Interactive Virtual Reality Fitness Game using Microsoft Kinect (KineFit)

by

Mohd Zuhairi Bin Mohd Zubir

Dissertation submitted in partial fulfillment of

the requirement for the

Bachelor of Computer Information Sciences (Hons)

(Information and Communication Technology)

SEPTEMBER 2011

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Interactive Virtual Reality Fitness Game using Microsoft Kinect (KineFit)

by

Mohd Zuhairi Bin Mohd Zubir

A project dissertation submitted to the

Information and Communication Technology Programme

Universiti Teknologi PETRONAS

In partial fulfillment of the requirement for the

BACHELOR OF COMPUTER INFORMATION SCIENCES (Hons)

(INFORMATION AND COMMUNICATION TECHNOLOGY)

Approved by,

(AP Dr. Dayang Rohaya Bt Awang Rambli)

DAYANG ROHAYA AWANG RAMBLI
Associate Professor
Computer and Information Sciences
Universiti Teknologi PETRONAS
31750 Tronoh
Perak Darul Ridzuan, MALAYSIA

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Zuhairi Bin Mohd Zubir

ABSTRACT

KineFit is an interactive Virtual Reality (VR) fitness training application that utilized the Kinect sensor as its main input device. Kinect offers a controller-free gaming experience where user interacts with the game environment by using their whole body, hence, making the experience more natural and immersive. The game is incorporated with a gesture-based interface that removes any use of mouse and keyboard as a means to navigate the game environment. Moreover, this project is undertaken to motivate exercise as well as to inculcate healthy living culture among Malaysians since obesity has becoming a critical issue in the country lately. In addition, the lack of exercise is one of the primary reasons that lead to obesity, which in turn is caused by the lack of time, motivation and dull exercise routine. Furthermore, most video games are desktop-based environment that limits the users' movement, thus, promoting sedentary lifestyle. Hence, KineFit is undertaken to change the current attitude and moves towards active lifestyle. Currently, KineFit consists of two exercise modules but flexible for expansion and uses only the Kinect sensor as the input device. This project implemented the incremental model which offers flexibility in time, requirements, manpower and risks. A total of 14 users participated in 2 different prototype testing to test the usability of the system and the users' perception of the game on their motivation, engagement and enjoyment to perform the exercise. The result of the first prototype testing is encouraging as users felt motivated to complete the exercise while having fun at the same time. The users suggested that the modules should be refined for better user engagement. The second prototype testing improved in terms of engagement as the exercise modules are changed based on data gathered on the first prototype testing. Suggested future works for expansion are by adding a jogging module and implementing an Artificial Intelligence (A.I) on character that is able to interact with the user to give the game more depth, motivation, engagement and importantly, enjoyment of performing exercise at the comfort of users' living room.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 PROJECT WORK BACKGROUND

Virtual Reality (VR) refers to the use of computer graphic system to provide a 'virtual' or 'synthetic' immersive experience in an interactive 3D environment. The door to VR has been successfully opened by Ivan Sutherland through his invention of the first head mounted display in 1968. From there, many devices such as the virtual cockpit in 1987 emerged to make the users feel immersed in a synthetic space. In 2006, Nintendo released the Wii that is capable of motion sensing which allows users to interact with virtual objects using gestures powered by optical sensor technology. Recently, the interest in VR grows further with the release of Microsoft's motion sensor, Kinect.

Microsoft marketed the Kinect sensor as a 'controller-free gaming and entertainment experience' for the Xbox 360 game console. It can track full-body motion and provides facial and voice recognition. It's a milestone in the line of VR devices as users don't need to wear special gears to immerse themselves in the virtual environment. Aside from its low price tag of RM 450, it eliminates the physical boundaries between the physical world and the virtual world, thus creating a more effective sense of vivid presence in the synthetic environment.

By integrating the Kinect sensor with VR, it provides a powerful combination in an exercise environment. Recently, video games with motion controllers have been proven to increase energy expenditure which provides benefits by reducing sedentary activities (Lyons et al, 2011). With the integration of Kinect for this project, dubbed as 'KineFit', it can provide more effective interactivity in exercise compared to the Wii Remote. Thus, an interactive VR fitness video game provides superb alternative and capable of solving common problems associated with exercise routine.

1.2 PROBLEM STATEMENT

According to World Health Organization (WHO), Malaysia is ranked sixth among Asian countries with high adult obesity rate (Top News US, 2010). The Malaysian government has been serious in fighting obesity with the latest action to record Body Mass Index (BMI) of students in report cards (Pak, 2011). In addition, the government said that one in six Malaysians is either overweight or obese. Obesity can be defined as the state of abnormal fatness that leads to critical health problems such as heart failure and diabetes. Disturbingly, around 1.5 million of Malaysians have diabetes which is primarily caused by the lack of physical exercise (Vortex Centrum Ltd, 2011). Moreover, a large number of obesity cases are due to extreme caloric consumption and lack of physical exercise (Lau et al, 2007). The lack of physical exercise has been revealed by WHO as one of the leading cause of 3.2 million people's death each year (AFP, 2011). Thus, the lack of physical exercise has been identified as the key problem in this project and is contributed by lack of time, motivation and dull exercise routine.

- **<u>Lack of time</u>**

According to Malaysian Employment Act, a typical working individual has to work a maximum of 8 working hours per day. On the other hand, American Time Use Survey (ATUS) revealed that working and related activities accounted for 8.7 hours on an average work day for employees' ages 25 to 54 with children (Bureau of Labor Statistics, 2011) as shown in Figure 1. Figure 2 showcases that individuals age 15 and above spent 5 hours on leisure and sports activities. Disturbingly, watching TV accounted for 2.8 hours while only 19 minutes is spent on sports, exercise and recreation activities. Thus, individuals especially the working group has limited time to conduct physical exercises. More often, they would prefer watching TV, playing games and spend quality time with their family when there are not working, especially during the weekend. Furthermore, physical exercises may require individuals to go to a fitness center or nearby park. Since time is of the essence, a busy individual has to adjust his or her work schedule for travelling to the nearby fitness center or park which incurs more time slot on an average day.

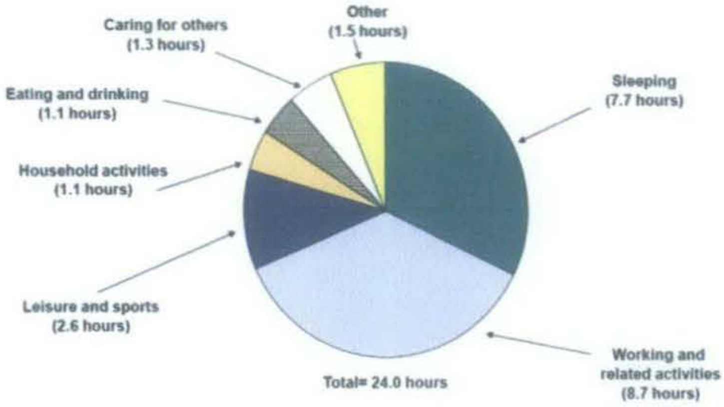


Figure 1: Average work day for employees' ages 25 to 54 with children

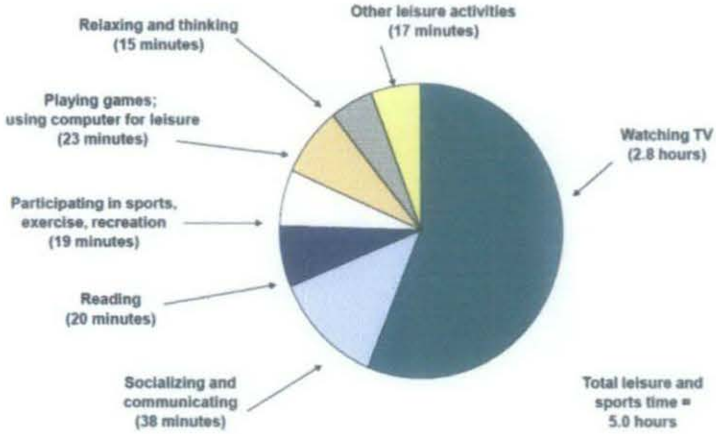


Figure 2: Breakdown of leisure me on an average day

- **Lack of motivation**

Motivation is the act of providing meaning and incentive to a behavior. In this context, it defines as the act that drives individuals to exercise. However, many individuals decided not to exercise despite the positive benefits it brings to health. The lack of motivation is counted as one of the primary reasons for physical inactivity (Canadian Fitness and Lifestyle Research Institute, 2005). Collaboration between researchers at the London Metropolitan University and fitness operator, Fitness First discovered that individuals become motivated when the staff at the fitness operator interacts with them by giving encouragement and feedback (Medical News Today, 2009). Hiring a personal trainer provides similar experiences but at a very high cost which ironically, may lead to a decrease in motivation for certain individuals. A typical cost for personal trainer in Malaysia ranges from RM 80 to

RM 150 per hour (Fitness Malaysia, 2010). On the other hand, environment factors such as weather are identified as a barrier to physical exercise (Oxford Journals , 2011). Bad weather conditions such as rain and hot temperature makes it difficult for individuals to perform outdoor physical exercise which consequently reduce their sense of motivation.

- **Dull exercise routine**

Dull exercise routine has been identified as one of the excuses made by individuals to avoid performing physical exercise (Zied & Winter, 2007). Day & Forsyth (2006) stated that it is a challenge to search for exercises program that 'excites and exhilarates' individuals. Running on a treadmill and lifting weights are the examples of typical exercise routine. Exercise routine and motivation are inter-related and a challenging process. Griffis (2009) exerted that it is a challenge to remain in an exercise routine without acquiring motivation. In essence, dull exercise routine may lead to a decrease in motivation level among indviduals and vice versa.

1.3 PROJECT SIGNIFICANCE

This project is undertaken to solve the critical issue of obesity in Malaysia that has reached critical rate as stated in section 1.2. The lack of exercise due to lack of time, motivation and dull exercise routine must be solved as exercise provides many health benefits which are covered in section 2.3. Furthermore, the combination of exercise and video game is hoped to encourage users to exercise in a fun way. Besides that, most video games are desktop based which limits users' movement and eventually promotes sedentary behavior. By implementing an interactive VR fitness game using Kinect, the problem stated in section 1.2 can be solved and potentially reduce the obesity rates in Malaysia.

- **<u>Time issue</u>**

The interactive VR fitness game allows individual to exercise at home instead of going to the fitness center or park. Thus, it saves a lot of individual's time as the experiences of outdoor physical activities are implemented in the program. By referring to figure 2, the combination of game and exercise saves time and open up time slots for end users to perform other activities in their daily life.

- **<u>Motivation and exercise routine issue</u>**

Since motivation and exercise routine is inter-related as described earlier, KineFit will implement a videogame approach to provide fun and engaging exercise activities. Furthermore, motivation issue such as bad weather is no longer valid as the program is done indoor. To further boost users' motivation level, KineFit will include motivational elements such as highlighting the benefits of exercise and fun exercise modules to keep them motivated and engaged for a long time.

1.4 PROJECT OBJECTIVES

Based on the relevancy of the project as stated in section 1.3, the objectives of this project are:

- To develop a Kinect game-based interactive VR fitness training application in order to motivate exercise as well as to inculcate healthy living culture among Malaysians
- To create a gesture-based user interface for the developed game application
- To investigate users' perception on the use of developed game on their motivation, engagement and enjoyment to perform exercise

1.5 PROJECT SCOPE

KineFit will take 1 year of project development time to solve the lack of exercise among individuals. Kinect is used as the only VR sensor for detecting full body motion of the end users. The 3D environment and objects will be created using a powerful 3D game engine called Unity3D. This tool offers superb physics engine and flexible scripting that can speed up game development process. The game's targeted group of user is 10 years old and above but will limit to 20 – 22 years old for testing purposes due to limited access to users below and beyond that range. Early in development stage, the game consists of two exercise modules which are 'Warm-Up' and 'Jogging'. However, targeted users suggested adding more gaming elements to the aforementioned exercise modules. Thus, the game now consists of three exercise modules which are 'Catch the Ball', 'Collision Attack' and 'Jogging' modules. However, the 'Jogging' module has to be suspended from development due to technical difficulties with Kinect and time constraint. However, the game will be flexible enough to achieve scalability in which new modules can be integrated in the future.

