Kinect Gestural Interaction for a Collaboration Game

João Paulo Prioste Rodrigues

Thesis to obtain the Master of Science Degree in Information Systems and Computer Engineering

Examination Committee
Chairperson: Prof. Nuno João Neves Mamede
Supervisors: Prof. Rui Filipe Fernandes Prada
Prof. Francisco António Chaves Saraiva de Melo
Member of the Committee: Prof. Alfredo Manuel dos Santos Ferreira Júnior

October 2013
Acknowledgments

First of all, I would like to thank the academy and my two advisors for letting me have the opportunity to do this dissertation, which afforded me with a much better cognition and knowledge about the Kinect and the Wii Remote technology together with a more global overview and criticism within the challenges of collaboration games and game interaction variety. Would also like to thank my very good friends Roberto Silva, João Fernandes and Vitor Mansur that helped me with many tips about the dissertation document.

I would like to give a very exclusive thanks to my parents and Ana Patricia Soares which have gladly helped me establish and accurate all interactions done in this dissertation, since I always needed a 'partner' to test my interactions before real tests were done to the participants. I would also like to give a special thanks to my very good friend Michael Martins which cheerfully lent his Wii motion controls (since I did not had), and one assistant of the Madeira University (UMa) Cristina Camacho which have both helped me to acquire the permission of a large private room in the Madeira University with great conditions and space to perfectly test all Kinect and Wii interactions developed with the participants. Finally, I would like to thank all participants that have participated in all tests done and a rather special one to those that helped me gather other participants.
Resumo

Muitas diferentes tecnologias usadas para jogos, como o Microsoft Kinect e a Nintendo Wii Remote, têm sido notáveis para o crescimento de jogos gestuais. Mesmo assim, a competição entre os jogadores parece estar integrado na maioria dos jogos de vídeo na indústria de vídeo jogos. No entanto, características de colaboração podem conduzir a novas experiências de jogo que pode interessar a alguns jogadores. Esta tese discute algumas interações gestuais distintas usando o Kinect, e relaciona-as com a possibilidade de elas próprias poderem melhorar a colaboração entre os jogadores. Os controles escolhidos para cada interação são simples e foram testados em um jogo de colaboração casual chamado Geometry Friends. Dos diferentes controles, quatro diferentes tipos de interação foram escolhidos para serem testados: interação com as mãos, interação com o corpo todo, interação com objetos e uma interação colaborativa. Além disso, uma interação de controle de movimento usando a Wii foi devidamente comparada relacionadamente a vários aspectos diferentes. Gestos naturais, a sensação de colaboração, reconhecimento dos gestos, a exaustão dos gestos e problemas de espaço são alguns dos aspectos que foram comparados entre todas as interações testadas. Os testes revelaram que o Geometry Friends pode alcançar um verdadeiro sentimento de colaboração, e este sentimento varia de acordo com uma mudança de interação, mas no entanto não foi encontrada nenhuma relação direta entre fatores naturais/jogabilidade e o sentido de colaboração dos jogadores. Tudo isso contribuiu para concluir de que mais tutoriais e mudanças de dificuldade devem ser avaliados com cuidado ao alterar a interação do jogo, especialmente quando se muda para uma interação gestual.

Palavras-chave: Kinect, Wii Remote, Geometry Friends, Colaboração, Interação Gestual, Reconhecimento Gestual
Abstract

Different game technologies as the Microsoft Kinect and the Nintendo Wii Remote has been remarkable for the growth of motion gaming. Even so, competition between players seems to be integrated in most video games in the video game industry. Yet, collaboration features can carry new game experiences that can interest some players. This thesis discusses some distinct Kinect gestural interaction and relates them to if they can enhance the collaboration feeling between players. The controls chosen for each interaction are simple and were tested in a casual collaboration game called Geometry Friends. From the different controls, four different types of interaction were chosen to be tested: Hand interaction, Full-Body interaction, Tangible interaction and Collaboration gestures interaction. Furthermore, a Wii motion control interaction was properly compared within many different aspects. Natural gestures, collaboration sense, gesture recognition, gesture exhaustion and space issues are some of the aspects compared between all interaction tested. The tests revealed that Geometry Friends can achieve true collaboration sense and this sense vary with an interaction change, yet no direct correlation was found between natural/playability factors and the collaboration sense of the players. All this contributed to conclude that more tutorials and difficulty changes should be evaluated carefully when changing the game interaction, especially when changing to a gestural interaction.

Keywords: Kinect, Wii Remote, Geometry Friends, Collaboration, Gesture Interaction, Gesture Recognition
# Contents

Acknowledgments ................................................................. iii
Resumo .................................................................................... v
Abstract .................................................................................. vii
List of Tables ............................................................................ xiii
List of Figures ........................................................................... xvi
Glossary .................................................................................... xvii

1 Introduction ............................................................................. 1
   1.1 Context and Motivation ..................................................... 1
   1.2 Problem ............................................................................ 1
   1.3 Dissertation Statement and Goals ...................................... 2
   1.4 Document Outline ........................................................... 2

2 Overview of Geometry Friends ................................................ 3

3 Related Work ........................................................................... 5
   3.1 Collaboration ...................................................................... 5
       3.1.1 Collaboration brings new gaming experiences .............. 5
       3.1.2 Changing game experience by changing interaction .... 6
   3.2 Gestural Interactions ......................................................... 7
       3.2.1 Touch Interaction ....................................................... 7
       3.2.2 Hand Interaction ....................................................... 8
       3.2.3 Two Handed Interaction ......................................... 10
       3.2.4 Natural User Interaction vs Graphical User Interaction . 10
       3.2.5 Natural user interface model .................................... 11
       3.2.6 Full Body Interaction ............................................. 12
       3.2.7 Dance Central body interaction ................................ 12
       3.2.8 Collaboration gestures ............................................ 14
       3.2.9 Tangible objects to easy identification ....................... 15
   3.3 Kinect and Wii technology ............................................... 16
       3.3.1 Kinect for Windows SDK ........................................ 16
       3.3.2 OpenNI ................................................................. 16
3.3.3 Kinect SDK vs OpenNI .................................................. 16
3.3.4 Kinect limitations ...................................................... 17
3.3.5 Wii vs Kinect .......................................................... 18

4 Solution ................................................................................. 21
  4.1 More Natural ............................................................... 21
  4.2 More Playable .............................................................. 22
  4.3 More Collaboration ....................................................... 22
  4.4 Four different Kinect interactions to compare vs Wii Remote ........................................... 22
    4.4.1 First Interaction: Hand interaction ........................................ 23
    4.4.2 Second Interaction: Full-Body Interaction .................................. 23
    4.4.3 Third Interaction: Collaboration Gestures Interaction ......................... 23
    4.4.4 Fourth Interaction: Tangible Interaction ........................................ 24
  4.5 Hand Interaction Proposed Solution ...................................... 24
  4.6 Full-Body Interaction Proposed Solution ................................... 26
  4.7 Collaboration Interaction Proposed Solution .................................. 28
  4.8 Tangible Interaction Proposed Solution ...................................... 29
  4.9 Wii Interaction ............................................................. 31
  4.10 Menu Interaction Proposed Solution ...................................... 32
    4.10.1 Level Select menu ....................................................... 33
    4.10.2 Main menu ............................................................. 34

5 Evaluation .............................................................................. 35
  5.1 How to evaluate natural interaction? ..................................... 35
  5.2 How to evaluate playability? .............................................. 35
    5.2.1 Question-Answer: Playability ............................................. 36
  5.3 How to evaluate collaboration? ......................................... 37
    5.3.1 Question-Answer: Collaboration sense .................................. 37
  5.4 How to evaluate fun? ...................................................... 38
  5.5 Participants ................................................................. 38
  5.6 Procedure ................................................................. 39

6 Results .................................................................................. 41
  6.1 Natural Results ............................................................. 41
    6.1.1 Skeleton natural gestures .................................................. 41
    6.1.2 Wii natural gestures ...................................................... 42
    6.1.3 Tangible interaction natural gestures .................................... 43
    6.1.4 Natural Summary ........................................................ 43
  6.2 Playability results .......................................................... 44
    6.2.1 Hand interaction playability factor ....................................... 44
# List of Tables

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Hand Gesture Recognition Accuracy [23]</td>
<td>9</td>
</tr>
<tr>
<td>6.1</td>
<td>Summary of all Natural Results</td>
<td>43</td>
</tr>
<tr>
<td>6.2</td>
<td>Summary of all Playability Results</td>
<td>46</td>
</tr>
<tr>
<td>6.3</td>
<td>Summary of all Collaboration Sense Results</td>
<td>48</td>
</tr>
<tr>
<td>6.4</td>
<td>Summary of all Main Menu Results</td>
<td>49</td>
</tr>
<tr>
<td>6.5</td>
<td>Summary of all Factor Results</td>
<td>50</td>
</tr>
</tbody>
</table>
List of Figures

2.1 Geometry Friends game actions [14] .................................................. 3
2.2 GeometryFriends Level Example .......................................................... 4
3.1 Group members form a chain of hands in order to exit CollabDraw [28] .......... 8
3.2 Hand Gestures for a media player [42] ................................................... 9
3.3 KinectSkeleton Program [26] ............................................................... 12
3.4 MMD Program [26] ............................................................................. 12
3.5 Dance Central Flashcards ................................................................. 13
3.6 Dance Central menu interaction ......................................................... 13
3.7 Dance Central menu selection ......................................................... 13
3.8 Collaboration gesture to draw a stroke with different widths [28] ............ 15
3.9 Recommend playable distance for Kinect ................................................ 18
4.1 Hand Interaction Movement .............................................................. 25
4.2 Hand Interaction Transformations ...................................................... 26
4.3 Full-Body Interaction Movement .......................................................... 27
4.4 Full-Body Interaction Transformations ................................................ 27
4.5 Collaboration Interaction Square Transformations .................................... 28
4.6 Collaboration Interaction Enlarge Transformations ................................... 29
4.7 Collaboration Interaction Full-Body Proposal ........................................... 29
4.8 Circle Interaction .............................................................................. 30
4.9 Circle Tangible Object ........................................................................ 30
4.10 Square Tangible Objects .................................................................... 30
4.11 Square Interaction ............................................................................ 31
4.12 Wii Interaction Movement ................................................................... 31
4.13 Wii Square Transformations .................................................................. 32
4.14 Wii Circle Transformations .................................................................. 32
4.15 Geometry Friends Level Select Menu .................................................. 33
4.16 Geometry Friends Main Menu ............................................................ 34
5.1 Questionnaire answer factor .................................................................. 36
6.1 New high natural factor gestures detected
Glossary

**AI** *Artificial intelligence* - computer science that studies and develops intelligent machines and software.

**CLI** *Command Line Interface* - A type of interface with devices/games.

**GUI** *Graphical User Interface* - A type of interface with devices/games.

**MMD** *Mikumikudance* - Application for creating 3D animations using players body joints.

**NUI** *Natural User Interface* - A type of interface with devices/games.

**RGB** *Red Green Blue* - Color Model for the reproduction of colors in electronic devices.

**SD** *Standard Deviation* - Variation or dispersion of mean values

**SDK** *Software Development Kit* - A set of software development tools to create applications.
Chapter 1

Introduction

1.1 Context and Motivation

Video games are continuously evolving and so does the mechanisms to play them. In the beginning only few buttons were incorporated in most input methods that controlled the games. But with the development of more and more complex games, the number of buttons incorporated increased. In the last past years, this complex numbers of buttons are being decreased and countered by motion control. Motion control in gaming had many premature starts, thus failing for the expected purpose. Nintendo Wii Remote was the first true success in motion gaming, even if it still relies on some traditional button/joystick controller input. The pure motion gaming with controller-less experience would arrive with Microsoft Kinect for the Xbox 360 console. These new interactions with games brings new forms of how to play games and at the same time bringing a lot of new revolution games to the market.

