

Design Guidelines for Multiplayer Video Games on Multi-touch Displays

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The proliferation of multi-touch, tabletop display systems during the last few years have made them an attractive option for interactive, multiuser applications such as museum exhibits and video games. While there is a large body of research on the use of multi-touch and tabletop devices in general purpose applications, far less research has investigated the use of these systems in video games and other entertainment applications. This paper provides a set of guidelines specific to multi-touch displays that can be used to augment existing video game development principles. Through example, we illustrate how the unique capabilities of multi-touch displays can be leveraged to create unique forms of gameplay that offer highly engaging multiplayer game experience. We describe three multiplayer games that have been developed by students as part of an interdisciplinary course in video game design.

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1. INTRODUCTION

Multi-touch displays are touch-sensitive screens that allow users to interact with graphical applications using their fingers. Unlike traditional touch-screens commonly used in ATM machines and other consumer devices, multi-touch displays are able to register a large number of distinct touch points (typically in the tens) simultaneously. This allows users to interact with the display using more than one finger or hand at a time, which expands the possible interaction schemes and enhances user experience. Additionally, a multi-touch screen allows multiple users to simultaneously interact with the display when the screen surface is large enough to accommodate them. This enables possibilities for a new generation of collaborative, multi-user, interactive applications.

The enhanced user experience has made multi-touch displays an attractive option for many applications in which multiple people need to collaborate to achieve a common goal. For example, museums are exploiting multi-touch displays to build interactive exhibits in which visitors work together to complete specific tasks supporting a common

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learning goal [Leigh 2009]. Scientists are also leveraging these displays to generate interactive visualizations that support collaborative investigation and analysis of complex, large datasets. More recently, video game developers have started to view multi-touch displays as an emerging platform for multiplayer games. Traditional computer games such as Pong [Gross et al. 2008] have been “ported” to tabletop multi-touch platforms, allowing a social, multiplayer experience.

A number of characteristics make multi-touch displays an attractive platform for multiplayer games. In video game consoles and PC-based games, each player receives a separate view of the environment, and interact with the game using a dedicated controller which typically allow the player exclusive control over a subset of characters or objects in the game. By contrast, players in tabletop multi-touch displays share a single environment, and interact with the game using a shared but powerful interface that enables complex interactions to be conveyed intuitively. This allows for a more social, face-to-face interaction between the players. Moreover, because the players share the same input device, they do need to have exclusive control over certain characters or objects, enabling a more fluid control scheme to be used in the game. The improved social interaction, and the ability to cooperatively share control over the game enables unique interaction modalities that encourage collaboration between players and foster high-level problem solving, leading to increased enjoyment by players. These characteristics can also be exploited by serious video games to offer engaging, social gameplay in which participants collaborate to play the game while learning the intended concepts at the same time.

While there are well-established design paradigms and principles for games targeting traditional video game hardware (such as consoles and PCs), these techniques fall short when applied directly to radically different hardware platforms such as multi-touch displays. As the hardware interface changes, the interaction scheme associated with the game can change dramatically, which in turn can significantly influence many aspects of gameplay. For example, a multiplayer game for a tabletop multi-touch display has to present a consistent view for all participants regardless of the position they are viewing it from. Game designers need to be aware of these aspects in order to leverage the affordances of multi-touch displays and design around their limitations. There have been some attempts at porting existing video games to multi-touch platforms (For example, Warcraft [PQ-Labs 2008] and The Sims [Tse et al. 2007]). However, these ports often resort to emulating the mouse with input from the multi-touch screen, resulting in a single-player game that does not take advantage of the multiplayer capability of multi-touch displays.

The goal of this paper is to aid game developers in understanding how the unique capabilities of multi-touch displays can be leveraged to create unique forms of gameplay that offer highly engaging multiplayer gaming experience. Additionally, the limitations of the technology and their effect on gameplay are also illuminated. We discuss these issues in the context of a number of games that were developed during two iterations of a semester-long video game design course. During this course, groups of students majoring in Art and Computer Science designed and developed, from the ground-up, video games for TacTile, an LCD-based multi-touch display that supports as many as 500 simultaneous touches [TacTile 2008, Leigh et al. 2009]. It is important to note that we define multi-touch displays in this paper as displays that can sense more than two simultaneous touches, and can physically accommodate at least two users. Therefore we do not include iPhone and Android games as part of this discussion.

The rest of the paper is organized as follows. Section 2 reviews previous research on multi-touch video games. In Section 3, we discuss the methodology used in the research leading to the conclusions of this paper. Section 4 describes the development platform. Section 5 describes three different multiplayer video games designed for TacTile, and

documents different approaches for effective multiplayer gameplay. Section 6 summarizes the lessons learned and provides some guidelines for prospective developers of multi-touch video games. We conclude the paper in Section 7 and give future research directions.

2. RELATED WORK

Tabletop and multi-touch displays have attracted large interest from the Human-Computer Interaction community due to their intuitiveness and suitability for group-oriented tasks. There is a large body of research on the use of these displays in collaborative, computer-supported tasks. A classical example is the work of Scott et al. [2003]. The vast majority of the literature on multi-touch and tabletop displays however focuses on general-purpose, work-oriented tasks, as opposed to video games. While many of the conclusions and guidelines found in that body of research can be conceivably generalized to games, there are a number of unique factors that have to be considered when designing multiplayer video games, including enjoyment and competition between players.