CHAPTER 2

LITERATURE REVIEW

The combination of physical exercise and video game concept has been around for almost two decades. The term is known as 'Exergaming' that applies exercise activities in video games (Sinclair, Hingston, & Masek, 2007). The introduction of the 'Power Pad' from Nintendo in 1988 allows players to control the running movement of their virtual characters by running on the 'Power Pad' (Bogost, 2005) . Currently, newer system such as the Nintendo Wii and Xbox 360 released their own motion sensor devices, Wii Remote and Kinect, respectively, that provides more interactivity and immersive experience in video game.

Research on this matter has discovered that exergaming were 6 times more likely to be retainable in comparison with physical exercise alone (Waine, 2007). Furthermore, exergaming has been credited to eliminate the notion of video gaming as merely a sedentary activity but a healthy lifestyle (Herald & Lewis, 2009). In this section, a critical analysis on existing VR application in physical exercise is undertaken on two different angles; Research projects and commercial applications that share common theme and goals with KineFit project. The critical analysis methods highlight the project features, objectives, advantages and disadvantages as well as similarities and differences to help identifying the features in KineFit project.

Lastly, a health related research on common terms are identified and explained to ensure the terms are not confused with one another. Furthermore, the features of KineFit are related with these terms to highlight the healthy benefits that it brings to the end users.

2.1 RESEARCH PROJECTS

Mokka et al (2003) developed a captivating fitness computer game in their Virtual Fitness Centre (Virku) research project that aims to motivate and enrich the exercise experience. The game features a bodily user interface that consists of an exercise bicycle and a 3D virtual environment. Interestingly, the 3D virtual environment reflects familiar real-life environment, in this case, the Ruka Hill in Finland, which is generated from the actual map information. The exercise bicycle serves as the only VR sensor whereby the pedaling effort is related to the surface profile of the virtual environment. For example, the participant will have to increase their effort when riding uphill and decreases it when going downhill. The game aim is to cycle around the virtual environment and strives to achieve the best time to complete the cycling track.

The objective of the fitness computer game in Virku is 'to integrate the features of exercise and the playing of computer games to create an immersive and motivating training session'. Based on a critical analysis on Virku, three positive aspects and one negative element of the game have been identified. Firstly, the virtual environment affects the pedaling effort by the participant on the exercise bicycle. The usage of this bodily user interface provides the sense of presence for the participants in the virtual environment. In VR, presence is defined as the feeling of being in another space that is different from the actual location due to the effects of computer-generated simulation (Heeter, 1992). Thus, the sense of presence is very important to provide the participant the excitement and achieve the 'sense of being there' in a virtual environment (Bystrom K. , 1999). Moreover, a pilot test has been conducted in Virku and showed that the familiarity of the virtual environment of Ruka Hill proved to increase the participant's motivation. The result from the pilot test also revealed that the virtual training is more enjoyable compared with the actual cycling which can be lonely and boring. However, in long term, participant might eventually get boring due to the limited choice of training routine that Virku provides. The figure below showcases the fitness computer game in action.

Figure 3: Fitness Computer Program in Virku

On the other hand, Ruttkay & Welbergen (2008) developed an Intelligent Virtual Agent (IVA) for a Reactive Virtual Trainer (RVT) project. In this project, the IVA is capable of acting similarly to a real professional trainer. It features the ability of the IVA to present the physical exercise to the participants, performing the physical exercise with the participants, monitors their movement, ensuring the exercise is performed correctly and provide feedback and motivation to them. The IVA can track the movement of the participants through the usage of a single-camera vision system based on ParleVision components. The ParleVision system can be used in many computer vision applications such as hand tracking, environment surveillance, facial expression and human pose (Human Media Interaction of University of Twente, 2010). The single-camera vision system tracks the movement of the participants by identifying color-coded markers on them.

The main objective of RVT project is to develop an intriguing IVA with rich functionalities of professional trainers. Preliminary evaluation has been conducted and revealed that participants got engaged with the IVA and made several of them sweat. The concept of motivating and providing feedbacks on participant's inaccurate exercise position are certainly intriguing. Since the RVT project is in the initial stage, the result of the evaluation showed that the IVA sometimes provide misleading 'wrong' feedback. The figure below is the screenshot of IVA in action.

Figure 4: Screenshot of IVA

Based on these two projects, several similarities and differences have been identified. First and foremost, these projects provide motivation experience to the end users. In Virku, motivation is achieved through the excitement of exploring familiar territories of the virtual environment. IVA provides similar experience as a real professional trainer by providing emphatic feedback to keep the users motivated. Apart from that, both projects successfully engaged the users through its features. Virku project's training routine proved to be enjoyable while IVA managed to engage users to perform the exercise routine.

In terms of differences, these projects use different VR input sensor to capture the user's movement. In Virku, the exercise bicycle is used to capture the user's movement in the virtual environment while IVA monitors user's exercise movement through a single-camera vision system. By analyzing these projects features, objective, advantages and disadvantages as well as similarities and differences, improvement can be made in KineFit project to solve the lack of motivation and dull exercise routine problems as stated in section 1.2.

In the RTV project, the IVA analyzes the user's motion through the use of camera and body markers placed on the users. In KineFit, Kinect is used to capture user's motion without any necessary body markers. The familiarity of virtual environment offered in Virku is taken into consideration. KineFit offers the opportunity for users to immerse themselves in a soothing virtual local environment to achieve the sense of presence as acquired in Virku. However, KineFit will offer two exercise modules, in contrast with Virku to provide more variety and engagement with the users.

2.2 COMMERCIAL APPLICATIONS

EA Sports Active 2 is an exergame developed by EA Canada and released on November 16, 2010 in North America for Xbox 360. The game provides intensive features to optimize exercise experiences (EA Sports , 2010). Uniquely, it has a built-in heart rate sensor that can track user's heart rate in real-time. The game supports wireless full body motion tracking that utilizes Kinect to register user's full exercise movements. Moreover, it has a virtual personal trainer to guide and motivate users. Apart from that, it contains a massive collection of over 70 exercises and activities to choose from as well calories counter to track user's calories burn. The VR sensors used are Kinect and EA's heart rate sensor to track full body motion and heart rate, respectively.

According to EA Sports chief, Peter Moore, the game and its predecessor are designed to provide exercise routines that focus on serious weight loss training (Totilo, 2008). He also stated that the game offers opportunity for people who don't have time to work out or uncomfortable to do so in public (Thorsen, 2008). Dr. John Porcari of University of Wisconsin concluded that this game passed the fitness guideline put forth by the American College of Sports Medicine (ACM) (EA , 2010). EA Sports Active 2 provides many positive aspects to users. The Kinect has been proved to be successful in tracking user's full body motion without the need to use a controller or body strap. The heart rate and calories counter monitoring system adds value to track user's intensity performance while the huge number of exercises can engage user's for a long time. However, the use of Kinect has been reported to require at least six by eight foot space and the Kinect is placed around three to four feet off the ground to ensure the tracking is possible when conducting exercise on the ground (IGN Xbox 360, 2010).

Figure 5: EA Sports Ac ve 2 with Heart Monitor sensor

Wii Fit Plus is another popular exergame developed by Nintendo and released on October 4, 2009 in North America. The game features 4 different types of exercise activities; Yoga, strength, training, aerobic and balance that total up to 55 fun activities (WiiFit Plus, 2009). It uses the Wii Remote to detect the user's motion and a unique peripheral called the Wii Balance Board that is capable of measuring user's weight and center of balance (COB). It has been reported to work on muscles and improving balance for patients undergoing physiotherapy (Kovic, 2008). Apart from having a virtual personal trainer as a method of motivation, the Wii Fit Plus provides 'Body Test' functionality that measures the user's Body Mass Index (BMI). BMI uses height and weight to classify underweight, overweight and obesity in adults (WHO, 2011) and can served as a diet motivation tool.

Wii Fit Plus designer, Hiroshi Matsunaga exerted that the game is developed to make exercises fun and engaging that the whole family can enjoy (Iwata, 2008). Critical reception of the game has been generally positive due to its fun exercise and has been used by health and fitness clubs in USA (Andrew, 2008). However, the game simple nature is also criticized as it does not offer serious workout regime. Carrol et al (2009) conducted research to test the eficacy of the game and found that the six most challenging activities were not adequate enough to maintain or enhance cardiorespiratory endurance as defined by the American College of Sports Medicine (ACSM). The usage of BMI has been reported to be unjustly. A child in UK was upset with the miscalculation of her BMI as being 'overweight' and Nintendo apologized with a statement that the calculation may not be accurate for children due to 'varying level of developments' (BBC News , 2008).

Figure 6: Wii Fit Plus's fun and imagina ve gameplay

Several similarities and differences have been identified in EA Sports Active 2 and Wii Fit Plus. Both games offer intuitive calorie counter function to track user's calories burn. These games offer a virtual personal trainer that boosts the user's motivation during exercise routines. Other than that, these games provide huge collection of activities that can engage users in exercise for a long time that effectively reduce boredom.

The main difference between these games is that EA Sports Actve 2 focuses on high intensity workout for weight loss while Wii Fit Plus provides lower intensity workout based on stretching and balance routines (Thorsen, 2008). Apart from that, EA Sports Active utilizes two VR inputs; Kinect and heart rate sensor while Wii Fit Plus uses the Wii Remote and Wii Balance Board as the VR sensors.

For the purpose of this project, KineFit can track total calories burned during workout as implemented in EA Sports Active 2 and Wii Fit Plus. However, KineFit calorie tracking will not be able to determine the relationship between food calorie intake and calories burned during workout as in these games due to its complexity and time constraint. Furthermore, KineFit combines aspects from both games by implementing high intensity and low intensity workout. The 'Catch the Ball' module in KineFit is a form of low intensity workout while 'Collision Attack' requires high intensity performance by users. Moreover, KineFit will not implement the BMI calculation due its low effectiveness in measuring a person height as reported in section 2.2. Lastly, KineFit will only provide two different exercises compared to the huge collection that both games offered due to time constraint and limited manpower.

2.3 HEALTH RELATED RESEARCH

Clarification on common terms such as physical activity, exercise and fitness must be done as each of these terms provide different concept and meaning in health related research. Caspersen, Powell, & Christenson (1985) defined physical activity as 'any bodily movement produced by skeletal muscles that result in energy expenditure'. In addition, sports are one of the categories in physical activity and exercise has been identified as a subcategory of sports. The same article provides the definition of exercise as similar to physical activity, albeit with additional information which highlight it as 'structured and planned' activities conducted to increase or maintain the fitness level in individuals. For instance, jogging for 30 minutes and for 3 times a day is a form of exercise. In contrast with physical activity and exercise, fitness is identified as the attributes needed to perform physical activity while still having enough energy to enjoy other activities. Thus, KineFit project is considered to be a unique form of exercise known as 'exergaming' as defined earlier in this chapter's introduction which is capable of improving individual's fitness level due to its healthy modules.

