

Spellbound: An activity-based outdoor mobile multiplayer game

by

Misha Sra

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Abstract

Traditional outdoor recreation is physically and emotionally rewarding from goal directed social activities and encourages a connection with the real world but can be logistically difficult. Online gaming allows people to play together despite physical distances and differences in time zones. Players enjoy new experiences in awe-inspiring interactive worlds while effectively inactive. This project is a physically active outdoor social game that embeds a layer of fantasy and challenge in the real world employing location-based technologies available on mobile phones. Requiring the game be multiplayer in real-time and played in a physical space presents certain limitations in the design of input and output mechanics. This project demonstrates how those constraints were managed to create a compelling experience. A sixteen people evaluation validates the concept while observations and feedback suggest future improvements.

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Chapter 1

Introduction

Games are now accessible in multiple forms and can be played anywhere and anytime. They are available on computers, consoles, handhelds, and mobile phones, as well as playable on streets, in water, in playgrounds or on boards. Games can be single-player, multiplayer and massively multiplayer and can last anywhere from a few minutes to several years. Challenge is the lure of games; continual feedback and progress their reward. According to Jane McGonigal, a game designer and author, “reasonably assured progress” is one of the reasons why people spend so much time playing online games, doing this new form of voluntary and “satisfying work”.

Spellbound is a smartphone activity-based multiplayer game that is played outdoors with friends. The players are divided into two teams and they use physical actions and speech to interact with the characters in the virtual world to complete missions. The gameplay is viewable on the web after each play session to allow players to relive and share their experience.

1.1 Scenarios

Mary is a graduate student and her work requires her to spend hours at a computer. She also likes to play online games with her friends adding to her sedentary lifestyle. When the weather is nice she enjoys eating lunch with her colleagues outdoors instead of at her desk. Finding the time and motivation to exercise and socialize is difficult

for her as work takes precedence over everything and sadly she feels resigned to her lifestyle. She believes an ideal activity should be both social and physical, fit into her lifestyle, and be interesting enough to sustain. She has explored the gym a few times but finds exercising alone boring. Team sports are exciting but the rigid schedules make it difficult for her to commit for an entire season.

Looking to try a new approach, she downloads a new game to her smartphone called Spellbound. The game promises to provide a quick workout without having to go to the gym, by turning each activity session into a short and fast competitive game with friends. On a sunny day, she and her friends go outside, start the app and right away find themselves split into two teams embroiled in battle for territory and virtual resources, in a fantasy world overlaid on the outdoor space around them. Each team undertakes three missions that require players to run, jump, spin and do other physical actions for achieving goals in the virtual world. After a short fifteen minute burst of action, the game is over and Mary goes back to her office having enjoyed the quick workout as well as feeling the emotional benefits of having connected with her peers. Mary especially likes the physical actions the game asks her to do and the competition that pushes her to jump higher and run faster than anyone else. She now looks forward to playing daily and to creating her own games and stories.

Mark is a middle school teacher and is constantly on the lookout for new team activities for his students. He decides to create a game in Spellbound targeted at his students, adding an element of learning to it. He divides the class into multiple teams and runs parallel sessions of the game during recess. The missions involve physical actions like hopping, punching, tossing, and running to interact with the virtual game. The players also collect atoms to create molecules that fight the enemy disease. Though Mark does not play video games he can see the benefits of using one for his lessons. Not only do his students learn chemistry, they also learn teamwork and sportsmanship. Because it is a short game, students switch teams and experience the same game and thus the same lesson from different perspectives during each play session. After each session, Mark and his students review the game online, discuss the lessons learned and collaborate to create the next game.

1.2 Goals for this thesis

The goal of this thesis is to create a fun, fast, competitive, multiplayer, outdoor action-based game for the smartphone. The hope is to create a playful source of rich and meaningful interactivity between people in the real world. The intention is for the game to be created and joined spontaneously by a group of people and played anywhere, and to design a system for supporting and creating digital pick-up games. There exist several team games which are fun but they either follow rigid schedules like those of amateur sports leagues or require special places and equipment to play like laser tag or are entirely sedentary like online games. Creating a physically active game that is engaging for a group of people and playable spontaneously in any public outdoor space will be a challenge.

Chapter 2

Background

Gone are the days when we could spare time for walks or play a pick-up game of basketball at the neighborhood park. In 2008, the U.S. Department of Health and Services released the first comprehensive set of guidelines on physical activity with information for policy makers, health educators, health providers, and the public[1]. According to their website, more than 80 percent of adults and adolescents do not meet the guidelines for both aerobic and muscle-strengthening activities. Even though we understand the benefits of exercise, fitting it into our daily schedules is not easy. The idea of exercising may also be less appealing for reasons like boredom, no access to neighborhood play areas or equipment, expense, and lack of information. For those who prefer not to exercise alone, added limitations may be unavailability of group activities, or the inability to commit to rigid schedules of recreational sports teams. Any of these reasons can be difficult to overcome compounded by uncertainty and lack of motivation resulting in discouragement and inaction. In this work, I have focused on simple physical actions like jumping, spinning, and running incorporated in a virtual game. These actions do not require any additional equipment other than the ubiquitous smartphone and can be accomplished anywhere.

A major challenge of sticking with an exercise schedule is motivation. While some individuals find exercising an autotelic¹ activity, for several others it is a chore

¹A thing which is autotelic is described as “having a purpose in and not apart from itself” [9]. Mihaly Csikszentmihalyi describes people who are internally driven, and as such may exhibit a sense of purpose and curiosity, as autotelic [23]

and likely to be skipped in favor of work or something else. Perhaps because the benefits of exercise become slowly visible over an extended period of time in contrast with seeing the results of our effort “immediately and vividly” while playing a video game, exercising fails to be on top of our lists. This raises the question of how some people are able to manage the short term discomfort of exercise with the long term reward? Self Determination Theory, as described by Deci and Ryan (1985), suggests intrinsic motivation (“I like doing this”) may be the answer. McGonigal describes intrinsic motivation as the individuals desire to accomplish something without an external reward mechanic that is spurred by rewards like satisfaction, achievement, social connection, and meaning. She believes playing games offers us these rewards making them engines of our happiness.

2.1 Play, Fun and Games

In his book *Homo Ludens*, Dutch historian Johan Huizinga claims play is older than culture and fun characterizes the essence of play. Huizinga defines play as “a free activity standing quite consciously outside ‘ordinary life’ as being ‘not serious but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner. It promotes the formation of social groupings [50].”

Koster (2005), in the book *A Theory of Fun for Game Design*, argues fun is the feeling we get when we are learning, and games are fun only as long as players are not consistently successful. He writes “games are puzzles – they are about cognition and learning to analyze patterns. However, as soon as players master the patterns the game becomes boring and not fun”. That’s why, Koster says, “most long lasting games are competitive as they lead to an endless supply of varied puzzles” like the PvP² instancing in MMO³ games which involves battling other players instead of the

²Player vs. Player

³Massively Multiplayer Online

predictable and thus boring NPCs⁴.

In Spellbound, two teams compete in real-time for virtual resources and domination in a mobile location-based game. Each virtual game is procedurally generated and the play experience depends on group of players and the location of the game. Costikyan believes it is the social nature of games that makes them so compelling despite the fundamental contradiction of the human condition where we are simultaneously individuals and social beings[22]. The *fiero*⁵ of a successful raid with *guildies* in World of Warcraft; the banter and play after a softball victory; even the table talk during a card game — these are the experiences you cherish about playing games with friends.

Massively multiplayer online games like World of Warcraft or League of Legends involve synchronized teamwork enabling people to achieve things that would be difficult or impossible to do alone in these games. The collaboration involves planning and strategy. Victory is accomplished when each player plays their role well and in perfect coordination with their team members.. Research shows that social interaction among players in an online game world plays an important role in creating a community within the game environment [39] and making social games fun. McGonigal says, “Games build strong social bonds that lead to more active social networks. The more time we spend interacting within our social networks, the more likely we are to generate a subset of positive emotions known as ‘prosocial emotions’. Prosocial emotions – including love, compassions, admiration and devotion – are feel-good emotions that are directed toward others. They’re crucial to our long-term happiness because they help create lasting social bonds”.

Unlike MMOs, not every game requires hours of time to be satisfying as shown by the interest in and popularity of “casual games”. These are games that people may play on their tablets, phones or computers and in short bursts of time to relax, pass time, feel a sense of achievement or explore something new. Most such games are single-player or asynchronously multiplayer. More than 15 million people are

⁴A non-player character in controlled by the computer through artificial intelligence[84].

⁵Fiero is the Italian word for “pride”, and it’s something adopted by game designers to describe an emotional high, something we feel after we triumph over adversity[74].

playing the match-three mobile and social game Candy Crush Saga daily[40]. In the game, players create rows or columns with at least three candies of the same color to remove them making room for more. The social gameplay is asynchronous where players initiate interaction with members in their social network asking for help, unlocking levels, or restoring lives. Koster believes social components like social obligation, connectedness, and leaderboard competitiveness are a huge part of why social games work and lack of a friend network is one of the strongest indicators of a player likely to quit. Costikyan argues several of today's games played on social networks like Facebook are not social. He asserts there is no cooperation involved with others in these games even though they provide several hooks for inter-player interaction like the “gifting” system in Farmville where players are urged to send free gifts to their social contacts that are playing the same game[22].

Online social games are not always about playing with friends like the guilds in World of Warcraft. Players get together to “raid” or play as a team to get through challenging areas of the game and usually they are a group of strangers who learn to coordinate, train, and work together while sharing a common sense of purpose and belonging. In a game like League of Legends, playing with strangers may be the only option at times. Playing with people you do not know in real life can also mean having to deal with anti-social behavior resulting from the social anonymity of computer-mediated communication[56]. To regulate people’s online behavior, Lessig discussed four modalities: laws, norms, markets, and code[64]. The most common modalities used are norms and code like the “Tribunal System” implemented by Riot Games, the developer of League of Legends, designed to reduce toxic behavior like negative chat, offensive language, and verbal abuse in the game[109]

Recreational team sports are a blend between social and physical activity. They are fun and healthy endeavors involving dynamic interaction between players and the acquisition of skill. Team sports tend to be available mostly during the summer and require learning specific skills that may be daunting for some. They also require players to be co-located at specific times leading to potential scheduling conflicts which could limit participation. MMO games solve most of these problems at the

expense of losing the physical activity element. Playing games with the Kinect⁶, PlayStation Move⁷ or the Wii⁸ adds back the physical activity into digital gameplay but limits the multiplayer aspect to two people for most games.

Games are inherently performative[8] as they demand action from players to forward the gameplay. Spectator sports like American football or basketball are characterized by the presence of people watching the event live or through broadcast media. Electronic Sports or eSports comprise the competitive play of online games and players are recognized as professional athletes [114]. Similar to traditional sports, live broadcasts of Electronic Sports (eSports) also command large audiences and prizes like The International[108] which is an ongoing Dota2 world championship with \$2.8 million prize at stake this year. Spellbound is played outdoors in public spaces. Bringing in the audience to share the overall experience is part of the design of Spellbound.

Electronic games were once limited to the indoor environment. With mobile phones, ubiquitous play is now possible in places where it was not previously available. In 2001, the Swedish company Its Alive made BotFighters[6] which was the first commercial entertaining use of location-based technology using a phones physical position to allow players to track and kill each others virtual personas. Spellbound is a digital action-based social game played outdoors. Unlike sports, it is playable anywhere and requires no special equipment other than the ubiquitous mobile smartphone. Unlike online games, it allows the players to be free from the constraints of the 2D/3D screen based worlds of their computers and participate in a game that is interwoven with the real world and is available on demand at any place and any time. Spellbound uses a player's movement in space as the primary game input mechanic and translates the movement into meaningful action in the virtual world. The activity data is captured using sensors on the mobile phone and is interpreted as jumping, spinning, running, walking, and standing. Successfully completed actions are communicated to the game server, which then broadcasts an altered and updated

⁶Kinect is a motion sensing input device by Microsoft for the Xbox 360 video game console[57].

⁷PlayStation Move is a motion sensing game controller by Sony Computer Entertainment for the PlayStation 3 video game console[91]

⁸The Wii is a video game console by Nintendo with a wireless controller that can detect movement in three dimensions [116]

game state to all the players. The outdoor location inspires players to engage with their environment in a different way while the game design demands collaboration and strategy. As players move freely over a wide area they maintain coherent social contact in both the real and virtual worlds. Player interaction has direct impact on the progress and outcome of Spellbound, unlike most current “social games”, where each player is in his own “atomistic” world making the core gameplay inherently “solitaire in nature” [22].

Chapter 3

Related Work

Spellbound is a location and activity-based collaborative and competitive multiplayer digital game that uses physical action and speech recognition for interacting with the virtual world. Today most of the commercial mobile digital games fall into four categories: search and find (Geocaching [41], Feeding Yoshi [11]), running (Tourality [112], OnTheRun[31]), chase and combat (Shadow Cities [98], Life is Crime [65]) and, territory building (Tapcity [106], Life is Magic [66]) games. Since Spellbound exists at the intersection of many categories, it derives from pioneering work in several mobile game and other projects.

3.1 Location-based games

Gameplay in location-based games (LBGs) takes into account the real world location of the players. The games depend on movements and activities taking place in both real and virtual spaces at the same time and involve the use of portable digital technologies as interfaces between the digital and physical realm [26]. LBGs allow us to use computation to transcend our abilities and extend our human powers [80]. LBGs are not limited to a screen, nor are they limited to the physical world. A characteristic of location-based applications is the creation of a “doubled perception of space”, where users simultaneously see the physical space as well as its digital representation mapped on a mobile device. This is in contrast to the early Internet

where physical spaces were perceived independently of digital spaces [27]. Movement is a significant feature of LBGs [12] [81]. This is different from physical games such as the Nintendo Wii games and Xbox Kinect games that tie players to a location in front of a stationary screen[102]. One cannot play an LBG staying at one location; game-related actions must be performed at different locations during the game. However, this basic characteristic is ignored by several commercially available LBGs that allow players to make progress in the game without requiring them to move in physical space.

