GAME BASED REHABILITATION

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Game Based Rehabilitation

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DEDICATION

Every challenging work needs self-effort as well as indirect support of elders. I would like to dedicate it to my sweet and loving

Father & Mother

Whose affection, love, encouragement and prayers of day and night make me able to get success and honor.
ABSTRACT OF THE THESIS

Game Based Rehabilitation
by
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Master of Science in Computer Science
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Impaired standing balance and stroke incidences occur 800,000 times every year and are expected to rise as the population ages. The neurological impairments that can result from a stroke incident include hemiparesis (paralysis of one side of the body), coordination difficulties, apraxia (inability to perform particular purposive actions), and impairments in postural control that have a detrimental effect on a person’s functional ability and increase their risk of falling.

The use of exercise and conventional physical therapy is one way and is considered the standard way of improving the standing balance. Although the conventional physical therapy has often been shown to improve balance and mobility, poor adherence and inadequate exercise techniques often result in poor outcome for the patient and delay their balance recovery.

There is growing evidence that the game based rehabilitation for balance control improves the body balance. The primary measure to balance stability is the center of pressure of the body. Currently the physical therapist has no validated system to precisely quantify center of pressure, an important component for standing balance. However Nintendo Wii Balance Board (WBB) is able to measure this center of pressure and it can be used to monitor sensitive change in the balance. Hence coupling the game based rehabilitation with the WBB results in a useful rehabilitation tool for recovering standing balance. Given that the WBB is portable, widely available, and a low cost, it can provide the average clinician with a standing balance game based rehabilitation tool suitable for the clinical setting once software is provided.
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CHAPTER 1

INTRODUCTION

Standing balance is an important ability especially with older generation people or with a stroke incidence. It has been estimated that approximately about 800,000 stroke incidence happen every year [1]. The projected number is expected to increase as the population grows. The most common neurological impairments that can result from a stroke incident are impairments in postural control that have a detrimental effect on a person’s functional ability and increase the risk of falling, hemiparesis (paralysis of one side of the body), coordination difficulties and apraxia (inability to perform particular purposive actions, as a result of brain damage). Impaired standing balance can also occur naturally as we get older [2]. Rehabilitation for the impaired standing balance is becoming necessary especially with growing stroke incidents [3]. Currently, the use of exercises and physical therapy is the common way to improve the standing balance [4]. Even though the physical therapy is considered the standard treatment and has shown to improve the balance mobility, often poor adherence and inadequate exercise techniques result in poor outcome for the patient and in turn delay their recovery. There has also been growing evidence that game based rehabilitation will improve the body balance functionality and reduce the risk of falling [5].

The key measurement in body balance stability is the center of pressure of the body [6]. However, there is currently no validated system, which can precisely quantify the center of pressure of the body. The recent introduction of commercial activity promoting gaming systems such as Nintendo Wii [7], Dance Dance Revolution [8], Sony Eye Toy [9], and Xbox Kinect [10] require player physical motion and, in some cases weight shifts as an input tool to control the gameplay. These activity promoting gaming systems are introduced as a tool to motivate sedentary gamers, but they could also be used as an effective interface for game based rehabilitation to replace visual feedback exercises and to monitor even more precise balance changes as the visual feedback exercises are often error prone.
Commercial activity-promoting gaming systems provide a potentially attractive means to facilitate exercise and rehabilitation. One among them is Wii Balance Board (WBB). The force plate is the most widely accepted tool for assessing standing balance and WBB is an example of it [11]. WBB has shown to measure the center of pressure and it can be used to monitor sensitive change in the balance [11]. It is portable, inexpensive (~USD$100) [12]. Hence coupling the game based rehabilitation with the WBB results in a rehabilitation tool for recovering standing balance. We have developed a computer video game that uses WBB as an interface. The goal is to provide a center of pressure-controlled video game to improve the standing balance exercise for dynamic balance control. We expect the motivational and challenging aspects of the video game to increase the subject’s desire to perform the exercise and complete the rehabilitation process.

