BallBouncer: Interactive Games for Theater Audiences

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Figure 1: Ball bouncer in action. Left photograph of audience participating, right image captured from the video feed to the data projector.

Abstract

Members of a theater audience see themselves in a mirror image projected on to a large screen. This 'mirror' is augmented by virtual balls that bounce realistically when hit by the audience. The effect is created with a computer and a single camera. It is robust and convincing and we have devised several different games that an audience can play.

Since 2005, we have displayed these games publicly at two international science fairs, and to many student groups. We usually explain the rules of the games briefly, but even this is hardly necessary. People learned to manipulate the virtual objects intuitively and could infer the rules of scoring in only a few minutes. Our games encourage cooperation and provide an enjoyable, active group experience without making individuals self conscious.

1 Introduction and Background

Audience participation is probably as old as theater, and team games like football have their origins in chasing games played by crowds. But with the help of a computer, we can create games for a theater audience where everyone can join in but no one is exposed as the volunteer of the moment.

In 2005, we set out to create an interactive experience for the audience at the GRAPHITE Electronic Theater[1]. It was loosely modeled on theater pre-shows from the SIGGRAPH conferences but with some restrictions. We did not want special hardware for the participants and we wanted to use only standard computer cameras and projectors which we already had and that would continue to be cheaply available.

In 1991 an interactive entertainment system named *Cinematrix* was presented at the SIGGRAPH Electronic Theater. Each member of the audience had a light, reflective paddle, red on one side, green on the other. By holding it up you could vote red or green. This simple idea was developed into a controller for the game of *Pong* and two halves of the audience controlled the game by voting in real time to move their team's game paddle up or down on the screen. [Car93] These ideas were developed by Dan Aminzade et al. who describe interaction by leaning in their seats, batting a real beach ball or using laser pointers. [MAPS02]

Real balls filled with helium were also used in the game *Squidball* which was tested on 4000 participants at SIGGRAPH 2004. The balloons were knocked around by the audience, and the tracked image of the balls was used to hit targets on the screen. [BCD+05]

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All these games focus their interaction on the 2D environment of the screen, ignoring the 3D environment of the players. The game that we have developed, *Ballbouncer*, incorporates the auditorium's 3D environment with the goal of increasing the sense of being part of the game rather than interacting at a distance.

2 Concept and Objectives

The concept of our game is that from a single camera at the front of an auditorium we are able to model a simplified version of most theaters. We use this simple model to allow the participants to interact with virtual objects that are projected into the model of the room (see Figure 1). The simplest model is that of balls bouncing around the auditorium with people hitting them back and forth.

We can extract 3D information from the 2D video stream by assuming that the players are in tiered seating. The depth of a row of players can be inferred from the y-position in the video image.

Ballbouncer has been developed to be used in an auditorium without an extended setup period or user training. Therefore the games had to be:

- Intuitive - the interaction must be obvious and immediate.
- Consistent - the games and interactions with the objects must be consistent with real world interactions.
- Natural - no devices are needed by the player to interact with the game.

To test different styles of games and the reaction from the audience we designed four games, each with a different combination of cooperation and scoring. Cooperation came in three varieties: unfocused, whole auditorium cooperative goals, or team based competitive play.

Over the course of five different demonstrations these four games were compared and refined:

- Beach Balls - the audience can just bounce the balls around the virtual room. (individual - no score)
- Bubble Pop - this introduces scoring and more focused action. (individual - single score)
- Basketball - provides a collective goal and focus for the interaction learned in the beach ball setup. (cooperative - single score)
- Time Bomb - competitive play between left and right. This is the interaction that is most "game like" (cooperative - competitive two scores)

3 Realization

The games in *BallBouncer* rely on the ability to detect the motion of the audience and respond to the motion by changing the velocity of balls in a virtual 3D model of an auditorium.

3.1 Motion Recognition

The video input can come from any standard USB2[2] or FireWire camera. The camera is centered beneath the display screen. From the video input a difference image is created by calculating a simple pixel subtraction every frame.

The real time motion is calculated as the center of pixels that are above a movement threshold in the bounding box of a ball projected into the video input. The motion vector is calculated as the vector from the center of the active pixels to the ball center. This impulse vector is added to the acceleration of the ball when the ball is close to the virtual seat plane, as it is "within reach" of the audience.

3.2 Depth Detection

Estimating a 3D movement vector from a 2D input requires additional assumptions about the type of movement and the intended result. The 2D camera image can be projected onto the virtual seat plane as shown in Figure 2. Movement near the ball can be assumed to be directed toward the ball, and therefore a force vector can be applied from the center of movement toward the ball's center. This calculation is in three dimensions in the virtual environment, and so the balls are able to move up and down the plane as well as left and right.