Based on thorough literature review in section 2.1 and 2.2, KineFit will implement two types of exercise modules which are 'Collision Attack' and 'Catch the Ball', which will be explained in depth in section 3. 'Collision Attack' is a modified version of a typical punching bag exercise used in fitness center which is primarily targeted towards professional boxers as well as routine exercise for the masses. It's a form of physical exercise that provides several health benefits. Nall (2011) revealed that perfoming punching bag exercise can relieve stress as it symbolizes a healthier way of expressing anger without hurting anyone. Furthermore, Diamond (2009) suggested combining mental expressions while performing exercise such as punching bag to release stress for good. Apart from that, Davis (2010) asserted that punching bag exercise improves muscle development, cardiovascular endurance and hand-eye coordination. The 'Collision Attack' and 'Catch the Ball' modules in KineFit adopt a video game concept to make the exercise more fun, engaging and motivational. John Gabrielli, a neuroscientist in MIT revealed that players are encouraged to play challenging video games and strive to get better and acquire high scores before moving up to more difficult level in the game (Anthes, 2009).

CHAPTER 3

METHODOLOGY

3.1 EVOLUTIONARY SOFTWARE PROCESS MODELS

A software project depends heavily on the process, methods and tools for development in order to ensure success and reduce risks in the project life cycle. Based on a thorough analysis, the best software process model to be implemented in this project is the evolutionary software process models. In the evolutionary software process models, there are four types of software methodology; the incremental model, the spiral model, the WINWIN spiral model and the concurrent development model (Pressman, 2001). It has been decided that KineFit will be most suitable to follow the incremental model due to the following justifications.

In general, the incremental model delivers a series of 'increments' which is designed to be the subset of the software. The process is iterated after each increment is delivered until the finalize software is completed. The main reason to justify the selection of this method is the flexibility in time, requirements, manpower and risks. Since the project must be completed in 1 year time, this method can generate an early working system during the software life cycle which can be tested and debug easily during the iteration process. The method can also compensate to new requirements that might exist as the project progress. Since the software is delivered through increments and not as a whole, a large number of programmers are not needed to work on each increment. Furthermore, the possibility of undesired event in this project can be reduced as the method breaks down the problem into smaller chunks. Thus, it reduces the complexity of the project by reducing the scope to only a smaller problem at one time.

The project consists of four activities which are:

1. Planning & Analysis
2. Design
3. Implementation
4. Delivery of increment(s)

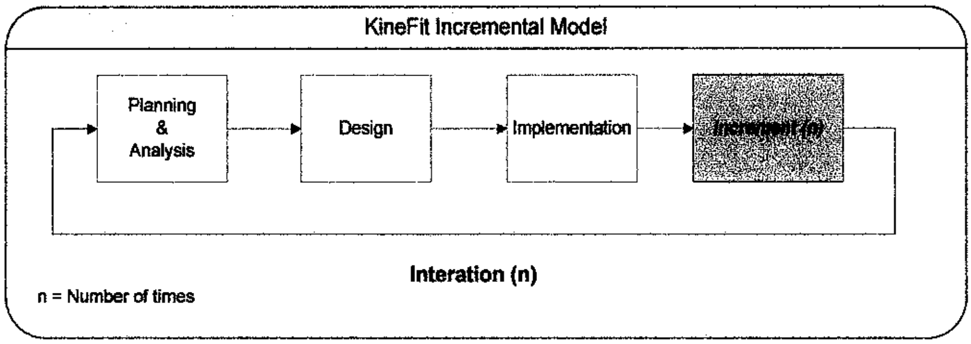


Figure 7: KineFit Incremental Model

3.2 PROJECT ACTIVITIES

3.2.1 Planning & Analysis

In the first stage of the software development life cycle, requirement gathering process is initialized in the planning phase and intensified in the analysis phase. In planning, necessary tools needed for the software development such as hardware and software are identified. Importantly, the predetermined and soon-to-be features of KineFit will be outlined in this phase. A Gantt chart is created to provide visual representation of the project progress and guidance to complete it in a timely manner. Furthermore, a flow chart is designed to illustrate the flow of each possible activity in KineFit as detailed in chapter 4. The tools required for this project are explained in great depth in the following paragraph.

a) Hardware

The Kinect sensor is required to generate three-dimensional moving objects and human beings by utilizing its 3D depth camera. The full body motion tracking capability can be achieve and serve as the input for users to immerse in the virtual environment offered in KineFit project. Apart from that, a high-end PC desktop with sufficiently fast CPU and GPU is required to develop the features of KineFit Project.

b) Software

An integrated development environment for game creation known as Unity 3D is used for KineFit project. Unity 3D is used because it offers powerful automated physics engine such as collision detection, bump mapping, rigid body and more which speeds up game development greatly. This allows programmers to focus their attention towards scripting the game flow in which Unity 3D offers interchangeable programming languages which are C#, JavaScript and Boo. Furthermore, Unity 3D is the only known game engine that supports the integration of Kinect sensorial data through OpenNi, NITE and Sensor Kinect drivers which opens wide range of possibilities for developing controller-less gaming experience.

Since Kinect is hacked legally to work with major operating systems such as Windows and Linux, OpenNI, PrimeSense's NITE middleware and Sensor Kinect drivers are required to establish the connection between Kinect and PC. In general, OpenNI provides a general framework for obtaining data from Kinect such as depth image. On the other hand, PrimeSense's NITE middleware consists of skeleton-tracking data and gesture recognition library that allow programmers to write Natural Interface (NI) application. Sensor Kinect driver serves as the interface between NITE middleware and the Kinect itself.

For software development, Unity 3D built-in script editor is used for developing algorithm and scripts for the game flow. In order to utilize Kinect's sensorial data and used it with Unity 3D, a Unity-OpenNI binding script developed by a team called Zigfu is required and available for free.

c) Features

In the analysis phase, the features of KineFit are listed based on thorough literature review as discussed in section 2 and project scope in section 1.5. The propose features of KineFit are:

- Game consists of two modules: 'Catch the Ball' and 'Collision Attack'.
- A gesture-based user interface.

3.2.2 Design

The design phase translates the requirements defined in section 3.2.1 into a representation of the software. Thus, the expected output is a set of design elements such as screen layout diagrams as shown below. The following diagrams serve as a visual flow of the expected final product.