LBGs explore the boundaries between real and fictional as they merge virtual and physical environments affecting a player’s perception of and behavior in everyday spaces. The outcome of an LBG is affected by the player’s interaction with physical locations and movement in a physical environment [26]. LBGs encompass 1) *Spatiality*: space and place, digital space, mediated spaces (physical and digital), locations as play-spaces. 2) *Structure*: rules, frames, fiction and authenticity, and uncertainty and ambiguity. 3) *Interface*: location aware devices, seams, and objects and players. 4) *Player experience*: motivation, mobility, meaning and, flow [102].

Newer location-based games are looking at other embedded mobile technologies like NFC (near field communication), Bluetooth, UWB (ultra wide band), P2P networking, and Wi-Fi Direct or Android Beam. Spellbound is a location-based game that uses speech recognition and activity detection using various sensors like the magnetometer, accelerometer, and gyroscope commonly available on smartphones for interacting with the virtual world through actions in the real world.

In most games, location is used as a setting rather than as part of the gameplay with some exceptions like OnTheRun [31], an audio-only running game that provides turn-by-turn directions with an evolving story based on changes in the player’s real-world location. LBGs that use location for gameplay relate to it in various ways. They can be independent of location when they are not attached to a specific place such as BotFighters and OnTheRun or be location-specific such as REXplorer [95]. Site-adaptable[78] games like Feeding Yoshi[11] form the middle ground where the content of the game can be adapted to generic elements found in most places.

Geocaching (2000) is one of the oldest LBGs where players hide and seek caches or treasures using GPS sensors. *Geodashing*, on the other hand, requires players to simply visit a randomly selected “dashpoint” within a certain time limit not requiring them to leave anything at that waypoint.



Figure 3-1: Examples of cache found at sites. (Courtesy of www.geocaching.com)

Shadow Cities (Grey Area, 2010) Shadow Cities (Grey Area, 2010) is a multiplayer game where players align with the Architect or the Animator factions. It has the essentials of a traditional MMORPG like XP (experience points), leveling, mana, and spells layered on top of real-world locations inviting exploration by players hoping to cast one more spell to thwart one more enemy in the neighborhood. Players living outside large urban areas can participate by jumping between conflict zones via player-created beacons. The game is about territorial conflict and control where weekly skirmishes occur between the two factions, rewarding players with unique medals and achievements. The game is integrated with Facebook allowing players to ask friends for help or share experiences. Making friends is necessary for getting access to beacons, which serve as waypoints allowing players to move away from their physical location to other parts of the world for completing missions. It is a location-based game that can be enjoyed from the comfort of your couch and a social game that is playable without bothering real-world friends to play with you.

The game is not location-specific and uses the player’s location for the game setting more than for game input so players do not need to physically move to play the game.



Figure 3-2: Three screens from Shadow Cities: Location, team chat, and attack spell. (Courtesy of www.shadowcities.com)

This contradicts the idea of movement being a significant feature of a LBG. Instead the players can start the game whenever they have physically moved someplace new during the course of their normal day. All the interaction is screen based and players cast an attack spell by drawing a Z on the screen. Qonqr (2012) is a location-based social game of Risk meets FourSquare. Players however, do not need to move around physically to play the game but their reach grows as they level up and they can build bases in zones far from their geographical location. Spellbound incorporates the player's location and movement as input mechanics required to achieve goals and make progress in the game.

Parallel Zombies (PerBlue, 2012) is a RPG ¹ played on Google Maps satellite view where players interact in real-time with others in their neighborhood. Points of interest in a city like historical sites, parks, plazas and global landmarks like Stonehenge or the Pyramids are associated with missions. Travel is accomplished virtually through Trade Hubs that are accessed for a small fee and through Highway Signs. Players can also travel by completing missions and are rewarded by being transported to more difficult missions in other parts of the world. The interaction is entirely screen based with multi-touch controls. Co-op play allows players to join others for completing missions together with no PvP (player vs. player) element.

¹role-playing game

Like Shadow Cities, the player does not need to physically move around to play the game and the player location again acts more like a setting that provides context for the entirely virtual game.

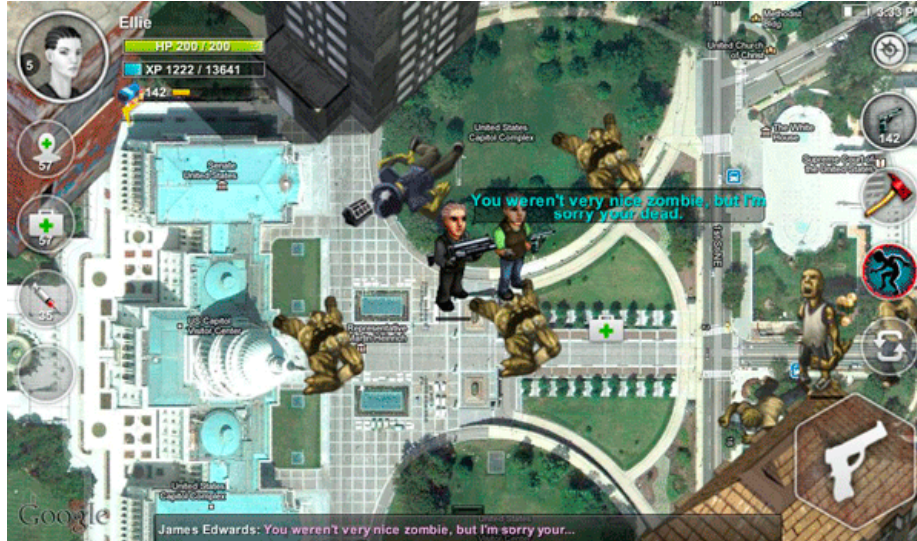


Figure 3-3: Screen from Parallel Zombies showing player avatars on Google Satellite Maps. (Courtesy of www.digitaltrends.com)

Can You See Me Now (Flintham et al., 2003) Three runners in the real world try to capture up to 20 online players in this mixed reality game.

Runners try to surround the virtual players but the online players can listen in to the real world players walkie-talkie conversations and move accordingly. Phrases such as “I’m waiting for the Green Man” from a runner can reveal that the person was waiting at a pedestrian crossing, meaning that online players had a chance to escape [12]. In a play test, runners found a way to exploit GPS inaccuracy by luring online players into zones with higher accuracy and ambushing them. This is an example of a scheduled site-specific game and would be a poor fit for use as a spontaneous multiplayer digital game.

Mobbles, 2012) is location-based Pokémon & Tamagotchi [104] combo. The player needs to find the Mobbles at real-world locations and take care of them, level them up, trade them, and battle with them. Once a Mobble is captured, it is no longer

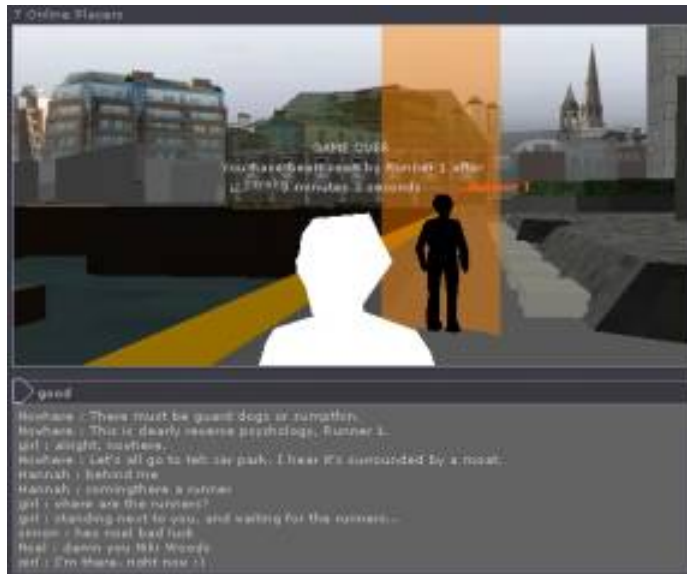


Figure 3-4: The online player is represented by the white shape, the real world runner by the black. (Courtesy of blasttheory.co.uk)

available for other players to capture and new Mobbles appear in the wild every week. Spellbound uses the idea of collecting virtual items located at real-world locations and once collected the item disappears from the map and is no longer available for other players to collect.



Figure 3-5: Two screens from Mobbles: mobble in a room, locating mobbles on Google Maps.

OnTheRun (Donahoe, 2011) is an audio-only game played outdoors while running as an alternative to running with music. The game uses adaptive route planning and a navigation system that provides turn-by-turn directions to guide the player along their pre-determined route, putting the player at the center of a fugitive storyline with narration, sounds and music. Spellbound builds on this experience by incorporating additional physical actions and speech recognition as game input while adding visual and haptic output elements.

3.2 Exergames

Exergames are video games that are also a form of exercise which rely on technologies that can track the players body movements like the Microsoft Kinect, Nintendo Wii, and the Playstation Move. Notable games available on the market are Dance Central (Harmonix Music Systems, 2010 – 2012), Kinect Adventures (Good Science Studio, 2010), Zumba Fitness Core (Majesco, 2012), Adidas miCoach (Lightning Fish, 2013). Players use their entire bodies as a controller to complete short game challenges.



Figure 3-6: Players jump to make their avatars jump on screen in Kinect Adventures. (Courtesy of www.g4tv.com)

The games usually mimic real life activities like dancing, kayaking or fighting. Most exercise games are played indoors and are rarely multiplayer beyond two people. Mobile activity based multiplayer games like Spellbound do not exist yet. Getting

a multiplayer computer game to work reliably outdoors in real-time is difficult but playing with friends in the real world is worth the effort.

3.3 Fitness Games

Fitness games use activity trackers to record players exercise statistics and use those for progress in a virtual game. They do little to make the exercise activity more fun but focus instead on the number of points collected during exercise and offering progress in a related virtual game. Spellbound attempts to create some of the of-line interaction these fitness apps provide while making the actual play and exercise experience fun and engaging.

Fish'n'Steps (Lin, 2006) is a competitive game where the players daily step count measured by a pedometer is used to feed their virtual fish. The players compete to have the largest fish motivating them to walk daily.

NikeFuel Missions (Nike, 2012) The game uses the Nike+ FuelBand pedometer to track and monitor player movement by challenging players to earn a specific amount of NikeFuel points in order to move to the next level. Real world athletes offer advice and suggest products to help the player accomplish their missions.

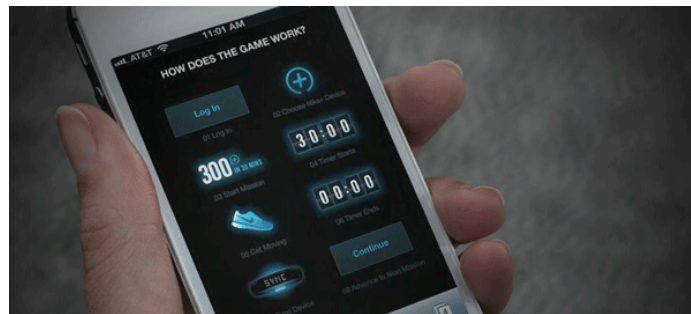


Figure 3-7: NikeFuel Missions screen showing goal and timer. (Courtesy of www.nike.com)

Apptivater (Apptiv, 2013) is a game that tracks a players activity and rewards them for achieving goals with a built-in personal trainer. The game uses competi-

tiveness to get the highest score in a group and competing against other teams as incentives to motivate fitness. It is essentially a combination of a social game with an activity tracker.

Fitocracy (2011) is a social network that uses points as rewards to people for achieving fitness goals. Users log their exercise activity selecting from a collection of activities and entering details like distance run or weight lifted. Points are awarded on the estimated fitness benefit of each activity and after reaching a certain point threshold, the user levels up. Users also receive badges for completing a set of related activities. Fitocracy is also a social network, which allows users to follow others, view and comment on their workouts and join interest groups.

3.4 Casual Games

These games are targeted at a mass audience and can have any type of gameplay distinguished by their simple rules and interfaces popular on mobile phones. Pac-Man (1980)[89], Tetris (1984)[107], Microsoft Solitaire (1990)[100] and Bejeweled (2001) are all considered successful casual games. In 2008, social network games became popular with the release of Happy Farm (2008)[48] in China followed by Facebook games like FarmVille (2009)[36] and YoVille (2008). Popular genres in casual games include: puzzle games (Match 3, Professor Layton series), hidden object games (Mystery Case File series), adventure games (Nancy Drew series), strategy games (Cake Mania series), arcade & action games (Plants vs Zombies, Peggle series), word & trivia games (Bookworm Adventure series), card & board games (Luxor Mahjong) [18].

3.5 No-graphics Digital Games

Most games rely on visuals to create the game experience though there are some experimental audio-only games developed for the novelty of the gameplay or for the

blind.

Papa Sangre (Somethin' else, 2010) puts the player into a dark fantasy world navigable by tapping the phone screen to walk. The goal is to survive and reach the exit beacon. To add more context and realism, the player also hears the sound of the characters footsteps and breathing in addition to growling enemies. Stereo sound helps orient the player and find their way to the exit.

Magnetize Me (Copenhagen Game Collective, 2013) is a two-player game where one player is mounted with 2- 5 Playstation Move Controllers while the other player is mounted with a blue and a yellow magnet. As the game begins a random Move controller lights up either blue or yellow indicating the magnet it should be connected to. The players then need to hold the controller and the magnet close together while still dancing to the beat to get a high score.

Johann Sebastian Joust (Wilson, 2011) is a 2 to 7 player contact sport using the Playstation Move controller. The goal is to jostle the other players controllers while protecting your own where the sensitivity of the controller is dependent on the musical selections from J.S. Bach's Brandenburg Concertos. As the speed of the music increases so does the controllers tolerance and the player can move more rapidly without setting off their controller and being knocked out of the game.

3.6 Mixed-reality Games

Mixed-reality games encompass Alternate Reality and Augmented Reality games where physical and virtual worlds interact in real-time. Researchers from the Mixed Reality Lab sum up the characteristics of the experience playing these new types of games set in everyday spaces.

These new kinds of experience, variously known as pervasive, mobile, alternate, or mixed reality games are emerging to exploit the exciting possibilities of interacting in public places. A unique feature of these experiences is the way in which they



Figure 3-8: Players try to jostle opponents' controller while protecting their own. (Courtesy of www.jsjoust.com)

juxtapose the fictional world of a digital game with the physical world that surrounds the player, encouraging participants to explore the relationships between the real and the virtual, drawing on the fabric of the everyday world as material to enhance the digital experience, and exploiting the frisson of carrying out “secret” interactions in public[13].