1.1 Rehabilitation

Rehabilitation exercises are essential in progressing the recovery of people with diminished motor skills. Several factors can contribute to the degradation of our balance system, such as decrease in processing efficient sensory information with age, disabling neurologic and musculoskeletal conditions and repeated falls or near falls can lead to a decline in performance. This may in turn result in self-induced functional limitations [13]. Walking and standing balance involves many essential motor and sensory processes such as central nervous system (CNS), spatial orientation and attention. Feed-forward cognitive science illustrates the desired future behavior or path to a goal and initiates preparatory movements used to maintain balance for anticipated disturbances. Feedback information is used in response to unexpected disturbances or when preparatory movements fail. Experience plays a role in being able to better anticipate disturbances [14]. CNS interprets sensory information from visual, vestibular, and somatosensory inputs. Vestibular and somatosensory inputs are complex sensory systems in the human body, which contributes to balance and the sense of spatial orientation. The CNS can then take preventive and corrective actions and mediate between conflicting sensory information [15, 16]. Each sensory input provides unique information regarding the alignment and relative motions of internal or external references. In the absence of one these inputs, balance can still be maintained but the compensatory actions become larger.
Balance impairment, mobility restriction and falling are serious problems facing older adults and many people with neurologic disorders (ex: stroke, traumatic head injuries, spinal cord injuries, Parkinson’s disease, multiple sclerosis, diabetic peripheral neuropathy). Moore et al. explain the linkages between individual ageing and the prevalence of various chronic health conditions, functional limitation and receipt of help in activities of daily living. Their analysis imply that increase in demand for a range of health related services will be 50% to 100% greater than the growth in the total elderly population [17]. In another study conducted by Boult et al. concludes that in future, the primary prevention or effective treatment of cerebrovascular disease, arthritis, and possibly coronary artery disease may produce a modest reduction in the incidence of severe functional limitations [18]. For many of these populations, even small disturbances result in a fall, increasing the likelihood of an injury. Mobility limitations and increased fall risk will precipitate patient dependency on assistance for basic activities of daily living. This in turn will result in reduced levels of physical activity.

Medical research related to the treatment and management of neurologic conditions has focused on minimizing brain injury in the acute phase, promoting early restoring of the flow of blood from the ischemic brain, developing neuroprotection drugs, and replacement drug therapy. Another treatment is to promote functional improvement in balance and mobility through rehabilitation.
CHAPTER 2

BACKGROUND RESEARCH

2.1 GAME BASED REHABILITATION

The concept of game based rehabilitation and serious games has gained much interest in recent years. Rehabilitation is used to perform biomechanical exercises to recover neuromotor abilities [19]. Lloyd Mudiwa’s research shows that patients with neurological and vestibular diseases could benefit from incorporating popular video-game consoles into balance rehabilitation program [20]. Video-game based rehabilitation has shown to replace traditional rehabilitation exercises in brain injury such as traumatic brain injury and stroke [21]. Borghese et al. has presented with a novel game engine specifically designed to guide rehabilitation at home [22]. Video games are considered more entertaining, motivating and engaging their users. Mainetti et al. went a step ahead and shown that video games can be integrated into the infrastructure that allows patients discharged from the hospital to continue rehabilitation at home under remote monitoring by the hospital [23]. There is also evidence that rehabilitation for upper limb stroke has been accomplished by video game principle [24]. Ricardo Dorigueto has evaluated the balance rehabilitation with virtual reality games in elderly and vestibular disorders and the results suggest that virtual reality games are effective in improving the dynamic balance in older people with balance disorder [25].

2.2 SERIOUS GAMES

Serious games are games that are designed for other than pure entertainment. Serious game applications designed and implemented for military, clinical settings, educational purpose and in government have produced positive outcomes [26]. The study by Bolliger et al. has shown that learning perception with the use of interactive tutorials has shown significant benefits [27]. Currently, the majority of the serious games are used for training purpose in different fields such as training on aircraft repair, train employees on board. Part
of which is because of the introduction of attractive game interfaces into the global market. In 2013 “Playing to Win: Gamification and Serious Games in Organizational Learning” survey conducted by Association for Talent Development (ATD) formerly known as American Society for Training and Development (ASTD), 25 percent of responding organizations indicated that they are using gamification for training and development [28]. Gamification is the concept of applying game mechanics and game design techniques to engage and motivate people to achieve their goal.

