setting which infers the intended play setting on the play stage. For example, when the physical setting is dark because the lights have been turned off, the background of the play stage automatically switches to a night scene reflecting a different interactive mood.

9. SCENE CARDS

When children are engaged in pretend play, they often have several locations around the house designated as different play settings, for instance a spaceport in the bedroom or the surface of the moon in the living room. To reflect this variety, scene cards are used in *Purple Crayon* to allow children to manually change the play stages to desired play settings. Scene cards are RFID tags in the size of credit cards. Colorful pictures denoting the scenes represented by

the tags are taped on the cards. To change the setting of a play stage, children simply select a desired scene card and place it over the RFID reader equipped with the display. The ID of the card is interpreted, and the background is changed instantly. Some example scene cards in *Purple Crayon* include a mushroom house, a honey factory, and the Taj Mahal.

10. MIXED REALITY INTERACTION

Mixed reality is a display technique which allows virtual 3D content to be overlaid on top of physical scenes, commonly using live video and visual tracking. In *Purple Crayon*, the mixed reality development system, ARToolKitPlus [10], is used to provide visual tracking. This system allows 3D content to be rendered in the correct orientation on top of physical markers seen in the video. We enhanced one of the play stages, a large wall mounted plasma display and a table surface directly in front, with mixed reality capabilities. A web cam is placed underneath the display overlooking the table surface to deliver live video of the physical environment, and a marker attached to a stick is used as a physical handle for moving virtual entities on the display. The camera and ARToolKitPlus track the movement of the physical marker on the table surface, and the virtual entity is rendered on top of the marker. Therefore, moving the marker directly relates to moving the virtual entity. This interaction technique allows virtual entities to be played with in a more direct manner.

11. DISCUSSION

The core interaction intended for *Purple Crayon* was fully implemented and appears to work smoothly. Using *Harold and the Purple Crayon* as an inspiration, various techniques for interacting with virtual entities have been explored. To truly evaluate the effectiveness of this electronic entertainment environment as a means to encourage social interaction within the domestic setting, thorough qualitative user studies with young children (ages 8 – 12) are intended. At this point we are able to speculate on how our *Purple Crayon* can be used and how it can benefit social interaction. First, our system allows children to enhance and manifest pretend play in a realistic and tangible manner in the physical environment. Children can sketch an entity that will immediately come to life and join their physical environment. The entity can be moved from one location to the other, reacting to physical actions and to changes in the environment. Second, by using rich multimedia content, the virtual entities and virtual environments which used to exist only within children's minds are made more explicit and visible to everyone within the physical environment. This means others (e.g. other children or parents) can easily comment on or join the game because they can clearly see the play stages and the virtual entities on them. By introducing a variety of techniques for physical interaction, the process of gameplay is made understandable to observers. For example, when someone sees a child walking toward a display with the tablet PC, he or she knows that the child is going to change the configuration of that play stage and becomes interested in the actions of the child. Based on the observations he or she makes, comments or suggestions can then be given to the child to help them construct the play stage. Finally, because the play environment is distributed around a physical setting, there are many opportunities for collaboration. For example, two children playing together can help each other transport virtual entities from play stage to play stage, or they can share virtual entities they have created with each other.

12. CONCLUSION

With the increasing popularity of electronic entertainment, abstract controls often required for gameplay are hindering the potential for social interaction especially in domestic settings. *Purple Crayon*, an interactive electronic entertainment environment for children, attempts to reclaim the sociable qualities of traditional entertainment occurring in the physical world. By combining intuitive physical interaction with rich multimedia content, social interaction is encouraged because the actions for gameplay are made transparent and understandable to observers, inviting them to comment on or even join the games. Using play stages and sketch pad metaphors, virtual entities and virtual environments are given a sense of physical presence, connecting them to the physical world. Several techniques for physical interaction have been explored and demonstrated in *Purple Crayon,* showing the feasibility and promise of the approach. With interests in electronic entertainment continuing to grow, we believe it is crucial to consider and carefully design interaction involved in gameplay which are closely associated with innate sociable behaviours and can have a significant impact on the social meaning of entertainment as an activity.

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