In recent years, the interest in the application of multi-touch and tabletop displays to multiplayer gaming has increased. A number of classical video games have been ported to these platforms. One example is a multi-touch adaptation of the famous Atari Pong game [Gross et al. 2008]. The game is played with a single gesture that consists of a two-finger tap to form a racket and bounce the ball.

Esenther et al. describe two multiplayer, multi-touch games [2005]. In the first game, players compete to find a special ball with a swirling pattern out of groups of blue balls. The hardware platform allows the identity of the player touching the table to be reliably deduced. Therefore, the game knows the identity of the winning player who finds the special ball first. In the second game, the players cooperate with each other to eliminate balls from the screen by touching them. Some special balls require at least two people to touch the balls simultaneously, which results in elimination. The hardware platform used here allows for distinguishing touches and associating them with different users. However this feature requires a special hardware setup, and is not available in most commodity multi-touch platforms.

Other research investigated the social aspects of multiplayer games on multi-touch and tabletop displays. Khaled et al. describe two collaborative, multiplayer games. Both games revolve around moving a set of items on the screen and arranging them in some predetermined fashion, with the players collaborating to complete the task in a limited time [2009]. Wolfe et al. describe a low-cost, projector-based, multi-touch platform targeted at game developers [2008]. A sample game is illustrated, with players cooperating to eliminate asteroids. Missiles are fired by touching the surface, destroying asteroids in their vicinity. There has also been some interest in the use of multi-touch, collaborative gaming for social development. Examples are found in Piper et al. [2006] and Al Mahmud et al. [2007].

Some researchers also started to investigate the potential of multi-touch displays in multiplayer games. Tse et al. study behavioral patterns in cooperative gameplay on a multi-touch display to deduce guidelines for multiplayer video games [2007]. Their study uses ports of two existing single-user, commercial games to a multi-touch tabletop platform. The interaction scheme was transformed to accept a rich set of gestures for performing different commands. Our experience from the video game design class however suggests that attempting to adapt existing single-user games to multi-touch displays often leads to games that do not take full advantage of the potential of these platform.

The studies above offer examples of multiplayer games for tabletop and multi-touch devices. However, most of them focus on the user experience and social interaction

between players that arise in these platforms. There is little work that systematically investigates and illuminates unique gameplay concepts that can be practically utilized by prospective game developers to build engaging multiplayer games for multi-touch, tabletop displays. We believe that the unique features of multi-touch displays call for novel game concepts and interaction schemes that are designed from ground-up to take full advantage of the capabilities these platforms have.

3. METHODOLOGY

To investigate multi-touch games as emerging platforms for video games, we conducted a study as part of a video game design course. The goal of the study was to explore how unique capabilities of multi-touch displays could be leveraged to develop engaging multiplayer video games, and to derive a set of principles that can augment existing video game development principles. The study was conducted as part of a video game design course taught simultaneously at the University of Illinois at Chicago and Louisiana State University. The semester-long course was taught twice in 2009 and 2010 with the participation of 29 and 40 students, respectively. Students who took the course were a mixture of undergraduate and graduate students majoring in either Computer Science or Art. A total of 15 teams were formed throughout the two iterations of the course, with each team composed of three to five students. Each team was tasked with developing a multiplayer game concept suitable for a tabletop, multi-touch display, and implementing the game on the TacTile system.

The materials of the course were designed to illustrate a vertical slice of the video-game design process. Therefore, the projects emphasized completeness and polish of the final game products. Due to the novelty of the platform, no priori design guidelines existed for the design of multiplayer video games on multi-touch displays. Therefore, the student teams received continuous feedback from the instructors throughout the semester-long course, leading to numerous design and implementation cycles. This iterative process allowed the students to overcome some limitations of the platform and devise novel gameplay schemes that leverage the unique affordances of tabletop, multi-touch displays.

At the end of the semester, the games were demonstrated to a panel of judges. The panel was assembled from expert video game developers from the industry, as well as Computer Science faculty with research background in Computer Graphics, Human-Computer Interaction, and Learning Sciences. The panel evaluated and ranked the 15 games on criteria that included gameplay design, interaction design, art design, sound design, and technical achievement. The three games we describe in this paper were chosen as they encompass most of the successful interaction schemes that were developed, and form the bases of the guidelines described in this paper.

4. DEVELOPMENT PLATFORM

The video games were developed on TacTile, a tabletop, LCD-based, multi-touch display with a 52-inch screen that supports resolutions up to 1080p HD (1920×1080) [TacTile]. The device was built using consumer off-the-shelf components. The first version of TacTile was assembled at the Electronic Visualization Laboratory at the University of Illinois at Chicago. Subsequent clones were later built at Louisiana State University and the Science Museum of Minnesota. TacTile is capable of tracking up to 500 fingers simultaneously across the display surface, making it ideal for groups of two to four people. The finger tracking utilizes the Frustrated Total Internal Reflection (FTIR) technique [Han 2005]. The device uses three infrared cameras that are tucked underneath the LCD display. A custom tracking application receives images from the cameras and analyzes them using traditional computer vision techniques to determine finger location. The video games were implemented using Processing [Reas 2003]. To

simplify the game development, a Java API was developed to provide game developers easy access to the finger tracking information without the need to implement computer vision code. Although the games sampled in this study were developed and evaluated on TacTile, the analysis and the guidelines reported in the paper apply equally to other tabletop, multi-touch platforms, such as Microsoft Surface [Microsoft Surface].