3.2.2.1 Scene 1: KineFit Splash Screen

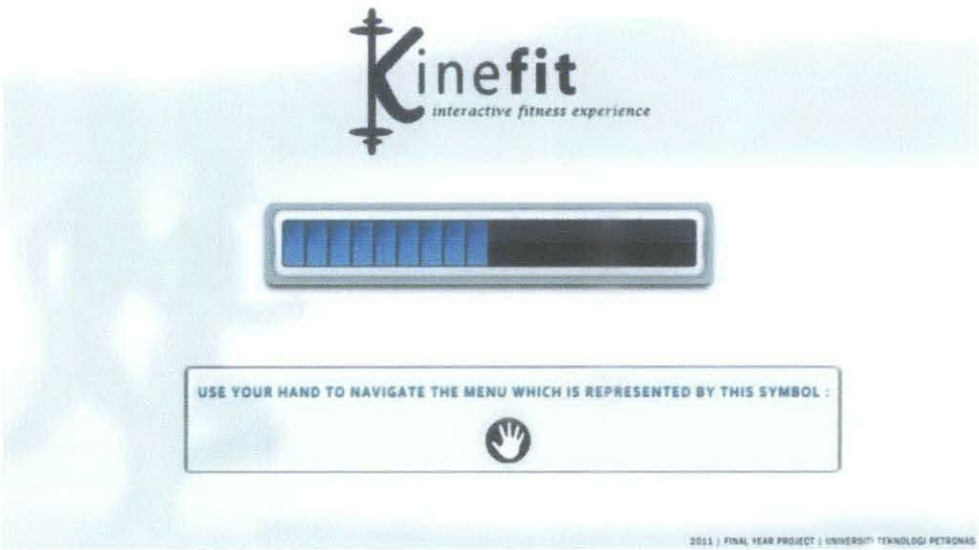


Figure 8: KineFit Loading Screen

3.2.2.2 Scene 2: KineFit Main Menu

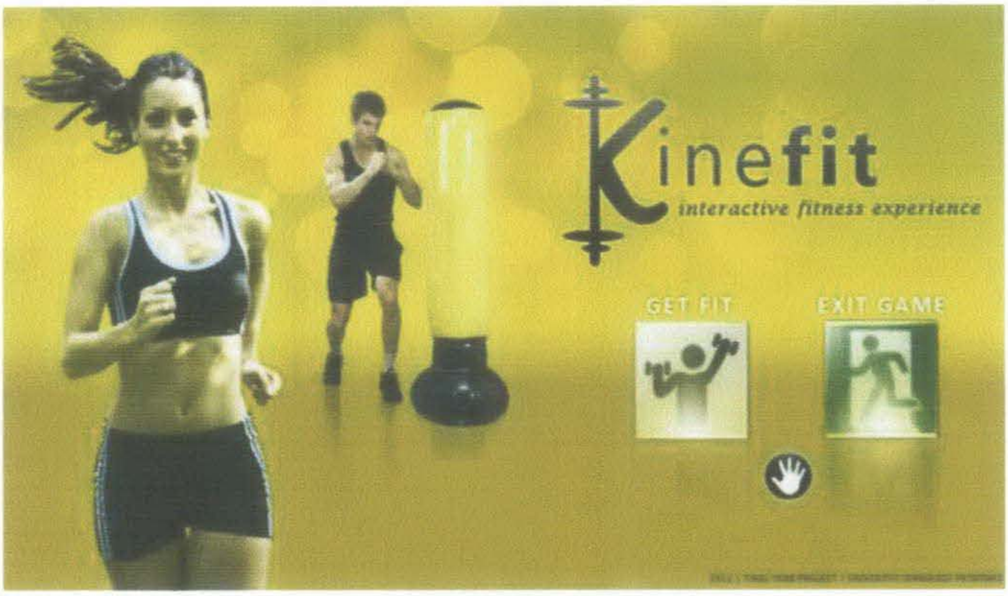


Figure 9: KineFit Main Menu Screen

3.2.2.3 Scene 3: KineFit Training Modules Menu

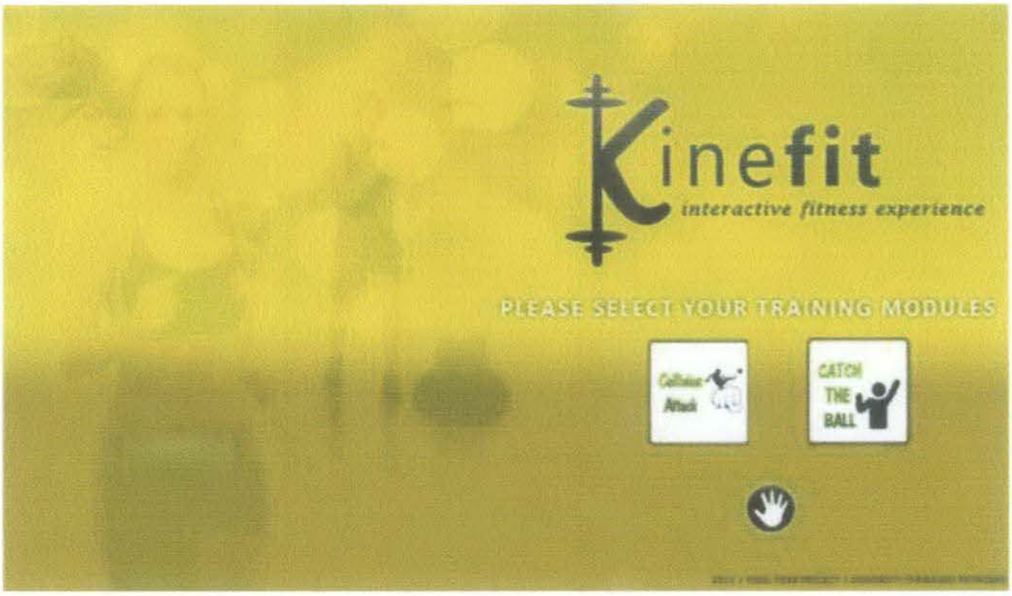


Figure 10: KineFit Training Modules Screen

3.2.2.4 Scene 4: KineFit Catch the Ball Module

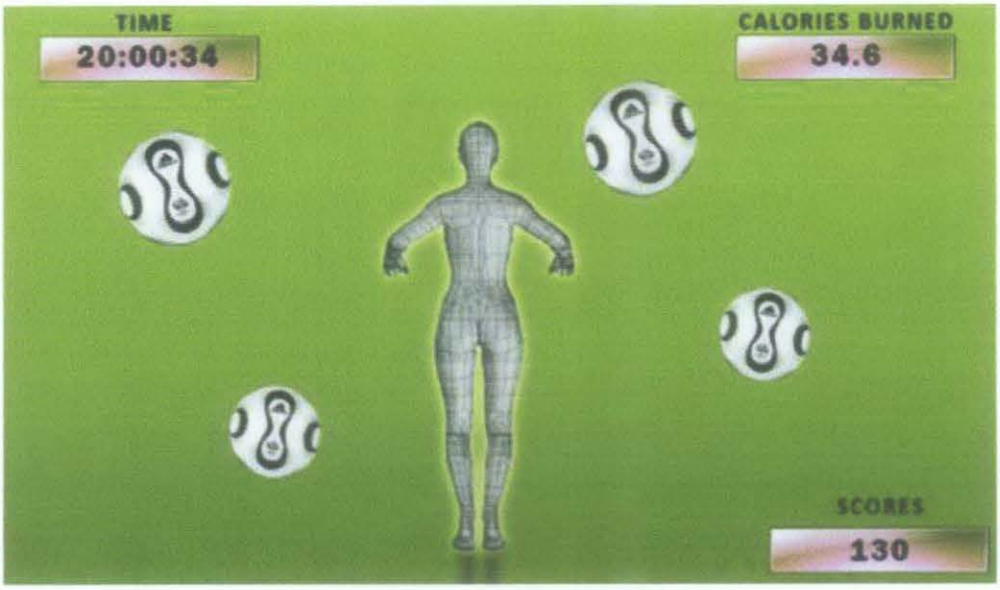


Figure 11: KineFit Catch the Ball Screen

3.2.2.5 Scene 5: KineFit Collision Attack Module

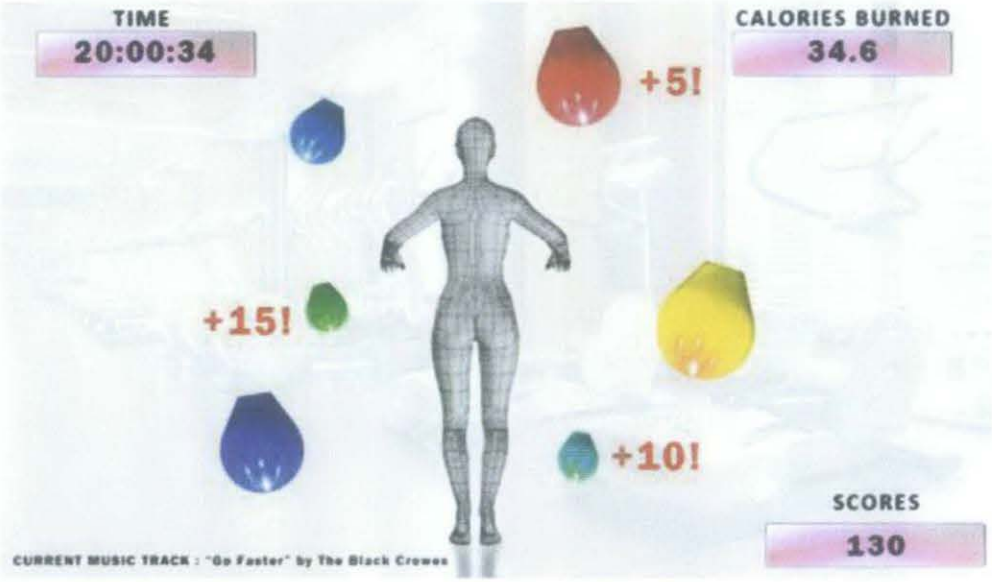


Figure 12: KineFit Collision A ack Screen

3.2.2.6 Scene 6: KineFit High Scores

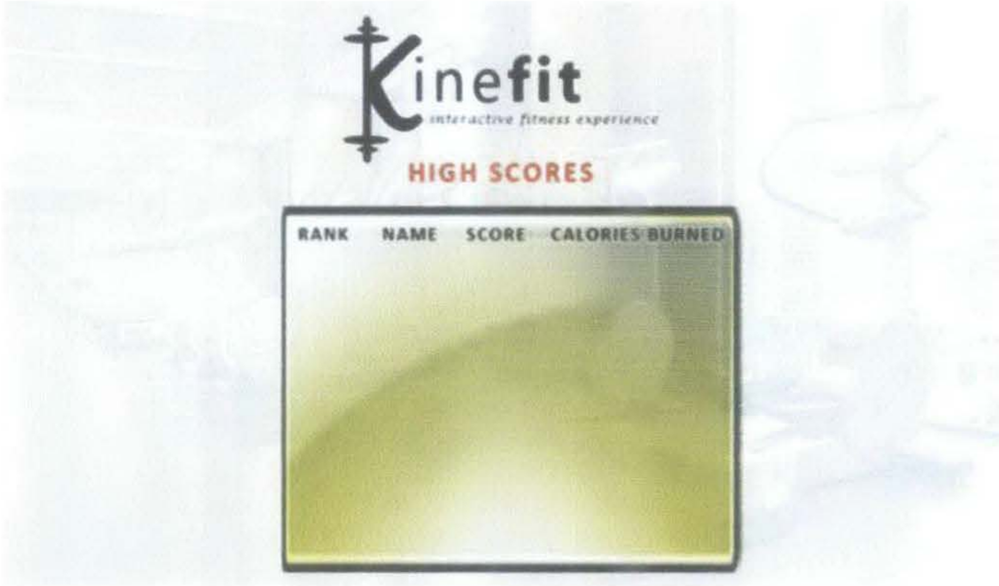


Figure 13: KineFit High Scores Screen

3.2.3 Implementation

The implementation phase consists of code and testing activities. Each feature of KineFit is coded using Unity built-in script editor and tested to uncover errors as well as ensure that the desired input produces the expected output. The desired feature is discussed with the targeted end users as well as the project's supervisor to acquire their feedback which is used as an input in the next iteration cycle of this project. The Gantt chart in Appendix A depicted the progress of this project that highlights several milestones achieved within the time frame.

CHAPTER 4

RESULT AND DISCUSSION

4.0 DATA GATHERING AND ANALYSIS

In general, data gathering is the process of collecting information from appropriate sources such as documents, reports and targeted end users to satisfy the project's objectives defined earlier in section 1.4. The targeted end user is the primarily source of information while observation and questionnaire are selected as the main data gathering techniques for this project.

Since the project involves the use of Kinect, a relatively new technology in the market, there are currently no concrete research done to test the usability of Kinect with games or applications. Reviews on Kinect's video game titles are the only source of information in documentation form that can help understand user's perceptions towards this new technology. For instance, 'Your Shape Fitness Evolved', a Kinect-based exercise game similar to KineFit project, received an average of 4 out of 5 stars from 339 customers in Amazon website (Amazon.com, 2011). However, these reviews are specifically tailored towards this game, hence, information regarding Kinect usability with video game, is not valid to use with KineFit project, thus, justify the need to use the targeted end users as the only source of information.

Observation involves monitoring and recording the project activities conducted by the end users which will be used for interpretation and drawing conclusions. Since KineFit project requires end users to move around and interact with the game objects in real time, observation allows developer of the project to understand end users' behavior and easily determine whether they are comfortable using Kinect as the main input device for this project. As for questionnaire, System Usability Scale (SUS) is used as it offers 'quick and dirty' way of assessing usability of system at low cost. Furthermore, it has been widely used in many evaluations for its robustness and reliability in measuring usability in terms of effectiveness and efficiency of the system as well as the user's satisfaction towards it.

4.1 SYSTEM PROTOTYPE

Before observation and questionnaire can take place, a prototype of the game is required to conduct the necessary experimentation. Prototype is critical as it allows the targeted users to see the game's structure, design and overall impression of how the finished product will look like. The following section will detailed the system architecture, flow chart and screenshots of the prototype design.

4.1.1 System Architecture

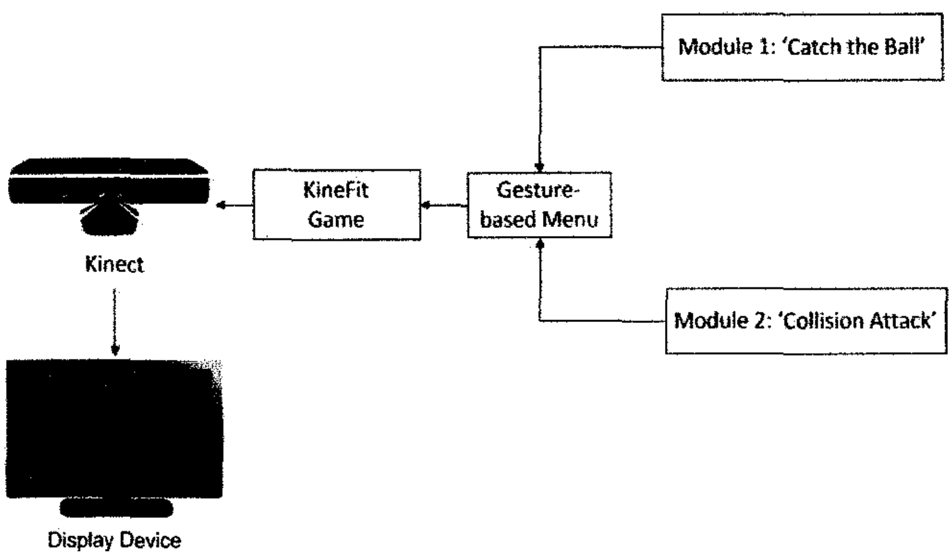


Figure 14: KineFit System Architecture

Based on the figure above, each module in KineFit game is integrated through a gesture-based user interface that only requires the user's hand to navigate the entire game. This is achieved through Kinect's depth camera which is able to isolate the user's hand from the background image through point-to-point distance calculation of the depth image. Kinect is used as an input device that bridges the virtual environment created in KineFit with any graphical display device that outputs the game for user's interaction.