Rider Spoke, Mixed Reality Lab, 2009 combines theater with gameplay and technology. Cyclists, equipped with hand-held computers, record and hide short digital messages in places around the city for others to find them. The public participates in co-authoring the piece and experiencing it.

Gulliver's Box, Ars Electronica Futurelab, 2003 is a mixed reality installation with visitors live projected as 3D figures into virtual worlds, creating a new medium of expression somewhere between theater, film and installation.

Chapter 4

Spellbound

Jane McGonigal, in her book *Reality is Broken*, writes about the various kinds of work involved in playing a game, why people voluntarily choose to spend hours doing this work, and why they care about it. She presents games, especially online games that increasingly involve teamwork “emphasizing collaboration, cooperation, and contributions to a larger group”, as the ideal activity that millions of individuals choose to make their lives more rewarding.

Spellbound is designed with a focus on real-time teamwork and the challenges are created to allow people to contribute to the success of their team both through missions they complete individually as well as through those that require collaboration with team members. Strategy and speed play a role in determining the outcome of the game while physical and voice-based inputs create a new form of interaction and connection with the virtual game. The system focuses on activity detection via sensors on smartphones. Sharing of player presence information across the game space is done using GPS technologies. Interaction with the game is conducted using voice and touch detected by the smartphone. Feedback and game status is shared between players via the game server in real-time and is supplemented with peripheral hardware devices that allow the user to experience the freedom of hands-free play. “When a city becomes the game board and the human players themselves become the proactive and highly unpredictable playing pieces, a host of technical and conceptual challenges arise” [69].

The idea of the human body controlling virtual avatars in a game is no longer new and people have enjoyed playing games using the Microsoft Kinect, Nintendo Wii, and the PlayStation Move game systems. However, using the human body as a game controller in an outdoor setting within a real-time multiplayer game context presented a unique set of challenges. I discuss the problems encountered during the design of Spellbound and outline ways in which I overcame them to create a fun experience in the chapter on Technical Challenges. Furthermore, I present some issues in creating other such games. An original intent of the game was to create a system that would require no touchscreen interaction but due to limited time and resources it was not fully realized for this first prototype. More discussion related to this is presented in the chapter on Future Work.

4.1 About

Spellbound is primarily a team based competitive treasure hunt combined with an activity, location, proximity and speech detection system. According to Nicklas et al., LBGs can depend on location information at different levels responding to proximity or to geographical location which are both used in Spellbound for progressing through the game. By situating the game in a physical environment, Spellbound provides players with a framework to produce meaning allowing them to transform the physical space into a platform for interaction[45]. Translating the game information onto the environment and interfacing between the LBG and the real world[83] allows players to create a meaningful experience.

The experience of playing Spellbound combines phenomenology of perception along with theories of play, culture, digital games, and everyday practices. Spatially expanded games are about discovery and altered perception[78]. Spellbound is set in public places and draws on embodied phenomena[32] allowing players to explore the boundaries between the real and virtual. Interlacing the game with “everyday life” by moving away from the centralized interface of an online game screen does cause an alteration of the sequential nature of interaction[102]. Whereas in the digital world

it is possible to control the flow of the game, the same is not true in an LBG when the system does not “know” what the player is about to do next. Dourish suggests addressing these issues through design that can guide actions into a sequential process. Dansey recommends integrating the inherent ambiguity into the design[25] to provide a frame for connecting locations, objects, events, and actions meaningfully and allowing players to create true meaning[27].

4.2 Concept

Two teams, the Bugs (red) and the Humans (blue) compete over two stages of the game. Each stage lasts about 5-7 minutes depending on how quickly the teams collaborate to complete the missions and collect or destroy the eggs. Missions require players to reach destinations in the play area and complete specific physical actions in order to earn virtual rewards useful in the second stage of the game. During each mission the player is guided by an NPC that explains the goal and the necessary actions to accomplish the goal. The game relies on the player’s location to calculate proximity to NPCs and interaction with NPCs is not allowed if players are too far from their geographic position. The game outputs a combination of audio, visual and haptic feedback, allowing the player to seamlessly engage with their team members, the physical environment, and with the game without having to constantly switch visual focus between their phone screen and the real world.

According to Ville Vesterinen, who made the commercially successful location-based game *Shadow Cities* [98], 74% of people who play location-based games play them at work or home and only 20% play them outdoors and on the move. This statistic is not surprising given that for most location-based games the players location is not a primary game mechanic. Trying to cater to a sedentary play style without making the location part of the game irrelevant is a problem faced by many game developers as they try to adapt existing game genres into the real world. In *Spellbound*, the real world becomes part of the gameplay as players locate hidden items in trees or discover NPCs standing by the stairs or sitting on benches.

4.3 Storyline

The Alien Bugs have landed on earth. As their ship crashed through the earth's atmosphere the Power Core was lost. The Bugs, with their advanced technologies, have transformed a large number of Humans to create a zombie Bug army. The Human coalition is actively recruiting and developing their technologies to help fight this new Bug army. Regular skirmishes erupt when the two sides collide and usually these battles are fast and decisive. Each player participates either as an Alien Bug attempting to conquer the Earth or as a Human trying to defend the Earth. The narrative is centered around the player and does not progress linearly.

4.4 Gameplay

When players join the game they are automatically added to a team. A game closes once six players have joined but a new one is created if there are more than six people interested in playing. Each team has three missions to complete during stage one and when a team completes all three, the game switches into stage two for both teams, preventing the slower team from completing their missions. It is in a team's best interest to complete their missions and earn abilities, which are useful during the second stage. In order to prove the game concept, I made three different types of missions that are played collaboratively and involve people jumping or spinning together. Additionally, the second or combat stage adds an element of strategy to the gameplay.

4.5 Missions

Spellbound has three different types of missions and each mission was designed to incorporate a unique interaction mechanic with the game. The "find" mission involves speech-based interaction with the game and detects player spinning action using the magnetometer + accelerometer on the phone. Initially, the spins were detected using gyroscope sensor data on the development phone but the test phones did not

have gyroscopes so this part of the code was re-written. The second mission detects player jumping action using the accelerometer on the phone. The last mission uses speech-based interaction but the goal of this mission was to create a slightly awkward situation for the players and invite participation from passers by. Benford et al. (2012) explore the deliberate use of uncomfortable social interactions as part of powerful cultural experiences and discuss an ethical framework for such interactions.

4.6 Stage One

4.6.1 Mission I

A primary mission for each team is to recover the lost Power Core. To do so, the players use their smartphone as a *sonar* device. They move around the game space while speaking “hootie” into the microphone and the phone responds audibly by telling them if they are getting *warmer* or *colder* relative to the geographical location of the Power Core. Each player wears a wristband and two armbands that are physical output devices. In addition to the audio output, the armband tugs on a player’s right or left shirtsleeve to point them in the direction of the Power Core. The teams are free to split up to cover maximum area in their attempt to locate the Power Core or they can look for it together. Since at least two players are required to complete a physical action to grab the Power Core once it is located, either strategy may work depending on the size of the game map and player communication. Once a player is within 20 meters of the Power Core, their proximity triggers the next event and the Core becomes visible on the game map with a loud ‘whoosh’ and the phone vibrates. The player’s attention is drawn to the screen and interaction is invited through spoken dialog.

On touching the Core, the player is asked to spin around three times in order to create a tornado, which is the only way the Core will become property of that player and team. The *spin* action needs to be completed by two players from one team, in proximity to each other and to the Core, in order to successfully dislodge the Core



Figure 4-1: Left: player speaks “hootie” into phone. Right: phone response trigger zones around the Power Core.

from its spot.



Figure 4-2: Players spin to collect the Power Core.

If the players do not spin three times, the mission will fail and the players will need to spin three times again in order to complete the mission. The combination of data from the accelerometer + magnetometer is used to calculate and count the number of spins. The players are notified of success or failure both via dialog boxes on the phone screen as well as through audio output. Each time a team successfully completes a mission, the wristband worn by each member of the other team vibrates and one LED lights up informing them of the mission progress of their enemy team adding to the sense of urgency for completing missions.

4.6.2 Mission II

This mission requires the players to approach a location on the map marked by an NPC. The virtual character talks to the player once they are within 20 meters distance and assigns them a task. The NPC marks the location where the task needs to be completed on the map. When the player approaches a task location, they hear spoken dialog and their phone vibrates to indicate proximity and ability to interact with the task marker on the map. They are asked to *jump* three times to squish the Bug Nest

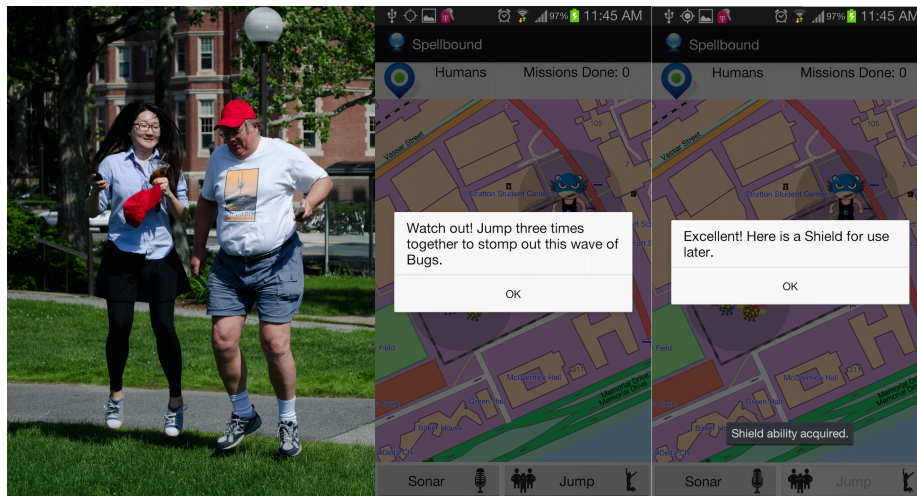


Figure 4-3: Players jump to stomp out bugs. Two screens from Spellbound: jump mission, mission success notification and reward.

or *jump* three times for starting the Jumpatron to transport the Bugs to a safe place. This action needs to be completed by all three players on a team together in order to be successful. If the players do not jump three times, the mission will fail and will need to be repeated. As a reward, the team is given the *shield* ability, which they can utilize during the combat stage.

4.6.3 Mission III

The last mission requires the players to approach another NPC on a different part of the game map. This NPC rewards them with the *transform/rescue* ability, which is useful during the second stage. The NPC asks the player to recruit someone from the general public into their team to help fight the Bugs or Humans, as the case may

be. The player is expected to approach a layperson in the play space, talk to them and ask them to speak “I am a smelly bug/human” into the players phone. Upon completion of that action, the phone responds with “Stinky Bug/Human detected. Transforming...” indicating the success of the recruitment mission, following which the player returns to the NPC to collect their reward. After all three missions are complete, the game switches to Stage Two.

4.7 Stage Two

Stage Two of the game is faster paced than Stage One. The game map displays ten eggs randomly placed and requires each team to run from egg to egg collecting or destroying them by virtue of proximity. No other action is required. The team that collects or destroys more eggs first wins. During this running frenzy, teams can attack each other using their transform ability, if they have one, which causes the affected enemy player to freeze in place until rescued by a fellow team member. Only the team that successfully completed its missions during the first stage will have the transform/rescue ability. To prevent themselves from being transformed players can use the shield ability, which is also earned by completing a mission in Stage One of the game. A team can also win by successfully transforming all three players of the opposite team. Speed and strategy are required to complete this stage while collaboration and exploration were the key elements of the first stage of gameplay.

4.8 Combat

Combat between the two teams happens in stage two of the game. By which time at least one team is expected to have successfully completed all missions and have received both the offense and defense abilities useful for combat. This makes the first stage a race between the two teams where not only does the winning team get the two abilities, they also block the slower team from finishing their missions and earning their abilities by forcing the game to switch to stage two.



Figure 4-4: Players from both teams run to grab a virtual egg.

Combat involves attacking the enemy team members and transforming them, which causes them to physically freeze in place and prevents them from collecting or destroying eggs thus slowing down a team's progress. Player's use a *radar* scanner for detecting nearby players. If an enemy or a frozen team member are found nearby, their location is marked by a red or blue dot on the radar screen. The player can then choose to cast the transform or the rescue ability by touching the appropriate button, which automatically affects the correct player shown on the radar and informs them of the incoming attack or rescue action. After each use the ability becomes unavailable for reuse for one minute preventing the players from spamming¹ it and forcing them to plan before using the ability. At times the players will need to make a strategic choice whether their attack should be used to transform an enemy player or rescue a frozen team member. Either decision could affect the outcome of the game since transforming all three enemy players will result in a win but having your entire team available to run around and collect or destroy more eggs may also result in a win.

¹Spamming, in the context of video games, refers to the repeated use of the same item or action [101]

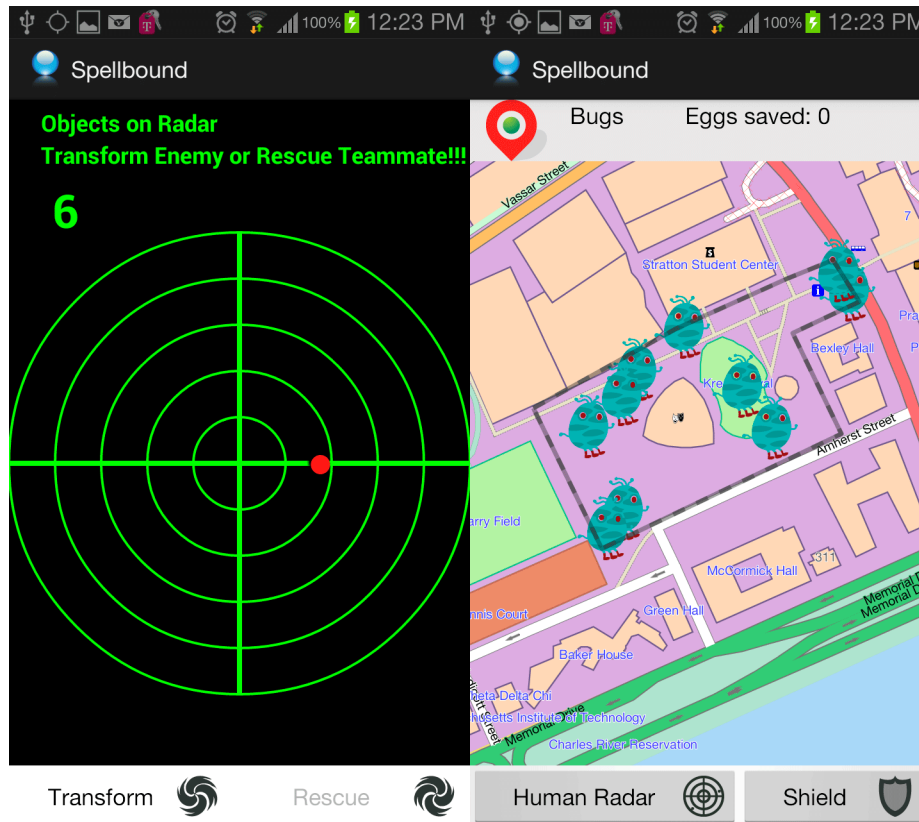


Figure 4-5: Two screens from Spellbound: enemy player on radar, placement of eggs on game map for Stage Two.