5. SAMPLE DEVELOPED GAMES

At the end of the semester, the students presented their game concepts and demonstrated the games in front of the judges' panel and audience. The judges played the games on the TacTile multi-touch display. The panel then evaluated and judges gave their opinions on the 15 games that were developed during the two iterations of the semester-long course. We selected three of the 15 games based on their quality and on the fact that they cover a wide range of effective multi-touch, multiplayer game concepts and interaction schemes. Students who developed the three chosen games were invited to submit a written report outlining their design. After analyzing the top-ranked games along with student reports, we discovered commonalities in the design and interaction schemes in the successful games. The guidelines we report in this paper were compiled derived from our analysis of those commonly recurring gameplay ideas and interaction schemes.

The top ranking game was *Zombie Apocalypse*, a multiplayer, cooperative, puzzle-solving game in which the players have to guide three characters safely away from zombies. The level can only be won if all the characters cooperate to solve the puzzle before the zombies overran them. The second game was *Galaxy Commander*, an adaptation of the iPhone-based *Galcon* [Galcon]. The game converts the single-player iPhone application into a two-player game in which players compete to conquer each other's planets. The third game was *Ball Buster*, a multiplayer competitive game similar in style to *Pong*. Groups of two to four players compete to throw balls at each other's targets on the opposite end of the screen, while protecting their own targets with temporarily deployed barriers. We describe each of these games in some detail, and discuss unique gameplay and interaction concepts that were found in each of them.

5.1. *Zombie Apocalypse*

Zombie Apocalypse is a multiplayer, cooperative, puzzle-solving game that revolves around three characters who have to be rescued to a safety zone and away from a horde of zombies. During the game, the players have to navigate the characters around a number of obstacles and solve a number of puzzles that require coordination between the characters. Figure 1 shows one of the levels in the game.

The game provides a top-down view of the current level, showing the entire map along with all the obstacles, characters, and zombies. The characters can be moved when the user touches the character and drags one's finger across the screen to the desired destination. This forms a path that the character automatically starts following. Each character is also armed with one weapon that can be activated by tapping one's finger inside a circle that surrounds the character. By moving the finger while it is inside the surrounding circle, the direction of firing can be specified allowing the player to target zombies. The three characters have weapons with varying potency and firing rate. For example one character has a flamethrower that is effective, but has a short range. Another character has a machine gun with a fast firing rate, but low potency.

To successfully complete a level in the game, the three characters have to escape to the safe zone without getting caught by the zombies. This requires coordination and cooperation between all the players. For example, in the first level, the characters are on one side of a river that runs across the entire length of the map, whereas the safe zone is on the other side of the river. On each side of the river there is a button that causes

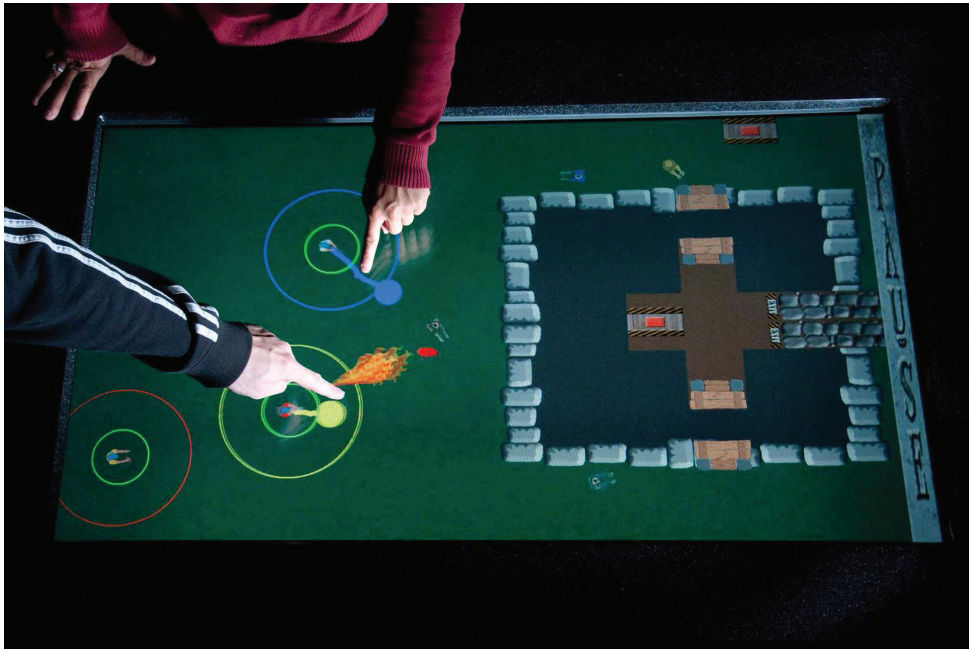


Fig. 1. **One of the levels available in *Zombie Apocalypse*.** The level is mapped in its entirety to the 52-inch screen. In this level, three characters have to cooperate to lower two bridges in order to cross to the safe zone on the right side of the screen.

a bridge to be lowered when one of the characters is standing on it, allowing the other two characters to pass over the river. However, one character has to remain standing on the button for the bridge to be lowered, as the bridge is retracted as soon as the character steps off the button. Additionally, whenever the button is pressed, an endless horde of zombies starts coming from the side of the screen toward the characters. To solve the puzzle, one character has to be guided to stand on the button on one side of the bridge while others cross. After the two characters pass to the other side of the river, one of them has to be guided to step over the second button, allowing the poor character left alone on the wrong side to pass the bridge, and then the three characters can proceed to the safe zone.