Many researchers have been exploring different approaches to play video games. But one feature still remains in most video games: competition. Yet, competition is not the only option that video games have. In collaboration games, like in Geometry Friends [14], the players may now play together to overcome challenges instead of fighting each other.

1.2 Problem

Many new forms of playing video games were introduced in the past years, but it is still unknown which is the best interaction mechanism to play them, and what are their limitations. Some interactions can be better for some type of games but worse for other ones. Regarding this, can an interaction change, like changing a Wii Remote interaction to a Kinect interaction, can also change the collaboration feeling of Geometry Friends? Can natural/playability factors affect this collaboration feeling? For this problem, different interactions types will be described along this document. The more suitable for Geometry Friends were extracted and tested in the game. Since the Kinect is a non-controller device (players are the controllers) while the Wii Remote still relies in it’s motion/button controls to play games, investigation about playability features like gesture recognition and natural interactions were possible factors to evaluate.
1.3 Dissertation Statement and Goals

The game was tested with the Microsoft Kinect and the Nintendo Wii Remote, so some research about several Kinect or Wii Remote games were searched and studied. In order to properly compare the Kinect with the Wii Remote within the collaboration sense measure, many different interaction were created for Kinect. *Geometry Friends* was already implemented and tested to work with the Nintendo Wii motion controller, so that Wii interaction was the one to be compare with the Kinect different interactions. Research about measures, problems, advantages and disadvantages that Wii Remote has when comparing with Kinect was been explored. All interaction tests were expected to gather information about natural gestures, collaboration sense and playability. The final goal of this dissertation was to have a proper comparison table that manifest advantages and disadvantages of each interaction tested. All these interactions are compared and discussed in this document results. The tests revealed that *Geometry Friends* can achieve true collaboration sense and this sense vary with an interaction change, yet no direct correlation was found between natural/playability factors and the collaboration sense of the players. All this contributed to conclude that more tutorials and difficulty changes should be evaluated carefully when changing the game interaction, especially when changing to a gestural interaction.

1.4 Document Outline

This document is structured throughout seven chapters. Chapter 1, in which this section is included, introduced the main context, problems and goals of the dissertation. Chapter 2 will describe the game where this solution was implemented and tested: *Geometry Friends*. In Chapter 3 will be where the related work comes, exploring the scientific community related to the problems announced. Chapter 4 is where the solution is describe in detail and all interaction implemented are illustrated and discussed. Chapter 5 will be divided by several sub-sections describing the evaluation procedure of all different factors evaluated. The results of the proposed solutions tests, will be described in chapter 6. Finally in chapter 7 and 8, it is announced the dissertation conclusion and future work.
Overview of Geometry Friends

Geometry Friends[14] is a casual game that attains collaboration between two player. The game runs in a two dimensional world with a physics engine. It is played by two players, wherein each player control a geometric shape, a circle or a rectangle. Each geometric shape has distinct possible actions (Figure 2.1).

![Figure 2.1: Geometry Friends game actions [14]](image)

The circle is able to move sideways (left or right), jump and morph. Morphing the circle shape means increasing or decreasing its size, consequently increasing or decreasing its weight. Like the circle, the rectangle can also move to both sides and morph, but the square can not jump. The morph ability works differently too. Using the morph ability, the square can stretch or contract its shape, always maintaining the same area.

Geometry Friends have a set of different levels to challenge the players. In order to complete each level, players must catch all purple collectible diamonds scattered across the level (a level example can be seen in Figure 2.2). Since Geometry Friends is a collaboration game, some of the diamonds can not be possible to reach without the cooperation of both players. This means that some diamonds are in places only reachable if both the rectangle and the circle coordinate their individual actions. The circle and the rectangle can also collide against each other. By combining their actions, players can achieve different results. Taking the level in figure 2.2 as an example, the rectangle can stretch while having the
circle on top, allowing the circle to reach otherwise inaccessible spots while jumping. These combined actions are what makes the game collaborative, since most levels are designed to be impossible to complete without at least one combined action.

Figure 2.2: GeometryFriends Level Example
Chapter 3

Related Work

3.1 Collaboration

The video games industry has a vast number of game types, but it seems more competitive games are developed than collaboration games. Most of these competitive games have a winner and a loser, but in fact anyone has to lose in video games. The collaboration games are based in the approach wherein the only way to win is for everyone to win.

Like in massively multiplayer online games (MMOGs) some collaborative mechanisms may be prominent, but the collaboration feeling about those mechanisms are not directly achieved [44]. For example, the ‘honor system’ implemented in America’s army (2002) is more of a system designed to entice people to play in team. The truth is that every player just plays their own way [24]. Another example is Legend of Zelda: Four Swords Adventures (2004). Even the producer of the game, Eiji Aonuma, stated that “although it is a game that four players have to cooperate to solve puzzles, when you play it, you actually end up competing a lot more in that game than you do cooperating” [27]. Behaving competitively in a collaborative scenario is exactly what should not happen in a collaborative game. Yet, cooperative mechanics are encouragement to perceive players into participate collaboratively.

3.1.1 Collaboration brings new gaming experiences

In collaborations games nobody has to lose, but can this bring new game experiences to the players? This section describes some lessons about how to use the collaboration features so that a player can fell a different gaming experience comparing to other individual games. The first problem is to completely abolish the feeling of competition. Collaboration games may have some challenges, but certainly not competition features. To counter problems of competitiveness, a collaborative game should give players a certain tension, so that they can perceive both individually utility and team utility [44].

In Wolfenstein: Enemy Territory (2003), a player can play the game as a solo soldier and even win the game singlehandedly, if skillful enough. That is what collaboration games should avoid. These games should prevent players to win games alone, thus giving the fell that they need his partners to win the game. However, each player should be allowed to make his/her own decisions and take actions without
the consent of others players [44]. Although players can be influenced by others to do some specific action, each player must feel they have the control. Online gaming usually does not have this problem, but games in which players play aside may have (like Geometry Friends). A good game must recall too that letting one player choose all the actions in the game (namely influencing all other players to perform those actions) may turn the game boring for others. Scotland yard (1982), for instance, can become boring since one player can actually tell everyone what to do. But, viewing from a game mechanic perspective, there are some techniques that can balance this problem [44]. One technique is to give the players different game mechanics to play with each character in the game. Making the controls difficult enough so that one player can not control both of them at the same time, is another way to contribute for collaboration. Hiding some resources so that each player only sees their own can also be good, since it forces communication (even more in online gaming). All these technique manages to introduce players the need of good coordination, communication and decision making.

After players perform their actions, they must be able to identify payoffs back to their decisions [44]. This means that players need to be able to reflect and perceive the consequences of their chosen actions. For example, a fight with a very hard monster with a game. Although one of the players can sacrifice itself to easily defeat the monster, the consequences of that action have to be evident in the next stages of the games. The game have to engage the players with satisfying results so that they care about the outcome of the game. If players do not care about the outcome of their choices, they will not fell motivated to collaborate with other players. At the same time, if the outcome is unsatisfying (either boring or random), they are unlikely to learn anything and may leave the game. Like in any game, the challenges have to evolve in order to demonstrate a different experience in each game. In fact, collaboration games face unique problems with ‘replayability’. The repeatability of a game can be countered by setup changing (like changing difficulty or adding some more random elements) or randomization the resources and obstacles through the course of the game [44].

Some methods described here are already implemented in Geometry Friends. For instance, in the monster example discussed before, there is actually an overlapping with another parameter of collaboration games. That is the bestow of different abilities or responsibilities upon the players, which tend to encourage team members to make selfless decisions. This feature is clearly embedded in Geometry Friends, since each player has different abilities regarding which of the two geometry figures (circle or square) are attributed to the player. The feel of helping and responsibility can sure make an collaboration game worthy of new gaming experiences.

### 3.1.2 Changing game experience by changing interaction

Video games are controlled by their input controls (e.g. motion controls) and these input controls are controlled by the players. This means that changing game input controls changes the way the players play the game. One can think in video games as an information gatherer to analyze how players are doing, and provide at the same time information in the game display (or screen). But video games are more than that. For example, one important concern in collaboration games is communication.
Changing the medium for communication can dramatically change how participants collaborate [44]. In [35], an exploration about communication space was done comparing between board games and video games. The study objective was to promote social interaction rather than isolation. The authors argue that for the most part of board games, the interface is simply present to facilitate interactions between people, not interactions with the game. This promotes that speech interaction as a way to control a game does not help collaboration, since speech interaction does not facilitate interactions between people.

3.2 Gestural Interactions

Gestural interaction it is not a dream anymore, its reality. Implementations of gesture-based arcade games like *Tetris* and *Pong*¹, gesture recognition toolkits², or even posture recognition³ are becoming ever more common. Attempts to mimic the interface of the *Minority Report* movie became even more popular⁴. The large number of research clearly shows that gesture controlled technologies are now in the interest of the people. It has been about 30 years of research, but the first commercial products of gesture technology launched only in 2003, 23 years after the research started [4]. Still, the entertainment industry is the main target of the products. But health care and home appliance industries are also investing on gesture recognition as it becomes intuitive and natural.

With the development of the Kinect, even more researches joined the business and even more games based on gesture interaction came along. Kinect can acknowledge patterns in the human body, but the performance depends much how it is implemented. Researches start by defining maps of body part movement to a set of gestures [13]. To do this, specifications of a set of rules or conditions on the movements of the body parts are refined by testing their performance on a set of test subjects. Such rules can be: 'if both feet simultaneously move upwards, then a jump gesture should be detected'. Since the gestures are detected by a set of test subjects, complex gestures should be avoided. Simple and few gestures should be introduced in a game, in order to increase Kinect gesture recognition and decrease confusion between gestures [10, 42].

