Save ‘Em:
Physical Gameplay using Augmented Reality Techniques

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ABSTRACT

We present *Save ‘Em*, an augmented reality-based computer game designed to explore the challenge of making computer games more immersive and engaging by moving gameplay to the physical environment.

As in the classic computer game, *Lemmings*, *Save ‘Em* is based on maneuvering a group of slow-witted characters called Dudes through a treacherous maze. Using augmented reality techniques, *Save ‘Em* places virtual game entities directly within the player’s physical environment; gameplay takes place on a real game board rather than on a computer screen, and the Dudes’ fate is tied directly to the player’s physical actions.

In this paper we discuss our *Save ‘Em* game implementation and use our current findings to explain how moving game interaction from the virtual domain into the physical world using augmented reality can affect both gameplay and the players’ overall experience.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems – *Artificial, augmented and virtual realities.*

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies, interaction styles.*

K.8.0 [**Personal Computing**]: General – *games.*

General Terms

Design.

Keywords

Computer games, gaming, interfaces, augmented reality, mixed reality, immersion, control methods.

1. INTRODUCTION

There are a number of reasons why people play computer games, but personal enjoyment or “fun” is arguably the most common. A “fun” game means different things to different people – on the surface, fun is highly subjective. But we believe that there exists a group of core concepts – inherent in all games – which contribute to all players’ enjoyment, regardless of their personal preferences. One of these concepts is immersion: the process by which a player dedicates his or her focus to the game, and becomes emotionally involved in its progression. Immersion is valuable to computer gaming because it facilitates escapism; it eases players into to leaving their day-to-day concerns behind and allows them to engage exclusively on the tasks before them. What’s more, this intense focus can amplify feelings of accomplishment as players complete tasks within the game. If we assume that immersive games are more enjoyable, then a question naturally arises: How can games be designed to foster the immersion of their players?

Historically, game developers have sought to immerse players through enhanced realism. This has typically been achieved through graphical improvements, although improvements to physics engines, artificial intelligence algorithms and sound systems have also played their part. However, in recent years the focus has shifted, and immersion is increasingly being cultivated through the use of novel game interfaces, particularly novel control devices [7]. Many game developers are eschewing traditional, generic input devices such as keyboards and gamepads and creating specialized controllers, designed specifically for a single game. By using controllers which create a simple, intuitive mapping between the player’s actions and their effects, a significant barrier to immersion is removed. A good interface can reduce the player’s need to memorize complicated and often arbitrary key mappings in order to accomplish their goals. Rather, it can allow the player to act naturally, translating physical actions into appropriate outcomes in the game environment.

In this paper, we present *Save ‘Em* (Figure 1), an augmented reality game played with a simple, intuitive control device: a handheld “wand”. We argue that augmented reality techniques, such as the ones we used in *Save ‘Em*, can harnesses the power of nontraditional control and display interfaces to create gameplay which is accessible, immersive and most importantly, fun.

Figure 1: The World of *Save 'Em*.

2. RELATED WORK

Within the last decade, novel control interfaces for computer games which enable new ways to play have become increasingly common, occasionally even serving as the catalyst for a brand new genre. Consider the "rhythm games" which achieved widespread recognition in North America following the release of *Dance Dance Revolution* [3] in 1998. Rhythm games are part of a genre which challenges players to perform to a musical beat by dancing, playing bongos, or strumming a guitar. The hallmark of these games is their elaborate controllers which seek to mimic real-life analogues. For example, the guitar-shaped controller that comes packaged with the 2005 release *Guitar Hero* [5] is in fact a ¾ scale model of a Gibson SG guitar.

Despite their recent success, the use of game-specific controllers which enable new ways of playing is not a new development; light-gun peripherals have been a staple of shooting games for more than thirty years. The most recognizable example of a light-gun peripheral is likely the Nintendo Zapper [9], which was released alongside *Duck Hunt* [4] in 1985. However, many arcade cabinets with built-in gun peripherals predate *Duck Hunt*, including *Desert Gun* which was released by Midway in 1977 and *Triple Hunt*, released by Atari in the same year. Since their inception, light-guns have survived and even thrived and shooting games – complete with light-gun peripherals – are now ubiquitous in arcades.