4.1.2 Flow Chart

4.1.2.1 KineFit Overview Flow Chart

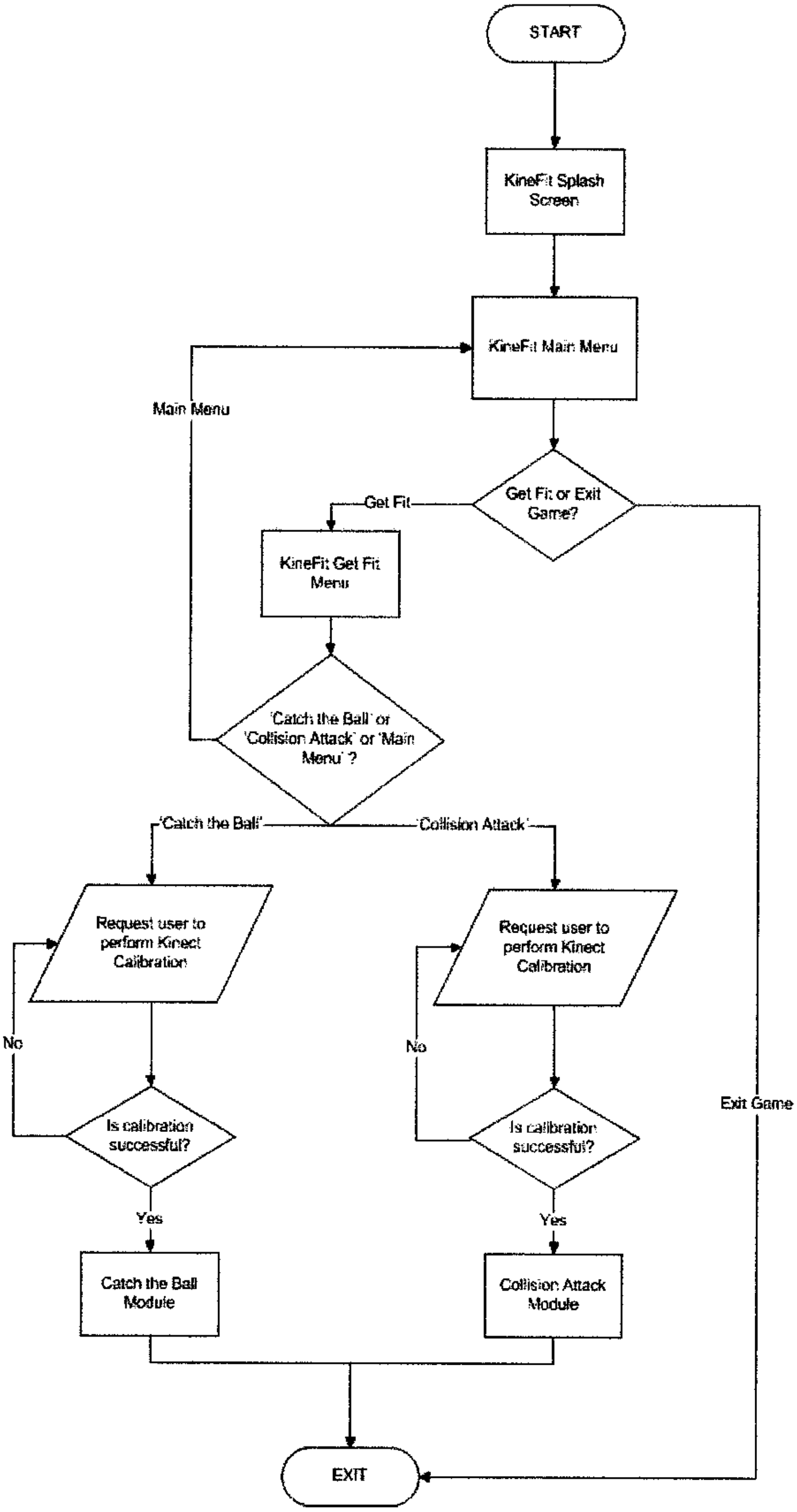


Figure 15: KineFit Overall Flow Chart

4.1.2.2 KineFit 'Catch the Ball' Flow Chart

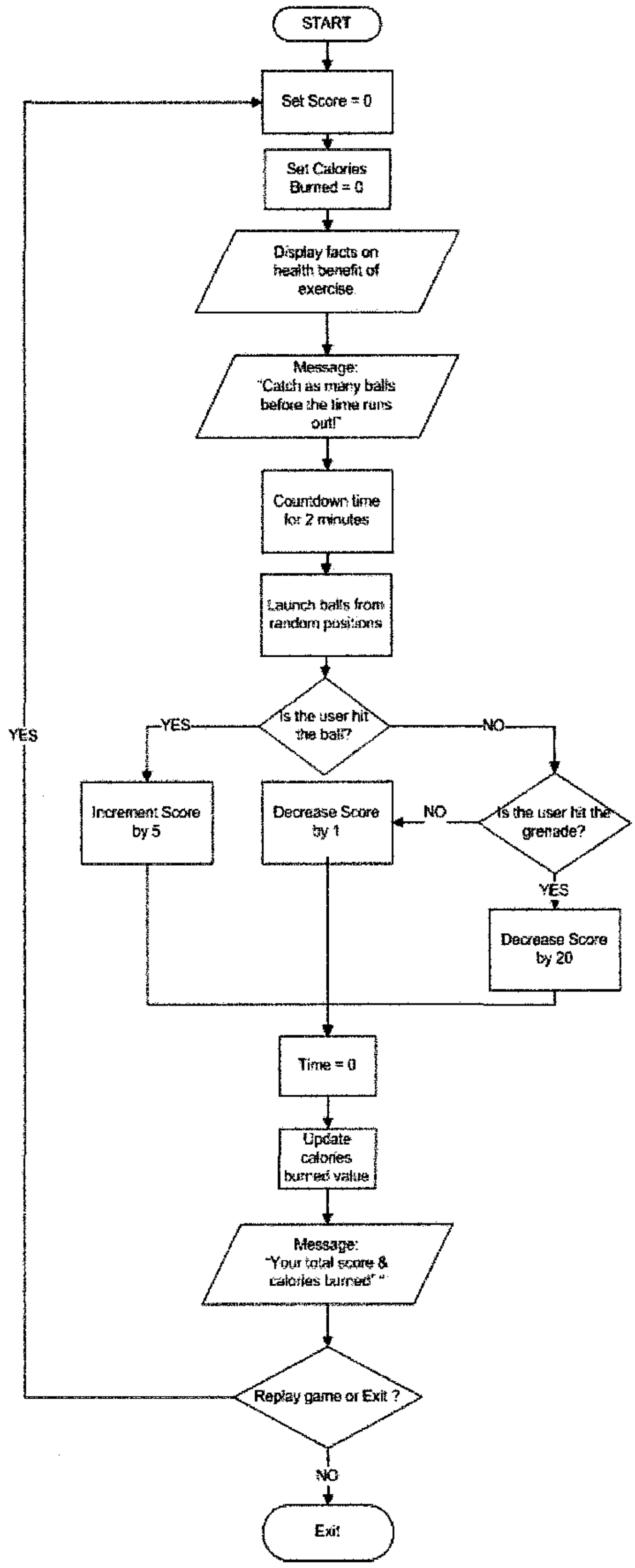


Figure 16: KineFit Catch the Ball Flow Chart

4.1.2.3 KineFit 'Collision Attack' Flow Chart

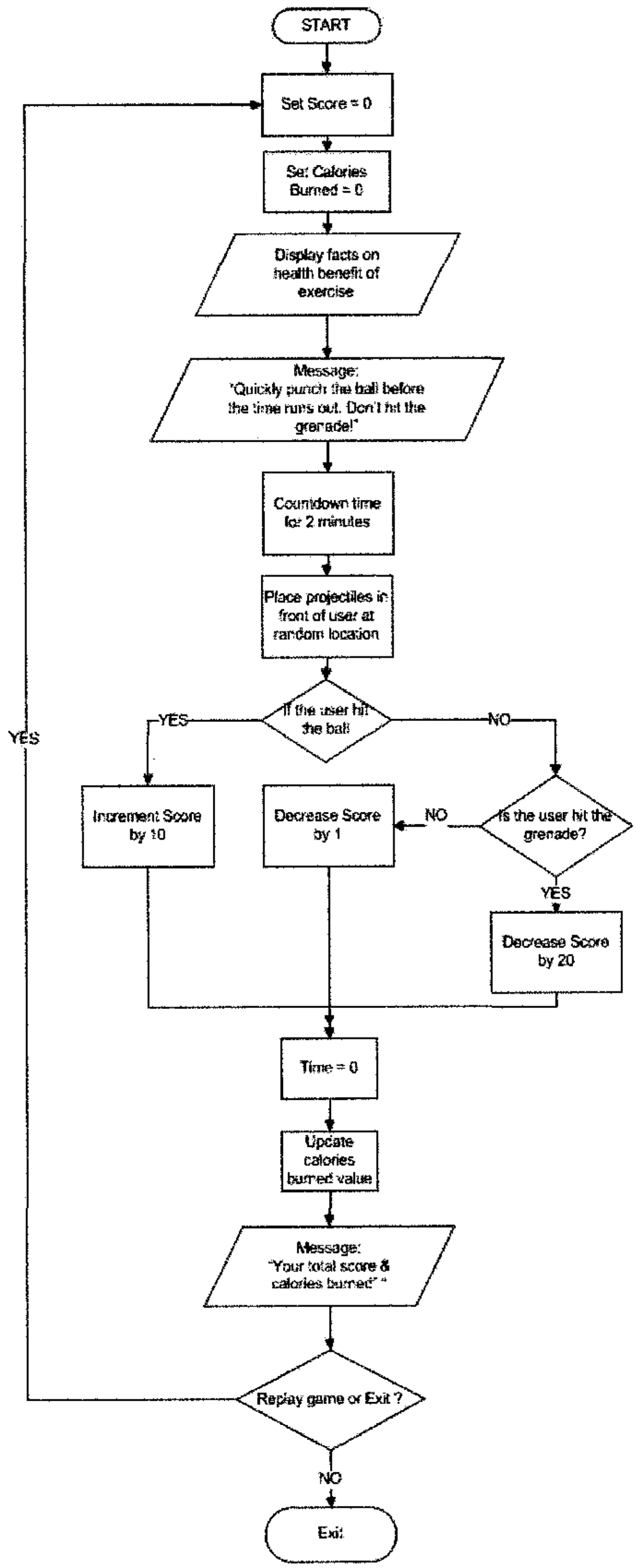


Figure 17: KineFit Collision A ack Flow Chart

4.1.3 Prototype screenshots

Figure 18: KineFit Prototype Splash Screen

The loading screen displays the important message of exercise regularly to users with the aim to inform and motivate them to play this game.

Figure 19: KineFit Prototype Main Menu

The gesture-based main menu presented three options for user to choose from; 'Collision Attack' module, 'Catch the Ball' module and exit game option. The cursor is denoted by a small sphere with trailing particles as shown above. Whenever the user moves the cursor to either one of the options, a small clock will appear on the top left of the screen. When the time runs out, the user will be taken to that particular option.

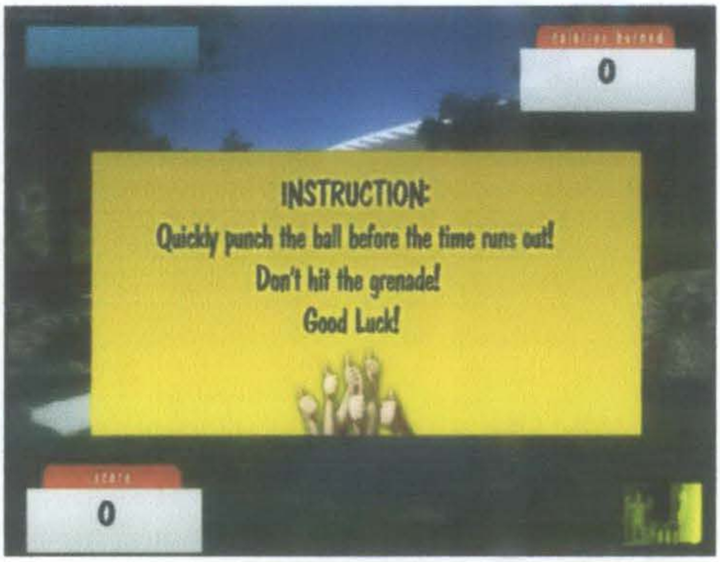


Figure 20: KineFit Catch the Ball Prototype Instruc on Screen

The screen above is displayed before the module starts. The top left bar shows the time while the bottom left shows the current score of the user. The top right corner displays the amount of calories burned while the bottom right corner displays the depth image of the user in real time.

Figure 21: KineFit Collision A ack Module Prototype Screen

'Collision Attack' module will randomly spawn projectiles from different locations in front of the users. Users will need to punch as many balls as they can before the time runs out. To add more challenge, grenades are launched at any point of time and user will need to avoid it or it will deduct the score greatly. When the timer ends, the game will stop and present user's total score.