Figure 2 illustrates cooperative game play in *Zombie Apocalypse*. The smaller frame in Figure 2 illustrates the two gestures used in the game: The player on top is activating the weapon with a tap-to-shoot gesture, while the player on left is moving the character by dragging his finger across the screen to draw path for the character to follow.

Findings. One of the principle issues that have to be taken into account when developing a game for a multi-touch, tabletop display is the orientation of the view. In traditional video game platforms, each player typically has his/her own screen, or the screen is split to show a separate view for each player. In either case, the player is looking at a separate screen or a non-overlapping area of the screen. Therefore, the game does not need to present a consistent orientation or view for all players. In tabletop, multi-touch displays, the players usually stand on different sides of the display to maximize screen use. Therefore, multi-touch games have to present a single consistent view for all the players. The *Zombie Apocalypse* game presents a top-down view of the entire level on the screen, which makes it consistently viewable from all four sides of the display.

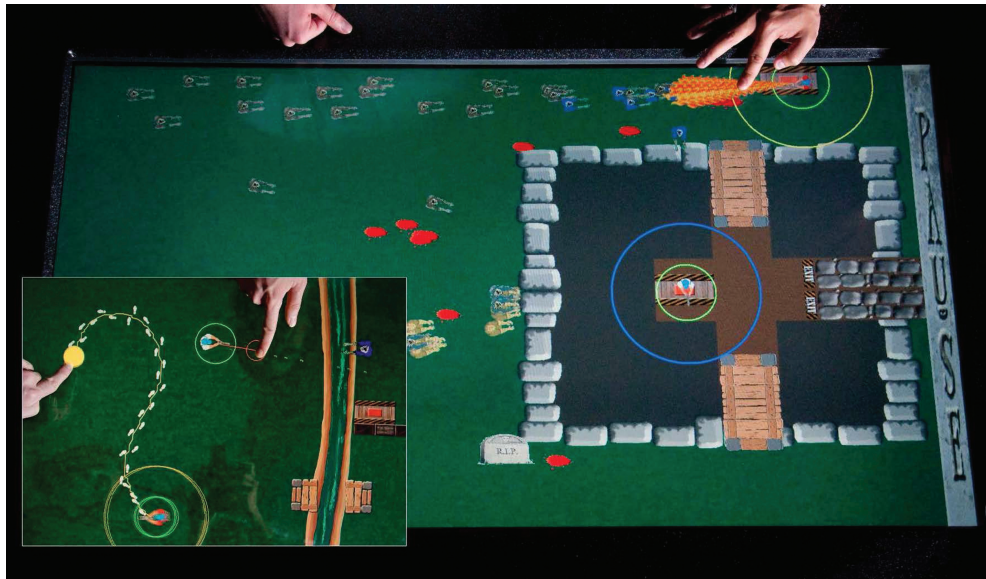


Fig. 2. **Cooperative gameplay in *Zombie Apocalypse*.** The large frame shows the flame-throwing character on the top-right corner. The flame-thrower has opened the top bridge for the machine-gun character, which has already crossed to the safe zone. The machine-gun character now holds the switch for the lower bridge. It is up to the flame-thrower to make it to the lower bridge and cross to the safe zone. However, as a horde of zombies attack, it is difficult and requires a team effort to clear the zombies. The smaller frame illustrates the gestures. The player on top is performing tap-to-shoot gesture. The player on the left is moving the character by dragging it across the screen, drawing a path for the character to follow.

Presenting a single, consistent view of the entire level affords a number of opportunities, which can be leveraged in cooperative games. In traditional multiplayer games that depend on team cohesion and cooperation, it is not always straightforward for the players to devise a single strategy to complete the objectives of the game. This is because players normally have access to different, limited, and self-centered view of the level. Thus, in order to complete a level, players usually resort to trial and error. An advantage of mapping the entire game level to the physical display is that all players have complete situational awareness. This enhances the potential for social interaction between the players. These interactions include information sharing, strategic planning, and coordination between players during gameplay. This fosters higher-level problem-solving discourse, which can be exploited by serious games, which typically have an underlying educational goal.

Another common issue to consider in cooperative, multiplayer games that have multiple characters is partitioning the control of characters among all players. The traditional scheme for dealing with this issue is to assign a single character to every player, and allowing the player exclusive control over that character only during the entire level. A limitation of this approach is that the characters need to have balanced roles in the game. This includes comparable abilities, and equal influence over the events and outcomes of the game. Ignoring this principle would likely lead to frustration of players who have limited power or influence. Multi-touch displays however provide an opportunity to get around this limitation by allowing a player to interact with all characters throughout the experience. For example, In *Zombie Apocalypse*, players can easily shuffle between characters by simply touching the desired character on the screen. Moreover, players can negotiate in real-time among themselves who should be controlling what character. This decision can be based on which player is standing

closer to the character's position, for example. More importantly, this allows all the players to experience all the different characters, leading to more options and possibly increased player engagement. This scheme however, works only in cooperative games in which all the players are working towards a common goal. Different control schemes have to be devised for competitive games.