3.2.1 Touch Interaction

When discussing gestural interaction, features about touch interaction have to be considered. This is because some implementations of these features are still gathered in Kinect (and others) gestural interaction. For example, in *Kinect Sports* (2011) the menus are designed just like a touch screen, i.e., it is designed with big buttons to ensure successful targeting of the touch event. Additionally, the active region of the buttons can be expanded [3]. *Kinect Sports* even uses these button features in the pause

---

⁴ [http://www.kconnolly.net/Post.aspx?Title=I+have+the+Minority+Report+UI+and+You+Don’t](http://www.kconnolly.net/Post.aspx?Title=I+have+the+Minority+Report+UI+and+You+Don’t) (last accessed November 19th, 2013)
menus or in cinematics (with the button to skip the cinematic).

But interface is different than interaction, and interaction is what was extracted. Big buttons may be good, but finding a good way to use them is better. In *Kinect Sports* the user can control the screen with one hand just like a computer mouse. The problem is that if a computer mouse or even a Wii Remote is being used, their would had some buttons implicit in them (in the mouse/Wii Remote) to click on the buttons of the screen. With Kinect, there are zero buttons. The only interaction possible is using the body (or speech), so different ways to do the ‘click’ have been explored. Again, in *Kinect Sports* the ‘click’ move is changed to a ‘wait’ move, meaning that if the player holds their hand above an screen button for a set period of time, the button is ‘clicked’. For helping with the procedure, an hand marker always follows the players hand so that the players know where is ‘clicking’. Another click move example is used in a kitchen Kinect application [30] where to press a button, the user rapidly move their active joint (the right hand for example) toward the Kinect, like they are pushing the button. There are many Kinect SDK's out there too that attain the touch features, and many of them can be useful for the menu of *Geometry Friends*.

These touch features can be used as collaboration features too. For example in the *CollabDraw* application studied in [28], the ‘exit’ move requires the consent of all group members. To accomplish the ‘exit’ move, all users must hold hands, and then one of the ‘chain’ members touches the table surface with a single finger (Figure 3.1). Another similar example is the ‘clear screen’ gesture, which needs all members of the group to simultaneously perform the ‘erase’ motion (which can be viewed as the ‘click’ move mentioned before). These techniques can be used in the *Geometry Friends* menu too by making the two players hold their hands in order to press a desired button.

![Figure 3.1: Group members form a chain of hands in order to exit CollabDraw [28]](image)

### 3.2.2 Hand Interaction

Most of the researches done for gestural interaction are based on hand gestures. Direct control can be immediate, but limited in the number of choices [9]. One of the most common used interactions in Kinect video games is the use of players hands as an input device. This comes from the fact that people use hands for anything in everyday life. Bringing this fact to games can make players feel more natural when interacting with the game.

A hand gesture recognition system are split in three main modules: hand segmentation, hand track-
ing and gesture recognition [32]. In the touch interaction sub-section above, it was discussed the usability of hand tracking where it can be used as a hand icon cursor in the screen to help players choose the desired screen button for instance. The hand segmentation module is how the Kinect can detect the players hands and fingers. How this hand segmentation is combined with gesture recognition is what can affect gameplay, since if it is not well implemented it could lead to an action delay. A gesture is acknowledged by a set of rules, as mentioned before. This set of rules is what gesture recognition is all about and is what Kinect waits for recognizing from the players. In the real world there is a large variety of hand gestures, in which even hand gesture alphabets were created. Many of these hand gestures could be used in Kinect games, but only some of them are used. This is because some gestures are more easily acknowledged by Kinect than others. Yi Li et al. [23] provides reviews for different hand gestures recognition, and the accurate acknowledged by Kinect (Table 3.1).

<table>
<thead>
<tr>
<th>Gestures</th>
<th>Start</th>
<th>Thumb-up</th>
<th>Thumb-down</th>
<th>L</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy(%)</td>
<td>99</td>
<td>89.5</td>
<td>88.25</td>
<td>91</td>
<td>90.5</td>
</tr>
<tr>
<td>Range(%)</td>
<td>98-100</td>
<td>86-96</td>
<td>85-94</td>
<td>88-97</td>
<td>89-94</td>
</tr>
<tr>
<td>Gestures</td>
<td>Okay</td>
<td>Victory</td>
<td>Star Trek</td>
<td>I ♥ U</td>
<td></td>
</tr>
<tr>
<td>Accuracy(%)</td>
<td>84.75</td>
<td>89.25</td>
<td>84</td>
<td>85-25</td>
<td></td>
</tr>
<tr>
<td>Range(%)</td>
<td>70-96</td>
<td>85-92</td>
<td>80-89</td>
<td>84-90</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1: Hand Gesture Recognition Accuracy [23]

As can be seen from Yi Li’s research, not all gestures are acknowledged the same way. For the “Start Gesture”, the accuracy is nearly 100%, and the fingers were perfectly identified. As for others, one can conclude that the ‘Okay’, ‘Star Trek’ and the ‘I love you’ gestures are poorly acknowledged by Kinect comparing with others, and thus should not be used.

Yang et al. [42] proposed another gesture recognition system using depth information provided by Kinect, which was able to recognize eight gestures (Figure 3.2), designed to control a media player, with an overall accuracy of 96.66 %. Yang system takes more advantage from the hand tracking module, instead of the finger and hand segmentation module that Yi Li have. Comparing with Yi Li’s research, hand tracking gestures are more precise then the hand segmentation gestures using for Kinect application, but reducing the number of actions in both modules leaded to better results.

Figure 3.2: Hand Gestures for a media player [42]
3.2.3 Two Handed Interaction

In everyday life, most activities mostly involve the use of both hands. This is the case when people deal cards, play a musical instrument, or take notes. Furthermore, using a two-handed interaction can reduce the gap between novice and expert players [32]. In the past subsection, the accuracy were significantly increased for all gestures if the users use both hands to do the same gestures. But even if it increases accuracy, there is no point in using both hands to do the same thing without any purpose. Buxton and Myers [10] concluded that performance can be improved by splitting tasks between the two hands instead of using the two hands for the same thing. The Gunstringer takes advantage of task splitting using two handed interaction. In the game, it uses one hand to aim and shoot, and the other one for moving the character (left, right or jumping). It is to remark that the shooting hand is intended to be the players dominant arm because it is the arm that is needed most.

Another example is Child of Eden (2011) which uses a two handed interaction too, but as an alternate two hand interaction instead of a real time task split interaction. In the game, players do more damage to some enemies depending which hand it uses, meaning that in some cases left hand will do more damage and sometimes right hand is the way to go. The advantage here is that by altering between hands the player exhaustion is minimized, which could happen in a one-handed interface (like touch interaction). Yet Child of Eden uses some gestures that need both hands to do same thing, for example to execute a special attack.

3.2.4 Natural User Interaction vs Graphical User Interaction

A large variety of simulators for entertainment (or not) are widely used in their respective fields, combined with its virtual environments with real interaction devices (e.g., the driving seat of a car) [2]. Like in all games, these simulators need training to master, but these have the particularity training with familiar interface and familiar interaction devices (e.g., the steering wheel). Many other examples including military [45], fire safety [38], medical triage [21] and crisis management training [33] use this concept, but use a mouse and keyboard interface. Mouse and keyboard interface may be easy for those who play nowadays video games and are familiarize in navigating in 3D virtual environments, but might not be so easy for does that are not. Unlike a driving simulator, players have to learn how to use the interface, but do not gain any benefit when applying the game skills in the real world [42]. The fundamental idea that makes people believe natural user interface are the future is that natural user interfaces are designed to reuse existing skills (like running) for interacting appropriately with content [5].

The way in which players interacts with video games changed dramatically with the introduction of the Wii Remote. Suddenly, players could interact with games using motion gestures rather than simply pushing buttons only. More recently, the introduction of Microsoft’s Kinect came to revolutionize the market even more, with a motion sensing device that allows players to interact freely using their whole body. The Kinect provides a low cost opportunity for creating gestures interfaces, and thus can help developers to introduce natural interface features in games (or application).

Natural User Interface (NUI) promise to introduce more natural ways of interacting with application
into people’s professional and private life [17]. Many NUI designers and researchers have focused on evaluating natural gesture sets in different aspects. Among them are the multi-touch interaction, gestures visual feedback and gestures learnability. However touch-screen or gestures interaction does not mean NUI. Without fundamental changes of the interface content and functionality, gesture or touch-screen interaction will not bring revolution to the promise of truly natural interfaces [17]. Without these changes, developers might fall into the trap of making a step backward into the era of rote learning of command line interface (CLI), except with gestures. Natural User interface is more than just the input or output device, and it is more than just the computing device itself. NUI is a new way of thinking about how people interact with content [5].

And still, a question has been asked by many: will natural user interfaces (NUI) replace the nowadays graphical user interfaces (GUI)? The answer is simple: did the graphical user interface (GUI) replace the command line interface (CLI)? The truth is that GUI effectively took over the role of the CLI, but the CLI is still used for specialized tasks where it is best at, primarily at programming tasks and certain system administration. The same is occurring with NUI. The natural user interface may take over the general purpose of graphical user interfaces, but GUI will, must certainly, still be used where the GUI is the most effective. Researchers believe NUI is now the more capable, easier to learn, and easier to use technology, like GUI was for CLI before [5].

### 3.2.5 Natural user interface model

Modeling a natural user interface is not easy, but it can be found some of the major tips for creating natural user interfaces in [5]. In this book it says that NUI needs to be well designed, reuse existing skills and appropriate interface with content. Humans are experts in different skills that they have gained along their human life. They have been practicing for years. Skills like human-human communication, both verbal and non-verbal are learned along life, and some of those are implemented in many games. It is up to the players to extract the practices they have been learning and use these existing skills (not gaming skills) to interact in the most appropriate way with games. But as discussed in the last subsection, NUI is not a specific input device or modality. A game (or application) could be considered to have a GUI or a NUI depending upon the interaction design that has been implemented. Natural user interface in games should take advantage of any interaction technology they are implemented on, as long as they focus on reusing existing skills. An interface is considered natural if it "exploits skills that people have acquired through a lifetime of living in the world" [5].