Given the growth in the serious games and the gamification market for rehabilitation purpose. Researchers, clinicians and physical therapists can take advantage of game consoles such as WBB as a rehabilitation tool for game based rehabilitation. Using these ideas and results, we have developed a video game specifically targeting for rehabilitation of standing balance. Our video game uses a PC and the WBB as an interface. We hypothesize that the video game will increase the player’s desire to perform their rehabilitation exercises. Therefore, the patients should exhibit improved dynamic balance control post game sessions.

2.3 PROPRIOCEPTION

Proprioception is the sensation of balance, position or posture due to stimuli, originating from within the body, which stimulates receptors located within our muscles, tendons, joints and the vestibular apparatus of the inner ear. The stimuli receptors referred within our body are called proprioceptors [29]. Proprioception has been shown as an important tool in preventing and rehabilitating athletic injuries [30]. Kelly Westlake et al. conducted randomized controlled trials to investigate the effect of sensory-specific balance training on proprioceptive reintegration [31]. The subjects in their study were 36 older participants who were healthy. Subjects were randomly assigned to a balance exercise group or fall prevention education group. The aim was to measure the center of pressure (COP). The results of their study shows that the short-term enhanced postural responses to proprioceptive reintegration following sensory-specific balance exercise program were supportive. Researches are also using proprioception in balance training and have had positive response. Nagy et al. conducted 8-week training course on elderly people and young subjects [32]. Static postural stability was measured during standing on a single force platform first with eyes open and then with eyes closed. Sway of the body was analyzed on a
force plate in elderly and young subjects. The results suggest that the participant’s balance confidence and the control of the balance improved in response to the training. Based on the above study and research, we have tried to incorporate the sensation of balance and posture of the body when there is no direct output seen on the screen using blackout mats (see Section 7.2.5). This has been accomplished by taking away the visual for a short length of the game to activate the proprioceptors in the body.

**2.4 Game Interfaces and Wii Balance Board**

Activity gaming systems (see Chapter 1) provide a potentially attractive means to facilitate exercise and can be used as a tool to increase the activity levels in otherwise sedentary gamers. The commercial gaming systems are relatively inexpensive and can be located in a person’s home, making more convenient.

Out of the activity gaming systems we chose the WBB as it is simple sophistication and a large user base with home and clinical based user interface for rehabilitation and exercise [33]. Using the Wii Sports has been cited as a possible tool to enhance the process of rehabilitation. Anecdotally, the Wii is used in a number of settings within the National Health Service (NHS) in the United Kingdom [34], such as for the elderly and patients with pathologies (stroke, amputation and Parkinson disease). The Wii has also been employed to facilitate rehabilitation at Department of Veterans Affairs (VA) centers in the United States [35]. In 2007, seven VA facilities reported having a Wii, but by 2008, more than 80 facilities reported having at least one Wii [28]. For patients with amputation, Nintendo requested that Ossur UK (Manchester, United Kingdom), a manufacture of prostheses for people with lower-limb amputation, produce an advisory document on the suitability of Wii exercise as a recreation or rehabilitation tool [36]. These guidelines have been adopted by the British Association of Chartered Physiotherapists in Amputee Rehabilitation, who produced a document aimed at guiding therapists using Wii Fit with patients with amputation in the NHS [37]. A case study of an 89-year-old multiple faller who attended six 1-hour treatment sessions of Wii Bowling showed improved balance and possibly reduced the risk of falls [38].

The WBB is shaped like a household body scale, with a plain white top and under (Figure 2.1, Figure 2.2). It runs on four AA batteries as a power source, which can power the
board for about 60 hours. The board uses Bluetooth technology for communications and COP sensors that are used to measure the user’s center of pressure (the location of the intersection between an imaginary line drawn vertically through the center of mass and the surface of the balance board) and weight.