A defensive shield ability provides immunity from a transform attack but does not impede an incoming rescue attempt. It is cast by touching the shield button on the screen and its protective effect lasts one minute. After which time, the shield needs to be re-cast by the player upon himself or herself. The player who casts the transform ability does not know if the enemy shield is up and is taking a chance by attacking the enemy. If they fail to transform the enemy because their shield was up, the player will need to wait a full minute, the cooldown² period, before they are able to reuse their transform ability. Meanwhile the player under attack is free to run and move to a different part of the game map and no longer be within transform distance. The transform/rescue ability only works when the target player is within 30 meters radius at the time of radar scan.

²Cooldown is, in numerous video games, the minimum length of time that the player needs to wait after using an ability before they can use it again. One can think of cooldown as the reload time and firing rate of weapons [20].

4.9 Hardware

Most mobile phone games use the phone screen as both the input and the output mechanism and the player needs to pay full attention to the screen to receive feedback on their progress. Spellbound uses custom designed hardware as the output medium for providing game information.

The wristband is an output device worn by each player. It has an array of three LEDs³ and a small vibration motor. Each LED represents one mission in Stage One of the game. The wristband communicates with the player's smartphone through a IOIO⁴ board to access updated game information. Each time a team completes a mission, the wristbands worn by the enemy team vibrate and one LED turns on. The red or Bugs team wears wristbands with blue LEDs informing them of the quest progress of the blue or Humans team.

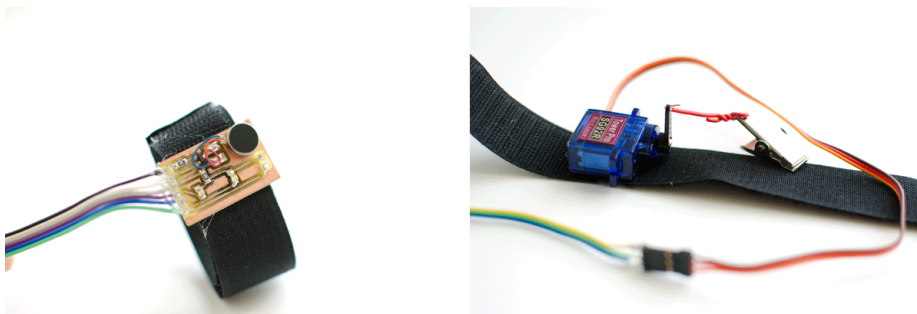


Figure 4-6: Left: wristband showing three LEDs and a vibration motor. Right: armband showing a servo motor arm connected with a wire to a badge clip.

As I wrote code for the 'find' mission using the sonar metaphor, I felt the need to provide some guidance to the player in their search for the virtual item. Simply telling them they were getting warmer or colder as they moved in physical space seemed insufficient. This led to the idea of creating a device with vibration motors that could be put on the players shoes. The motor on the right or left shoe would vibrate to tell the player to take a right or left turn. However, due to another similar project at the Lab using vibration motors on shoes, I decided to create something

³Light-emitting diodes

⁴The IOIO is a board that provides a host machine the capability of interfacing with external hardware over a variety of commonly used protocols. The original IOIO board has been specifically designed to work with Android devices[52].

different, using the idea of tugging on a shirtsleeve to catch a person's attention, for giving players directions.

The armband is composed of a servo motor and a wire that connects the motor arm to a badge clip. The motor is mounted on a Velcro band and worn on the upper arm by the player. The clip is snapped onto the player's shirt such that each time the motor arm moves the shirt gets tugged. Each player wears two such armbands. While attempting to locate the Power Core using the sonar mechanic, the player is assisted in their search by the armbands which direct them to take a left or right turn with a tug simultaneously as they receive audio output from the phone to guide them in their search. This is a playful mechanic similar to a child catching an adult's attention by tugging on their shirtsleeve. To determine which sleeve should be tugged, I calculate the difference between the bearing of the player and that of the Power Core. Based on the quadrant in which the resulting angle falls, the left or the right sleeve servo is powered on.

The three types of immersion a) challenge-based b) imaginative, and c) sensory[33] can provide a multi sensory feedback system to support the emergence of meaningful play. Several research projects use vibration motors for navigation while Spellbound uses vibrotactile feedback in a mobile game context.

In the Gentle Guide project the motors are mounted on the wrist of a person's hands to communicate left or right directions[15]. The Active Belt uses eight motors that have different pulse intervals of vibration to present distance to a destination[113]. Van Erp et al. look at coding distance with varying vibration patterns[115]. Vibrotactile information systems have also been used in cars by locating actuators on the driver's body to indicate direction. Haptic arrays to offer two dimensional direction information have been attempted[105]. Bial et al. mount four actuators on the fingertips in a prototype navigation system integrated into two gloves. The system also incorporates a visual display screen and feedback is a) only tactile, b) only visual, and c) combined[30]. The haptic compass, a belt with twelve vibrating motors, connects to the wearer's phone and buzzes the appropriate motor determining which way is north. A similar belt out of the U.S. Army Research Office has eight motors that

receive signals from a GPS device to guide soldiers along a route without having to look at a GPS device or a map[49].

4.10 Dialog and Sound Effects

The dialog in the game is minimal and is presented both as audio as well as text that appears on the phone screen. The audio plays automatically when the player is in geographical proximity of the virtual entities whereas the text dialog boxes appear when the player interacts with the game characters using touch gestures. Sound effects play on the completion or failure of missions, on switching of the game stage, on collection/destruction of eggs, on the success or failure of combat abilities, and when the game ends. Hearing the same sounds reinforces the action it represents and helps build an association for the player, further minimizing reliance on visual data and contributing to the player's sense of "being there" in the game. Online video games additionally use the characteristics of visual displays to encourage a sense of presence, including image quality; image size and viewing distance, which together determine the proportion of a user's visual field occupied by an image; motion and color; variables related to the perception of dimensionality; and the use of a variety of camera techniques[68].

Sounds are tied to actions as well as to geographical proximity to NPC locations providing an added layer of feedback and minimizing the need to look at the phone screen. The sounds play loudly to be heard over the normal outdoor noises. I considered using stereo audio but since I was not tracking the players head orientation, I assumed it would be more distracting and inaccurate than helpful.

The NPC voices are pre-recorded and so are limited. If the player repeats the mission, they will hear the same recording again.

4.11 Animation

There is minimal animation in the game in Stage Two where the player uses a radar visualization to locate nearby enemies or frozen teammates to transform/rescue them. This is by design as the goal of the game was to minimize player focus and attention on the screen and instead provide means to enhance interaction with the real players and the physical environment. There is greater focus on audio and haptic output to convey information to the player.

The radar was originally designed to display on top of the game map but a bug in the Mapsforge[72] library made that impossible without involving a full rewrite all the map related code using a newer version of the library. Due to limited time, I instead decided to create a new radar activity that works independent of the map. In Android, an activity is a single, focused thing that the user can do. The radar scans to find players within 30 meters radius of the player running the scanner. If it finds any enemy players, it calculates the direction of that player relative to the player scanning the area and displays a dot in the appropriate location on the radar. If it finds any teammates that have been transformed, it displays them similarly on the phone.

When the transform or rescue buttons are pressed, the player inside the scanned area receives a message on their phone telling them whether they have been frozen or rescued. At this point, they are expected to stop in their tracks or start moving if previously frozen. If the attacked player has their shield turned on, the player attacking them will be notified after pressing the transform button that the attack has failed.

For calculating the placement of the enemy dot on the radar, I determine the angle between the player scanning with the radar and any players from the other team who are within 30 meters radius as the tan of the (difference in latitudes/difference in longitudes) of both players. I do a similar calculation with the friendly but frozen players.

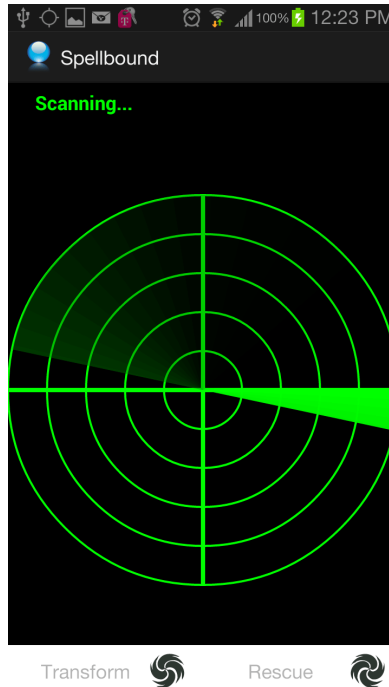


Figure 4-7: Screen from Spellbound: radar scanner running to detect nearby enemy players and frozen teammates.

4.12 Music

Dynamic or procedurally generated audio is now used in many video games where specific events initiated by the player cause the background music to change. In Proteus[93], a video game by David Kanaga and Ed Key, exploring a 3D island triggers sound effects tying physical space exploration to musical discovery. Since progress in the video game is based on player input, no two players will have the same exact audio experience playing Proteus.

Music influences player emotion, communicates the game atmosphere and draws players into the game. Amnesia, a horror game, would not be scary at all if it used a soundtrack similar to the iconic 8-bit music from the Super Mario Bros. (1985)[103] or the Tetris (1984). Spellbound currently has no soundtrack and a future version will benefit immensely from dynamic audio content.

Chapter 5

Iterative Game Design

5.1 Boardgame

The first step I took in designing the game was to conceive the rules and mechanics and implement them in a board game. A few of the mechanics used in the design of the board game were: turn-based play, dice rolling, cooperative play, action points, point-to-point movement, role playing, risk and reward set in a fantasy world.

The game map was overlaid on a small part of the MIT campus. A list of complementary spells like build/destroy, trap/reveal and, freeze/thaw was created. To give each player a distinct role three classes were added: Trapper, Wizard, Guardian. The goal was to locate the enemy base and steal the magic orb while the intent was to build a competitive game that played like a team sport.

I tied the spells to roles, giving each player class two primary and two secondary spells. For example the Trapper's primary spells allowed them to set traps and to release frozen teammates, their two-player spell, 'shatter' allowed them to break a shield and their three-player spell 'steal' allowed them to steal the magic orb.

I spent considerable time designing and testing the game using mechanics specific to board games like movement on a grid, turn-based play, and action points for casting spells, with the goal of testing rules and balancing roles for the final outdoor game. This part of the process was also a way to ascertain if the game was easy to learn and fun to play.



Figure 5-1: One spell card showing the number of action points, area of effect, class the spell belongs to, and information about the spell.

Here are some of the questions I thought about while designing the board game: How much can a player move in each turn? How many squares or how much area will each spell cover? How big is each teams' home base? How will sonar work in the board game? How long will a spell effect last? How will the player be notified? Is there a spell cooldown? Is there a spell casting time? How many action points will a spell cost? Will each spell cost the same number of action points? Will players need to take notes while playing? Can a player cast multiple spells in one turn? How will counter-spells work? Can a frozen player be attacked again? How will traps be triggered? Do players have endless action points? Can they move and cast a spell in the same turn?

The board game was iteratively designed and play tested four times. In the two-person play test phase, the game lasted about 15-20 minutes on average. A four-person play test continued for 45 minutes before being abandoned. This made me question the idea of designing an outdoor game using a board game prototype. Were turn-based movements on a 2D map grid a valid representation of the fluid movements of players in 3D physical space? Players did spend a lot of time calculating movement on the grid and that took away from the real game. Some players also found the number of spells overwhelming and complex. The most interesting aspect of this play test was seeing cooperative gameplay emerge fluidly. One team said playing



Figure 5-2: One of the board game maps overlaid on the MIT campus map with a medium size grid. The black buildings and the brown areas are out of bounds.

strategically necessitated cooperation but their play style was in contrast with that of the other team where both team members played independently.

Designing and play testing the board game provided a good start for the outdoor game design. Even though it was not meant as an exact mapping of the outdoor game, it helped me understand basic game design concepts like balancing roles and abilities. Another important thing I learned was to keep gameplay simple especially since in the outdoor environment coordination and communication between players and movement across large spaces would add complexity to the game. The board game also helped me formulate a list of verbs, which became the basis of creating a movement vocabulary for the outdoor version of the game.

5.2 Paper Prototype

The goal of this play test was to determine the length of playtime, to learn if rules were clear and easy to follow, whether the player felt lost, confused or frustrated at

any point, and if the game was fun and engaging. I also wanted to learn if cooperation and teamwork were employed in solving puzzles and how the players felt about using an outdoor public space differently.

I printed out two copies of the map created for the board game. The teams were composed of three players each plus a person who carried the map and acted as the *GPS navigator*. The players could not see the map but were allowed limited interaction with the navigator. This was comparable to interfacing with the smartphone through speech-based interaction and receiving feedback through headphones. Blue and red paper squares of different sizes pasted on each map indicated the location of magic crystals and NPCs. This eliminated the need for the navigator to count the grid size for determining distance and location of virtual items from the player and helped move the gameplay along smoothly.