But games can not be just ‘a walk in the park’ game. Players want challenge. Humans can rely on another human feature: the innate ability to learn. Therefore, players can add skills to their natural abilities, likewise they need to learn new skills in order to adapt to a given environment in their human life. However, learned skills are different than innate abilities because players must choose if they want to learn the desirable skill or not. If new skills are to be introduced to players in order to play the game, these new skills must be naturally learned by players. Once learned, it should become natural and easy to repeat, like any other natural abilities that people learn in the human lifetime.
3.2.6 Full Body Interaction

Full Body Interaction is an ultimate gesture interaction that gathers gestures from all the previously discussed interaction methods. Microsoft’s Kinect can already track the player’s whole body and integrates the body state information into the game. Many Kinect applications and SDKs are scattered across the World Wide Web, yet most uses some particular body joints to recognize and track player’s body actions. For example, KinectSkeleton (Figure 3.3) is a game in which Scratch, the main character, can map the positions of the user skeleton [26] and use them to animate the character. In the animation department, Mikumikudance (Figure 3.4), commonly abbreviated to MMD, it is a free application that can be used for creating 3D animations without coding. Although MMD was not initially designed for Kinect, a plug-in was implemented and expanded to get the motion of all Kinect joints detected from the players. Figure 3.4 is a screen capture of a 3D model, mapping the movements of the user (the red man) [26].

![Figure 3.3: KinectSkeleton Program [26]](image1.png)  
![Figure 3.4: MMD Program [26]](image2.png)

However, in Geometry Friends body skeletons or animations are not so important since the game does not have humanoids characters. In a first approach, players can be confused on how gesture may be performed to conduct actions in the game. Therefore games have to convey kinematics (the features of motion of the body) to players by giving some instructions. But as discussed in the previous subsection, Kinect can attain a good natural interaction without real world context (e.g. living characters), if carefully designed. By using default actions in the game (e.g., player jumping equals ball jumping) or asking players to perform actions as they feel most natural, a set of natural gestures can be obtained just by players free movements. A similar test was conducted in [13] for a first person shooter game and a music player application. These tests included text, image and video instructions to see how much information is needed to give to the players so that they can understand and perform the necessary actions correctly. The research indicates that less instruction are needed when executing a more natural action.

3.2.7 Dance Central body interaction

Dance Central has an interesting feature for gestural interaction. The game brings an ample variety of dance steps, called ‘Flashcards’, taking advantage of the Kinect technology. Every Flashcard is a new move to master, and a new way to interact with the game. Flashcards examples can be found in figure
3.5. Giving some examples, this section details some of these new interactions and addresses how they can be used in *Geometry Friends*.

Like in most games, the interaction with the virtual world is controlled by introducing simple inputs, for instance a simple button press. If gestures are the inputs of the game, then gestures must be simple, otherwise it just makes the game more challenging and perhaps frustrating for the players. Most *Dance Central* moves detect arms and legs position, but more importantly is that it can use the detection to trigger simple actions in the game. Unless having difficult controls is part of the game mechanics, games should ease the input for players. *Geometry Friends* is designed to be a puzzle game and thus shall have simple controls.

Aside from the various menus in *Geometry Friends*, the game presents two main characters that are simple to control. One character is a circle while the other is a square, each having different features like previously explained (Figure 2.1 in page 3). *Dance Central* Flashcard can attain to simulate these two character features by gestural input. As notified before the inputs have to be simple, so the Flashcards were retrieved from easy mode. Movement for instance can be achieved by simply moving the player's arms, legs or body to the intended direction (e.g. Figure 3.5.1 to figure 3.5.4). Transformation could take advantage of hand or arm gestures instead (e.g. Figure 3.5.5 to figure 3.5.9), and many other ones could be used to pause, exit or replay the game. The only issue is that the combination of these gestures must be possible. For example, if the 'jump move' make use of both legs (like a player jump) and the movement use up legs to move too, a player would not be able to jump for a desired direction.

In the menus, *Dance Central* introduces a distinct interaction from the usually big button interaction discussed in the touch interaction subsection. The main goal of *Dance Central* is to make players dance with music a lot, so many musics are imbibed in the game. Selecting from a vast number of musics would be a rough problem using big button interaction, but *Dance Central* manages to compose a good gestural interaction that solved the problem. Instead of using an hand cursor, players must hold their right arm out to the side, just like figure 3.6 indicates. Then moving the right arm up and down iterates...
between the different options (or musics). To select the desired option, the players simply have to 'slap' the screen, by simply moving the right arm through the left side, as figure 3.7 describes.

### 3.2.8 Collaboration gestures

Since the appearance of wall-sized interactive displays, many researchers have been studying shared display for multiple user usage [28]. An example of a shared display interface was described in the previous section when discussing touch interaction (Page 7). In some Kinect games, the opportunity of playing side by side with a friend is viable. But expecting Kinect to record and track everything, like blinking an eye to do an action, can be a rough approach. Most research do not leverages from all the high-level representation of the human body (e.g. skeleton). Instead research focus in the collection of low-level features since full-body tracking is still a challenging problem [43].

In [43] it is described eight possible interactions between two persons using the Kinect technology. To detect the two persons, different features were explored, like joint features (distance from two points, for instance right hand to left hand) and velocity features. Unfortunately, the results were not so good since the maximum detection rate has 80% for the joint features. However joint points had a low confusion rate comparing with others, and even some gestures like moving right and left had above 8% confusion rate. This again comes with the knowledge that 'less is more', meaning that the less gestures are used for a game, the more accurate it becomes. Yet this does not mean the recognition will be better, so simple gestures can always be a good approach.

Most Kinect games can be played alone. This means one-player mode controls have to be introduced too for games to be playable. However these controls are retained when these games changes to a two-player mode. Therefore a player will play the game the same way, regardless of how many players are playing. Players can have a different experience, but the controls will remain the same. This concludes that the two-player mode in games turns to be rather a two one-player mode. A second player always turns to be a cooperation partner to help out, but cooperation can be attained though other ways. One way is with the addition of cooperation controls. Cooperative controls, like gestures, interpret the gestures of more than one player as contributing to a single, combined command [28]. Unlike a two one-player mode, one player cannot perform an action in the game, without the others response. These gestures can be induced as a new way for all players to be more collaborative.

Gestures as an input device can so attain collaboration between players. Yet both players gestures should have divisible and meaningful features. If one player could do the same (or similar) gestures faster and without the helping of a second player, then the combination of the two gestures is meaningless. It just makes inputs to be difficult. This does not mean the gestures have to be complex enough so that one player could not do it, or it would have the same result. The gestures have to be simple, and the combination of them must be simple too, but divisible. An input channel has to be an input device that provides independent input to the game [40]. For instance, mouse and keyboard would not be considered separated input channels since the keyboard can have dependence upon the mouse for certain tasks. These two are considered as a unique single input channel, and should not be divisible by

14
two users. So dividing up tasks by giving one player the mouse and the other the keyboard is not likely to result in a good collaborative experience.

Figure 3.8: Collaboration gesture to draw a stroke with different widths [28]

So what could lead to a good collaboration experience using combining gestures? This depends upon the game type. Almost anything could be considered a good collaboration gesture, but the players have to feel they are collaborating. Giving the example of the CollabDraw touch interface, two users could create a stroke and modified it through combining gestures [28]. For the whole gesture to be achieved, user A must draw the strokes using a single finger while user B places two fingers on the surface to determine the stroke width (Figure 3.8). Although one user could do it alone, this move could be rather harder to be achieved if only one user tried to do it.

3.2.9 Tangible objects to easy identification

Another approach for Kinect problems when detecting human gestures can be to use external tangible objects with the purpose of easily identifying player’s actions. Although this approach is a bit against Kinect slogan ‘you are the controller’, it can really increase Kinect performance. External gloves for instance, are items that have been seen in games consoles or application. This could be good for a boxing game since Kinect would have fewer problems detecting gloves instead of player’s hand. Plus, wearing colored gloves helps color segmentation and can greatly increase the reality of the boxing game [31]. This way the player will not lose the perspective of ‘you are the controller’. It is to remark that the idea here is that gloves or other objects are only carried for better Kinect accuracy recognition. The item itself is not meant to have any electronic device to interact with Kinect, it is just for recognition purposes. This means there is no additional expensive tools that have to be bought to play the game.

A Kinect game called Geek Run 5 explores Kinect in this different perspective. In this game players have to move cubes (yes, physical cubes) from one point to another. The player himself is not really the one who interacts with Kinect, but the cubes. The cubes themselves are just what the player’s controls in the game. Like before, the cubes are not mean to have any type of electronic element inside it, yet they become the interface between the player and the virtual world. By placing the cubes in the correct position, the game character avoids the obstacles and/or opens up a new path in the game. The game

5http://geekrun.ch/ (last accessed November 19th, 2013)
is designed for collaboration between two players (at least), since players need to react quickly to the
game and cannot manage to control all the cubes at once.

3.3  Kinect and Wii technology

Before getting to the solution chapter, the upcoming sections will discussed Kinect key features and
available SDKs, together with its limitations. Later on, a comparison with the Wii Remote is made to
understand the pros and cons of the Kinect and Wii technology.

3.3.1  Kinect for Windows SDK

Kinect had explosive sales after its USA launch on 4 November, 2011, selling more than one million
units in 10 days [26]. The technology intention was to be used in entertainment in combination with
Microsoft Xbox 360. However, the huge number of hackers\(^6\) shows that many applications of gesture
motion sensing can be used outside of gaming [11]. Thanks to the hackers success and release of
open source drivers [15], Kinect can now be used for software programs other than with the Microsoft
Xbox 360. Knowing this, Microsoft released a non-commercial Kinect software development kit (SDK)
for Windows and a commercial version later on [26]. This Kinect SDK can be downloaded from the
Microsoft website\(^7\). It comes along with some examples of use in various computer languages.

3.3.2  OpenNI

The open-source framework called OpenNI\(^8\) can also gather and use the depth data provided by Kinect.
By feeding the depth data into OpenNI it allows several joints to be tracked in 3D with joint recognition
algorithms. This framework is only one of the many hacked Kinect SDKs out there, but is by far the most
used [16].

Together with the open-source driver called Sensor Kinect (by PrimeSense) and NITE (OpenNI
Compliant Middleware Binaries and Libraries), the OpenNI framework can be used with Microsoft Win-
dows [11] too. It also comes along with some interesting sample programs to test.

3.3.3  Kinect SDK vs OpenNI

Many application exist for Kinect (a lot from www.kinecthacks.net), meaning that there would be many
alternatives to implement and recognize gestures with the Kinect technology. But many rely upon Kinect
SDK or OpenNI, so these ones were chosen for testing. Any of these two alternatives can be developed
in C# for Microsoft Visual Studio (and others), the same computer language and console that has been
used for Geometry Friends. So each gesture was tested for each application in Microsoft Visual Studio

\(^6\)http://www.kinecthacks.net/ (last accessed November 19th, 2013)
\(^8\)http://www.openni.org/ (last accessed November 19th, 2013)
using C#. This chapter compares and discusses some of the major features for gesture recognition that Kinect SDK and OpenNI have.