Table 2.1. WBB Dimensions and Weight

| Dimensions | 2.09 inches (h)  
|            | 20.12 inches (w)  
|            | 12.44 inches (d)  |
| Weight     | 7.72 pounds       |

Figure 2.1. Wii balance board topside.
Figure 2.2. Wii balance board underside.
CHAPTER 3

GAME DESCRIPTION AND FRAMEWORK

3.1 GAME DESCRIPTION

Our game prototype is developed using Microsoft XNA 4.0 game framework. The game is fully compatible with a PC and uses the WBB as an interactive input device. The WBB device is connected to the PC via Bluetooth.

The balance board has four sensors located on the underside corners of the board (Figure 2.2). The sensors have the capability of measuring the COP. The WBB broadcasts the data in the form of X and Y coordinates. Rather than being used/transmitted to the Nintendo Wii console, the data from the sensors are captured by the PC using Bluetooth. Our prototype gets the X and Y coordinates from the balance board and processes those as input to the game.

Within the game, the player is presented with a ball and a tilting board with obstacles and a finish hole on it. The player must shift the weight while standing on the WBB such that the ball gets to the finish hole evading any obstacles, which are on the board. The board tilt motion is accomplished by leaning while standing on the balance board.

To challenge the user, obstacles on the board in the video game are placed in such a way that the user has to shift weight in all the directions in a controlled manner and maintain the weight shift. In more advanced levels of the game, the screen blackouts for a short length of the board using blackout mats (see Section 7.2.5). However the game will be running in the background during the absence of a visual. This technique is designed to test the proprioception of the player (see Section 2.3).

The game has scoring which depends on the time taken for the ball to make it to the finish hole and the number of levels completed at the end. The game also has sound on the background to keep the player engaged in the game. Table 3.1 shows the summary of the game levels.
### 3.1 Game Levels Summary

<table>
<thead>
<tr>
<th>Levels</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>No barriers</td>
</tr>
<tr>
<td>Level 2</td>
<td>Barriers</td>
</tr>
<tr>
<td>Level 3</td>
<td>Barriers + blackout mats</td>
</tr>
</tbody>
</table>

### 3.2 Microsoft XNA Game Programming Framework

Microsoft XNA framework is provided by Microsoft and is a set of tools with a managed runtime environment that facilitates video game development and management. XNA Game Studio is a collection of tools based on Visual C# and the .NET Framework Common Language Runtime (CLR) that makes it easier to write games for Windows and the Xbox 360 game console. XNA provides developers with a skeleton to begin with and to develop and manage our own game.

XNA Game Studio uses the XNA Framework Content Pipeline, which facilitates incorporating content such as sounds, images and game models into the game. One of the reasons for its popularity is its ability to develop games for both PC and Xbox 360 consoles thus, giving it a wider audience. And the icing on the cake is the fact that it is free to use for all education related purposes. The XNA game studio 4.0 runs on multiple version of Microsoft Visual Studio 2010. The developer has to first install either Visual Studio 2010 Standard Edition or higher to install the XNA game studio. The setup for XNA game studio is straightforward and has easy to follow instructions with the download file [39].

I chose to work with the XNA game-programming framework due to its powerful capabilities in the 2D and 3D game design technology. XNA has the capability of executing the programs in a loop-based environment and therefore the game is automatically always refreshed. Portability of XNA game from one platform to another is added advantage of using XNA game studio. XNA is non-event driven programing with high-performance memory framework, which gives it faster runtime execution environment. Moreover the basic XNA game engine is already in place for the developers to start their own game.
CHAPTER 4

GAME DESIGN

XNA consists of boilerplate code that interacts with low-level graphics including audio and input hardware. XNA supports different platform and makes it easy by abstracting the low-level hardware code. XNA provides a broad framework to decode player’s input, game state management, game window management, the game loop to update and draw the game, graphics methods to optimize the 3D graphics, audio management and basic user interface controls to streamline the game development. Segregating the game logic and game visuals from low level engine code makes it helpful for game developers/programmers to focus on gameplay.