The game started with both teams (A and B) asked to run in opposite directions from the starting point outside the entrance of the Media Lab on the MIT campus. Their goal was to find all the crystals and make it back to the starting point first. The players on Team A (I followed Team A) started by yelling “hootie” to which the GPS navigator responded with ‘hot’, ‘warm’ or ‘cold’ based on the player’s distance from the nearest crystal on the map. The immediate response from the navigator helped the players orient themselves and start walking in the direction of the crystal. Since there was only one navigator per team, all players stayed together while attempting the missions. The first crystal was deliberately placed close to the starting point in order to help the players learn the game while playing it. As they approached the crystal the navigator announced “you have found a crystal” and asked them to complete an action in order to collect the crystal. The first action required all players to run around three times in a small circle to collect the crystal. Having found their first crystal, everyone continued with great interest and motivation to find the next one. Walking on campus yelling and running around in circles attracted stares from passers-by which added to the excitement of playing the game. In fact, a player on team A, who was quite stressed and disinterested at the beginning of the game, relaxed by the silliness of it all and joined in with great enthusiasm, prodding her

team to hurry and find all the crystals before the other team.

The players ran around until they encountered an NPC at the corner of Ames and Amherst Streets who gave them a quest to accomplish where they had to raise their arms in the air and spin around three times while yelling ‘Aperio!’ to collect the next crystal. Team B showed up at the same location just as Team A was leaving. Seeing each other brought out the competition and everyone ran to look for the next crystal. At the end of all quests, the teams had to run back to the starting point while trying to “freeze” the other team to prevent them from making it to the starting point. Freezing simply involved yelling ‘Freeze!’ from a distance after spotting the enemy team players. Both teams ended up ‘freezing’ each other just short of the starting point. The game lasted 15 minutes and everyones jackets and coats came off on a cold January day. The running and jumping and spinning had given them all a good workout.

The laughter and playful banter was evidence of a successful game. Some of them expressed surprise at their own ability to ‘exercise’ and were amused by the reactions their actions elicited in the students on campus. They enjoyed the workout but determined 15 minutes was the perfect amount of playtime. It was suggested that multiple such short missions could be designed leading toward a larger goal and played over several days.

5.3 Digital prototype

Based on the paper prototype, I designed and created the digital prototype. There were some changes to the gameplay and design because of technical challenges as described in the next chapter. The user experience is described in the chapter on Evaluation.

Chapter 6

Technical Challenges

The code for this project consists of an Android App written in Java. The map was rendered using data from the OpenStreetMap project. Signal processing was initially done with Matlab running on a server and later translated into Java to run locally on the phone.

6.1 Map Representation

The game is overlaid on a map of the MIT Campus. The game space boundary was created using the “create map” function of the browser-based Google Maps. The resulting data was saved as a KML¹ file, imported into the App code and parsed programmatically to display a colored boundary layer on top of the MIT Campus map demarcating the play area. Similarly, a separate KML file marking out the boundaries of all the buildings in the play area was created. This was done to dynamically generate a new game by automatically placing the NPCs inside the game map boundary but outside the building boundaries and added variety to game.

Based on the KML file, I determine the diagonally opposite corner points as represented by the minimum and maximum latitude/longitude values to create a boundary rectangle. These points do not match the exact corner points of the boundary KML

¹Keyhole Markup Language is an XML notation for expressing geographic annotations and visualization on 2D or 3D online maps [59].



Figure 6-1: Screen from Spellbound: game area boundary marked by dashed gray line showing two NPCs and the Power Core.

shape but encompass the KML shape creating a small contained area inside which location points are randomly generated.

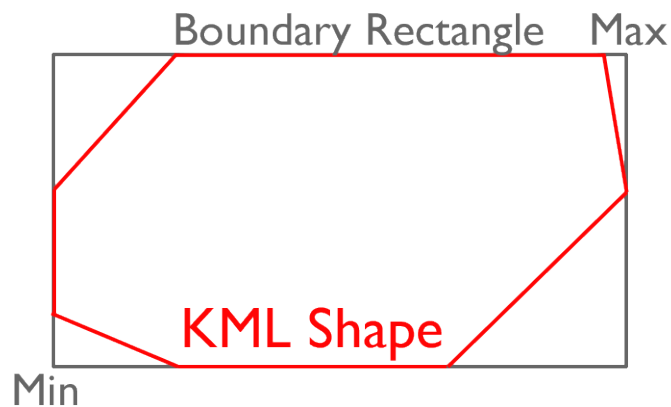


Figure 6-2: The min and max location values are used to create the boundary rectangle outside the KML shape.

After a point is randomly generated inside the boundary rectangle, it is checked to see if it falls inside the shape defined by the KML file and outside the building boundaries. This reduces the number of computations required to find a valid location for placing an NPC on the game map and loads the game faster for better user experience. Once a valid point is found, it is checked against all previous valid points for overlap and only accepted if it meets certain minimum distance requirements

between the points. The size of the game map, the number of buildings in the game space and the minimum distance required between points affect computation time and speed.

A future version of Spellbound would benefit from a user friendly interface to create the play area map that does not involve using a separate tool like Google Maps to create the KML files. This will allow anyone to easily create and play a game anywhere.

6.2 Map Preparation

Google Maps was initially the primary game interface. Low and/or unavailable outdoor Wi-Fi signal on the MIT Campus together with poor 3G/4G/Edge signal on my development phone made the map interface occasionally unresponsive. The game would freeze while the phone tried to locate network signal and when the player moved into an area with better connectivity, the frozen user interface would recover or crash. This was frustrating and unreliable leading to poor user experience. The first solution was to cache map tiles reducing the need to connect to the Google Map Servers continually while outdoors. However, Google Maps terms of service do not allow pre-fetching, caching or storing any map content except through the Google Maps App and the Google Android Maps API v2 does not have any mechanism to use a cached map.

6.2.1 Map Data

The next solution was to create an entirely offline map that would meet the following requirements:

- save the map locally on the phone's SDCARD;
- cache the map tiles to load faster;
- load and display the map without an Internet connection

- pan, zoom, and interact with the map similar to interacting with the Google Maps App; and
- display markers on the offline map to reflect the player's current location and continually update the marker as the player moved around in space.

OpenStreetMap data was freely available and did not have any restrictions for offline use. Map tiles for each zoom level needed to be exported from OpenStreetMaps (OSM) and rendered before they could be used in my App. For rendering the tile data, I explored multiple options. Maperative exported the tiles as bitmaps (.png) and SVG files which I could save on the SDCARD of the phone or bundle it with the App depending on the total size. Mobile Atlas Creator allowed selecting zoom levels and exporting tiles, however it was banned by OSM due to its excessive bandwidth consumption while downloading tiles. TileMill exported a single .png instead of multiple tiles for the different zoom levels.

6.2.2 Map Display

Google Android Maps API v2

I created a test app using the downloaded .png tile images with a custom *TileProvider* based on the Google Maps Android API v2. It worked well but the setup required the application to be online for communicating with the Google Map Servers at least once to validate the API key. As I was exploring a completely offline map solution, using the Google Android Maps API v2 did not fit the requirements at that time. In hindsight, since I ended up creating an outdoor Wi-Fi network to support the game, it would have been more efficient to use the Google Maps Android API v2 with the OSM map data instead of using a third party library like Mapsforge since a 100% offline solution was no longer imperative.

Osmdroid

Creating the map tiles was an involved process. After downloading a .pbk file for Massachusetts from geofabrik.de, I imported it onto PostgreSQL (an open source

object relational database) and exported data from PostgreSQL to TileMill. Once in TileMill, I was able to export the data as .mbtiles which is the map data format needed by the osmdroid library. The test app I created using the osmdroid library worked successfully but the code to process and render the .mbtiles was unnecessarily complicated so I abandoned this approach in search of a simpler more elegant solution.

Mapsforge

I downloaded the boston.osm.pbf file from [ftp.mapsforge.org/maps](ftp://ftp.mapsforge.org/maps). Using Osmosis, I converted the .pbf file into a .map file that Mapsforge could load into Android using MapView. Osmosis .41 could not work with mapsforge-map-write.3 so I had to use an older version of Osmosis (.40.1). After processing the map through Osmosis, I was able to save it on my phone and display it through my App. I was also able to display a marker for my current GPS location on the offline map and my marker moved on the map as I moved around in physical space. This met all my requirements for an offline map interface for my App and I was ready to get back to programming the game after this unexpected but major digression.

Initially, changing the default center and zoom level of the .map file was only possible by editing the .map file with Hex Fiend or recreating it with Osmosis passing it the zoom level and the location coordinates of the desired center of the map. A minor update to the Mapsforge library allowed these changes to be made through code.

Much later, as I was coding Stage Two of the game, I came across a bug in Mapsforge that forced me to make changes to the game user interface. Switching to Google Maps or updating Mapsforge would have meant rewriting almost the whole App so I implemented a design solution to work around the Mapsforge bug. This led to creating a Radar scanner activity for finding nearby enemies and the visualization added to the game atmosphere emphasizing the idea of hunting down Alien Bugs.

Tile System

Usually the map is not stored as a single image file but as tiles. At the zoom level zero, the whole world is a single square image (usually 256×256 though CloudMade offers OSM 64×64 tiles for mobile use). A “tileset” typically includes enough tiles to form a very large image, if they were shown all at once, and also several zoom levels [111]. It is more like a quad tree where each node (tile) has four children (4 tiles). Every increase in zoom level adds $4^{\text{zoom level}}$ more tiles. So at zoom level 10, the world is made up of 4^{10} tiles or 1,048,576 tiles which explains why OSM banned Mobile Atlas Creator from downloading tiles directly from the OSM servers.

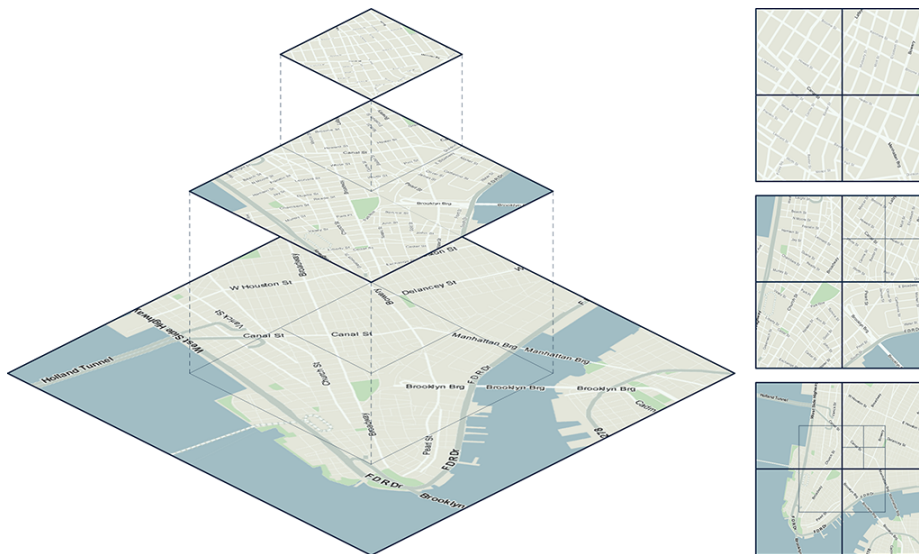


Figure 6-3: Tiles and zoom levels. (Courtesy of workshops.opengeo.org).

6.3 Voice Input

Android’s Speech Recognition service requires the phone to be online at all times since the speech processing is handled by Google Servers. The design of the game required the engine to recognize and respond immediately to the users speech command. When network connectivity dropped the App would freeze or not respond at all. With the release of Jelly Bean or Android version 4.2.2. Google has made offline speech recognition available to third party app developers for many device-based commands.

All my test phones were running a much older Android version 2.3.4 and it was requested that I not root and update the phones without trying other solutions first.

My solution to the problem was to forego speech recognition and focus on speech detection instead. As long as there was voice input, the system would use it and respond accordingly. Word recognition was not a requirement of gameplay. If connectivity were not an issue, speech recognition could be used in a more meaningful way affecting game progress and the user experience. In the final version of Spellbound the spoken word was used as a signal to the phone for calculating the player's location relative to a virtual object's location on the game map. This reduced the high failure rate on account of spoken accents and inherent difficulty of the word "hootie" which often registered as hoody, sweetie or, hottie even for native speakers. I experimented with different words and phrases but ran into similar recognition failures that adversely affected the user experience. Since it was not the meaning of the word that was important but the intent of the spoken communication, the implemented solution seemed like a reasonable compromise.

6.4 Network Connectivity

Another issue related to poor outdoor network connection was lag². The lag threw the teams out of sync at times and caused the players to see completed missions as incomplete.

For a synchronous multiplayer game, it is essential that all players in a team see the same exact game state on their screens. The basic design of Spellbound involves a client-server model where the client (player's smartphone) communicates with the server (Parse cloud app platform) by caching data and sending it whenever a network connection becomes available. To minimize bandwidth usage, data being sent and received is small chunks of text, which is processed on the client and rendered as markers or NPCs or other visuals as needed. All clients receive current world state

²In online gaming, lag is noticeable delay between the action of players and the reaction of the server[62].

from the server and generate video and audio output based on these updates. Doing this asynchronously prevents the user interface thread from locking up when there is no network connection and the client is attempting to send data to the backend. The Android system also guards against unresponsive applications by displaying a dialog that says your app has stopped responding, usually due to network access issues or a blocked UI thread.

Fetching data from the server is handled in separate threads that run automatically every few seconds depending on the type of data being fetched. This data is then sent to the user interface thread to be displayed and the user interface will only update once the data is available to display. This prevents the UI from displaying incomplete information or locking up and since each client is talking to the same server, having threads and async tasks allows for all clients to stay in sync with minimal latency.

Generating packets to send to the server and processing received packets on the client can only be done as often as the client is able to update its local state. The latency may have been a function of physical distance to the server. Utilizing Wi-Fi network instead of wired network may have been subject to lag depending on the architecture of the wireless network and electromagnetic interference leading to lost packets or simply network congestion as noticed during the first play test session.

6.5 Player Location

The player's current and most accurate location is retrieved by the client and displayed directly on the map, without being sent to the server, with a scheduled task that runs every second. If the phone has GPS, Wi-Fi and phone network enabled, the frequency of location updates is much higher than when only GPS is available. The accuracy is also higher when all means of determining user location are used instead of only using GPS. This was another reason that prompted me to setup an outdoor Wi-Fi network for the game since the test phones did not have any data or phone connection to help improve location sensing.