5.2. Galaxy Commander

Galaxy Commander is a competitive two-player game inspired by the iPhone-based Galcon application [Galcon]. Much like the original Galcon, the game revolves around two teams, a red and a blue team, each controlled by one of the two players who compete to conquer all the planets in the galaxy. The two players stand on opposing sides of the display. Each player starts off with one planet and proceeds to conquer more planets throughout the game. Planets conquered by one of the players continuously produce spaceships, which can be later used to invade other planets. The number of spaceships stationed in each planet is indicated on the planet. The main method of conquering additional planets is by dispatching a fleet of spaceships from one of the planets already controlled by the player to a new one. This can be done by holding down an allied planet and dragging one's finger to another planet. While player is performing the gesture, an arrow extends from the source planet to the player's finger, providing visual feedback. A quick beep is sounded when the player completes the drag gesture. The fleet will either attempt to occupy neutral planets, seize opposing planets, or reinforce allied planets. An attempt to seize is successful if the number of spaceships in the invading fleet exceeds the number of inhabitants garrisoned on the planet. The size of the invading fleet can also be increased once spaceships from multiple allied planets are dispatched simultaneously, this is done by dragging one's finger to visit several allied planets, before ending the drag at the target planet. Figure 3 illustrates this feature.

The overall objective of each player is to dominate the opponent's planets, which occurs once all the planets have been conquered. Additional special abilities such as shields and weapons of mass destruction have also been introduced. The deployment of these enhancements follows the same drag and release gesture used for attacking planets.

Findings. Similar to *Zombie Apocalypse*, *Galaxy Commander* also uses a top-down view that shows the entire level. Since the game was designed to be playable by two players, the textual elements such as the number of spaceships in each planet are rendered in two orientations, making it easier for both players to read. Additionally, the main icons including planets and spaceships were designed to be symmetric, making them easily recognizable from both sides of the display. On the other hand, the user interface elements, which consist of two buttons to activate the special abilities are replicated for each player, and positioned close to the side on which the player is standing. Much like *Zombie Apocalypse*, both players can access the main interaction area; these players compete to conquer more neutral planets as well as invade each other's planets. A side effect of this layout is that a player can dispatch spaceships from his/her own planets, as well as from those planets owned by the opponent. Although the stated rules of the game do not allow that, there is no easy way of technically enforcing this rule. Most touch displays (including *TacTile*) identify touch points only, and cannot associate these points with a specific user. This led to some unexpected interactions when the game was demonstrated to judges and audience members. For example, one player prevented his opponent, who was attempting to dispatch spaceships to invade one of his planets, by physically blocking the opponent's hand and preventing her from completing the drag gesture to dispatch invading spaceships. While these situations are



Fig. 3. **Players mobilizing their spaceships for attack in Galaxy Commander with a simple drag gesture.** Both players are linking planetary resources together across multiple planets to form a larger attack fleet.

technically recognized as “cheating”, their spontaneity greatly enhanced the enjoyment of the game by the players.

5.3. Ball Buster

Ball Buster is a fast-paced, competitive, multiplayer game that was designed to be played by two to four players, with each player standing on one of the four sides of the display. Each player has a rectangular Goal Area where five targets are located. The Goal Area is positioned near the side on which the player is standing. The goal of the game is to hit other players’ targets and protect one’s own. A player attacks opponents by “shooting” balls from within the Goal Area. A shoot gesture consists of touching the Goal Area, pulling back, and releasing the touch. This gesture is intended to mimic a slingshot being used to throw balls. To defend against incoming balls, players can deploy temporary barriers. A barrier is created using a simultaneous two-finger tap gesture outside the Goal Area, deploying a straight-line barrier between the two fingers. A ball ricocheting off a barrier changes direction and ownership, causing it to become a hazard to opponents. The barrier remains active for few seconds and “pops” automatically when it has expired. The length of the barrier can be adjusted by modulating the gap between the two fingers when tapping.

The goal of the game is to eliminate opponents by hitting their targets. A player is eliminated when he/she loses all their targets, and the last remaining player becomes the winner. Figure 4 shows four users playing the game. The two gestures are illustrated in Figure 5. In the picture, the player is aiming a ball at an opponent using the shoot gesture with his right hand, while simultaneously deploying a barrier to protect the Goal Area with his left hand. A canon icon allows the player to aim the ball accurately at the opponent’s Goal Area.

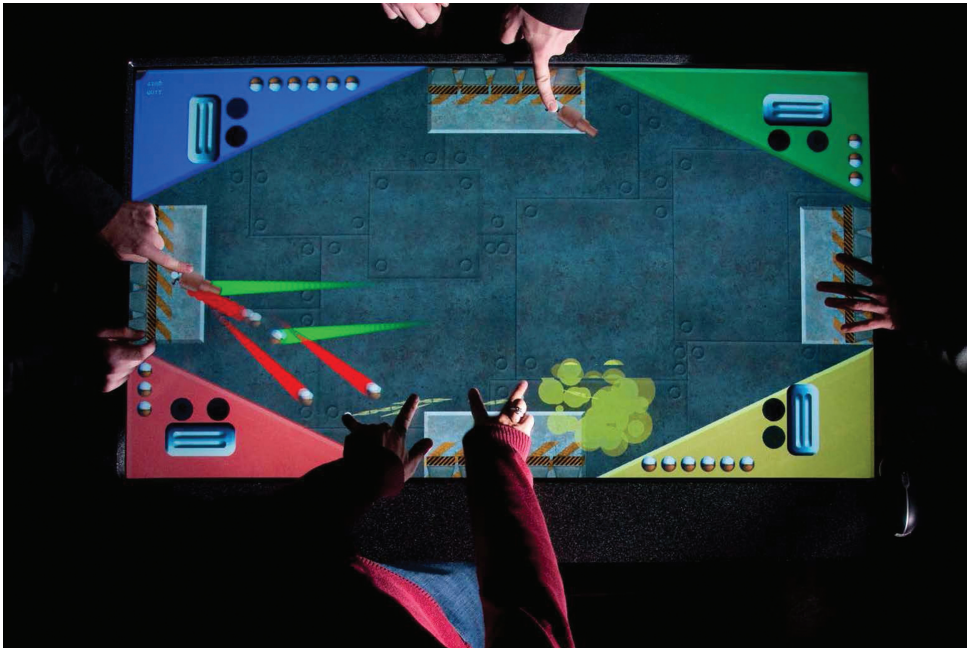


Fig. 4. **Four users playing Ball Buster.** The players on the left side and top side are performing the shooting gesture, while the player on the bottom is using the two-finger tap gesture to create two separate barriers.