4.1 GAME DESIGN DETAIL

Unlike Windows applications where most of the applications are event driven, games are not event-driven. Game programs have a game loop that is continuously active, constantly processing player input and updating the state of the objects that exist within the game world. The loop (game loop) executes 60 times per second. Therefore the objects in the game play appear to be active all the time, even when the player is not active.

In XNA games, the game loop is already managed for the game developers. The XNA game exposes certain game state changes in the game loop processing. The most notable of these methods are:

4.1.1 Initialize

This method is invoked before the game enters the loop. It is the constructor for the game. The logic that should happen or the initial environment for the game code happens in this method. We have created game objects such as SplashScreen, Backgrounds, Level1, Level2 and Level3 and start up tasks such as SplashScreen.SetData(Title, GameState) and
Components.Add(Background) in this method. Those objects declared in the initialize method will exist as long as the game is running.

4.1.2 LoadContent

This method is called when your game has graphics resource to load. This method is called only once.

4.1.3 Update

This method is part of the loop where it will be called once per iteration of the game loop. Typically the update method has the actual game logic in it. The logic will mainly involve processing the player’s input and updating the game state and the game objects. For example, if we discover that the player has leaned towards forward on the WBB, that means the table needs to be tilted and the ball should move towards the gravitational force.

4.1.4 Draw

This method is also part of the game loop. It is called once per iteration of the game loop which means that the game screen is cleared and redrawn every 16 milliseconds. Typically, we will draw any visible game objects on the screen to the player.

4.1.5 UnloadContent

Typically there needs to be a method to unload the game objects at the end of the game. This method servers that purpose. This method is called only once. But is mainly used to unload graphics related objects.

Figure 4.1 [39] shows the lifecycle of the XNA game, complete with the Update and Draw method forming a game loop.
CHAPTER 5

GAME ARCHITECTURE

5.1 Input/Output

The balance board communicates with the PC using Bluetooth. When the WBB is connected to the PC, the input to the game is the center of pressure in the form of X and Y coordinates, which is broadcasted by the Nintendo WBB. The X and Y coordinates are then processed and converted to reflect in the game screen by corresponding tilt motion of the game board. The ball movement in the game is in response to the board tilt motion. The game uses a set of libraries (WiimoteLib) to communicate with the Nintendo WBB. The library is freely downloadable [40].

5.2 About WiimoteLib

Nintendo WBB and Nintendo Wii Remote are the controllers for Nintendo Wii system. The controllers for the Wii system communicate via Bluetooth. Because of that, we can leverage these controllers for our game as they communicate via the Bluetooth protocol. When the WBB is paired with the PC, it will be identified as a human interface compliant device (HID). Hence to connect to the device, we must use the HID and Device Management Win32 APIs. Unfortunately, there is no built-in support for these APIs in the current .NET runtime. But these APIs are defined in the Windows Driver Kit (WDK). P/Invoke allows to directly call the methods of the Win32 API from .NET. The WiimoteLib library in our game code provides these calls to the Windows Driver. The process to begin communicating with the WBB is as follows:

1. Get the GUID of the HID class defined by Windows
2. Get a handle to the list of all the devices which are part of the HID class
3. Walk through those devices and get detailed information about each
4. Compare the product ID and the vendor ID of each device to the known WBB product ID and the vendor ID
5. If found, create a FileStream to read or write to the device
6. Clear up the device list