The Android Developers website lists the following challenges in determining

player location:

- Multiple location sources - GPS, Wi-Fi, Cell-ID can each provide a clue to the players location. However, determining which to use and trust is a matter of trade-offs in accuracy, speed, and battery-efficiency.
- Player movement - Because of constantly changing location the code needs to account for the movement by re-estimating the player location often.
- Varying accuracy - Location estimates from the various sources are not consistent in their accuracy and the most recent update is not necessarily the most accurate. A location obtained 5 seconds ago from one source may be more accurate than one obtained 2 seconds ago from another or even the same source

In Spellbound, the player starts the app on the phone and the application immediately starts listening for location updates from the registered location providers (GPS and Network) in the background. While the player continues through the splash screen to add their name and select a photograph for use in the game, the application attempts to get and maintain a ‘current best estimate’ of the player’s location by filtering out new but less accurate fixes. According to Google user interface responsiveness guidelines 100 to 200 milliseconds is where users will start to perceive slowness and since GPS easily takes a few seconds to get a good fix, the above design model provides enough time for the system to get a good location fix without making the player wait for the App to catch up.

A scheduled task runs in a separate thread every 3 seconds sending the best estimate of the player’s current location to Parse from where that location information is sync’d to all the players’ phones and displayed on their maps.

6.6 Game Server

Multiplayer games usually follow the client-server model. The server is a program that allows clients to communicate with it and it communicates with other clients

that are connected to it. I decided to use Parse as it provided both a data storage model as well as a programming API. Another option was writing a separate web server to communicate with a backend database. The Parse API is simple to use and allows for interacting with data using an object model, which works very well with Java. Other useful features for me were the ability to graphically view the number of API requests made by the app over time, view stored data through a browser-based interface and export data for backup. A few problems that I encountered were the unavailability of service at times and slow response at others.

6.7 Resuming Play

ANDROID_ID is a 64-bit number that is randomly generated on the device's first boot and is expected to stay constant for the lifetime of the device though the value may change if a factory reset is performed. This ID satisfied the requirements for uniqueness and lifetime that I needed to manage the identity of devices joining a game. By saving this ID in Parse and checking against it, I was able to allow a device to join the game if the player accidentally hit the back button too many times or if the game crashed on the phone and had to be restarted.

6.8 Initialization

When the Spellbound application is started for the first time a new game is created and initialized. The location listener is started to estimate the player's physical location. The offline game map is loaded; missions are selected from a set, matched up with actions and stored locally on the player's phone as well as added to Parse. The sounds and other assets that are bundled with the App are preloaded at initialization and the sound listener is started. A Bluetooth connection is established with the IOIO board to communicate with the wrist and armbands.

6.9 Activity Detection

Spellbound involves activity detection using data from the accelerometer, magnetometer and gyroscope. The game system does not continually monitor sensor data for recognizing differences in signal patterns but instead starts recording sensor data when the player interacts with an NPC and indicates readiness to initiate physical action like a jump or a spin. The sensor data is then collected for 5 seconds and processed. In the case of jumps, a peak counting algorithm is employed to count the number of jumps. In the case of counting the number of spins, data from all three sensors is collected and the azimuth is calculated. A spin-calculating algorithm is used to count the number of spins based on a 360° change in azimuth from its starting value. On the test phones, unlike the development phone, sensor fusion could not be used because they lacked gyroscopes. For calculating spins, only magnetometer and accelerometer data was used.

An easy way to get the attitude of an Android device is to use the *SensorManager.getOrientation()* method to get the three orientation angles.

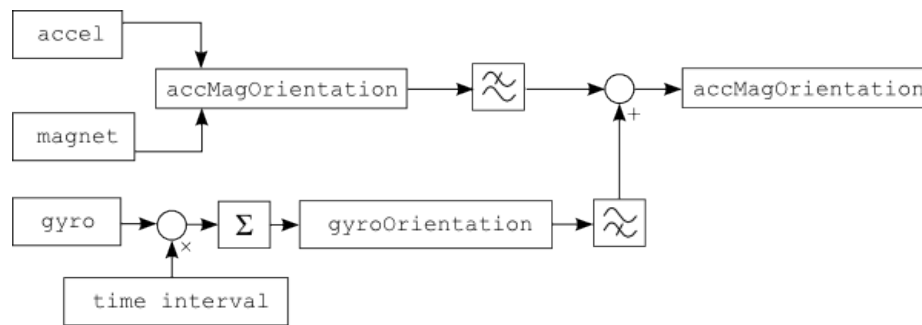


Figure 6-4: Diagrammatic representation of sensor fusion and filtering. (Courtesy of thousand-thoughts.com).

These are based on the accelerometer and magnetometer output. The accelerometer provides the gravity vector and the magnetometer is the compass. The data from both these sensors is enough to calculate the devices orientation. However both sensor outputs are inaccurate and the data from the magnetometer is especially noisy. The gyroscope provides more accurate output, the angular rotation speeds for all three axes with a quick response time. Multiplying the angular speed with the time interval

between the current and the last sensor output yields the rotation increment and the sum of these increments gives the absolute orientation of the device. As errors get introduced on each iteration, they add up over time resulting in a slow rotation of the calculated orientation called the gyro drift. To optimize, the gyroscope output is applied only for orientation changes in short time intervals while the accelerometer/magnetometer values are used over long periods of time. This is equivalent to low-pass filtering the accelerometer and magnetometer signals and high-pass filtering the gyroscope signals [3]. The overall sensor fusion and filtering looks like this:

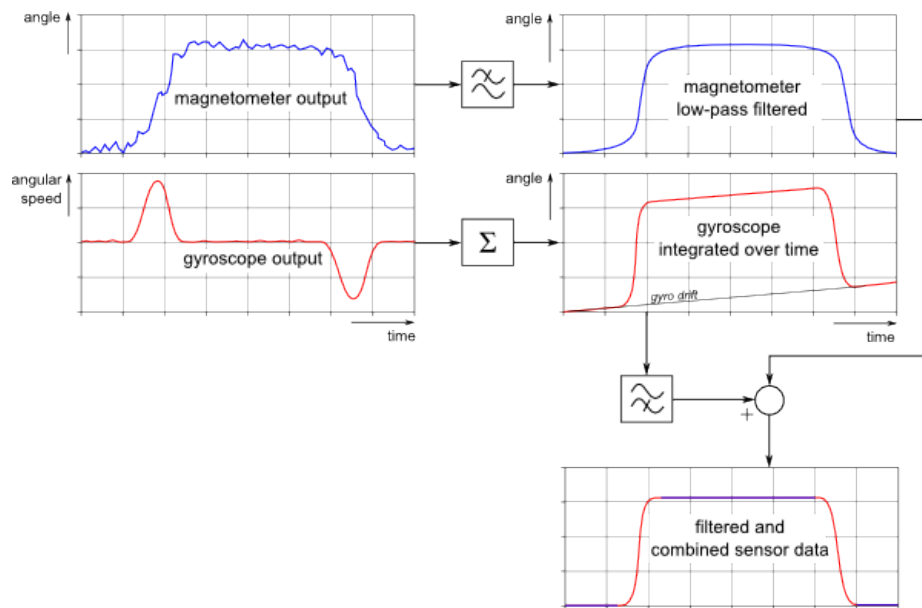


Figure 6-5: Diagrammatic representation of the filtering process showing gyro drift in the integrated gyroscope signal. (Courtesy of thousand-thoughts.com).

Chapter 7

Evaluation

Spellbound software was evaluated by fourteen testers recruited through an email sent to the entire Media Lab. Eight female and six male players, age ranging 22 – 61 years, played a total of six sessions where one session included the entire game comprising Stage I and Stage II. Tests were conducted on consecutive days allowing me time to fix bugs and adjust the setup before each test as needed. Testers provided immediate verbal feedback after each game session (Appendix D) and filled out an online questionnaire (Appendix C) after the playtest. The hardware was evaluated by two testers at locations different from the software playtest location. This chapter is about the testing process, challenges faced and the feedback gathered.

7.1 Game Setup

7.1.1 Phones

In order to minimize differences in experience as well as available features, I used phones of the same make, model, and Android version for all players and all tests. Of the test phones available, I had the option of picking the HTC Wildfire S or the HTC Droid Incredible. The Droid had a larger screen (3.7 vs. 3.2), a higher resolution (720 x 1280 vs. 320 x 480) and, higher density (252ppi vs. 180ppi). It also had an HDPI screen vs. the MDPI screen on the Wildfire though the phone used for app

development had an XHDPI screen. To understand what the difference in screen density means in terms of creating assets for an app, an icon of size 48px x 48px on an MDPI screen would need to be created as a 72px x 72px icon for an HDPI screen and a 96px x 96px icon for an XHDPI screen.

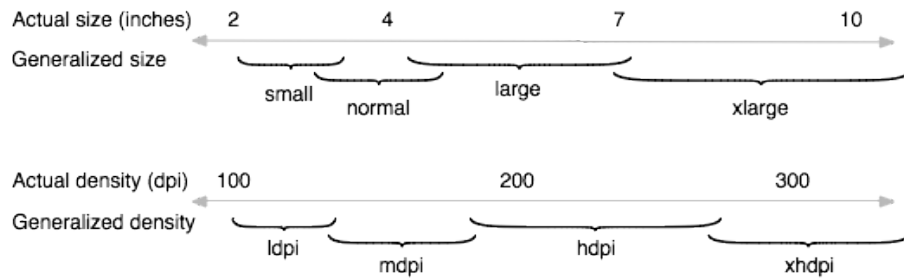


Figure 7-1: Illustration of how Android roughly maps actual sizes and densities of device screens to generalized sized and densities. Courtesy of developer.android.com

As I had six Droids available but only four Wildfires, and they were closer in specs to the phone I had used for development, I used the Droids for all playtesting. Although Android performs scaling and resizing to make the app work on different screen sizes, for good user experience it is worth the effort to design the application for different screen sizes, orientations, resolutions and densities. To optimize the app’s UI for any of the generalized screen sizes and densities, alternative resources and layouts should be provided. Ideally the app would achieve “density independence” i.e. preserve the physical size of user interface elements when displayed on screens with different densities. The Android system helps the app achieve density independence by scaling dp units as appropriate for the current screen density and by scaling the drawable resources to the appropriate size based on the current screen density [4].

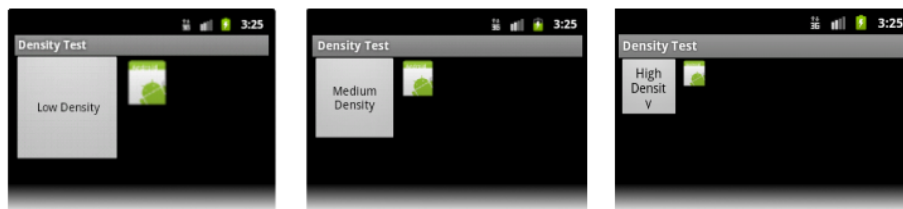


Figure 7-2: Example application without support for different densities as shown on low, medium, and high density screens. Courtesy of developer.android.com

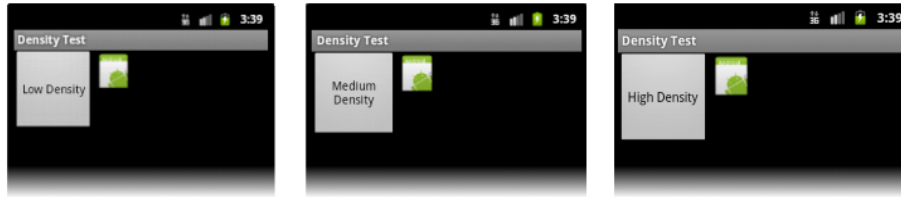


Figure 7-3: Example application with good support for different densities (it is density independent), as shown on low, medium, and high density screens. Courtesy of developer.android.com

Despite all phones being the same, two of them displayed a lot of GPS inaccuracy. After testing them in the space planned for playtesting, I made some adjustments to the placement of the NPCs on the game map to take into consideration the GPS inaccuracy. In an outdoor scenario, GPS can be inaccurate for various reasons and I had designed the game such that GPS accuracy was not a requirement for successful gameplay. However, there were times when players were closer to the buildings trying to complete an action when GPS inaccuracy became too great and affected playability. I fixed this issue by creating games that placed the NPCs and other virtual items away from the buildings in the play area. One player after the second day of playtesting said she used the GPS inaccuracy as an aspect of the game while another player expressed frustration at the inaccuracy.

The hardware playtest was done using testers' own Android devices that were much newer than those used for the software playtest and were therefore able to communicate over bluetooth with the IOIO board. The devices were also able to connect to the service provider data network and displayed a high GPS accuracy to within a few meters outdoors. This allowed the game to be created and played anywhere as I did not need to setup an outdoor Wi-Fi network at a pre-determined location to provide connectivity.

7.1.2 Wi-Fi Network

The test phones were borrowed from the MIT Center for Mobile Learning. They did not have active phone and data connections. This coupled with varying strengths and limited bandwidth of existing campus Wi-Fi signal outdoors made setting up my

own Wi-Fi network to support playtesting mandatory.

My first attempt to solve the network availability issue was to setup my macbook connected to an Ethernet port to act as an Access Point (AP) to which all phones would connect. To create this I purchased a high gain, omni-directional, high-speed wireless antenna compatible with IEEE 802.11b/g/n wireless standards. My goal was to use this antenna to create the AP while using the internal Wi-Fi antenna or the Ethernet port to connect to the MIT network. After several unsuccessful attempts with multiple versions of drivers and software to create the above setup I decided to setup my own Wi-Fi network outdoors. Even if I had been successful with this AP setup, the maximum range of the high gain antenna was approximately 200 feet, which was much smaller than the actual play area. It was easy to setup the mac's internal Wi-Fi as an AP but that was not very helpful since it has a limited range of only about 50 feet. I reviewed several other high dBi antennas and tested another one that only worked with a Windows system. Again, the range on that antenna was also limited to a maximum of 200 feet. Antennas that supported longer distances were directional and looked like small satellite dishes. To provide coverage in the entire play area, I would need several of them and would need a way to connect them to the MIT wireless network as well as a power source. I rejected this solution as it was expensive and seemed excessive for what I needed for the 15 minutes of game play.

I designed a few network solutions with the goal of finding the simplest, cheapest, and the easiest setup that would require minimal help from the MIT Information Services & Technology (IST) office. The Media Lab had two outdoor Wi-Fi networks that provided coverage outside the Lab. One of them was decommissioned several years ago while the other was turned off due to ongoing roof maintenance so neither was a workable solution for me. Also, the positioning of the APs provided network coverage limited to the immediate vicinity of the building and my game space extended well beyond that.