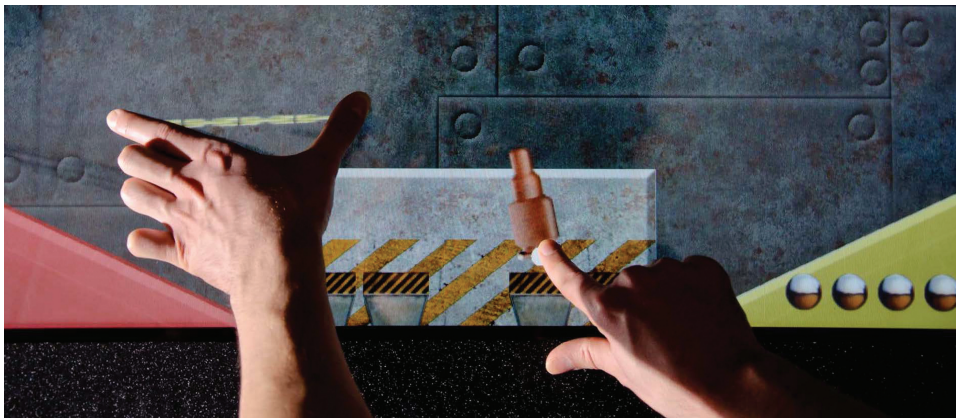


Fig. 5. **A player performing the two gestures in Ball Buster simultaneously.** The left hand is deploying a barrier using the two-finger tap gesture. The right hand is performing the shoot gesture in the Goal Area. While performing the shoot, a canon icon provides visual feedback and allows the player to aim the ball by sliding the finger left or right, causing the canon to rotate. Once the finger is released, the ball is thrown and the canon disappears.

Findings. The control scheme for Ball Buster consists of a small set of gestures. The entire game is played with only two gestures: pulling back and releasing to shoot and two-finger tap to defend. Additional visual cues are given by the graphical representation of cannons and barriers (Figure 5).

Good multi-touch gestures are intuitive and easy to learn. The intuitiveness of a gesture can be greatly enhanced by designing physically inspired gestures. For example, the shoot gesture in *Ball Buster* is inspired from the act of pulling the string of a slingshot and releasing it to throw a ball. The effect of this similarity can be noticed in first-time players, some of who were initially confused about how to perform the gesture. However, once told to imagine using a slingshot to throw the balls, players almost immediately learned the gesture and started performing it successfully. Another factor to consider is the influence of the gesture on game dynamics. For example, the shooting gesture was designed to allow accurate aiming of balls. An alternative shooting gesture could have used a quick fling movement, where players fling a finger in the Goal Area to throw a ball. However, the fling gesture, although faster to perform, does not offer the same accuracy. Moreover, a fling gesture would have increased the pace of an already fast-paced game.

The game designer often needs to balance conflicting factors when designing gestures. For example, an earlier prototype of *Ball Buster* had a “draw” gesture that allowed players to deploy barriers while brushing with one finger. Although this gesture was found to be more intuitive than the final two-finger tap, the drawing gesture required more time to complete, leaving the players with less time to react to an incoming ball. Therefore, although more intuitive, the draw gesture was dropped in favor of the two-fingers tap gesture which can be completed in less time.

Gestures should also be evaluated from an ergonomic point of view. Gestures that need to be performed repetitiously throughout the game need special consideration. For example, sliding fingers across the screen generates friction, causing discomfort to the player (or what we fondly call the “Flaming Finger Syndrome”). Therefore, gestures that exhibit potential for fatigue and discomfort should be kept at minimum, and perhaps even avoided in fast-paced games.

6. LESSONS LEARNED AND DESIGN GUIDELINES

Multi-touch displays offer great potential for a new generation of engaging, multiplayer games. The fact that all the players share the same input and output device creates opportunities for embodied social interaction between the players, and fosters high-level, collaborative problem solving. This can be used to create a wide variety of gaming experience ranging from purely entertainment-centered games to serious games supporting learning goals. It is tempting to apply the same techniques and principles for traditional video games to multi-touch platforms. However, due to the uniqueness of this platform, game developers have to learn to break free from some of the previous notions of game interaction and control techniques. Although this at first may sound limiting, one needs to consider the unique affordances of multi-touch displays, which have the potential for fostering a more social gaming experience than what is currently possible with traditional game consoles and PC-based games.

After analyzing the games presented in Section 5 along with the opinions of the judging panel, we have derived a set of guidelines for prospective multi-touch game developers. Table I summarizes the guidelines that have been discussed in this paper. These guidelines are not intended as a step-by-step methodology for multi-touch game development. Instead they are intended to augment existing game development guidelines that a game developer may already use. For example, Schell’s *Art of Game Design* methodology [Schell 2008] uses a collection of lenses through which game designers examine and critically question their gameplay design. Schell’s lenses are presented as a deck of 100 game design cards. One can potentially extend Schell’s approach by developing additional lenses (or cards to the deck) that are specific to multi-touch game design. These are presented below.