The major feature of the Kinect technology is that it is supposed to recognize the players body joints and use them to recognize a set of rules or conditions on the movements of these body joints to create actions in the game. All these body joints together create a skeleton of the players, and thus the skeleton recognition is the first important step of the Kinect and the first feature to be tested. Both SDKs (Kinect SDK and OpenNI) can track 20 joints of the human body and can track two players simultaneous (with a little lag times in the mere milliseconds) [16]. However, OpenNI’s tracking system requires the players to hold a calibration pose until it can truly identify and begin tracking all the players body joints. This is not necessarily with the Kinect SDK since it uses a specialized system that compares known images of humans with the Kinect data received [37], allowing to quickly (less than a second in most cases) generate all body joints. This is great in a walk in/walk out situation, which could not be granted by the OpenNI, since if some player would walk out of the Kinect range, that player would have to do the calibration pose again.

For color basic interactions like *Geek Run*, where the players skeleton tracking is not important, the color camera would be the more important feature to recognition. In this feature, the Kinect for Windows SDK is able to grab a full 1024x768 resolution color image, while the OpenNI is only capable to get a scaled down 800x600 resolution [16].

Aside for skeleton and color recognition, Kinect is capable of use speech recognition for controlling the game actions too. In this feature, OpenNI has no capability or support to record audio from the Kinect device, it is remarkable the need of the Kinect for Windows SDK to truly use the Kinect speech recognition skills [16]. However, the usability of speech recognition may be limited when the room gets noisy. Since *Geometry Friends* is a collaborative game that requires communication between players (especially for new players) the room may get noisy, thus complicating Kinect speech recognition. Because of this, the speech recognition was not considered in the proposed solution.

As a concluded result, the Kinect for Windows SDK showed superior joint tracking and a higher resolution access to the color cameras when comparing with the OpenNI. Yet, there are still reasons to consider that OpenNI has an alternative since it has completely supported across consoles (including most major Linux distributions and OS X) while Kinect SDK is not. Since the dissertation objective does not include which computer console to use and as *Geometry Friends* is implemented in Visual Studio using XNA, it was more viable to use the Kinect for Windows SDK and thus it was used for all interaction proposed.

### 3.3.4 Kinect limitations

Kinect has several limitation and some of those are implicit in every manual of a Kinect game. First of all, there is a limitation on distance usage (0.8m minimum to 3.5m maximum user distance). This can restrictive for families that do not have large living spaces (a common situation in Japan and Europe). In a Kinect game manual, it recommends 1.8m (6feet) for one player and 2.4m (8feet) for two players.
Furthermore when playing together, the players have to give each other some space.

Some minor issues like being in front of the camera in order to track the player’s body correctly have to be insured too. For instance, the best way for the Kinect to track the player’s hands for menus interface is to move the hands in front of the player’s body. Unfortunately another issue arises from this. If the depth camera does not identify a body part (e.g. head), that body part would be hidden in the game as well [11]. For this issue, the xbox team wrote a tracking algorithm that rejects these ‘bad’ skeletons and only accepts the ‘good’ ones⁹. So theoretically Kinect could track the player’s skeletal body with its depth camera and the Kinect database of poses. This is in fact true, but only for standing poses. This is due to Kinect database having standing poses only. Therefore the Kinect will only work when the player is standing, even when navigating through menus [37].

Another issue is lighting exposure, i.e. the sunlight. Good lighting helps the Kinect sensor to recognize the player, but direct exposure to sunlight might interfere with the sensor. Wearing a jacket with big, floppy sleeves, a skirt, or a dress can also confuse the Kinect sensor. It may think they are extra body parts.

### 3.3.5 Wii vs Kinect

Nintendo’s Wii Remote was the first true success with motion gaming, but still relying on traditional button/joystick controller input. Wii Remote is still for nearly anyone, but mainly for casual gamers like kids. The Microsoft Kinect instead, revealed that pure motion gaming with controller-less experience can be achieved. These new interactions with games brings new forms of how to play games and at the same time bringing a lot of new revolution games to the market. Still a lot of question have been put against these technology and many comparisons were made. Questions like ‘will Kinect gesture gameplay combined with superior graphics make the Wii Remote seem like an inconsequential toy, or will the cost make the difference’; ‘will game developers come up with more interesting movement ideas now that there are more consoles to develop for, or will this just create the number of cheap mini-game

---

⁹http://users.dickinson.edu/ jmac/selected-talks/kinect.pdf (last accessed November 19th, 2013)
collections and exercise games?’. Regarding these questions, this sub chapter will discuss Wii Remote and Kinect advantages and disadvantages that influences the game experience and overall playability.

Beginning with the most questionable feature, the Kinect required environment physical space in which Kinect games has to be played can be very restrictive for families that do not have large spaces or luxurious living rooms\(^{10}\). As said in the previous chapter, the Kinect requires (not just suggests) a play area of about 2 x 2 meters (6 x 6 feet) of clear space\(^{11}\). This problematic feature is further increased when playing with more than one player (\textit{Geometry Friends} case), which requires at least 2.4 meters (8 feet) away from the Kinect sensor plus the distance from each other that they actually need to do the gestures. Lastly, playersl need an area without a lot of traffic (like kids or animals jumping in and out of the game) since the Kinect sensor can confuse them with the actual players that were playing the game. It’s very magical, unless something interrupts the game. The Wii Remote is more forgiving in terms of space, and it is easier to set up. All the players need to do is attach a sensor bar, and even the Wii Fit board is self-contained\(^{10}\). It delivers a better system for playing in cramped quarters, such as dorm rooms or kid’s bedrooms. This feature was a major statement in this dissertation tests.

The Kinect has a controller-free gameplay combining with an motion-heavy game that is perfect for fitness nuts, families, and casual players like kids\(^{10}\). Even non-gaming people may be impressed and play it. Although navigation with Kinect can be temperamental, the game play feeling without a controller is considered intuitive and easy [25]. Not to forgot that one of the key aspects of the Kinect development was to generate an excitement promotion of the natural user interface (NUI) paradigm [11]. It’s just right for anyone who is "afraid" of a controller. Game play is also easier for young kids who don’t get the hand-eye coordination for controller-based games. However, hard-core gamers would not considered that Kinect replace the satisfaction of precision-dependent tilt-based physics of the Wii Remote [22]. In fact, the Kinect Controller-free makes first-person shooters and other precision titles nearly impossible to attribute \(^{12}\).

When comparing with the Wii Remote, one of the major feature that Kinect is challenged is about how precision the gesture recognition can be. The fact is that the actual response has a lot to do with the game it being played, but Kinect itself is fairly accurate with minimum lag between the players movements and the reciprocal moves in the game [25]. However, Kinect will only work when the players are standing due to the Kinect database having standing poses only. Though there is certainly nothing wrong with getting gamers off the couch, Kinect loses to players who want to play games, but are too tired after a long day at work to actually get off the couch [25]. In [6], a major comparison between Wii Remote and Kinect about the energy cost exhaustion in similar games types, concludes that there was no significant difference between the two systems for any of the measured tested, although the Kinect had slightly greater values.

Summarizing, the Kinect has an impressive body tracking algorithms and unique controller-free experience, which is great for casual gaming parties and workouts since it also promotes natural user


interface. Yet, it requires a lot of room to play, hard-core gamers may not feel so much satisfied with insufficient precision, an it requires to do standing poses which can lead to gesture exhaustion. This calls for an evaluation within gesture recognition, gestures difficulty, gesture exhaustion and the environment physical space to properly compare the Wii Remote with the Kinect.
Chapter 4

Solution

Along this document there has been described many interactions with several devices and consoles. So far as is known, each interaction is design for each device, and changing interaction may penalize the device and vice-versa [20]. Many researches have already compared several devices (in this case, video consoles devices [18]) to whom is the best for their interaction or specific game type. For motion control gaming devices, many studies and research have already compare Kinect and Wii Remote [18, 41], as it was here done. But most comparisons accord to some specific interaction and most of all are single-player researches. In this dissertation, it was researched if the Kinect can be compared with the Wii Remote in collaboration games. Single player games can be intuitive, easy and fun to play, yet not communicative and family fun designed. Most games with motion and gestural control are design more purposely for families, and not for an specific single player. That is why most games for Wii or Kinect can be played with two players. But as explain before in this document, two-player games are much different from collaborative games, even if both players seek the same goal.

After investigating how several researchers solved their motion control [7, 13, 18, 31, 34, 42], collaboration issues [28, 44], it has been developed several interactions for Kinect to compare with the currently Wii interaction. A solution is described to attain collaboration through Geometry Friends with the Kinect and compare latter with the Wii Remote. The proposed solution mainly focuses on gestures since the way players perform the gestures can influences his/her sense of collaboration.

4.1 More Natural

Gestural gaming introduces new forms of playing games as being seen in many Kinect games. In fact, interactions evolved from being code based that only few could understand, to a natural first time understandable interactions that anyone could understand [5]. Since players like to understand all mechanics and everything that is going on in the game, game developers (and overall user-based developers) have been focusing very hard in natural user interactions [12, 20, 29]. It is true that even if some particular interaction is not so good, there are many players that could adapt to it and still enjoy the game. But there will always be newbies and bad players that might not understand be interaction or find it to much
confusing to learn, thus disliking the game because of that. So basically, the more natural an interaction can be, the more understandable it will become. This way more players will like the game, resulting in more enjoyable gameplay for everyone.

4.2 More Playable

Playability is the one thing games can not avoid. If buttons are supposed to do something, those things must happen in the game. In the same way, if gestures are done correctly, the game has to recognize them correctly to. If gestures are not recognized correctly, players became frustrated about the game since they would need to constantly repeat the gestures to make it recognized. Plus, if the device would not recognize his/her gestures when players needed thus missing the desirable timing to execute the move, then they would feel even more frustrated. So basically, more playability indicates less frustration and then contributing to more fun.

4.3 More Collaboration

As spoken all over this document [28, 44], collaboration games can bring new different experiences to the game industry. But still, true collaboration games are not easily done, since players tend to do what it is good or fun for themselves and not for the entire team or partner [24, 44]. The reason why to evaluate this feature was to see if true collaboration can be the intense of the joy of the game, instead of the joy of winning alone.