Players also expect the ball to bounce up away from the seat plane which makes it easier to generate believable ball movement. For a more detailed description of the detection algorithms see [Sie06].

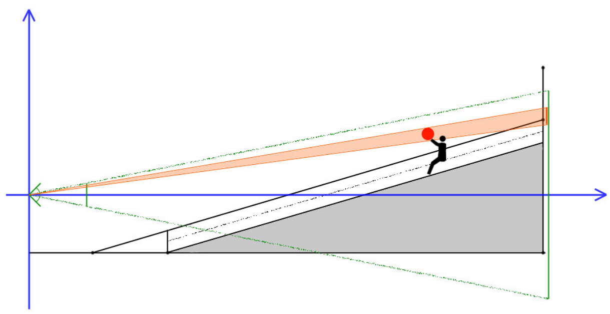

Figure 2: Projection of an area of movement found from the camera into the model of the auditorium

3.3 Augmentation

It is important for the intuitive nature of the interaction that the augmenting items, the virtual balls, behave in a similar way to real balls. This was achieved by modeling the physics of balls and their masses (see [Kel06]. The balls interacting with the walls and each other help to reinforce the perception that the balls are really in the environment. This illusion is further reinforced by synchronized audio output and by placing a shadow on the seat

[2]We used the Playstation2™EyeToy™camera in either 640x480 at 15fps or 320x240 at 30fps.

	Act+	Act	Part.	InAct.	Tot.
MC BB	10	14	21	15	60
MC TB	18	13	19	10	60
HoS BB	0	67	77	18	162
HoS TB	1	87	63	11	162

Table 1: Players shown by interactivity category. MC = Music Camp, HoS = Hands on Science, BB = Beach Ball, TB = Time Bomb

plane directly below the ball. The shadow is particularly important for indicating when a ball is within reach.

The balls in our game augment the mirror image of the input video. This allows instant feedback as to the difference between action and response. If the player cannot hit the ball with the mirrored version of themselves, they can see that they are out of range. This simplicity is vital to the success of the interaction.

4 Results

To evaluate the success of *BallBouncer* we questioned the players and analyzed the video records of the games. This provides both subjective and objective measures of audience enjoyment and participation. The games were tested with five large audiences, each time with an improved version of the program.

To assess subjective engagement, players were asked if they liked the games, and which game was their favorite. All of the games met with enthusiasm from each audience, with the strongest positive response coming for the undirected beach balls and the competitive time bomb games.

This subjective success is also matched by the analysis of the video recording of the play sessions. The recordings are analyzed for movement near the balls and individual player response. These behaviors are graded from highly active to inactive, giving an objective analysis of the engagement of players with the games.

The definitions we used are: highly active (standing up or moving across multiple seats), active (aways hitting a ball in range), participating (hitting ball at least once in 5 minutes), and inactive (no movement directed at the balls).

Table 1 shows the breakdown of players into each category for two different audience groups.

The general trend is that players in the competitive bomb game are more active than the other games, and are more likely to stand up and move to reach balls. The combination of competition and focusing attention on a single ball motivated players to become more active, with the number of highly active players increasing as the game progressed.

The video analysis of activity correlates well with the audience's self assessment of their engagement.

5 Conclusion and Future Work

Using motion recognition as a user interface for crowds works very well and is met with enthusiasm. Our game, *BallBouncer*, enables members of a theater audience to bounce virtual beach balls around, pop bubbles, dunk basketballs and avoid time bombs, all in 3D. The players can interact by simply moving their arms while watching themselves on a large wall display as in a mirror. The interaction is natural and intuitive as it does not require the use of additional devices such as paddles, and the players already have the experience of playing with real balls.

The very enthusiastic response of the players has encouraged us to explore the possibilities of developing more games which go beyond simple balls to the control of more complex objects (e.g. fish in an aquarium). The competitive games seem to be the most engaging and so will be our focus.

Future work will incorporate analysis of the interaction of crowd and balls in real time. This allows dynamic adjustment of the gaming parameters (e.g. increase the number of beach balls) to spread, more evenly, the opportunities to interact with the balls. Whether *BallBouncer* can be extended to locations with level seat planes is also part of future research. Nevertheless, the results suggest that *BallBouncer* can already be used to entertain a crowd during the breaks in sporting events, or before films in movie theaters (cf. [MSN07]).

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