Butterfly Effect:
An Augmented Reality Puzzle Game

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Abstract

Butterfly Effect is a 3D puzzle game using augmented reality. The key motivation was to create a game that leverages the structure of the physical world during gameplay without requiring the computer to have a detailed model of the space. The butterflies are virtual, but the space the player navigates is physical. The player travels her environment, collecting the butterflies. For butterflies that are out of reach, the player can rotate the virtual world in 90 degree chunks about an arbitrary axis to bring them to an accessible location.

1. Introduction

Butterfly Effect is a 3D puzzle game using augmented reality, intended for the home audience on the next generation of video game consoles. The goal of this project is to explore the design of an interesting AR game that leverages the structure of the physical world during gameplay *without requiring the computer to have a detailed model of the world*? We focus on this issue because AR games are not likely to be feasible any time soon if they require accurate, detailed models of the world.

In Butterfly Effect, the player is presented with a widely distributed collection of virtual butterflies in a 3D volume around her. The game is played in any physical space that the player wishes; her real home, office, backyard, or park. The player moves around freely in her environment, collecting the butterflies by moving near them. The key challenge arises because the butterflies are scattered in all directions. For butterflies that are out of reach, the player can rotate the virtual world in 90 degree chunks about an axis she defines with her "Tornado Stick" (see below), eventually bringing the butterflies within reach.

In the rest of this paper, we present a set of design challenges and our solutions. We describe the current implementation along with its limitations and some thoughts on how to move forward with the design.

2. Design for Real World Constraints

This is not the first project to create an augmented reality game. Researchers at the National University of Singapore and the University of South Australia have each created adaptations of popular video games, PacMan and Quake respectively, in which the player embodies the protagonist or "avatar" and encounters virtual monsters in the real world [1][4]. In order to adapt the games, models of the real space were created ahead of time. Unfortunately, only fixed structures can be modeled; if someone parks a car on your power pellet while playing PacMan, you're out of luck, and while the monsters in Quake are willing to risk life and limb to eat the player, they are completely oblivious to bystanders. At the Human Interface Technology Laboratory New Zealand, the video game Worms was also adapted for AR [3]. Rather than the classic side view, the game world is displayed in 3D on a table, removing the need to model the world at all.

The Mosquito Hunt AR game on the Siemen's SX1 handset comes closest to our design goal, but does not require the user to move and interact with the world, because the mosquitos are shot from a distance. The world is, in effect, and interesting backdrop for the game. In Butterfly Effect, the practical constraints of the physical world prevent the player from reaching her goal. Butterflies must be captured, and are located in 3D around the user, who must

Figure 1. Player with gear.

Figure 2. Close-up of HMD.

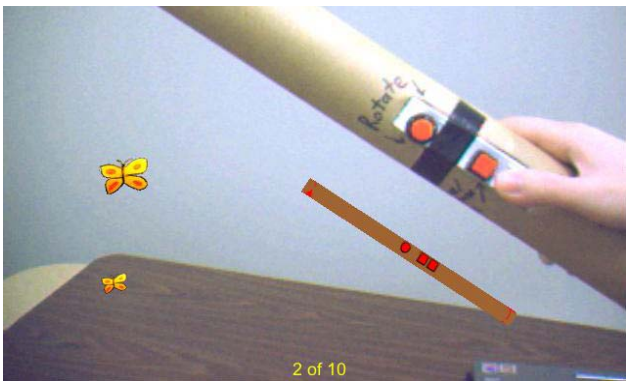

Figure 3. Screenshot with Tornado Stick and virtual axis.

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figure out how to reach them. Sessions of Butterfly Effect played in an apartment are different than those played in a house, and a single story ranch home requires different strategies than a multi-story townhouse.

Butterfly effect also takes other practical constraints into account. Since quick movement is generally harder to track accurately than slow, deliberate movement, and current displays tend to perform poorly during rapid head motion, we designed a puzzle game that encourages slow, deliberate movement rather than a fast-action shooting game.

3. Game Mechanics

Butterfly Effect is a fairly simple puzzle game in which the player manipulates either her physical or virtual environment in order to catch virtual butterflies. Butterfly Effect was implemented using the Designer's Augmented Reality Toolkit (DART) [2].

3.1. Equipment

The necessary equipment has been assembled into a backpack to play the game. This includes:

- ∞ Tornado Stick – the rotation controller
- ∞ Toshiba M200 TabletPC – to run the game
- ∞ Head-mounted display, combining an Intersese IS1200 VizTracker (for head position tracking with ceiling mounted fiducials), a firewire camera, and an opaque HMD
- ∞ Various cables and batteries

3.2. Gameplay

The objective of the game is to capture all of the butterflies. Butterflies do not move on their own, so the player must either move herself to the butterflies or move the butterflies to her. The player is free to alter her physical space in order to accomplish her task, for example, by opening doors or standing on ladders. The player's other option is to use the Tornado Stick to create a tornado to blow all of the butterflies around. The butterflies move in a circle perpendicular to the stick and stop 90˚ from where they started. The Tornado Stick moves all of the butterflies, not just one, so the challenge is to plan these 3D rotations to bring the most butterflies into reach.

In the original design, butterflies were captured using a butterfly net. To avoid the need for a second position tracking system a location based capture mechanism was designed. A butterfly is captured if it is within the player's field of view and if her head is close enough.

Rotations require the use of the Tornado Stick interface. The Tornado Stick can create a virtual axis, which is the line around which the butterflies will be rotated. The Tornado Stick has three buttons (Place/Remove Axis, Freeze/Move Axis, Perform Rotation). The metaphor of a tornado was adopted because describing the rotation behavior in terms of a sideways tornado helped players understand the cylindrical motion.

4. Challenges of play

The initial design of Butterfly Effect focused on the user overcoming physical obstacles in order to capture butterflies. An interesting side effect of not knowing the structure of the physical world is that it is hard for the game to control the difficulty of the level; it is unclear how to overcome this problem. As we move forward, we will focus instead on a different challenge, that of understanding the locations of the butterflies.

Judging distance is a well-known problem in AR environments, especially when one is trying to judge the distance of virtual objects without having them interact visually with the physical world. Since we do not model the physical world, occlusion based depth cues are not available to the player. Our approach to dealing with this problem will be to incorporate it into the game as a skill that must be mastered. Several other depth cues still apply, such as farther objects appearing smaller, and motion parallax; other cues can be added, such as a grid on a plane at the users feet and/or drop shadows to it from the butterflies

5. Conclusion

In this paper, we have described a compelling AR game (Butterfly Effect) that leverages the structure of the physical environment as part of gameplay, without requiring the computer maintain a model of the physical world.

6. Acknowledgements

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