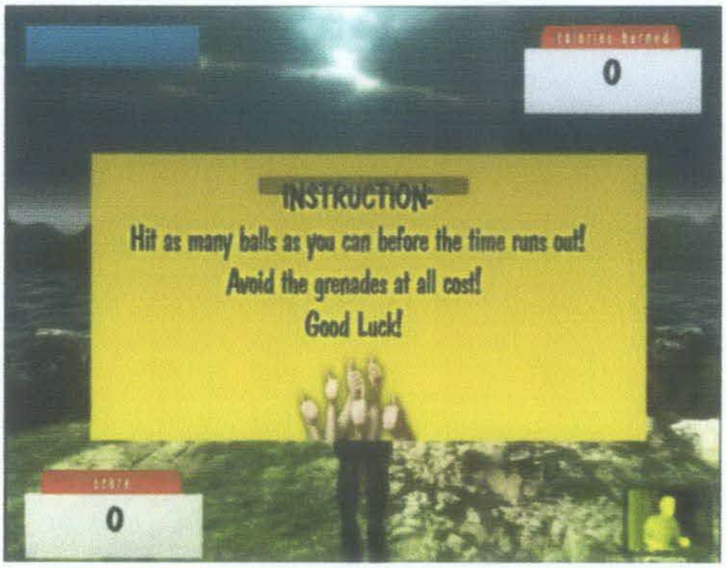


Figure 22: KineFit Catch the Ball Prototype Instruc on Screen

The screen above is displayed before the module starts. The top left bar shows the time while the bottom left shows the current score of the user. The top right corner displays the amount of calories burned while the bottom right corner displays the depth image of the user in real time.

Figure 23: KineFit Catch the Ball Prototype Screen

'Catch the Ball' module implemented similar concept with 'Collision Attack'. Instead of projectiles randomly appear in front of the users, the projectiles will be launched from afar and user will have to catch as many balls as they can and avoid incoming grenades. User may duck, crouch and do whatever they must to get a high score. Furthermore, the view is in 3rd person perspective where user can freely move around the 3D environment. When the timer ends, the game will stop and present user's total score.

4.2 USABILITY TESTING

Observation and SUS questionnaire is conducted in the developer's room with a Kinect sensor, an LCD screen and a high-end PC desktop as the required hardware. Prior to testing, the participated users are allowed to communicate freely to the developer on any ideas or issues that can help improve the prototype. Particularly, users' perception of the game on their motivation, engagement and enjoyment to perform exercise were stressed. During the test, the developer took notes on the user's behavior and comments. After each participated user finished their take on the game, a SUS questionnaire form were given to each of them in which they are required to answer 10 usability questions related to the context of the game as shown in Appendix B.

A total of 14 people took part in the prototype test. The prototype testing is conducted twice where by the prototype is adjusted and fixed based on users' comments and suggestions on the first test. The main criteria for selecting the users are their active participation in regular exercise. 8 users are identified as regularly exercised while the other 6 users exercised less. The users are within the 20-22 years old target range. Moreover, all of the participated users played video games regularly in their spare time. Both testing sessions took about 1 and a half hour to complete.

4.3 FINDINGS

In the first prototype test, users revealed that they felt motivated to complete each module of KineFit. The prime reason is because the modules are fun and different as it utilized the Kinect sensor. Users acknowledge the fact that Kinect is a hassle-free gaming experience. Moreover, users pointed out that the game makes them 'sweat' and 'energetic'.

In terms of engagement, users that regularly exercised felt that the game should add more interesting modules to retain their interest longer. Moreover, the game's mechanic felt clumsy at times due to unresponsiveness of the 3D model in the game to reflect users' movement in real time. However, all users acknowledged that the game makes exercise fun but requires more tinkering and polish to be more engaging. For instance, the 3D environment and model should be more interesting as well as improving the projectile mechanics of the flying balls in 'Catch the Ball' module. The comments and suggestions are taken into serious consideration to improve upon the prototype before conducting another usability testing.

SUS questionnaire were given to each of them after the developer conducted the observation data gathering technique. The chart below showcased the result of the prescribed questionnaire of the first prototype testing.

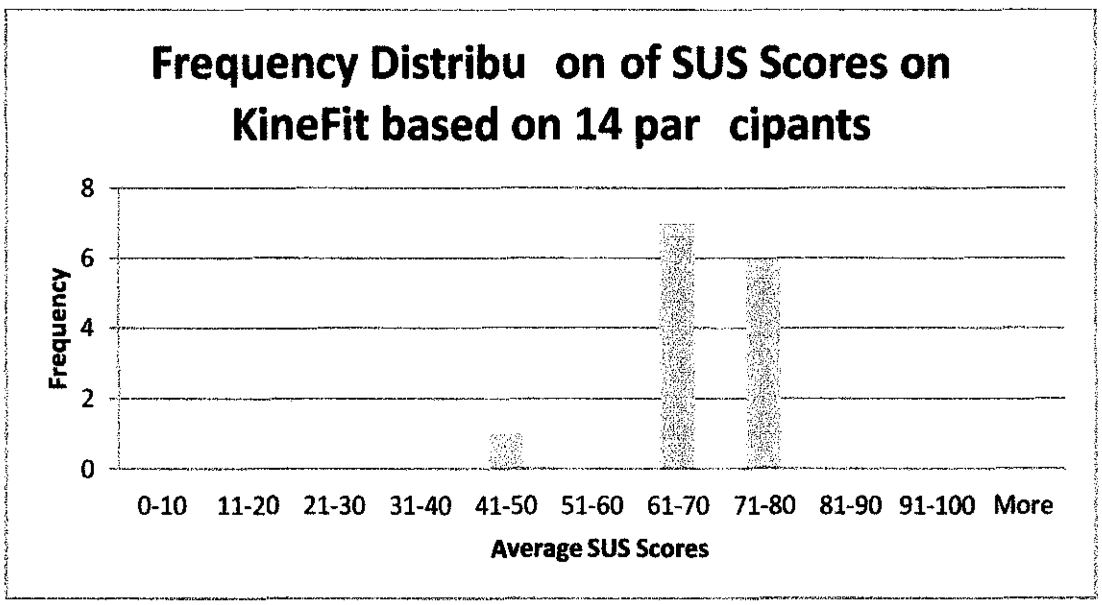


Figure 24: 1st SUS score result

Based on the figure above, the result is surprisingly well with 7 users gave a high 61-70 percent score for the SUS questionnaire and followed by 6 users with a 71-80 percent. On the other hand, 1 user gave a low 41-50 percent score for the questionnaire. In general, the game received an above average score in terms of usability context.

In the second prototype testing, the prototype has been modified and polished based on the comments, suggestions and result of the first usability testing. The same people involved in the first prototype testing took part in the second prototype testing. Users revealed that the exercise modules are still keeping them motivated to finish the game. Furthermore, the game is noted for being 'fresh' and 'exciting' as the game environment is completely different than the first version of the prototype.

In terms of engagement, users commented that the modules, 'Catch the Ball' and 'Collision Attack' have been tweaked to be more responsive and engaging than the previous version. Occasionally, the 3D model becomes unresponsive but the frequency of that happen is lower than the first prototype. Moreover, users acknowledged that the game is certainly more fun with a more interesting choice of 3D environment, particularly in 'Collision Attack' where the game took place in the garden overlooking UTP's Chancellor Hall. SUS questionnaire is conducted and below is the result of the second prototype testing.

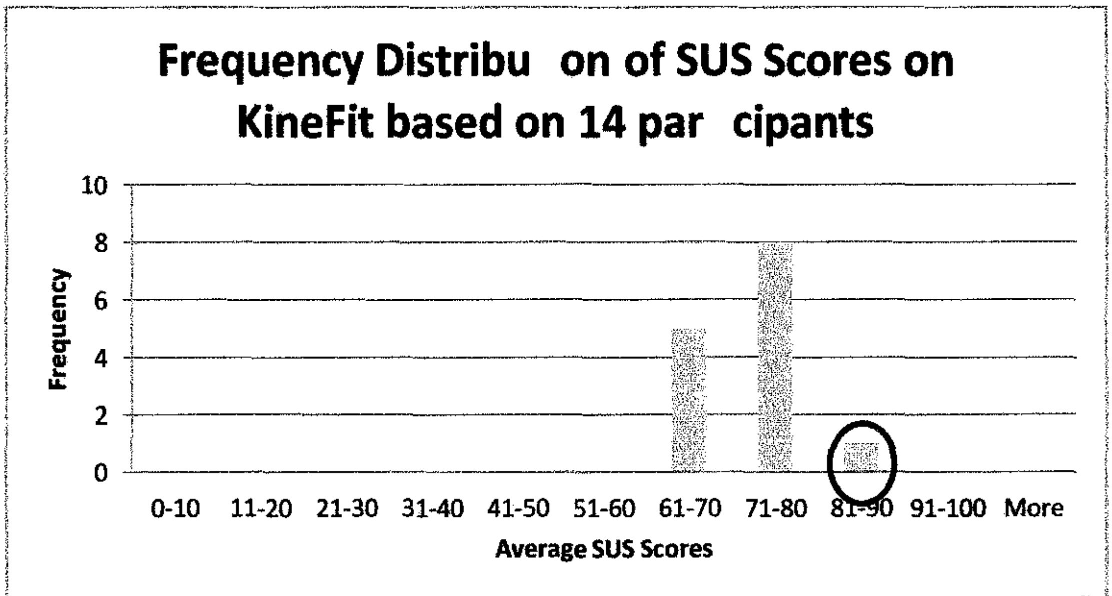


Figure 25: 2nd SUS score result

Based on the figure above, the result is better than the first prototype testing in which no user gave a score below 61 percent. Surprisingly, 1 user gave a high score of 81-90 percent for the questionnaire as highlighted by a red circle in the chart above. Overall, the result is above average and certainly better than the previously attempt usability testing.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

KineFit has been successful for the time being in its quest to motivate exercise and inculcate healthy living culture among Malaysians as reflected on the first part of the project's objectives in section 1.4, based on the early prototype testing. The utilization of Kinect sensor as a revolutionize way in gaming experience, as well as the fun modules offered in KineFit have made the first objective a moderate success.

In relation with the second objective, a gesture-based user interface is used to replace the standard mouse-and-keyboard approach normally seen in many games and desktop applications. Based on the findings in section 4.3, users felt that the modules in KineFit are integrated well with the controller-less Kinect sensor, which provides a captivating and intuitive way of navigating the game.

The last objective dealt with understanding the users' perception of the game on their motivation, engagement and enjoyment to perform exercise. The prototype testing as shown in section 4.3 revealed that users are motivated and enjoyed performing the exercise. Comments on making the game more engaging are taken into consideration and improved upon the second prototype testing as shown in figure 25. Further improvement on the game is based upon recommendations suggested by test users and discussed in the following section.

5.2 RECOMMENDATIONS

One of the ways to make the game more engaging is by adding depth into each module as suggested by some of the users. An artificial intelligent (AI) character with the ability to interact with the user is suggested to be implemented into new exercise modules such as 'Karate' or 'Jujitsu'. For future expansion, the suspended jogging module is in consideration once the technical difficulties of Kinect and Unity 3D game engine has been solved. Furthermore, more modules should be included in the next release of KineFit to make the overall game experience more fun, appealing and certainly encourage users to perform exercise with the hope to reduce the critical rate of obesity in Malaysia in the near future.