Of course, one cannot discuss revolutionary control devices without mentioning the Nintendo Wii [13]. Nintendo has never shied away from innovation; they were the first to popularize new concepts like force-feedback and touch screens in the North American console market. However, despite Nintendo's reputation as a proven innovator, many felt that the company risked alienating gamers when it was announced that the Wii would abandon the traditional two-handed gamepad in favor of a one-handed remote containing an embedded accelerometer. The long-term repercussions of this move remain to be seen, but one thing is for certain: Nintendo's unconventional approach to interaction has paid off – nearly nine months after its North American release, the demand for Wii consoles continues to exceed supply.

Though the Wii has set a new standard for physical interaction in the console market, researchers are still exploring methods to give players the freedom to physically interact with their games. One of these methods is augmented reality (AR); a display technique which seeks to integrate synthetic, virtual content with the user's physical environment through the use of head-mounted displays (HMDs), projectors or similar display devices [8]. Already, AR interfaces are finding applications in a wide variety of areas, including computer games. One of the best-known uses of AR in gaming is *ARQuake* [11], an augmented reality adaptation of id Software's first-person shooter, *Quake*. *ARQuake* takes the enemies from Quake and – with the aid of an HMD – superimposes them over the player's normal vision, putting her in the role of *Quake*'s protagonist. In contrast to *Quake* where

players move using a keyboard, *ARQuake* players are given free reign to walk (or run) through a real physical location as they gun down monsters.

Much as *ARQuake* draws inspiration from *Quake*, the *Human Pacman* project [2] is an augmented reality adaptation of Namco's 1980 classic, *Pac-man*. In *Human Pacman*, it is the goal of the player to collect a series of virtual pellets strewn across a physical arena. As players move, their movements are tracked using GPS monitors, and they can see the virtual pellets floating before them on their head-mounted displays. To collect pellets, players need merely to walk through them. *Human Pacman* also allows players to join the game as "ghosts", whose objective is to hunt down Pacman by chasing him through the arena and eventually coming close enough to touch him.

Augmented reality interfaces have remarkable potential for gaming, giving designers the power to place players directly in the center of the game, with action happening above, below and all around them. More importantly, by moving gameplay away from a monitor, augmented reality interfaces also tacitly encourages designers to break away from generic control peripherals such as the keyboard and embrace new, physically-based interaction techniques.

Save 'Em embraces the human-computer interaction theme of tangible interaction. Tangible user interfaces (TUIs) exploit our innate physical abilities by providing physical materialization of digital information and functions [12]. One key feature of TUIs is I/O unification (input/output unification, [10]). Usually, computer interfaces force us to shift our attention between a separated action space and perception space (for example, a mouse interface and a separate desktop display). TUIs, like any regular physical object, can couple users' action space with their perception space, allowing them to focus attention at one spatial location. In *Save 'Em*, I/O unification is achieved through the use of augmented reality techniques.

3. DESIGN

Our design goal in *Save 'Em* was to explore how current augmented reality techniques could be used to transfer gameplay to the physical environment. Our aim was to create a "casual game" in the tradition of *Tetris*: an experience which is accessible and still highly engaging; a game that could easily be picked up and intuitively played, providing immediate enjoyment for its players. Of course, in order to meet these goals, the game would have to be simple in both concept and control. For these reasons, we sought to integrate physical control devices as the cornerstone of *Save 'Em*'s design. It was our hope that a well-designed physical control scheme could leverage players' existing knowledge to provide easy-to-learn, intuitive gameplay. Our design for *Save 'Em* centers on a "board game" concept where a flat, rectangular physical area is designated as a playing surface, and all player interaction would happen on, above, or nearby this board.

Inspiration for *Save 'Em*'s gameplay came from Psygnosis's 1991 computer game, *Lemmings* [6]. In *Lemmings*, a group of ambling, mindless creatures are let lose in an arena filled with a series of deadly obstacles including fatal drops, pits of lava, and spring-loaded traps. It is the goal of the player to guide the lemmings safely past these hazards and into the arena's exit. This simple task is complicated by the fact that the player has no direct control over the lemmings themselves. In fact, all the player can do is assign behaviors (such as digging, or climbing) to the lemmings, who are otherwise free to walk to their inevitable death.