WiimoteLib for using with a Nintendo WBB is most famous library on the web [41]. It has good reviews by the users who express love for this library. The fact that the library is stable, free, easy to use and embed, gave us reason to use the library in our game code as oppose to writing one by ourselves. Out of the box the library provides the following namespace:

```csharp
namespace WiimoteLib
{
    public class Wiimote : IDisposable
    {
        public Wiimote();

        public string HIDDevicePath { get; }
        public Guid ID { get; }
        public WiimoteState WiimoteState { get; }

        public event EventHandler<WiimoteChangedEventArgs> WiimoteChanged;
        public event EventHandler<WiimoteExtensionChangedEventArgs> WiimoteExtensionChanged;

        public void Connect();
        public void Disconnect();
        public void Dispose();
        protected virtual void Dispose(bool disposing);
        public void GetStatus();
        public byte[] ReadData(int address, short size);
        public void SetLEDs(int leds);
        public void SetLEDs(bool led1, bool led2, bool led3, bool led4);
        public void SetReportType(InputReport type, bool continuous);
        public void SetReportType(InputReport type, IRSensitivity irSensitivity, bool continuous);
    }
}
```
public void SetRumble(bool on);
public void WriteData(int address, byte data);
public void WriteData(int address, byte size, byte[] buf);
}

To start with, we need to initiate the Bluetooth connection between the PC and the
WBB. The following code accomplishes the connection in BalanceBoard.cs
Wiimote balanceBoard = new Wiimote();
balanceBoard.Connect();

After the connection is successful, we set the light emitting diode (LED) on the
balance board to indicate the connection has been established. The following code sets the
LED in BalanceBoard.cs
balanceBoard.SetLEDs(1);

Our code interacts with the balance board to get the coordinates of the center of
gavity. The following code fetches the X and Y coordinates from the balance board in
update methods of Level1.cs, Level2.cs and Level3.cs
WiimoteState wiiState = BalanceBoard.getBalanceBoard().WiimoteState;
BalanceBoardState balanceBoard = wiiState.BalanceBoardState;
xCoordinate = balanceBoard.CenterOfGravity.X;
yCoordinate = balanceBoard.CenterOfGravity.Y;

The game uses the above X and Y coordinates from the WBB to act as the controller
during the game play. The Bluetooth connection to the WBB is automatically dropped off
when the game finishes.

The author of the WiimoteLib library maintains a list of .NET applications that use
WiimoteLib. Our rehab game software has been recognized and listed in the list of .NET
based wiimote applications [41].
CHAPTER 6

REQUIREMENTS AND GETTING STARTED

6.1 REQUIREMENTS FOR THE GAME

1. Rehab-game game software. The software can be downloaded from Github. No login is required to download the software.
2. WBB device
3. Windows operating system (Windows 7 versions and up)
4. Bluetooth capable PC or external Bluetooth device
5. Inbuilt speaker or external speaker for audio output. Although, the game software works without the speaker, it is recommended to have the audio as it enhances the engagement of the player into the game

6.2 GETTING STARTED WITH THE GAME

The following these step-by-step instructions will help in getting started with the game.

1. Download the game software. The total size of the software is almost 60MB
2. Unzip the downloaded file by right clicking on it and select “Extract All…”
3. Enter into the unzipped folder and you should see the following three items:
   - Application Files
   - rehabGame
   - setup
4. Install the software by double clicking the setup file
5. You might be prompted with the security warning, but click on the Install
6. Now you have the game software installed on your PC. But wait, before you start the game, the WBB needs to be connected first
7. Connecting the WBB to the PC is known to be the biggest sticky point of all. The WBB might not pair with and communicate with every Bluetooth device available. However, the following steps are known to work:
   a. Start your Bluetooth software on PC and have it search for a device
b. On the WBB, open the battery cover on the under side and hold the little red sync button

c. The WBB should show up in the list of devices as Nintendo RVL-WBC-01. If it isn’t there then start all over again from Step A

d. Click next to move your way through the installation wizard. If at any point you are asked to enter a security PIN, leave the number blank or click skip. Do not enter any number as it is not required

e. Now go back to the initial unzipped folder and double click on rehabGame application file to start the game

f. You should see that a blue light is solid on the WBB after you see the welcome page of the game. If you don’t see the blue light blinking or no light at all then go to step A and redo the steps all again.

g. If the WBB continues to not function, you likely have an incompatible Bluetooth device

8. That’s it. You are all set to play the game
CHAPTER 7

GAME OVERVIEW

7.1 CLASS DIAGRAM OF THE GAME CODE

Figure 7.1 represents the flow of the game in a class diagram view.