4.4 Four different Kinect interactions to compare vs Wii Remote

Since non-button interactions have arrived, game developers start wondering about different interactions that can be used [29]. Unlike Wii Remote, Kinect offers a non-linear control base. The Wii Remote however, needs to necessarily use a Wii Remote control to play Wii video games. This feature opens a wide variety of possibilities for Kinect, but this is not a necessarily advantage for Kinect. In fact, there was never a linear and natural use of Kinect that one could say it is the best for that game without even testing (unless the game itself use people lives workouts like in Kinect Dance Central).

From the research gathered [2, 5, 19], it is noticeable that using hands to play Kinect video games is a ‘should’, but certainly not a must. People use hands for everyday life, and hands itself have been used for playing games from all these years past, witnessing many different hand interactions. Since using hands can be a good requirement for different Kinect interactions, the next question is: can other body parts be useful for gaming to? Well, it is true that hands are very useful and most certainly will be good for differently gestures possibilities. But since Kinect does not use buttons itself, can hands alone have the utility to unify all gesture and mechanics used in Geometry Friends? Regarding this question, four different Kinect interactions were introduced in this dissertation. The following sub-chapters will describe every one separately.
4.4.1 First Interaction: Hand interaction

As said before, interactions with hands alone in games are a common use in many games [2, 29]. Examples of this are *Child of Eden* or the *The Gunstringer* video games developed for the Kinect. These examples surely explain themselves why only using hands for a Kinect interaction can be fun and viable. Regarding with the objective of the thesis, this interaction is meant to have few and simple gesture by merely using hands. This attains to an efficient gesture recognition with little or no fails together with a quickly learning curve, thereby delivering a more Playable ratio of the game. Therefore, this interaction is all about focusing in the Playability factor. Yet, since hands are used in everyday life, natural behaviors can be achieved, which would be a plus for this interaction.

4.4.2 Second Interaction: Full-Body Interaction

The Kinect surely extended players full body parts as interactions with the game. Hands alone are no longer the only usable body part that can be used for gaming. This is clearly shown in the natural dancing game *Dance Central*, which makes use of all body parts for dancing, from top (head) to bottom (feet). Comparing with hand interaction, full-body interaction can diverge with more possibly ways for interacting with the game that hand interaction alone can not. This means, more natural and simple ways to play games can be achieved. Yet, it is all about making other body parts useful and logical for gaming, and not only overdoing it when hands alone can do it more precisely and faster. For this interaction that uses other body parts rather than only hands as gestures, it is expected a less gesture exhaustion and better gesture recognition than all other interactions.

4.4.3 Third Interaction: Collaboration Gestures Interaction

For most games that have been seen for the Kinect of the Xbox 360 (and in other consoles to), games itself are used to be played with the exact same gestures in single player mode and in multi-player mode. This feature falls with the pitfall that games are made for a single player to be able to play the game, and multi-player mode are just for those who like to play with friends, family, etc. This method is most viable in many games, as it is used in most games nowadays. But this dissertation introduces the fact that players are tested when playing a collaboration game. Collaboration games are not meant for players who like to play games alone. Collaboration games need and are meant to be played with at least two players. Of course some AI (Artificial intelligence) could fix the problem for single-player mode, but this can and will most certainly ruin the collaboration experience that collaboration games want.

Attaining to a good collaboration feeling, this interaction use collaboration gestures to be more focused on the multi-player mode and collaboration with other people. These collaboration gestures are meant to use the gestures of different players as one single action in the game.
4.4.4 Fourth Interaction: Tangible Interaction

As said before, the Kinect does not have a linear base control as the Nintendo Wii, which necessarily needs the use of a Wii Remote control to play Wii video games. The purpose of Kinect was to use it for interacting with the game without any control mote needed. This feature is reinforced by Kinect slogan saying that ‘You are the controller’. Yet many tests were done and Kinect brand have developed and studied many different forms apart from body parts interactions. In fact, in the particularly game called *Geek Run*[^1], the interaction is not done with the player’s body parts, but with tangible objects. Of course, players are the ones that move the objects, but Kinect will only have to see were the objects are, rather then needing to know where the players are.

This particular interaction comes with the need of solving space environment and gesture recognition problems together with the realistic feature that tangible objects can deliver. The tangible objects were introduced to interact with the game, instead of the player skeletons. So far as is known, Kinect is not perfect when it comes to gesture recognition. Following a particular defined easy shaped object could easily be more accurate than following player’s body parts if correctly done. The feature that Kinect only works for step-up player position along with the space problematic for Kinect when it comes for a two-players mode, made this last interaction viable. This way, both players can either step-down in a chair and still have a nice time. Finally, this tangible interactions can also increase the realistic about the game showed. For example, if boxing gloves are used for the interaction of a boxing game for Kinect, it will surely be more realistic than without them.

4.5 Hand Interaction Proposed Solution

What player can do with hands for interacting with games is largely explored, regarding that many different interactions have been produced and implemented for hand interaction games. This includes using the hand tracking technique, hand gestures and still, but less commonly used, finger gesture interactions. Clearly, finger gestures is the less explored here since it requires to analyze and identify all finger of the players hands. The Kinect already has an algorithm that scans many body parts including both hands, but does not have any additional aid or support for finger tracking. However, there have been many researchers studding how to use Kinect for finger detection and some of them are viable and accurate. Yet, most of these finger detection algorithms work at close range, and are surely designed for one only single player to use it, not for two. Regarding this fact, finger gesture interaction has been excluded from option for the Kinect hand interaction.

From the existing Kinect games that uses hands as the main or only interaction for the game, it is remarkable that most of them use both hands to interact instead of just one. And this is remarkable not for games that is intuitive to use both hands, like in boxing games, because they only extract the interaction of real life situation (that is why most of these are called simulations games). What is in fact remarkable are those games that could choose to interact games with only one hand, but went to a

double hand interaction. Examples of these games are *Child of Eden* or *The Gunstringer* that makes use of both hands, but could rather make use of only one hand to interact, since the game itself does not need so many gestures. The reason here is the same reason why people use both hands in everyday life instead of one. It reduces the exhaustion of merely using only one hand and increases more gestures capability and options that one person can make. For this fact one hand interaction has been excluded from option too.

In the postmortem of the *The Gunstringer* game [29], the author recall that 'While early prototype tests included complex and overloaded arm movements (pattern matching, repetition, or velocity to differentiate between two similar motions), they quickly fell to the wayside if they didn’t “just work” for a casual player’. This quickly conclude why complex gestures should be avoided. In latter, the same author says that 'After some experimentation, we found that controlling the Gunstringer’s movement on one hand and using the other for target/fire gave us the best balance of accessibility'. Other application like *Kinoogle*[8, 39] also recall that navigation using only one hand is more intuitive. Furthermore, they have use the other hand as an action hand. Mohamed Alsheakhali et al. [1] further considers that dynamic gesture are more perceptive to fail with the Kinect sensor, rather than static gestures.

Regarding these studies [1, 8, 29, 39], it was decided to use both hands and tracking the hands with Kinect to recognize gestures to use in *Geometry Friends*. As to decide what gestures to use, it was been decided to use the same gesture as *The Gunstringer* game have. Seeing *The Gunstringer* gestures example, it is remarkable that the right hand is used to do the more active actions (shooting) while the left hand is used to do moves that are less used (moving, jumping). While the left, right and jump move are the less used actions in *The Gunstringer*, in *Geometry Friends* these are the most used. For this reason, the left, right and jump move was considered to be executed by the right hand, instead of the left hand. So, moving the right hand left or right was used for moving the polygons, and moving the right hand up was used to jump with the circle (Figure 4.1).

![Figure 4.1: Hand Interaction Movement](image)

The left hand was considered as the transformation hand. It was used for the remaining actions, which is the ball enlarge action and the square stretch or extend actions. As it can be seen in figure 4.2, to enlarge the circle, the player simply needs to put the left arm horizontally. To deform the square, two gestures are needed, one for each transformation. The ones proposed was to have the transformation hand raised to make the square thinner, or put the left arm horizontally (as the enlarge action of the circle) for the inverse purpose.
4.6 Full-Body Interaction Proposed Solution

Instead of tracking one particular point such as hands, full-body interaction is more focused on gesture using different body parts as one gesture. If only with hands alone there was a lot of diversion of gestures, with full-body the diversion is almost unlimited. Dance games like Dance Central are the proof of that. There are so many different moves in Dance Central that one could not memorize it all. The problem is what should be the moves to put into consideration for a Geometry Friends interaction. The first point here is that Geometry Friends is not an action game. Although it requires some fast timing actions, it is more of a puzzle game than a true action game. So the gestures needed here would be some calm ones rather than agitated and rough ones that can exhaust players more easily. Putting apart the Kinect games that use body parts for real life sense (like using body to dance, or using foots to play soccer), there are many few Kinect games that use body parts other than hands for gestures. So even if it is a full-body interaction that is wanted, the hands was considered the most usable body part to play the game, as many existing Kinect games use.

Taking in consideration some of the quick timing Dance Central moves to adapt in Geometry Friends, it was concluded that using all body parts are not necessarily and would only be wearing. It could result into a non natural way to think of an interaction and the learning curve could be drastically long. As said before, hands are the most useful body parts and so it was used for most gestures in this interaction. From Yang et al [42] and Yi li et al [23], it can be said that two-handed gestures can be more precise than one hand gestures. Regarding this, only the square and circle movement (left and right) is proposed so that it does not use hands. The proposed gestures for square and circle movement were the player’s head and body (Figure 4.3), since this gesture have been greatly valued in many 3D environment application [8, 36]. This move also delivers a natural way for players to understand when they are actually moving right or left.
Since movement does not require the player’s hands, both hands can be used for transformations. To reduce the number of gestures so that players get use to it faster, only two gestures were proposed. Both gestures are illustrated in figure 4.4. As illustrated, players have to raise both hands up to jump with the circle. In case of playing with the square, the square would get taller instead. Raising both hands in a horizontal position, served to make the square wider or to enlarge the circle. There was a caution to make both circle and square gestures equally, so that if players desire to change polygons it would be simple, not abdicating all gestures learned.
4.7 Collaboration Interaction Proposed Solution

The collaboration interaction is meant to bring gestures of both players together as one. This interaction is not common in most Kinect games and even in most games in general. Because of this feature, this interaction has measure by a common sense from the Geometry Friends actions. This time, players did not have specific control of the square or the circle. Both players controlled both of them. However, the movement of both circle and the square was proposed to be a single based gesture, since many collaboration gestures could be confusing and hard to memorize. This feature was also proposed because it gives players to know the important role of 'who I am'.