The task of coordinating virtual entities within a danger-filled arena seemed tailor-made for our board game concept, but the multi-behavioral controls of *Lemmings* were too complex to translate cleanly into the simple, accessible control interface we desired for *Save 'Em*. Ultimately, we opted for a similar but distinct concept. In *Save 'Em*, the player is tasked with herding a group of dim-witted virtual characters (who we affectionately refer to as "Dudes") through a danger-filled maze. As in *Lemmings*, the player is forced to complete this task without ever controlling the Dudes directly. Instead, the player must lure the Dudes by holding a physical object – a "control wand" – and moving it over the surface of the playing area. As the player moves the wand, any nearby Dudes will run directly toward its tip, allowing a strategic player to group Dudes and direct them past enemies and around traps, much as one might entice a mule to move using a carrot on a stick (Figures 2 to 4). A successful player will be able to keep casualties to a minimum as she moves the Dudes towards the maze's exit. As the player physically acts, her actions cause an immediate reaction in the virtual game board. This feedback creates a tight bond between the real and the virtual that makes the player feel as though the game world is very much a part of her own.

4. IMPLEMENTATION

The implementation of an augmented reality interface requires two key systems: a display system which allows the simultaneous display of both physical and digital entities, and a tracking system which gathers information about the player and the world around her. We selected an HMD as our display system in *Save 'Em* for two significant reasons. Firstly, the use of HMDs fosters immersion; by placing the display directly in front of the players' eyes peripheral distractions are blocked, allowing players to focus solely on the game. Further, an HMD is a hands-free display, which is necessary for compatibility with the handheld control wand we had decided upon for *Save 'Em*.

Save 'Em was implemented using the eMagin Z800 3D Visor HMD. We selected the Z800 over competing models based on its compelling feature set. The Z800 is one of the few commercially-available HMDs whose display resolution is 800 x 600 rather than the more common 640 x 480. Obviously, a higher resolution supports more attractive, more compelling graphics, which are important for creating believable virtual entities. The other novel feature offered by the Z800 is its built-in head-tracking. Although this feature was not used in *Save 'Em*, we felt that it could be valuable to future projects. The Z800 also includes a set of earpieces which allow players to hear *Save 'Em*'s music and sound effects.

The Z800 rests on the player's forehead, placing a small organic light-emitting diode (OLED) screen over each eye. Each display can be moved laterally to adjust the interpupilary distance, allowing wearers to focus the display to their liking. Because the Z800's OLED screens are opaque, it was necessary to attach a webcam to the front of the visor, roughly between the player's eyes. The video feed from this camera is augmented with graphical content provided by the *Save 'Em* game engine, then

Figure 2: While jets of fire erupt from the wall, the player holds the wand still, and the Dudes cluster around it.

Figure 3: As soon as the fire disappears, the player moves the wand to the other side of the board. The Dudes run to catch up.

Figure 4: By the time the fire has reappeared, the Dudes are safely on the other side.