Appendix A: Gantt chart and progress screenshots

Increment 1: Sample of skeleton tracking developed using OpenNI and NITE middleware

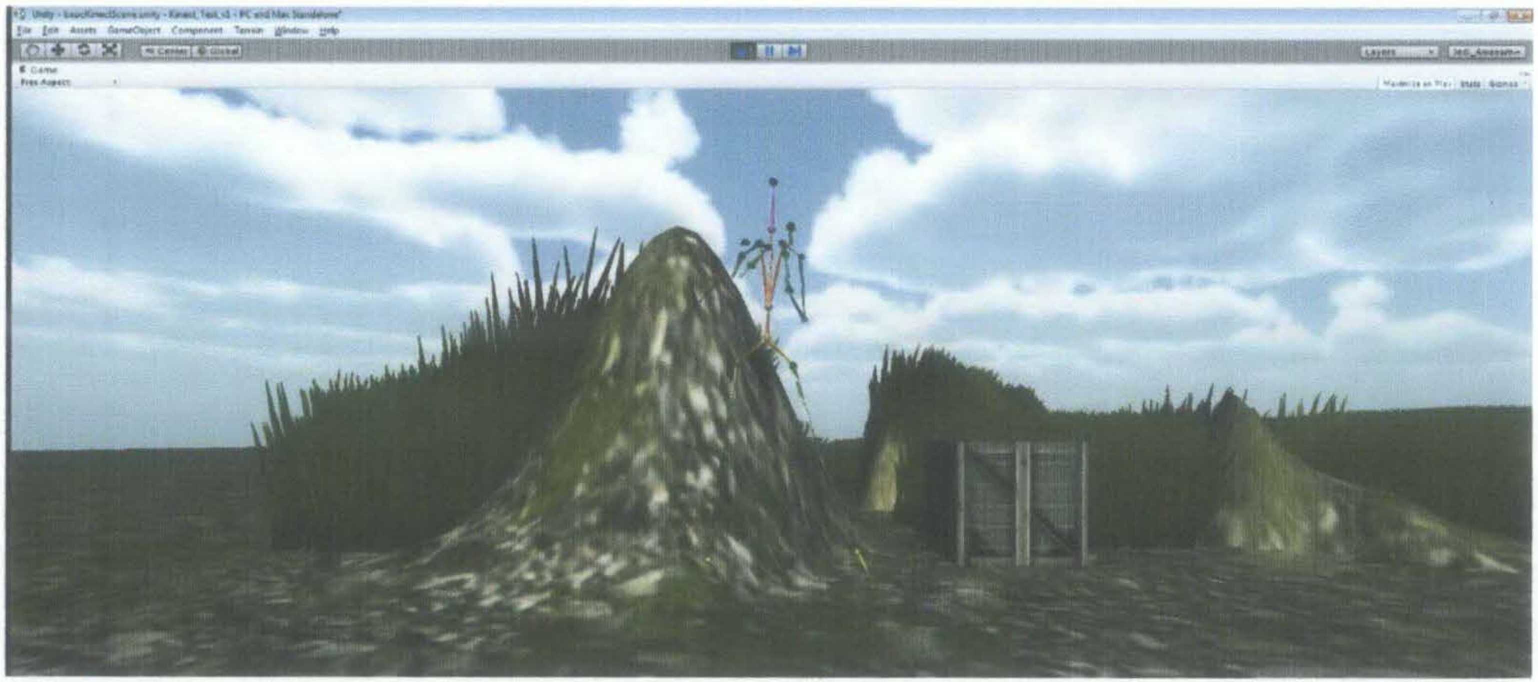
Activities	January	February	March	April	May
Planning & Analysis					
Design					
Implementation					

Screenshot:

Increment 2: Skeleton tracking using Unity 3D

Activities	July	August	September	October	November
Planning & Analysis					
Design					
Implementation					

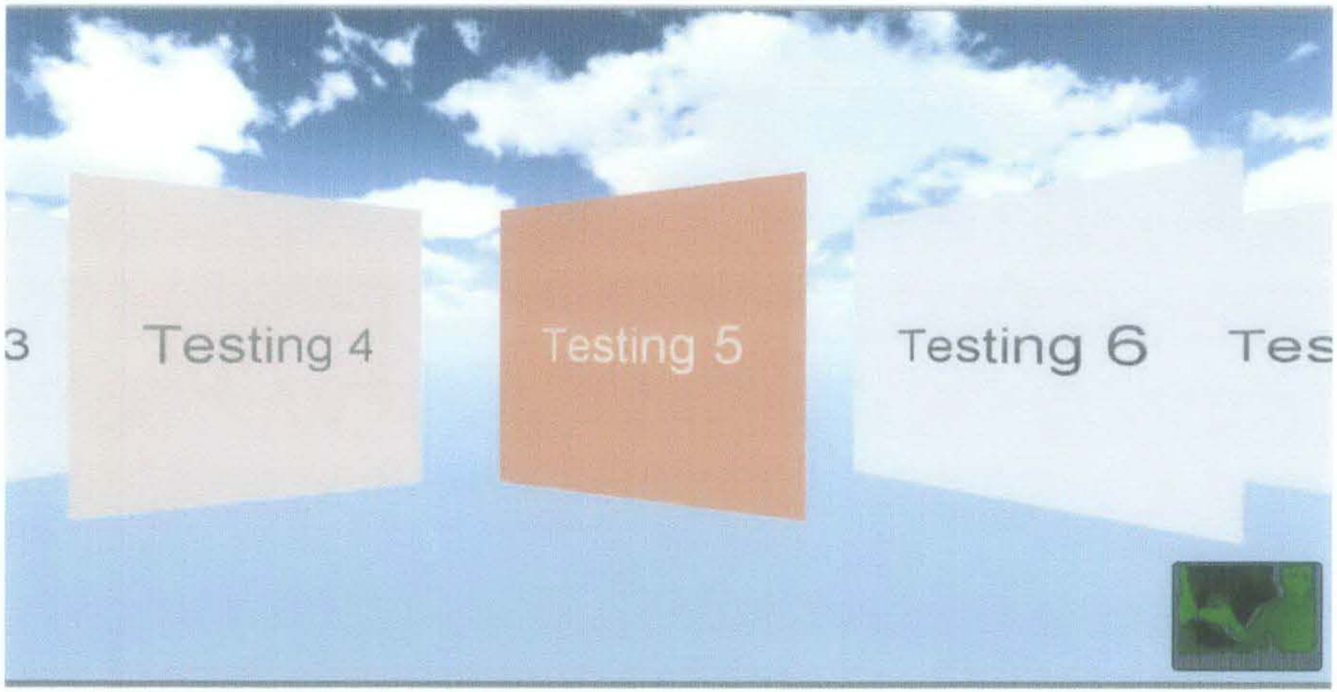
Screenshot:



Increment 3: Hand gesture interface test in Unity 3D

Activities	July	August	September	October	November
Planning & Analysis					
Design					
Implementation					

Screenshot:



Increment 4: 'Collision Attack' Module in Unity 3D

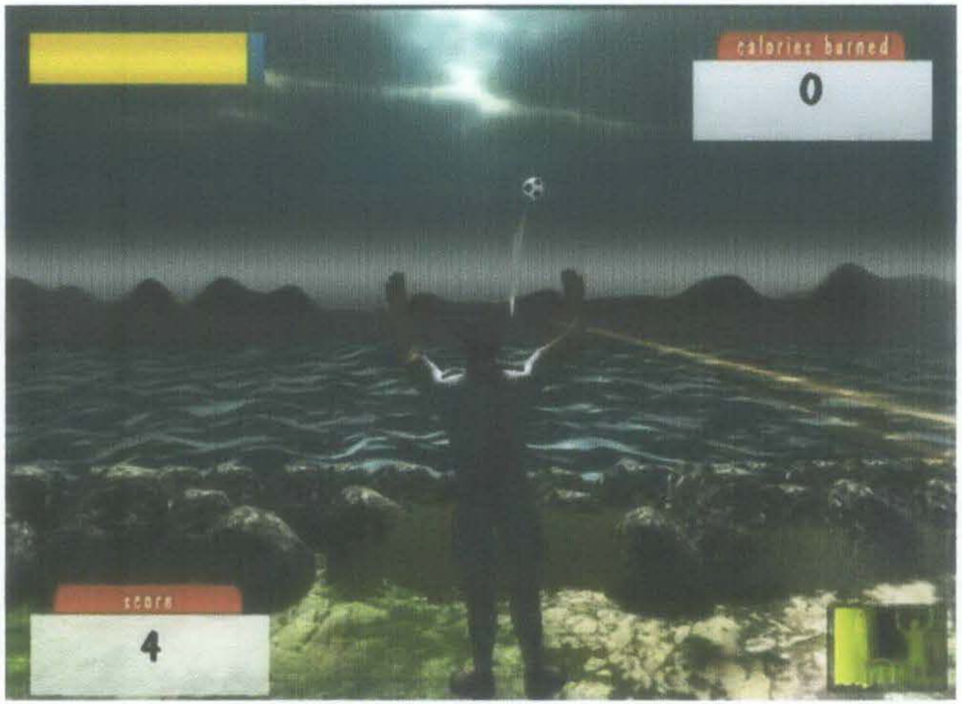
Activities	July	August	September	October	November
Planning & Analysis					
Design					
Implementation					

Screenshot (Left: In-game; Right: Actual location that inspired the in-game's look)

Increment 5: 'Catch the Ball' Module in Unity 3D

Activities	September	October	November	December	January
Planning & Analysis					
Design					
Implementation					

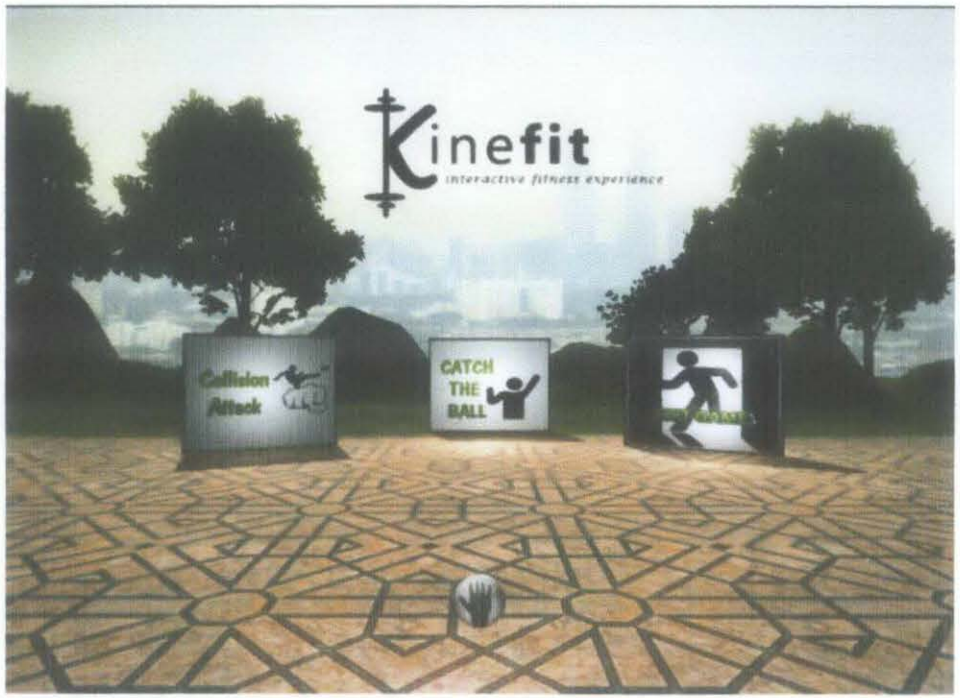
Screenshot:



Increment 6: Complete GUI with Hand Gesture Tracking in Unity 3D

Activities	September	October	November	December	January
Planning & Analysis					
ign					
Implementation					

Screenshot:



Appendix B: SUS Questionnaire Form

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

REFERENCES

Department of Kinesiology and Health. (1997, November 6). *The Bene ts of Exercise.* Retrieved March 12, 2011, from George State University: h p://www2.gsu.edu/~www t/bene ts.html

Ac vate3D. (2011). *REVOLUTIONARY approach to crea ng rich, robust in-game characters and worlds for mo on control games.* Retrieved March 18, 2011, from Ac vate3D: h p://ac vate3d.com/

AFP. (2011, February 3). *AFP.* Retrieved March 10, 2011, from AFP: h p://www.google.com/hostednews/afp/ar cle/ALeqM5hBS1r_o1lCGZfXWXrA2nFgRZklvw?docId=CNG.5059cec 0aba8394b7f8d99ed739f16.d11

Amazon.com. (2011). *Your Shape Fitness Evolved.* Retrieved November 2, 2011, from Amazon.com: h p://www.amazon.com/Your-Shape-Fitness-Evolved-Xbox-360/dp/B002I0H9WM

American Council Exercise (ACE). (2001). *Fit Facts: From the American Council on Exercise.* Retrieved April 21, 2011, from Ace Fitness: h p://www.ace tness.org/ acts/pdfs/ tfacts/itemid_86.pdf

Andrew. (2008, June 12). *Interview: Studeo55 owner on how Wii Fit has changed his health club forever.* Retrieved March 6, 2011, from Balance Board Blog: h p://www.balanceboardblog.com/2008/06/interview-studeo55-owner-on-how-wii- t.html

Anthes, E. (2009, October 9). *How video games are good for the brain.* Retrieved November 3, 2011, from Boston.com: h p://www.boston.com/news/health/ar cles/2009/10/12/how_video_games_are_good_for_the_brain/

Appleton, D. B. (1998, June 10). *Stretching and Flexibility: Everything you never wanted to know.* Retrieved April 20, 2011, from Brad Appleton's Home Page: h p://www.cmcrossroads.com/bradapp/docs/rec/stretching/stretching.pdf

Ballantyne, C. (2006). *Turbulence Training for Fat loss.* CB Athle c Consul ng.