I explored ready to deploy outdoor wireless solutions but they were prohibitively expensive and required considerable input from MIT IST. Ultimately, after meeting with the networking group at MIT, we designed a solution that would require no

equipment purchase and setup on my end but would require me to move my game map from East Campus to the space around Kresge Auditorium [61]. Even though the new space met the requirements for an urban play space, it had fewer buildings and was much smaller than the original play space. The smaller area necessitated changes in the game design which would affect the play time and user experience knowing that in an LBG, players are not just consumers but also creators of their experience as they find meaning in the context of the environment, the challenges, and the story.

7.1.3 Environment

I had the Wi-Fi equipment on loan for two weeks. The playtests could only be conducted on a weekday because the Kresge Auditorium was locked on weekends and the Ethernet ports to plug in the Wi-Fi APs were located indoors. The week of the playtest sessions was hot and rainy with large events at Kresge, leading to unavailability of parking making it harder to transport the APs and setup the equipment. Since LBGs are played in the real world, in physical space, they are affected by the ever changing elements in the environment.

7.1.4 Software Playtests

Playtest I

Tuesday, May 21 at 3:00pm. 7 testers. 3 per team. 1 observer.

I arrived at 2:30pm to setup the Wi-Fi network but the parking lot was full and the parking attendant allowed 5 minutes for me to carry all equipment (2 tripods mounted with APs, 100 feet of Ethernet cable, 6 test phones, 1 laptop, 1 backpack, 6 baseball caps, 1 power strip, 6 phone adapters) to Kresge. There were two events going on with a few hundred people in attendance and all I could do was hope for my wireless network to have enough bandwidth for the playtesters. The Kresge Oval was also off limits today due to fertilizer spray on the grass reducing the play area to an even smaller space.

The testers were scheduled to arrive at 3:00pm. The sixth tester arrived at 3:30pm by which time two other testers had to leave. Since the game does not have a tutorial, I explained the goal and showed a short presentation before starting. The first game session started with 5 players, 3 on one team (team1) and 2 on the other (team2). By talking to each other and experimenting everyone except tester1 on team2 figured out how to play the game. When the sixth tester arrived, I reset the game and expected everyone to have some understanding of the mechanics and rules after having played the first session. Tester1 had still not grasped the gameplay and I was eager to talk to them to understand the source of their confusion. Immediate feedback after the second session was that the game was too short but it was fun. Tester1 did not like interacting with the NPCs on the phone screen while another player loved the interaction with the characters especially since the NPCs revealed the next mission in the game and moved the story forward. Tester1 said they were confused because they thought the NPCs represented the enemy team players. This was valuable feedback and I made me think about different ways to teach the game to other testers.

The sixth tester liked the team aspect of the game because it meant not as much pressure on them as an individual. They also suggested assigning specific tasks to each player on the team and thought the game would be the perfect activity during breaks at work. Another player liked the sense of working with other people and splitting up the tasks. Almost everyone requested a tutorial to help them learn to play the game and before each of the next two test sessions, I walked the players through the game on a phone instead of showing a presentation. In addition, I asked testers to play the game twice using the first session as a tutorial to teach them the game. In all subsequent playtests players enjoyed the second session more and were able to play strategically.

The first day of testing was stressful due to the time delays, network lag and GPS inaccuracy issues, unexpected environment changes and problems with playing the game in a new space related to NPC placement and large AoE¹. A player offered to

¹Area of Effect or the minimum radial distance from the NPC within which the player is able to interact with the NPC.

use their own phone instead of the test phone to play the game, which could have helped alleviate network issues as any drops in wireless connectivity would cause the phone to switch to the data network. That would have been an ideal scenario if all playtesters had Android phones with the minimum OS version (2.3.4) but most players instead had Apple iPhone's and that was one of the reasons why I was using a set of test phones. Limiting the pool of potential players to those who own Android phones may have resulted in fewer playtesters. Another reason, as mentioned earlier, designing for the variety in Android phone hardware, sizes, and OS versions given the limited time to build a functional prototype was beyond the scope of the project.

Playtest II

Wednesday, May 22 at at 4:00pm. 4 testers. 2 per team.

The second playtest was conducted with fewer people because of feedback from the first test where players found the game playtime too short. The game is designed with 3 players per team in mind but it can easily accommodate fewer or more players with minor changes to missions. The second playtest ran smoothly and everyone enjoyed the game immensely. The biggest technical issue was the unavailability of the MIT SECURE N network, which the phones automatically connected to and had to be manually switched to the MIT GUEST wireless network that required relaunching the game on each phone.

It was incredible to see everyone jump around with joy, complete the missions and play the game enthusiastically. Comments like the desire to play it again and the demand for more such games were great. One tester said it made them feel like a kid playing with stuff that did not exist when they were a kid. Another player loved the storyline and the team aspect of the game but thought the one downside was the need to look at the phone while running around. A couple of players suggested designing a framework to allow them to create their own games and to increase the difficulty of challenges as they mastered the initial ones.

As a player went out of wireless network range, the App crashed but they were able to join right back without it affecting participation or enjoyment. The Red team

could not complete the “jumping” action because the GPS location on the game server differed vastly from their actual physical location. This was most likely due to using one of two phones with higher GPS inaccuracy and was easily solved during play by swapping phones. It is possible that the GPS may have had an error, the signal may have been blocked by the building or there may not have been enough satellites in the sky at that moment.

Feedback after the playtest was a demand for more background story and need for displaying an arrow instead of a marker on the map to help the player orient themselves. There was also some confusion between the “sonar” mechanic used to complete a mission by voice input and the “radar” display used in stage two to find nearby players for transforming or rescuing them.

Playtest III

Thursday, May 30 at 3:30pm. 4 testers. 2 per team.

The players swapped teams before playing the game a second time. Everyone got a chance to experience the game from two perspectives. They did not know that each new game is randomly generated within the demarcated play area and immediately ran to the the locations they remembered from the first session. This was amusing to watch and reminded me what Raph Koster said about how players always try to optimize and make the gameplay as predictable as possible [60]. One player tried to cheat by attempting to complete the mission that required talking to a passer by himself. There was nothing in the game design that prevented him from doing so. Another player on the same team wondered what would happen if there were no passers by for them to complete that mission.

Everyone had fun despite the heat as evident by responses to the online questionnaire. Immediate feedback was about the short duration of the game and occasional network latency. The physical activity detection worked well and that made the playtest glitch free.

7.2 Hardware Playtest

To evaluate the prototype, I recruited two participants (male), and conducted the study on two separate days. The first playtest was conducted in a Cambridge city block while the second one was conducted on MIT Campus. For the playtest, the participants wore a wristband and two armbands, one on each arm, and played the game.

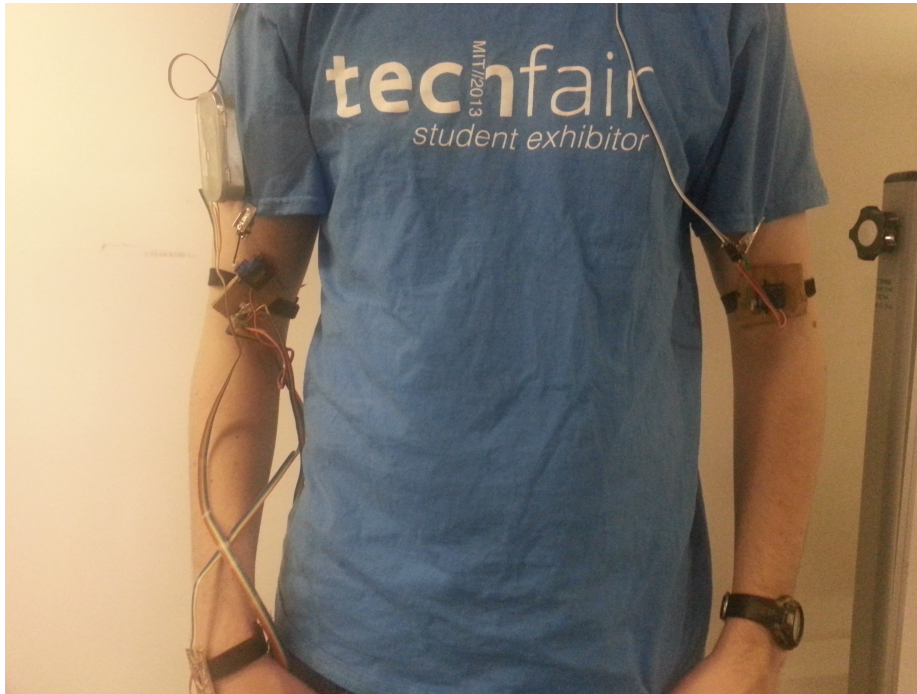


Figure 7-4: An early prototype of the hardware showing a wristband and two armbands connected to a IOIO board.

The goal of the study was to understand if and how the non-visual information devices affected the play experience. Overall, both players found the armband’s tug not strong enough to mimic a sleeve tug. One player said he came to rely upon it fairly quickly to guide him in his search though would have preferred shorter faster tugs.

The wristband affected player behavior dramatically. One player said he increased his speed and effort to locate the Power Core when he saw the first light come but switched to a different mission when the second light came on, “after the second light, I was full on panic mode”. He said he constantly glanced at the wristband to make

sure he didn't miss any information and remarked there was no thought between the wristband vibrating and him looking at it and felt the wrist was the perfect location for providing that information. Seeing the two lights also made him feel like he had already lost the game. Another player said the game made him go to a part of the MIT campus they had never seen before. He found the unintentional exploration an interesting aspect of playing the game.



Figure 7-5: GPS data for two players during a hardware playtest on MIT Campus mapped on Google Earth.

The advantage of playing a game in the real world is that it is a “vast and infinite changing resource of content” and designing a game by relating on a symbolic, iconic, or indexical relationship between real and fictional meaning of elements[78] can enhance player’s intermediation between everyday life and LBGs.

7.3 Observations and Feedback

The majority of the testers enjoyed the physical actions required to interact with the game. They especially liked the faster second stage, which involved a good bit of running to collect/destroy the eggs while freezing/rescuing others. People looked at their phones but communicated extensively in the real world to coordinate and plan mission completion or egg collection. Most teams stayed together to complete the missions and split up during the second stage to cover larger ground.

On the first day, having a large AoE, 40 meters to use GPS inaccuracy as a game feature, caused errors. The play area was small and the large AoE put the players in proximity of the NPCs almost as soon as they came out of Kresge. The hidden Power Core was visible right away and added to the confusion. I could not make immediate changes to the game which would lead to a few minutes of downtime and the game had already started later than expected. I fixed this issue for the next two tests by reducing the AoE to 30 and then to 20 meters and GPS was accurate to within 9-10 meters on four of the six phones.

Players had mixed reactions to the mission that needed them to ask a passer by to speak into the player's phone. Some players had no trepidations about doing this mission while others were self-conscious. However, all players who completed this mission enjoyed it, especially after they heard the light-hearted response from the phone, which also made the passer by feel like a participant in the game. Most of the players liked the sound effects and they particularly enjoyed the phone's response in this mission that made them laugh². After the game ended, they narrated their mission experience to everyone and felt a sense of pride almost at having successfully made a stranger verbally admit to being a stinky bug/human.

The sonar mission worked without any problems on day 2 and 3 after I fixed the issues encountered on day 1. People enjoyed wandering around yelling "hootie" though a couple of players from day 1 were not sure about how it related to the other two missions. Each time the players received a response from the phone notifying them of how close or far they were from the virtual item, they looked up from their screen in all directions as if visually confirming that they had indeed not yet found the Power Core. They enjoyed searching for this invisible item and were surprised and excited when it appeared on their screen when they reached the "hot zone" or within 20 meters of its geographical location. I also noticed some players looking up from the screen when they were interacting with an NPC as if the NPC were standing in front of them. Some players expressed a desire to collect real eggs instead of virtual

²The phone responds to the audience member's voice input of "I am a smelly Human" with "Stinky Human detected. Transforming..."

ones.

Players said a longer background story would help them feel more connected to the characters in the game. Several players relied upon the audio cues and did not read the mission text and had to ask their teammate about what to do next. All players agreed the game was too short and would have been even more fun if there were several more missions and if the game were played over a larger area. One player thought chasing after eggs in the second stage was difficult to do while trying to transform enemies.

All the testers walked or biked daily. Two of them exercised daily by participating in sports like basketball, rowing, hiking, swimming, soccer, tennis, triathlons, and windsurfing while two others were into running a few times per week. Overall, it was an active group that was excited to play Spellbound because the game demanded them to be physically active. One player particularly liked that the entire team had to jump together to complete a mission while another player thought this tech-driven approach to physical activity was a great way of meeting new and socializing with ‘old’ co-workers. They felt good being physically active and felt even better playing with friends.

Almost everyone agreed it was a social game where the “workout snuck in under the radar”. Most people mentioned having to go somewhere to exercise, like the gym, as their biggest reason for not exercising. Several of them thought that having short intense bursts of activity during the day or getting exercise through games or having an exercise buddy were some of the things that would make them more physically active.

While nobody commented on the audio in the game, one player said they enjoyed the sound effects and wanted more dramatic sounds to add to the fun. One player suggested having a push-to-talk with teammates and though this was a planned feature at the beginning of the project, it was dropped in favor of 3-way calling already available on phones, which was dropped because the test phones were not connected with a phone provider.

Most players found the voice interaction interesting and one player said it made

them felt like a secret agent in some organization and that made the game more interesting. Others felt it worked well, was fun and different while one player thought it felt “disconnected” and “hard to trust”. They thought it would help if the phone responded with something positive or negative based on their actions to make them feel like they were doing the right thing. Two players felt unsure if the system registered their voice command, which led to unnecessary repetition.

Another player thought the game made familiar surroundings more exciting and wanted to see more missions in the game and playtest again. Discussion of suggested improvements for a future version of Spellbound are included in the next chapter.

In any LBG experience, players are active in creating and exploring the boundaries of the game while the rules attempt to regulate their movements and present challenges. The players derive meaning from within the context of the environment, the rules, the objectives, the story, and their own knowledge and experience. The players, the game, and the environment are all part of the creation of a meaningful experience by inserting structure into ordinary space [102].