Table 1. This table summarizes guidelines for multi-touch game developers, citing examples in the surveyed games.

	Traditional Console/PC gaming	Multi-Touch	Recommendations for multi-touch games	Example
Visual Orientation	The display is usually vertical and faces the user. This provides a single orientation to the game experience.	Players are often standing on different sides of a horizontally placed display. Consequently, the game should be orientation-independent to accommodate players regardless of which side they are standing on.	A good technique is to design the game with a top-down vantage point.	All the successful games mentioned in this paper use this approach. While there were other games that provided different vantage points (e.g. split screen views), they tend to isolate the players from each other.
Ergonomic Considerations	Provides tactile feedback via depression of buttons, pushing of a joystick, or clicking a button. Users have been shown to be able to use devices for long periods of time.	A large source of fatigue that occurs in users is the Flaming Finger Syndrome. This is caused by friction induced by rapid or longer-term interaction with the touch device.	Using semi-symmetrical shapes for major characters or important objects helps players recognize them. Textual elements should be kept at minimum since they are hard to read from all possible viewpoints. If some text is required, it should be rendered in at least two orientations. This principle of symmetry should also be applied to the actual game logic. Restrict fast-twitch interactions to minimize Flaming Finger Syndrome. Eliminate the need for excessive rapid dragging.	Zombie Apocalypse displays a character's health as concentric rings rather than a bar at the "top" or "bottom". Ball Buster does not use text. Game variables such as the number of targets left for each player are represented using icons. Galaxy Commander mirrors all text for each of the two players. Given the top-down point of view for the games mentioned, movement and physics are confined to a 2D plane. This makes game logic and interactions uniform to all orientations. Ball Buster was designed with this in mind. Short finger pull-and-release gestures were used to launch balls. However, a limit was placed on the number of balls fired. This ensured a period of rest. Additionally, the barriers were implemented with a two-finger tap rather than a dragging motion.

Continued

Table 1. Continued

	Traditional Console/PC gaming	Multi-Touch	Recommendations for multi-touch games	Example
Interactions and Interface Ownership	Offer a dedicated controller with a finite number of inputs.	A touch device is a single input device. Consequently, no notion of ownership or player identification is implied.	Resist the urge to use software-based emulations of hardware interfaces where possible (e.g. virtual D-pads). It is difficult for players to both view the graphical elements and the interfaces at the same time if they are far apart. Integrating the interface with the graphics provides a solution to this.	Zombie Apocalypse originally used a virtual D-Pad interface at the corners of the screen for controlling the game characters, before it was eventually replaced with an interaction scheme that involved players directly manipulating the game characters.
			Minimize the need for players to memorize complex gestures. Choosing physically inspired gestures helps make them intuitive.	A player can navigate through each of the games mentioned with a small set of simple gestures. For example, Galaxy Commander's entire game play is based on a simple drag and release gesture. Ball Buster uses a slingshot-inspired gesture for ball throwing.
			In most cases there is no way to associate a player with a touch. Try to leverage this to enhance cooperative play.	Zombie Apocalypse accomplishes this quite effectively by allowing players to control any character on the screen. Additionally, a single character can be shared with one player controlling its movement while the other player controls the shooting.
			For competitive games, create a small-localized control area for each player. This reduces the possibility of players interfering with opponents' controls, and minimizes confusion by the gesture recognition system.	An example of a well-designed control area is Ball Buster's Goal Area, from which the player can throw balls at opponents. The Goal Area is positioned close to the player, thus eliminating interference.

6.1. Design Games to be Orientation Independent

In multi-touch, tabletop displays, players are usually standing on different sides of the device, with each player getting a view of the game from a different angle. For the game to be enjoyable by all players, it should present a consistent orientation to all of them, regardless of which side they are standing on. A good technique is to design the game with a top-down vantage point. This approach has been followed by all the successful games that were developed during the game class. Additionally, using semi-symmetrical shapes for objects and characters helps players easily recognize them from different vantage points. Text is inherently difficult to deal with, therefore it should be kept at minimum. If text is required, it should be rendered in at least two orientations whenever possible. For example, *Galaxy Commander* uses symmetric objects and provides two copies of the same textual element so it can be easily read by each of the players standing on opposing sides.

This principle should not only be applied to graphical elements, but should also be extended to game logic. For example, a game that includes a gravity component in one direction would be difficult to play by multiple players standing on different sides of the screen, as the game will violate basic physical intuition if looked at from the wrong side. Multi-touch displays offer the unique powerful idea sharing both the interface and output device by all players offers an opportunity of a more social experience.

Here we present an example of how to incorporate these guidelines into Schell's methodology by creating the "Lens of Orientation Independence." This lens says that a multi-touch game's orientation has a profound impact on game play. The following are critical questions that game designers might ask:

- Multi-touch displays typically have a long side and a short side. How does this asymmetry affect your gameplay?
- How does the orientation impact the number of players that can participate in the game?
- How does the orientation determine where and in what direction user-interface and textual elements are placed?

6.2. Control and Interaction

Input devices for traditional games usually revolve around a dedicated controller with a finite number of inputs. A multi-touch device offers a single input device with a potentially infinite number of input schemes. A challenge with most multi-touch platforms is that it is not technically feasible in most situations to associate touches with a particular user. This imposes significant changes on game interaction. Whether this is an issue or not depends on the nature of the game. A cooperative game where all the players are working together to achieve a common goal does not necessarily need to distinguish between the different players. The notion that all the players are treated equally by the game adds more potential for social interaction between them and fosters high-level problem solving.