BBC News . (2008, May 20). *Parents' anger at keep t game*. Retrieved March 17, 2011, from BBC News UK: h p://news.bbc.co.uk/2/hi/uk_news/england/lincolnshire/7410800.stm

Bertol, D. (1996). *Designing digital space: an architect's guide to virtual reality.* Wiley.

Bogost, I. (2005). *The Rhetoric of Exergaming.* Atlanta: The Georgia Ins tute of Technology.

Bureau of Labor Sta s cs. (2011, February). *American Time Use Survey.* Retrieved March 13, 2011, from Bureau of Labor Sta s cs: h p://www.bls.gov/tus/charts/chart1.pdf

Bystrom, K. (1999). A Conceptual Model of the Sense of Presence in Virtual Environments. *Presence: Teleoperators and Virtual Environments* , 241-244.

Bystrom, K. B. (1999). A Conceptual Model of the Sense of Presence in Virtual Environments. *Presence: Teleoperators and Virtual Environments* , 241-244.

Canadian Fitness and Lifestyle Research Ins tute. (2005). *No me, no energy, no mo va on*. Retrieved March 10, 2011, from Canadian Fitness and Lifestyle Research Ins tute: h p://www.c ri.ca/eng/lifestyle/1996/no_ me.php

Carrol, A., Porcari, J., Foster, C., & Anders, M. (2009, December). *Wii Fit or Wee Bit?* Retrieved March 17, 2011, from AceFitness: www.ace tness.org/ge it/studies/WiiFit102009.pdf

Casperen, J. C., Powell, E. K., & Christenson, M. G. (1985). Physical Ac vity, Exercise,and Physical Fitness:De ni ons and Dis nc ons for Health-Related Research. *Public Health Reports*, 126-130.

Chobdee, J. (N.d). *Crea ng Your Personal Fitness Plan*. Retrieved April 21, 2011, from UC Riverside Wellness Program: h p://wellness.ucr.edu/Crea ng%20Your%20Fitness%20Plan.pdf

Davis, K. (2010, June 7). *What Are the Bene ts of Speed Bag Training?* Retrieved November 1, 2011, from Livestrong: h p://www.livestrong.com/ar cle/141605-what-are-bene ts-speed-bag-training/

Diamond, S. D. (2009, September 27). *nger and Catharsis: Myth, Metaphor or Reality?* Retrieved November 1 , 2011, from Psychology Today: h p://www.psychologytoday.com/blog/evil-deeds/200909/anger-and-catharsis-myth-metaphor-or-reality

EA . (2010, June 2). *Scien c Study Proves E cacy of EA SPORTS Ac ve Digital Fitness Programs*. Retrieved March 17, 2011, from EA: h p://www.ea.com/news/scien c-study-proves-e cacy-of-ea-sports-ac ve

EA Sports . (2010). *EA SPORTS Ac ve 2*. Retrieved March 17, 2011, from EA: h p://www.ea.com/games/ea-sports-ac ve-2

Exercise.com. (2011). *High-Knee March*. Retrieved April 21, 2011, from Exercise.com Get Started Get Results: h p://www.exercise.com/exercise/high-knee-march

Fitness Malaysia. (2010, September 6). *Group Personal Training*. Retrieved March 11, 2011, from Fitness Malaysia: h p:// tnessmalaysiablog.blogspot.com/2010/09/group-personal-training.html

Heeter, C. (1992). Being There: The Subjec ve Experience of Presence. *Presence: Teleoperators and Virtual Environments*, 262-271.

Herald, C., & Lewis, N. (2009). *'Exergaming'may combat kids' sedentary lifestyles.*

Human Media Interac on of University of Twente. (2010). *ParleVision: Rapid Component of Computer Vision applica on*. Retrieved March 15, 2011, from Human Media Interac on (HMI): h p://hmi.ewi.utwente.nl/showcases/parlevision

IGN Xbox 360. (2010, December 2). *EA Sports Ac ve 2 Kinect Review*. Retrieved March 17, 2011, from IGN Xbox 360: h p://xbox360.ign.com/ar cles/113/1138093p1.html

Ivan, T. (2010, June 30). *Kinect Supports Two "Active Players" – Retailer*. Retrieved March 16, 2011, from Edge: h p://www.next-gen.biz/news/kinect-supports-two-%E2%80%9Cac ve-players%E2%80%9D-%E2%80%93-retailer

Iwata, S. (2008, July 8). *Iwata Asks, Volume 4: Wii Sports*. Retrieved March 17, 2011, from Nintendo: h p://www.nintendo.com/wii/what/iwataasks/volume-4/part-1

Jaret, P. (2007, May 3). *A Healthy Mix of Rest and Mo on*. Retrieved April 20, 2011, from The New York Times: h p://www.ny mes.com/2007/05/03/fashion/03Fitness.html?pagewanted=1

Kovic, I. D. (2008, October 29). *Nintendo Wii Fit for physiotherapy*. Retrieved March 17, 2011, from Wellsphere: h p://www.wellsphere.com/general-medicine-ar cle/nintendo-wii- t-for-physiotherapy/460917

Lyons, J. E., Tate, F. D., Ward, S. D., Ribisl, M. K., Bowling, M., & Kalyanaraman, S. (2012). Do Mo on Controllers Make Ac on Video Games Less Sedentary? A Randomized Experiment. *Journal of Obesity, Volume 2012*, 1-7.

Medical Dic onary. (2010). *Jogging*. Retrieved April 21, 2011, from Medical Dic onary: h p://www.medicaldic onaryweb.com/Jogging-de ni on/

Medical News Today. (2009, February 5). *University Research Reveals Secret To Exercise Mo va on*. Retrieved March 12, 2010, from Medical News Today: h p://www.medicalnewstoday.com/ar cles/137949.php

Metacri c. (2010, November 16). *EA Sports Ac ve 2 Xbox 360*. Retrieved March 17, 2011, from Metacri c: Keeping score of entertainment: h p://www.metacri c.com/game/xbox-360/ea-sports-ac ve-2

Mokka, S., Väätänen, A., Heinilä, J., & Välkkynen, P. (2003). Fitness Computer Game with a Bodily User Interface. *ICEC '03 Proceedings of the second interna onal conference on Entertainment compu ng*, 1-3.

Nall, R. (2011, June 14). *Why Is Hi ng a Punching Bag Good to Relieve Stress?* Retrieved November 1, 2011, from Livestrong: h p://www.livestrong.com/ar cle/354110-why-is-hi ng-a-punching-bag-good-to-relieve-stress/

Na onal Ins tute of Health. (2006). *Your Guide To Physical Ac vity and Your Heart*. Bethesda: NIH Publica on No. 06-5714.

Oxford Journals . (2011). *Health Promo onal Interna onal*. Retrieved March 12, 2011, from Barriers to regular exercise among adults at high risk or diagnosed with type 2 diabetes: a systema c review: h p://heapro.oxfordjournals.org/content/early/2009/09/30/heapro.dap031/T3.expansion

Pak, J. (2011, April 19). *Malaysia obesity campaign targets students*. Retrieved April 20, 2011, from BBC News Asia-Paci c: h p://www.bbc.co.uk/news/world-asia-paci c-13125559

Plantea, G., Aldridgea, A., Bogdena, R., & Hanelina, H. (2003). Might virtual reality promote the mood bene ts. *Computers in Human Behavior 19 (2003) 495–509*, 495-509.

Pressman, S. R. (2001). *So ware Engineering: A Prac oner's Approach*. New York: McGraw Hill.

Ru kay, J., & Welbergen, V. (2008). Elbows Higher! Performing, Observing and Correc ng Exercises by a Virtual Trainer. *IVA '08 Proceedings of the 8th interna onal conference on Intelligent Virtual Agents* (pp. 409-416). Berlin: Springer-Verlag.

Shellock, F., & Pren ce, W. (1985). Warming-up and stretching for improved physical performance and preven on of sports-related injuries. *Sports Med* , 267-278.

Sinclair, J., Hingston, P., & Masek, M. (2007). Considera ons for the design of exergames. *ACM Digital Library* , 289-296.

Smith, K. (2005). *Physical Fitness in Virtual Worlds.* Pennsylvania: The Pennsylvania State University.

Sports Injury Clinic. (2011). *Stretching exercises*. Retrieved April 21, 2011, from Sports Injury Clinic: h p://www.sportsinjuryclinic.net/cybertherapist/stretching/allstretches.php

Thorsen, T. (2008, November 13). *Q&A: EA Sports Ac ve-a ng Wii.* Retrieved March 17, 2011, from Gamespot Asia: h p://asia.gamespot.com/news/6201028.html

Top News US. (2010, August 12). *Malaysia Gains Sixth Rank in Asia in Obesity Rates.* Retrieved March 10, 2011, from Top News: News You Can See: h p://topnews.us/content/230086-malaysia-gains-sixth-rank-asia-obesity-rates

To lo, S. (2008, November 11). *EA Sports Chief Names His Brand's 2008 Highlight, Predicts Fitness Gaming Boom.* Retrieved March 17, 2011, from MTV Mul player: h p://mul playerblog.mtv.com/2008/11/20/peter-moore-names-ea-sports-highlight-predicts- tness-boom/

Vortex Centrum Ltd. (2011, April 19). *Public Health: Malaysia's aggressive a ack on juvenile obesity.* Retrieved April 20, 2011, from The Chief O cer's Network Your Business Advantage: h p://www.chiefo cers.net/888333888/cms/index.php/news/industries/health_care_pharma/public_health/public_health_malaysia_s_aggressive_a ack_on_juvenile_obesity

Waine, C. (2007, September). *TV/video games and child obesity.* Retrieved March 13, 2011, from Na onal Obesity Forum: h p://www.na onalobesityforum.org.uk/component/content/ar cle/1-nof-in-the-media/338-tvvideo-games-and-child-obesity.html

WHO. (2011). *BMI classi ca on.* Retrieved March 17, 2011, from World Health Organiza on (WHO): h p://apps.who.int/bmi/index.jsp?introPage=intro_3.html

WiiFit Plus. (2009). *What is Wii Fit Plus?* Retrieved March 17, 2011, from WiiFit Plus: h p://wii t.com/what-is-wii- t-plus/ac vi es.html