7.2 GAME PLAY

7.2.1 Game Start

The game begins with a welcome message on the screen. Prompting for an Enter key to start the game. The game starts with the first level. There are a total of 3 levels with increasing difficulty of order. Figure 7.2 shows the screenshot of the welcome screen. The background image has been taken from Nintendo [7].

7.2.2 Level 1

Level one has the simplest board without obstacles on it. Each level has 4 boards and every board has 30 seconds to complete. The top left on the screen shows the score of the game. The score is updated as soon as the player makes it through the board. Figure 7.3 shows the screenshot of the level 1 board. There are four boards of this kind in level 1 with finish holes placed on 4 different edges on each of 4 boards.

7.2.3 Change of Levels

Once all 4 boards of level 1 are complete, the game brings up the level change screen where the game is paused, and waits for the player to press Enter. It gives enough time for the player to get comfortable for the next level. Figure 7.4 shows the change of level screen.
Figure 7.1. Game class diagram.
Figure 7.2. Welcome screen screenshot.

Figure 7.3. Level 1 screenshot.
This level has a tougher board with hurdles on the board. The hurdles obstruct the ball movement and force player to pay more attention to the time. As said earlier the player has only 30 seconds to finish the board by rolling the ball to the finish hole. The Figure 7.5 shows a simple screenshot of the level 2.

7.2.5 Level 3

This level has the toughest boards. The board not only has hurdles on them, but also has blackout mats motivated by Nagy et al. [32] (see Section 2.2). Blackout mats blocks the display on the monitor when the ball is in contact with the mat. However the game is running and the ball movement will be happening in the background. The player has to carefully examine the game board and remember the board where the hurdles and finish hole are. The games will blackout the image, so the player must rely on his/her memory of the board. Figure 7.6 shows the screenshot of level 3 boards.

To make it harder, there are special cases in level 3 where the finish hole is inside the blackout mat, which takes a good sense of body balance and decision-making skill to exactly roll the ball to the finish hole. Figure 7.7 presents the screen shot of the special case where the finish hole is inside the blackout mat.
Figure 7.5. Level 2 screenshot.

Figure 7.6. Level 3 screenshot.
Figure 7.7. Level 3 special case screenshot.

Figure 7.8 shows the screenshot when the game is in the blackout state.

Figure 7.8. Level 3 blackout screenshot.
Figure 7.9 is the last board before the game completes. As shown the finish hole is in between the two adjacent blackout mats. This scenario makes it challenging for the player to complete as the player can barely see the ball movement.

![Figure 7.9. Level 3 end screenshot.](image)

### 7.2.6 Game Over

There are two ways the game can end.

1. The player timed out
2. The player finished all levels

The player time out can happen on any level if he/she takes more than 30 seconds to finish the board. On the other hand the game ends when he/she finished all the levels in the game.

The game over screen also has the end score. Figure 7.10 shows the sample game over screenshot. The score depends on how quickly the player completes the levels and also the number of levels completed by the player.

The player earns the game points as follows:

1. 50 points for every level completion
2. The equal number of points of time (seconds) spared by the player for every board in the game
Figure 7.10. Game over screenshot.
CHAPTER 8

RESULTS

8.1 USES AND FEEDBACK

The San Diego State University has the Fitness Clinic located in Peterson Gym, Room 151A [42]. The fitness clinic is for individuals with disabilities through the School of Exercise and Nutritional Sciences. The Fitness Clinic serves a wide variety of physical disabilities for those from San Diego and offers them an opportunity to reach their fitness and exercise capabilities. Clients’ ages from 2 to 98 years come to Fitness Clinic to develop skills to manage their disabilities. We were fortunate to have our game played by 3 people who were post stroke patients and one with advanced disability. The game was played 2 times every session with each session lasting for about 20 to 25 minutes. There were 2 sessions every week, 2 people played the game consistently all the way through the 4th session. The players commented that the game is enjoyable and most importantly playable by them. The players game scores were improved and showed progress in the levels completed every session. They were able to reach to the 3rd level of the game, but no one completed the game due to the difficulty level of Level 3. However the developer and others were able to complete all the 3 levels of the game.
CHAPTER 9

TROUBLESHOOTING

When a problem occurs while playing, don’t panic, instead, work the following way through some basic troubleshooting techniques and try to solve the problem.