As the Full-Body interaction, the collaboration interaction was not easy to gather solid gestures that could perfectly fit in Geometry Friends. The only feature that was acknowledged here was to make convenient the use of both hands again, to execute most gestures. The first question here was if making use of other body parts would gather efficient or not. Thinking in the opposite way, using both hands interaction would probably end up with too many gestures for just one hand, if the other hand is used for movement and jumping as the hand interaction. Even if the movement hand should have the jump action gathered, there would be still three gestures to do it with the other hand (Thin or Fat the square, or enlarge the circle). Three gestures are not too much, but if using other body parts would reduce this number, it would be easier to players to get used to it. And players would not have to memorize what each hand gesture is for. For this reason, it was remarkable the need of other body parts to interact. In fact, the first point was to cut down the square transformations using other body parts since it requires two gestures. The proposed solution was to use the distance between players to make these two gestures (Figure 4.5). This way the further the players are, the wider the square becomes and vice-versa. This simple idea converts two gestures to memorize into only one to memorize, since players only had to know that the square modifies according to their distance.

![Figure 4.5: Collaboration Interaction Square Transformations](image)

With the square transformations gone, actions are reduced to only two: jumping or enlarging the circle. Returning to the previously example when only one hand could be used for movement and jumping, this would make the other hand with the enlarge action only, which would be great. For the enlarge action it has proposed to use the one hand further from the other player (Figure 4.6). For the jump action, players had to use the opposite hand (Figure 4.7). In order to not confuse the movement hand with an action, the movement actions were proposed to be like the full-body interaction.
4.8 Tangible Interaction Proposed Solution

The tangible interaction was thinking about the Kinect as a form of bringing life to real life tangible objects, completely ignoring the fact that Kinect was created as a 'no controllers’ device. Although these objects have no controller chip added to communicate with Kinect, they will represent the main interaction with the Kinect game. The choice of which tangible object to choose was rather easy and logical, as Geometry Friends has already polygons to choose from. Yet, since the polygons in the game use transformation actions, this would be rather hard to transpose it in real life object actions.

Beginning with the circle (the easiest one, since it has less transformations), the polygon was transposed to a 3D circle object. For the actions, the interaction was measured again by a common sense from the Geometry Friends actions, since the tangible object should do exactly the same as the object in the game do. The circle actions was been carefully copied from the game actions. So for the left and right, players had to rotate the circle with his/her hands (of course they could rotate it using whatever they wanted, but with hands it is easier). Likewise, players had to translate the circle tangible object up, above head or so, to jump with the circle. The enlarge action was not so easily chosen since it could not have a direct action as the enlarge transformation in the game. For this action, it was proposed for player to translate the circle tangible object to the Kinect, so that the Kinect would see the circle larger and though the circle in the game would enlarge. A resume of all the circle actions described here are illustrated in figure 4.8.
In the other hand, the square actions were not so easy to directly implement in real life objects, since the square in the game is very deformable. A good direct tangible object to expect from the square action requirements would be some deformable plastic or gelatin one, which would not be a cost effective one. It should not be forgotten that the tangible objects should be at a cheap cost, since the objective here is to help the Kinect to identify the objects, not to communicate with Kinect. Even a cheap chip set in a non-deformable tangible object would be cheaper. For this reason, it was proposed the elaboration of a difference way of making these transformations. Similarly to the Collaboration Interaction, the distance here can be a good easy way to interact with the Kinect. This time it was used the distance between two square objects, instead of the distance between two players.

This way, with the help of two green rectangle tangible objects (thus each rectangle representing half of the square in the game), the square transformation problems were done for. The closer the two squares are (the minimum would be at clashing both rectangles) the thinner the square in the game would be and vice-versa. With the transformation problem solve, only the left and right actions are up to be done. Naturally, players would have to move from his/her place to move the square as the game logic would represent. But, as technically this would not bring good usability of the game objects and since this interaction is meant to be possibly played in a chair or so, the square movement has proposed to
be done by translating both rectangle objects to the right or left of the players body without the need of moving the body. All the square actions described here are illustrated in figure 4.11.

Figure 4.11: Square Interaction

4.9 Wii Interaction

The Wii Interaction was not changed from the pasted Geometry Friends Wii interaction implemented. Although this interaction was not done in this dissertation, simple and few controls were already implemented. This interaction uses only the Wii Remote to control the circle and a Wii Remote together with the Nunchuk to control the square. To move the circle, the players needed to tilt the Wii Remote to the sides (right and left). In the square case, the Nunchuk was the one needed to be tilt sideways to make the square move in the designated direction (Figure 4.12).

Figure 4.12: Wii Interaction Movement

The Wii Remote of the square was used instead for the square transformations. Pointing the Wii Remote up or down, make the square to stretch up or deform downwards respectively. Since this the
Wii Remote for the square is used for transformation, it was meant to be used in the hand of the players dominant arm (mostly, the right hand) with the Nunchul in the hand of the non-dominant arm (usually, the left hand) (Figure 4.13).

![Wii Remote and Nunchul](image1)

**Figure 4.13: Wii Square Transformations**

To jump with the circle, the player needed to shake up the Wii Remote. The more the players shake, the more the circle will jump. For the circle enlarge action, it makes uses of the B button of the Wii Remote. Pressing the B button would grew the circle to its maximum size, and released it would decreased to its original size (Figure 4.14). This makes the B button the only non-gestural or non-motion move of this interaction, accomplishing a good interaction to be compared with the Kinect.

![Circle enlargement](image2)

**Figure 4.14: Wii Circle Transformations**

### 4.10 Menu Interaction Proposed Solution

Now that all ‘in game’ interactions had been described, there was still one last interaction evaluated in this dissertation. Since every game has menus to begin with, the menus themselves have to be tested to research if they are appropriated for the game. The game can be great when playing, but if the game menus create headaches before even playing it, it can cause a worse perception of the game itself and cut off the excitement and experience that games could create.
4.10.1 Level Select menu

From the interactions researched, it was gathered and concluded that most Kinect games (and in general, motion control games), choose a big buttons interaction for menu interactions (for example, the menus of Kinect Sports). Geometry Friends level select menu (Figure 4.15) is designed with a big buttons menus perspective too, and thus should copy cat what most kinect games uses for menus. This generally is to control a cursor with the left or right hand and use it as a mouse in a computer is used.

![Figure 4.15: Geometry Friends Level Select Menu](image)

However, this dissertation covers five different interactions as described in above chapters, including an interaction with tangible objects. This means left or right hand cursor can not be considered to implement for every interaction proposed. Nevertheless, with the exception of the tangible interaction, it was proposed that the right hand was the cursor of all interactions proposed for the level select menus. Since only one player is needed to control the cursor, the first player was the one controlling it (the first player was the one that controlled the circle after level selection). In the tangible interaction, the circle was considered the cursor, instead of the right hand.

Besides hand tracking mechanism (cursor), every button needs a 'click' move. This 'click' move relied upon the interaction tested. This means that every interaction proposed above had different interactions in the level select menu. If using the hand interaction or the Full-Body interaction, the 'click' move was simply by doing 'nothing'. Players only needed to hold the cursor above the selected options for a short time, until the button was selected (just like Kinect Sports does). In the other hand, if testing the collaboration gestures interaction, the 'click' move was provided by the second player when he/she pushes his/her hand to the Kinect, equivalent as punching to the screen. Finally, if the tangible interaction is being tested, the ball was the cursor of the game instead, but the click move was by doing 'nothing' as before.
4.10.2 Main menu

The main menu of Geometry Friends (Figure 4.16 negates to use of big button usability, and gather instead words size buttons (single-player, multi-player, options...) as the interaction, much like non-motion games does. From the Kinect games that use these button words instead of big buttons, the one that was remarkable has the Dance Central mechanism (described in chapter 3.2.7). This one interesting mechanism was proposed for testing in the main menu of Geometry Friends, since it delivers an efficient way to navigate this type of menus.

![Geometry Friends Main Menu](image)

Figure 4.16: Geometry Friends Main Menu

If for some reason the results happen to be negative, the main menu will be considered that is inefficient with a words buttons interaction and thus should be modified, in future work, to a big buttons interaction as the level select menu have.
Chapter 5

Evaluation

5.1 How to evaluate natural interaction?

This natural factor was not truly evaluated since one can not not say the interaction is truly natural just by seeing it. The only thing that can be judge is some parameters like the number of errors and handling time, but that is parameters for the Playability factor below. What was evaluated here is what players do when they know nothing about the game. Before providing instruction to the participants, a natural interaction section was added first, before truly playing the game. In this section, player would only know what the two polygons (circle and square) can do. After explaining that, it was asked to participants to perform the movements as they feel is more natural. It has giving a time of one or two minutes to do so. All of this was recorded in a film from a common video camera. After testing is done, it was checked and noted every gesture that all participants have done in this section. Then it was evaluated if there were similarities between each different gestures noted and the gestures of all interactions proposed in this document. When similarities were found, the greater natural factor that interaction had.

5.2 How to evaluate playability?

The playability factor was evaluated through a gesture recognition accuracy section. This section was tested after providing instruction to the players on how to play the game. This way, players know what is supposed to happen in the game when a certain gesture is used. To further evaluate this feature, it has asked to players to play at least three levels of the game. This averagely resulted in a thirty minutes gameplay time, which was more than enough to evaluate gesture recognition.

Evaluating this factor was not an easy task, since the platform can not possibly know when it fails to recognize a gesture. Using the same video capture of the players gameplay (as the natural evaluation does) plus a video capture of the game, it was manually extracted the gesture recognition accuracy of each interaction. Manually counting either when it fails or succeeds to recognize a gesture resulted in a percentage, which was exactly what was needed here. This percentage was good to both evaluate playability and compare with other interactions. On the other hand, playability it is not only about gesture
recognition. For example, player may experience recognition fails and may not issue with these fails or not even perceive them. To complete a good playability factor, it was given some questions to them when the gameplay was finished, regarding many playability features. These questions regarded not only gesture recognition, but difficulty of the gestures, gesture exhaustion and the environment physical space issues in which the game has played too.

5.2.1 Question-Answer: Playability

In this section, it will be described every objective of each question done in the questionnaire provided to players after gameplay. Some questions were simply answered by 'Yes' or 'No', but most had a one to four factor (Figure 5.1) so that it is possible to extract more detailed information about these answer, resulting in a more diverse way to compare between different interactions.

<table>
<thead>
<tr>
<th>For the questions with (1-4) factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: No</td>
</tr>
<tr>
<td>2: Few times</td>
</tr>
<tr>
<td>3: Yes</td>
</tr>
<tr>
<td>4: Always/Almost always</td>
</tr>
</tbody>
</table>

Figure 5.1: Questionnaire answer factor

Within the context of the playability dimension and motion gaming problems, it has sought to answer four main playability problems: gesture recognition, gestures difficulty, gesture exhaustion and environment physical space. Beginning with the gesture recognition, the unique question made was 'Did you felt that the game was responsive and flawless in recognizing your gestures?'. Since gesture recognition was already being tested by others means, this question covers all enough information from the players perspective about gesture recognition. As said before, this question comes with the clause that player may experience recognition fails and may not issue with these fails or not even perceive them (and vice-versa).