On the other hand, a competitive game will likely need some way of distinguishing between the actions of different players. A good solution to this is to dedicate a private control area for each player inside where the player performs the actions that need to be identified. This area should be placed closer to the side on which the player is standing. *Ball Buster* employs this approach. Alternatively is a hybrid approach where there are private areas as well as shared areas accessible by all players, which could be employed in competitive games. The identity of the player performing actions in a shared area can be sometimes disambiguated from the context. For example, a player interacting with an object in the shared area can be assumed by the game to be the owner of that object. This technically does not prevent an opponent from interfering

with other objects he/she does not own. However, cheating is usually easily to detect as players can see all actions by all other players in the game.

Gestures are typically used to mediate the bulk of interactions with the game. As such, they have profound influence over many aspects of gameplay. Therefore, it is important for the designer to consider their implications on game dynamics, such as the pace of the game and the gesture's accuracy in conveying the intended action. Gestures are better when they are intuitive and easy to learn. Choosing gestures inspired by physical actions that metaphorically mimic the intended virtual action (such as the slingshot gesture in *Ball Buster*) can make them more intuitive.

"The Lens of Multi-touch Interface" draws the attention of the designer to the fact that a multi-touch, tabletop display provides a single input/output device that is shared by all players. The designer should therefore consider a user interface design that takes advantage of this expressiveness while addressing its limitation (namely the inability of disambiguating the identity of the players). The designer needs to address the following critical questions:

- In a competitive game, how does the user interface ensure that private game assets (such as a character) can be only interacted with by the rightful player?
- In a cooperative game scenario, what is the best interaction scheme that guarantees sharing of control and influence over the game between players? Do all the players have equal access to game assets?

Schell's deck of cards includes a "Lens of Control," which advocates simple and intuitive user interfaces to empower players and give them a sense of control over the game. Multi-touch gestures can be part of an effective interaction scheme. When evaluating gestures, the designer should consider the following questions:

- Can the proposed gesture be easily grasped and mastered by the player? Naturalistically inspired gestures (such as flicking) can be easily communicated to and mastered by most players making them intuitive.
- How quickly and accurately can the average player perform the gesture? What is the effect of an unsuccessfully or incorrectly detected gesture on gameplay?

6.3. Evaluate Ergonomics of Interactions

As with all other video game platforms, there is some potential for stress, fatigue, and possibly injury resulting from continuous and lengthy play. In multi-touch displays, there are two additional factors that might contribute to this risk, and game developers should be aware of them. In a large number of multi-touch, tabletop devices (including *TacTile*), users are usually standing around the table, as there is no sufficient room for sitting due to the fact that the depth of these devices is usually on the order of few feet. Users normally do not interact with the device for more than 30 minutes. Therefore, game developers should design levels to be completed within a time frame that is less than 30 minutes.

The input schemes used in the game should also be considered from an ergonomic point of view. For example, gestures should be designed to minimize stress that players might experience. One particular gesture that we found to be potentially stress inducing is brushing. As players repeatedly brush their fingers on the screen, their fingers suffer from friction with the display surface, causing some discomfort. Therefore, game developers should consider multiple gestures for a particular action, and evaluate them from the perspective of comfort.

"The Lens of Ergonomics" comprises the following questions:

- Does the game require significant time commitment on the part of the players? If so, how can the gameplay and progression be modified to encourage opportunistic play?

- Does the interaction scheme maintain the comfort of players within the intended playing time window?
- How can the gestures be improved to reduce stress on fingers (particularly the stress induced from the continuous brushing of fingers over the display)?

6.4. Design Around the Limitations of Multi-Touch Devices

The technology behind large-scale, multi-touch displays is still relatively new. These platforms still suffer from a number of limitations that lead to more challenges for game developers. The majority of multi-touch platforms rely on optical tracking techniques to determine the position of fingers (usually with infrared light). This creates potential for interference from external light sources. Some multi-touch displays work properly only if deployed in dark rooms with controlled lighting conditions. We expect this problem to become less of an issue with time as more robust tracking techniques are developed. However, game developers might need to take these issues into account until technical solutions are found.

Another technical limitation in multi-touch displays is input latency, that is, the time it takes the system to react to a finger touch. Typical multi-touch systems have latency on the order of few hundred milliseconds. While this is not a major issue for most games as players are usually quick to adapt to this latency, it might impose some challenges in faced-paced games.

A third limitation concerns the maximum number of touches the display can register simultaneously. Some multi-touch products support a limited number of simultaneous touches (typically between five to 10 touches), while other platforms (such as TacTile) can support hundreds of touches. A multi-touch game developer needs to be aware of this limitations and design gesture and interactions such that players to not exceed this limitation during typical game play.

“The Lens of Multi-touch Platform Limitations” comprises the following questions:

- How does the game design work to mitigate the permanent technological limitations of the platform such as the limited number of simultaneous touches?
- Considering the latency of the touch interface, is there enough time for the average player to react to game events?

7. CONCLUSIONS AND FUTURE WORK

As multi-touch displays continue to proliferate, it is inevitable that they will be a force in the realm of video games as well as other entertainment venues. Developers will be challenged by this technology. Successful responses will be games that harness the innovations and limitations of touch technology to form wholly new gameplay paradigms. This paper has provided, through guidelines and examples, a means for developers to begin to consider relevant issues such as display orientation, user-interaction, ergonomics, and technology limitations.

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