9.1 GENERAL TIPS FOR TROUBLESHOOTING

- **Always check for the Bluetooth connection:** Many computer problems are related to an issue in the connections. The easiest first step to troubleshoot is to disconnect and reconnect the WBB (see Section 6.2).

- **Isolate the problem:** If possible try to isolate the problem. For example if the game does not pick up the WBB, try to determine if the issue is with the WBB. If you have an extra WBB, you can alternate devices to see if the connected has the issue. When trying to isolate the problem, only make one change at a time.

- **Log messages:** Although log messages speak less for an end user, it might be helpful with a little bit of technical knowledge. The game logs the messages into a file called log.txt. The file can be found inside the working drive. Normally the root directory of the operating system typically C drive of the PC.
CHAPTER 10
CONCLUSION AND FUTURE WORK

10.1 CONCLUSION
The outcome demonstrates that the dynamic balance exercise can be effectively coupled to video game play. In addition to the application being enjoyable, it is affordable for at-home subjects and for clinical settings. This makes therapy approach cost effective. The built in proprioception test (see Section 7.2.5) inside the application makes the player motivated, challenged and keeps the player in the game while playing. We expect the patients to prefer playing the game over the standard therapeutic activities.

10.2 FUTURE WORK FOR GAME DEVELOPER
Since the project is the first of its kind, I call this version 1.0. There are enhancements that could be made in the future releases to make this game-based rehabilitation more interactive and effective.

Some of these include:

- The game laid the foundation and improvements could be made by introducing an interface with the therapist to know the progress of the game.
- Game configuration management could be implemented such as the therapist might want to redesign the board to make hurdles smaller or easier for the patient.
- It would be realistic if the therapist could receive/access the rehabilitation improvements such as patients playing the game at home want to transfer the game results to therapist in their office.
- The ability to record the day to day game progress in a database organized by patient ID
- The game has room for adding more levels in future releases.
REFERENCES


APPENDIX A

DEVELOPER GUIDE

The entry point for the game code starts with the Game1.cs file. It performs the initialization before executing the game. Game1 is also responsible for loading the content that the game code uses in its lifetime.

The following folder hierarchy is used to store the resources in GameContent resource folder.

**Game Audio**: Audio

**Spritefont**: Fonts

**3D Models**: Models

**Images**: Textures

Each level in the game is controlled and isolated by separate game components. It makes it easy to add an additional level on demand by just creating a game component and looping the component into the game in Game1.cs

The Log.cs file is the logger throughout the game execution. It is highly recommended to use the logging mechanism to make it convenient while debugging in case of exceptions. The logs are logged to a text file called log.txt in the parent directory of the PC.

The game has no mechanism to automatically record the scores of individual players. It could be accomplished by maintaining a database in the background and updating accordingly.
APPENDIX B

BRIAN PEEK
.NET-based Wimote Applications

The following is a list of the applications that I know about using my .NET Managed Library for the Nintendo Wimote:

- Retab Game by Stekken Memon
- Wii Remote Program Add-In for PowerPoint by Jeremy W
- PAL4TPS by Michael
- Wii-Physique by Michael and Eric
- Wimote controlled Lyric arm by Jesper Karlsson
- WaiControl and Tablet Interface by Aamir Mittal
- Wii Remote Dodgeball by John Licato
- Wagoop for Gameloft
- WiiWiiCracking by Joe King
- WiiHouse by Aaric Marginhoard
- WiiBox by Brian Oullette, Dave Odom, Matthew Brooks, Roy McCard
- LightShow Pro by David Johnson
- WiiCMI by Jorgen Niedenmann
- Wii Drum Synth by Richard Pope
- Windows Media Player Controller by Milot Shaha
- Wii Drum Mga by Zhao

A Wii Trainer by Ken Moore

http://brianpeek.com/page/net-based-wimote-applications