Rolling and Shooting: Two Augmented Reality Games

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Abstract
We present two fast-paced augmented reality games. One is a single-player game experienced through a head-worn display. The player manipulates a tracked board to guide a virtual ball through a dynamic maze of obstacles. Combining the 3DOF absolute orientation tracker on the head-worn display with 6DOF optical marker tracking allows the system to always account for the correct direction of gravity. The second game is a networked, two-player, first-person-shooter, in which tracked hand-held UMPCs are used to blast virtual dominoes off a table. Players' virtual locations are warped to keep them from physically interfering with each other.

Keywords
Augmented/Mixed reality, games, multi-user interaction, interference avoidance

ACM Classification Keywords
H.5.1 [**Information interfaces and presentation**]: Multimedia information systems—*Artificial, augmented, and virtual reality*; I.3.6 [**Computer graphics**]: Methodology and techniques—*Interaction techniques*; K.8.0 [**Personal computing]**: General—*Games*

General Terms
Design, experimentation, human factors

figure 1. Stereo, video see-through, head-worn display: Vuzix iWear Wrap920AR.

Introduction

Augmented reality [1], in which virtual graphics and sound are interactively overlaid on the real world, opens up new possibilities for computer games. In contrast to controlling gameplay with a button- and joystick-laden controller, and viewing the game through the window of a stationary display, augmented reality makes it possible to merge the game with our surrounding world. For example, the player might shoot zombies seen outdoors at full scale through a head-worn display [9] or viewed indoors in miniature through a hand-held computer [2], or use camera-tracked bicycle handlebars to steer a virtual vehicle around obstacles that grow out of the real floor [6].

Complementing this earlier work, we present two augmented reality games. Both are implemented with our Goblin XNA [3] software infrastructure, which is built on top of Microsoft XNA Game Studio 3.1 [4]. One of these games uses a hand-held game board for precise control of a virtual labyrinth maze, while the other demonstrates a novel physical interference avoidance technique in a fast-paced multiplayer first-person shooter.

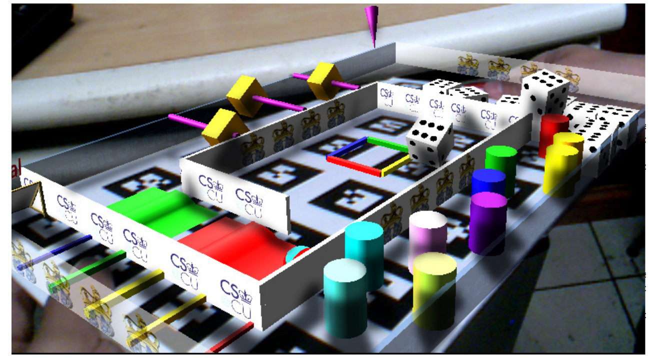

figure 2. The augmented marble game, viewed through a video see-through, head-worn display. The virtual marble and dice roll and slide as if acted on by gravity.

Augmented Marble Game

Our augmented marble game's player wears the video see-through, head-worn display shown in figure 1 [11]. The player holds a game board covered with a printed array of patterned optical markers. The markers are similar to those used in other augmented reality games, and are tracked by a camera in the head-worn display, using the ALVAR [10] tracking library, The player must guide a virtual ball through a maze of dynamic and static obstacles that appear on the board by tilting and translating the board, as shown in figure 2,.

Gravity in the game always points in the correct direction, no matter how the player's head and board are oriented relative to each other. This is possible because, in addition to optical tracking, the game takes advantage of a separate head tracker built into the head-worn display. The optical tracker determines the game board's position and orientation relative to the head-worn display. The built-in head tracker senses real gravitational acceleration to determine which way is "down," which we use to compute the direction of

figure 3. A player's view of the domino knock-down game.

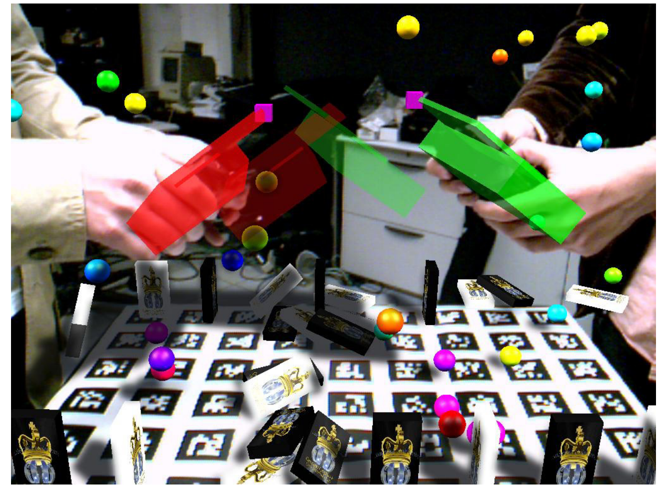

figure 4. Third-person view of the domino knock-down game. Automatically generated overlaid graphics demonstrate our redirected motion interference avoidance technique. Bright red (left) and green (right) models of the players' computers show their tracked physical locations. Darker, more transparent, red and green models show the displaced virtual locations that are used during gameplay.

gravitational acceleration to be applied in the game board's coordinate system. Thus, the marble and other game objects (e.g., dice) will roll or slide under the influence of gravity, which is simulated using the Newton Game Dynamics physics library [5].

Domino Knock-Down Game

Domino Knock-Down is a networked, two-player, first-person-shooter game. The players stand around a game table covered with an array of optical markers, which establishes a shared playing field. Each player holds a Sony VAIO UX series ultramobile personal computer (UMPC), which has a camera built into its back, allowing the UMPC to be tracked relative to the table. The player fires virtual balls at a configuration of virtual dominos on the field by tapping on the screen of their UMPC, as shown in figure 3. Each player is associated with their own set of uniquely colored dominos. The view through the UMPC's virtual camera is augmented with overlaid graphics generated by the UMPC, and tracked relative to the game table. The goal is to be the first to knock all of the other player's dominos off the table.

We have used Domino Knock-Down to explore how we can lessen the chance of the kind of physical interference that can occur during aggressive gameplay. The third-person view shown in figure 4 shows overlaid graphics that provide a visualization of redirected motion, an interference avoidance technique that we developed. Redirected motion [7], which is inspired by earlier work on redirected walking [8], transforms the 3D space in which the player manipulates their UMPC, to direct the UMPC away from the other player's UMPC to avoid physical interference. This is accomplished by dynamically shifting the virtual location of a UMPC ahead of its physical location when the UMPC is moved in the direction of the other player. As a result, the virtual view of the dominos through the UMPC makes it appear to be closer to the other player's UMPC, reducing the need for the user to move farther in that direction.

As described, the changing offset between the virtual and physical locations of the UMPC would be visible in the apparent motion of the virtual dominos relative to the pattern on the physical game board. To conceal this, we cover the board with a virtual texture, visible on the UMPC screen in figure 3. This texture extends beyond the edges of the board and is stationary relative to the virtual coordinate system within which the virtual location of the UMPC moves. While the physical board is fully obscured, other parts of the real world remain visible. A controlled study showed that players stayed significantly farther apart when redirected motion was enabled, yet did not notice the effect.

Acknowledgements
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