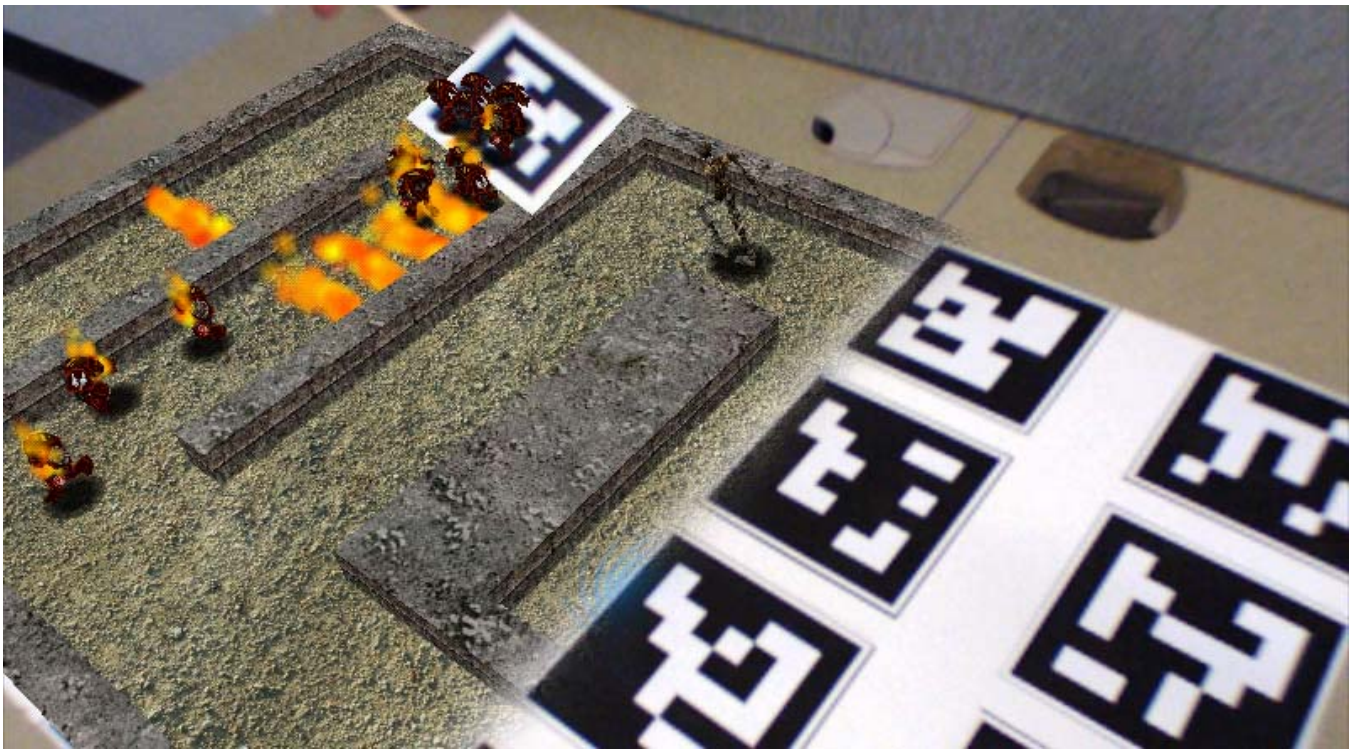

Figure 5: *Save 'Em*'s physical game board is overlaid with a vibrant virtual world.

routed to the screens of the HMD, allowing the wearer to effectively "see through" the display.

For tracking, *Save 'Em* employs the marker-based visual tracking provided by ARToolkitPlus [1]. Flat, high-contrast tracking markers have been affixed to the surface of the playing board (which is simply a poster board measuring 720 by 658 centimeters) as well the head of the control wand. Using computer-vision algorithms, ARToolkitPlus can identify the distance, position and orientation of these markers relative to the camera within any frame of video. By tracking the frames coming from the webcam affixed to our player's HMD it is possible to display virtual entities that retain their position and orientation in 3D space, regardless of the player's viewpoint.

The primary use of the visually-based tracking is to determine the position of the tracking markers in relation to the camera. However, by inverting the transformation matrix created by the tracking algorithm, the position of the camera in relation to the tracking markers can also be calculated. We've used this information in *Save 'Em* to create 3D positional audio, which changes as the player moves. By tracking the position of the player's head-mounted camera, we can effectively determine the distance between the player's head and the surface of the game board. By scaling a sound's volume based on the player's distance from the source, we've created an effect where, as the player moves his or her head closer to the board, sounds (such as the roar of a flame jet, or the moan of a zombie) get louder and louder, seeming to emanate from the virtual entities themselves. As the player moves her head away these ambient sounds once again fall silent, enhancing the illusion that the virtual entities of *Save 'Em* have a real, physical presence and are part of the player's world.

Marker-based tracking relies on having an unobstructed image of the tracking markers to provide adequate detection. Since the physical game board is overlaid with a virtual game environment, the player is not aware of the markers when playing the game (Figure 5). This could have been a problem in *Save 'Em* where players will often reach across the board, unknowingly obscuring markers with their arm. To solve this problem, *Save 'Em*'s playing surface has been covered with twenty evenly-spaced markers to provide redundancy. Since the relative position of each marker has been measured beforehand, the entire board can be effectively tracked based on the information provided by a single visible marker.