Chapter 8

Future Work

Spellbound is an exploration. I proposed a multiplayer location-based action game and demonstrated a working prototype. During the design and evaluation process, I identified a number of ways to improve both the technical aspects of the system as well as the design of the user experience. This chapter is about sharing these and future enhancements. I showed people enjoyed playing a real-time location-based multiplayer action game using non-traditional inputs like physical actions and voice with non-screen outputs like the wrist and armbands. In this chapter I will introduce some related ideas for future research.

8.1 Player Location

The current system takes into account the most recent best-known player location based on GPS and Wi-Fi signal data. The time taken to get a first location fix is often long so I start the Spellbound App on all the test phones early to give the system time to get the most accurate location fix. The code checks to see if the location retrieved is significantly newer than the previous estimate, if it is better or worse than the previous estimate, and whether GPS or Wi-Fi is the location provider. The returned value is used to place a marker on the player's map and saved to the game server for sharing with the team.

Setting the window of listening for location updates too small means less inter-

action with GPS and network location services and fewer locations to choose and estimate from. It also reduces the rate at which new updates appear which affects accuracy. Since time and distance properties affect how often the device will request a location update using the overloaded *LocationManager.requestLocationUpdates()* method, I determined these values heuristically by running the app on the test phones. These properties affect how aggressively the device requests location updates by minimum time elapsed and minimum distance traveled which affects the battery life significantly. The shorter the minimum time interval the faster the battery will be drained though battery was not a concern for Spellbound. Though highly accurate GPS location was not critical to gameplay and the game design could tolerate an error margin of 10+ meters, larger deviations could lead to player frustration.

A future system that leverages the phone's existing compass and accelerometer would help improve location detection. With knowledge of player direction from the compass, the accelerometer data could determine if the player was walking or running and assist the system in predicting the player's location a few seconds from now. Predicting location would allow the game server to stay a little ahead by pushing estimated player location data to all clients. By the time the phones receive and display the estimated location data the player's location in reality would match its representation on the map.

In an fast-paced online multiplayer game, network delays of even a few milliseconds can cause lag leading to inaccurate rendering of the game state and considerable desynchronization disrupting smooth gameplay. This effect is significantly noticeable in first-person shooter games. For optimal experience, player location and mission state data need to sync across all clients with minimal lag. Since Spellbound is a real-world multiplayer game, for location data the players only need to look up from their phone screens to locate players in the real world. Other methods for reducing delays are discussed in the chapter on Technical Challenges. Fang et al. discuss a method to estimate a user's position by creating a user activity map based on their past activities and an algorithm that makes reference to this map to find the most probable correct position. A similar adaptive particle filter may be of use in a future

version of Spellbound especially if the game is played over a larger space and for a longer period of time to allow the system to learn from past player behavior.

8.2 In-game Tutorial

Teaching a new person how to play a game without feeling overwhelmed, frustrated or intimidated is a key challenge of game design. Online games use a variety of teaching styles including separate tutorial areas, in-game walkthroughs, on-screen instructions, help buttons, and manuals. Of the three teaching methods I employed: tutorial by exposition, walkthrough demo on a phone, and playing the game, all players agreed playing the game was the most effective way to learn the game which made the subsequent play session more fun and enjoyable. A future version of Spellbound would have a contextual tutorial that would provide instructions when needed instead of an up-front out of context manual. Though the idea of providing a tutorial is arguable since games usually are about overcoming challenges and players discover the rules of the game by playing the game, as they did while playing Spellbound, it was the number one request. Learning by playing is based on the assumption that the player will be interested enough in the game to spend the time needed to learn the game.

8.3 Communication

One player expressed the desire for ‘push-to-talk’ to communicate with their team members. This was certainly on the original list of features but was dropped in favor of 3-way phone communication, which was dropped because the test phones did not have a phone connection. The play test area was small enough for players to quickly find and talk to each other but there would be need for a communication mechanism if the game is to be successfully played over a larger physical space.

8.4 Audio

There is currently no music in the game. Music which changes based on players actions (e.g. running or jumping) would be interesting and add to the game atmosphere greatly.

8.5 Spoken Dialog

My system uses spoken dialog to the make the player aware of their proximity to an NPC or other interactive element in the game. The dialogs are done in different voices and are different for both teams both in content and style but are limited to short phrases. The player still needs to read the dialog box to understand the mission requirements. A future version would use 100% spoken dialog where the player would interact with the NPC using speech recognition and the NPC would dynamically adjust its dialog based on that interaction. Such a system would do away with the reliance on the phone screen making the interaction feel natural and more connected with the real world. The next version of Spellbound will use Google Glass[42] to create a hands-free augmented reality play experience using some of the same input mechanics as the current system. The Google Glass will replace the wristbands, armbands and the phone screen.

In an outdoor scenario due to high ambient noise there is always a possibility for the player to not hear the spoken dialog or remember what was spoken so the system needs to be designed such that repetition is possible on demand and there are alternative means to access the same information. Aside from interacting with the game, other information such as progress and score could also be relayed verbally. This would make the system more personalized and would fill in the empty spaces when the player is not interacting with an NPC but is exploring the game map.

8.6 Play Anywhere

There are so many different aspects to game-making that at each step I found myself deciding between what needed to be done to create the prototype and what I wanted to create given the limited time. Professional game studios have specialized staff for various elements of a game like world design which sets the backstory and theme of the game, system design that creates the rules and algorithms, content design for creating characters and missions, writing for dialog and story, interface and audio design incorporating all sound effects and voice acting. In a game design company these roles are filled by programmers, artists and sound engineers who work together to create the experience for the end user and that is true even of small studios.

During the paper prototype stage one player had suggested building a series of games, each with a few missions, as part of a larger game that would last days. After the digital play test, two players suggested having a larger scale version of the Spellbound spread across campus or even the city. An expanded version of the current game creation system would allow anyone to create a game anywhere in the world. It would be similar to a level design tool, which is usually one of the first things made while creating a game. In Spellbound, I wrote custom code for four missions, counting the entire stage two of the game as a single mission. All the missions are considerably different since they each showcase a different sensor or sensor combination used to collect data and process the signal. A level and map design tool will be indispensable for creating a longer version of this game.

A future version would allow people to create their own game maps and missions in their neighborhoods, schools, parks, and plazas or wherever else they want to play. They would be able to create games for their communities and games with storylines of their own choosing tied with matching physical actions. For example someone could create an urban game with actions likes pushups, jumping jacks, and running while someone else could create a game in a forest that may have actions like waving arms and running around trees. Each of these games could have a different purpose: exercise, learning, exploration, discovery or a combination of any of these and more.

People could select music for their games and create dialog for detailed storylines. The limitation of the system would be the types of activities that are detectable. A compromise for adding variety in activities could be reliance on players for following the game rules and doing the required actions. Using sensor data to detect vigorous movement without classifying that movement as a pushup or an arm wave could be easily implemented. Jegers argues against too strict a control with the challenges given to the player since the players are in charge of the game world. He says the game should not be pre-programmed but offer players support in managing their game experience[53].

A characteristic of play defined by Callois and Huizinga is that play proceeds within its own proper boundaries of time and space governed by rules that all players must follow. This would be especially applicable in an outdoor game since LBGs are not set in fully designed spaces and it is not possible to make the technology and everything in the setting reinforce game rules and themes[16].

8.7 Identity

Adding an identity system and a leaderboard in the game to allow people to maintain their data across games and have their accomplishments like “achievement: 200 pushups” displayed. It would provide motivation for people to play and as a result become more active. An identity system would also give players the choice of which team they want to alliance with and help create personalized and contextualized missions.

8.8 Game Replay and Spectatorship

The current implementation of a browser-based game review system is incomplete. The GPS data is exported as KML to create “KML Tracks” which includes the time element. Tracks also store additional sensor data such as heart rate, cadence, temperature, and power and are displayed on Google Earth [46]. I believe the ability

to view the game could add another element to the gameplay by giving people the opportunity to relive and share the experience. It could also become a platform for live spectatorship of ongoing games bringing people from other parts of the world into the game. LBGs do not draw the players into an entirely imaginary world as an online games[54] rather, they draw play and fiction into real spaces[13] focusing on the relationship between the real and the virtual. LBGs link locations and places when locations acquire characteristics formerly attributed to places, namely their networked and dynamic aspects, their social aspects, and their meaningfulness[28] during and after gameplay leading to altered perceptions of space for both the players and the viewing audience.

8.9 Evaluation

The evaluation goal for Spellbound was to see if the system worked and if people enjoyed playing the game. It would be possible to investigate other interesting hypotheses if more games were made available, more players were able to play anywhere and at any time, and testing was conducted over a longer period. When using the system, do players go outdoors more often than usual? Are they more physically active? Are they happier? Do they feel more connected with the people they play with? To answer these questions I would need to compare data before, during and after using the system and over a long period of time.

8.10 Hardware

There are several ways to create a hands-free play experience like using Google Glass [42] or creating an audio-only game with peripheral hardware to provide vibrotactile feedback. A wristwatch like interactive device could be another possibility to create hands-free play while having access to the visual representations of the game and the added interactivity via the touchscreen. I am interested in further investigating the design space of mobile games using tactile feedback systems.

Chapter 9

Conclusion

The goal of this project was to create a playful source of rich and meaningful interactivity between people. The work shows that it is possible to create an engaging real-time location-based multiplayer mobile game experience that uses physical actions for interacting with the virtual world. It successfully incorporates hardware devices for assisting and informing players through haptic feedback, adding digital information to the physical world. It is more than just a “game layer” over the world. It generates the conditions for meaningful encounters between players and locations. Players experience the physical environment through the rules, goal, and story of the game which affect their perception of the physical space. The game provides new ways of moving within space and perceiving the physical world while meeting and interacting with people in play.

In real world sports the wall between the physical and the digital has been getting lower and thinner for quite some time. Instant replays bring stadiums to a standstill and diminish human judgement calls. Wired foul lines on tennis courts measure within a hairs-breadth the legality of a serve. Technology is used as a tool to augment what were once inviolable limits of human ability by acting as a precise and impartial judge.

Spellbound attempts to push technology into the background because player focus on the device screen can easily take their attention away from their surroundings turning an LBG into another virtual experience. Through the development of game design and use of audio and physical output devices, Spellbound allows players to

focus their attention on interacting with each other and their environment. The game exists at the boundary of digital and physical play using technology to enhance the experience by augmenting the players' abilities and the richness of the physical space.

Appendix A

Missions: Team Humans

An example gameplay progress and transcript for one team during stage one of the game.

Mission I: Power Trip

Player: Hootie

Phone: In the cold zone

(Left sleeve tugged)

Player: Hootie

Phone: Getting warmer

(Left sleeve tugged)

Player: Hootie

Phone: In the warm zone

(Right sleeve tugged)

Player: Hootie

Phone: Getting warmer

(Left sleeve tugged)

Player: Hootie

Phone: You have found the Power Core buried in the ground! Spin three times to generate a tornado to free it.

(Two players spin around three times.)

Phone: Well done tornado Spinners!

(Wristband worn by enemy team players vibrates and an LED turns on.)

or

Phone: Looks like you need to Spin again.

Mission II: Bug Juice

(Players go to location on the map marked by an NPC to interact with it)

Phone: Get out there and kills some Bugs!! They attack as a group so be sure to bring your entire team along for this mission.

(Players go to location marked on map showing the bugs that need to be killed. This location only appears after they have interacted with the NPC above to receive the mission)

Phone: Watch out! Jump three times together to stomp out this wave of Bugs.

(Three players jump together three times)

Phone: Excellent! Here is a Shield for user later.

(Wristband worn by enemy team players vibrates and another LED turns on.)

or

Phone: Looks like you need to jump again.

Mission III: Transformation

(Players go to another location on the map marked by a different NPC to interact with it)

Phone: Find a person not on your team and ask them to speak loudly into your

device “I am a smelly bug.” The device will detect their true identity, if they are friend or foe. Remember to come back and talk to me after you are done.

(Players looks for a passer by to speak with)

(After speaking with a stranger, the players return to the NPC)

Phone: Well done! Looks like the Bugs are agitated. Use this Transform ability in the next round of battle.

(Wristband worn by enemy team players vibrates and the third LED turns on.)

Appendix B

Questionnaire

Background

- Name
- Age
- Gender
- Do you have a smartphone?
- Do you play games? If yes, what kind and how often?
 - Video Games
 - Mobile Phone Games
 - Boardgames
 - Team Sports
 - Other
- Why do you play games? Or, if not, why not?

Activity Profile

- Do you enjoy outdoor physical activities? If yes, what kind and why?

- What types of things do you enjoy doing with friends? How often do you do them?
- Do you exercise? If yes, what kind and how often?
 - Walking
 - Running
 - Gym
 - Team Sports
 - Other
- If you selected “Never” for all of the above, what are some reasons that keep you from exercising?
 - It’s boring
 - It takes too much time
 - It’s a hassle to go to the gym
 - I’d rather hang out with friends
 - I’d rather work
 - Other
- What might make you be more physically active than you are?
 - Having a workout buddy
 - Making exercise feel like a game
 - Short intense bursts of activity during the day
 - Not having to somewhere specific (gym)
 - Other

Game

- Did you enjoy the game today?

- What aspect of today's game, if any, did you find fun?
- What aspects did you find frustrating?
- Was the goal clear? What would have helped?
- Was it too easy/difficult? Why?
- What did you think of the duration of the game (too short, long, just right)?
- What did you think of using physical activity as game input?
- What did you think of the game style (short, physical, social)?
- Did you feel like you got a little workout?
- What did you think of the voice interaction with the game?
- Was this a social activity or a physical activity for you?
- Would you play again?
- Would you want to invite your friends to play?
- Do you have other comments?

Appendix C

Post Playtest Interview

Gameplay

- Did you have fun?
- Were the missions interesting?
- Was there enough physical activity in the game?
- Was it useful to see your teammates on the map?
- Were you ever annoyed trying to locate the invisible Power Core?
- Did you ever wish you did not have to look at your phone?
- Did you like the three types of missions?
- What did you enjoy doing the most?
- What other things would you like to see on the screen?
- Were GPS inaccuracies frustrating?
- What did you think about communicating with your teammates in real life?
- Did you feel like you were on a mission to conquersave the earth?

Suggestions

- Would you like an audio only version of Spellbound?
- What if instead of this play area you could play all day and from anywhere?
- Would you like a more involved story and longer gameplay?
- Would you like to see a directed in-game tutorial that showed you how to play?
- Would you like a soundtrack to the game?
- Would you prefer more spoken dialog?

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