Save 'Em's game engine was written in C++. We selected C++ for several reasons; not only is C++ well-established as a desirable language for developing games and other graphics applications, but more significantly, it is also the only language for which ARToolkitPlus libraries are immediately available. *Save 'Em*'s graphical rendering was written in OpenGL, using an engine of our own design. All animated 3D models that appear in *Save 'Em* (particularly, the Dudes and the zombies) are freely-available .md2 (the *Quake II* model format) files, downloaded from the internet.

5. PRELIMINARY FINDINGS

Although a formal user study has yet to be conducted, a large number of players have already played the game in unstructured settings such as demonstration sessions and lab visits. Thus far, our observations of these players have been very encouraging in suggesting that the physical gameplay techniques we implemented accomplished our stated goals of creating an accessible, immersive and fun experience, effectively using

augmented reality techniques to move gameplay to the player's immediate physical surroundings. Although players seldom manage to "save the Dudes" on their first attempt, a significant majority of them will eagerly request to try again, whereupon they usually fare much better. In fact, many players (even those who do not typically play video games) manage to save most Dudes on their second or third try.

Perhaps the most encouraging sign of *Save 'Em*'s potential is that when the game is left running unattended, people have been observed to wander over and begin playing without invitation. We feel that this demonstrates *Save 'Em*'s general appeal, and further solidifies the notion that *Save 'Em* is an accessible, approachable game which people are eager to try. Why does *Save 'Em* appeal to players, even those without backgrounds in video gaming? We believe it is due to the game's easy-to-use controls which unify a player's actions with their effects in an intuitive way. Physically moving a wand with your hand is so natural that the game's learning curve is almost nonexistent. In fact, new players can usually begin playing straightaway after watching another player, even without explicit instructions on how to play. By using a simple pointing device as an interface for controlling *Save 'Em*, we've created a game that allows players to utilize their preexisting knowledge while playing. Anyone that has ever issued directions to a friend by pointing on a map will feel right at home guiding the Dudes through a maze by pointing with their control wand.

6. FUTURE WORK

As of this writing, *Save 'Em* exists as playable single-level demonstration, designed as a prototype to gauge the effectiveness of our proposed design. Based on the positive feedback we have received so far, a sensible avenue for future work would be to extend the scope of the game by adding new, more challenging levels which introduce new enemies, traps, and puzzle elements.

Following this, we also hope to conduct a more formal user study to evaluate the effectiveness of our interface. One possible study would entail re-implementing *Save 'Em* for a standard computer gaming platform, using a game controller or the traditional mouse-and-monitor interface. It would then be possible to perform a comparative user study to examine the relative appeal of each interface.

We are also working to extend our goal of promoting enjoyable gameplay through augmented reality techniques and simple, innovative control mechanisms with an altogether new augmented reality game entitled *Photogeist*. In *Photogeist*, players are placed in an augmented reality environment filled with virtual ghosts. The player's goal is to take as many pictures of the ghosts as possible using a handheld camera. The player is free to move around the augmented reality environment which integrates her physical surroundings with the virtual ghost entities. *Photogeist* makes use of the camera-tracking described in this paper, allowing for ghosts which move and react to the player's presence during gameplay. In order not to scare the ghosts, players will have to physically stalk and sneak behind them before taking a photograph. We believe that *Photogeist* will further demonstrate how augmented reality techniques can be used to enhance the flexibility and richness of physical game interaction.

7. CONCLUSION

Save 'Em is a preliminary exploration of how relatively simple augmented reality techniques can be used to move gameplay to the physical world and how this move influences a player's enjoyment.

Save 'Em allows us to explore this by immersing the player in an augmented reality environment, facing her with a virtual task unfolding on a real game board. Gameplay is controlled using the movement of a handheld wand, which is directly mapped to the actions of entities in the virtual game environment, unifying input and output in one space. *Save 'Em* also integrates an awareness of the player's physical location, enhancing the exploration of the game through sound effects that change dynamically according to relative distance and orientation between the player and the virtual entities of the game.

Based on a series of informal games, preliminary findings suggest that the *Save 'Em* augmented reality experience affords intuitive and highly entertaining gameplay.

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