The gestures within the Kinect games are made to be simple, yet gesture difficulty was evaluated because there are always some people that do not get it at first. The first question made to players about these feature was 'Did you felt difficulty in handling your polygon?'. However, since proud or arrogant player would possibly negate the fact that he/she played bad, a second question was made concerning the partner performance, which was 'Do you think your partner needed help in handling his/her polygon?'. This way, the first question answer together with the partner’s second question answer determined the gesture difficulty feature.

One of the biggest differences between the Wii Remote and Kinect is the environment physical space that is needed to play games. Since the Wii Remote still uses a controller to play games, it is still capable of playing games on a chair for example. Kinect games have been constantly punished by space problems, since not everyone has big rooms to play. Since a collaboration game with two players was evaluated here it further increases this measure problem. For the concern and evaluation of this measure, two question were made. One regarding to the physical space of the room and the other regarding the physical space between players. The questions were:
- Did you felt that the physical space to make your gestures was tight or restricted?
- Did you some fear that your partner, when interacting with the game, could accidentally hit you during the game?

Lastly, but not lest, it was evaluated the gesture exhaustion feature. This feature had an only directly question concerning 'Did you felt weariness with any member of the body? If yes, which one?’. This way, if players really had some weariness, they could quote which body member was exhausted and thus providing direct and useful information about gesture exhaustion.

5.3 How to evaluate collaboration?

Collaboration was a hard factor to measure since it can only be measure by the players feelings. Since it is not a programmatic measure, the collaboration sense was evaluated only through a questionnaire after the players have finished playing the game. This questionnaire was provided together with the playability questionnaire, meaning that only one questionnaire covering the two factors was made. However, there were two features to evaluate in this collaboration measure: The collaboration sense of the game and the collaboration sense of the interaction. These are two hard features to spread apart, since one depends of the other. Yet it is possible. The collaboration sense of the interaction was measured by direct questions about the collaboration feeling, while the collaboration sense of the game was measured by other questions regarding to the pleasure of winning, the repeatability of the game, the feeling of being losing or the need of playing alone.

5.3.1 Question-Answer: Collaboration sense

Like the questions made for playability, some questions for collaboration sense were simply answered by ‘Yes’ or ‘No’, but most had a one to four factor (Figure 5.1). Within the context of the collaboration dimension, there are lots of pitfalls that a game can make, but the main question was: can the interaction hide these pitfalls and encourage the use of collaboration? It has sought to answer five main problems for collaboration: collaboration feeling, winning pleaser, game repeatability, lose feeling and singularity problems. One thing that was considered when doing these questions was that players need reasons and intensives to play collaboratively in games. If the games themselves do not intense them to play collaboratively, they will not collaborate. So all these measures served to investigate if the interactions themselves intense the players to play collaboratively too.

Since the collaboration feeling was an important metric in this thesis, it occupied four questions in the questionnaire. These questions were:
- Did you felt usefully and responsible to complete any level?
- Do you felt you did a better performance than your partner?
- Do you think you could do better if you controlled by yourself the two polygons simultaneously?
- Do you felt you were collaborating with your partner?
These questions remarked all collaborative measures that an interaction could deliver. The sense of useful and responsive feeling is a must in collaboration games. Though this could be the game fault rather then the interaction fault, one can felt more usefully and responsible if the interaction delivers to players that quick timing responsibility that players need to react when his/her partner is expecting.

The second question relates to the difference between players experiences, although could be a bit tricky since experienced players would probably play better than novice players. Yet, in collaboration games, that difference should not be so big, so that novice players always enjoy playing collaboratively with experienced players or vice-versa.

The third was a rather easy question since it was a ‘yes’ or ‘no’ question. The objective here was to find out if the gestures were rather too easy or boring so that players felt that doing it alone was a better way. Players must feel like his/her partner is important and needed in the game, otherwise they would not be intense to play collaboratively. For last, the last question was a direct question to the collaboration sense and was expected to have the most positive result.

Aside from these questions about the collaboration sense of the interaction itself, it was necessary to collect information about the collaboration sense about the game. These questions concern about the pleaser of winning, the feeling of losing, the game repeatability, and the intensive of playing alone. All these questions abort a direct problem and are ‘Yes’ or ‘No’ questions, with the exception of the game repeatability questions. The questions were:

Pleaser of winning:
- Did you felt accomplished and satisfied after completing any level?

Feeling of losing:
- Did you felt you were losing at some point in the game?

Game Repeatability:
- Do you think the levels were repetitive?
- Do you think the gameplay was repetitive?

Intensive of playing alone:
- Do you felt the need of playing alone somewhere in a level, to pass that level faster?
- Do you think you could do some level alone?

5.4 How to evaluate fun?

For last, there was an additional direct question in the questionnaire about how fun the game was for participants (one to ten metric).

5.5 Participants

Participants were randomly chosen for each proposed solution, but since Geometry Friends is a two-players collaboration game there was needed two participants for each test. The mean of all tests gathered was around six tests for each interaction, gathering thus twelve participants for each interaction.
The only restriction was that each participant could only be part of one of the proposed solutions. This includes doing tests separately for the Wii Remote interaction too. This way, the participants would not confuse or compare the controls from a previous experience. These two facts were a must for the thesis conclusions. Not to forget that the objective here was to investigate what players feel and think about the same game, just by changing the interaction. If participants would rather experience another interaction, they would compare between them and conclude that one was worst than the other. Furthermore, they could gradually confuse the new controls with the old ones played, which could probably result in players disliking the second interaction. Concluding, making participants experience each interaction separately was a must.

5.6 Procedure

This chapter resumes the evaluation procedure of each test done. As slightly understandable from the above chapters, each test had three sections. There was a natural-interaction section, a gesture recognition accuracy section, and a collaboration sense section. Every step of the participants was recorder, using video capture of the game using Fraps and an another video capture with a normal camera to record the players entire gameplay.

Before the game itself starts, players had to past through the menus to start playing. Since most Kinect games use almost the same method of menu interactions, only one interaction for the menus was proposed (described better in above chapters). For this reason, the menu interaction was not included in the natural-interaction section, meaning that players were aware of the menu instructions when navigating them. Latter on, the gesture recognition method was used for the menu interaction too. Furthermore, there was two question added in the questionnaire regarding the menu interaction difficulty and collaboration sense. These questions regard if players care about the concern or interest of the partner when navigating through the menus (collaboration sense), and if it was too difficult to navigate (difficulty part).

After the menus navigation, the 'in game' interactions evaluation starts. The first section consisted in asking participants to perform the movements as they felt was more natural. This was done before providing instruction to the participants. The objective was to evaluate natural behavior of the proposed gestures of each interaction. If similarity gestures were found in the players gameplay videos when comparing to the proposed interaction gestures, the greater natural factor that interaction had. It was also gathered information about natural movements being used from the participant that were not proposed in this document. After this section, the participants were informed about the game controls, thus playing the game as proposed. Using both the video capture of the game and the video capture of the players entire gameplay, it was manually extracted the gesture recognition accuracy of each interaction.

At the end of each test, a questionnaire was made in order to gather information about many playability features and his/her sense of collaboration about the game. All answers here were gathered and a mean value for each question resulted in a percentage. The mean value of all answers of the playability part of the questionnaire together with the gesture recognition accuracy percentage determined the
Playability factor. Similarly, the mean value of all collaboration sense answers determined the Collaboration factor and the fun answers determined the Fun factor.
Chapter 6

Results

This chapter will describe the results from the evaluation process, i.e. the results from the tests effected. As described in the above chapter, the evaluation has divided by a natural, a playability, a collaboration sense and a fun factor. All these factors will be distributed in the following sub-chapters for each designated different interaction tested.

6.1 Natural Results

This subsection will discuss about all natural gestures that have been gathered along all tests done. Since the first three interactions (Hand, Full-Body and Collaboration gestures interaction) use skeleton gestures for playing, all the natural moves found in all these three interaction tests was gathered as one. The tangible and the Wii interaction was evaluated separately since they use different approaches.

6.1.1 Skeleton natural gestures

With the gather of many natural gestures moves from skeleton tracking, it was been found some peculiar new ones. But before that, it will be described the naturalistic of all proposed interactions. First of all, beginning with the non-movement gestures (transformation and jump), it is to remark that 80,77% of the players did the circle jump gesture (or square thin), and 73,08% of the players did the circle enlarge gesture (or square fat), of the full-body interaction (Figure 4.4) naturally. Furthermore, around 37% of these players performed these two gestures in the first place (before all others gestures) in the natural section and more than 60% of the same players performed it in the first three. This classifies these two gestures as very natural gesture moves. Comparing with the natural factor evaluation of the square transformation gestures of the hand interaction, it was disastrous. This is due that only 46,15% of the player did the square or circle enlarge gesture or the square thiner gesture (Figure 4.2). Although the circle jump gesture had a better result with 61,54% ratio, the full-body interaction demonstrated a much better naturalistic factor for the transformations gestures. Finally, it was disappointing (though it was expected a bad result) to find out that any set of players did not performed any of the two collaboration gestures for the circle jump and enlarge. However, if the naturalistic factor would be compared with what
each players does, then only one hand gesture had to be performed (Figure 4.6). This makes a 53.85% factor for the both the left hand and the right hand. The square transformations happen to be performed in only 30.77% of the tests and the players did not quiet get it how it has performed. This is because only one player had to move a little so that the a square transformation happened (Figure 4.5).

With the movement gestures, the ratios did not happen to be so high. This comes with the fact that the movement gestures represented a very restrict gesture, even considering similarities with the gestures proposed. Considering all the similarities with the Full-Body interaction gestures (Figure 4.3), only 30.77% of all players happen to perform this gesture. As the collaboration gestures interaction used the same gestures for movement, they have the same value.

The similarities of the hand interaction movement (Figure 4.1) revealed to be too far away of the proposed gestures real gestures (especially for the left side move). In fact, these similarities could turn to be a completely new gestures for movement. In the tests natural section, it was revealed two new peculiar gestures that somehow imitate the hand movement gestures. The two gestures are to simply air slap with the left or the right hand (Figure 6.1). The most interesting and strong argument of these two new gestures is that 57.69% (mean percentage of the two gestures) of the players performed these two gestures in the tests natural section, which assigns to a positive natural gesture factor.

If it was admitted that this new gesture using the right hand is similar with the current hand movement for the right, then it have an natural gesture factor of 50% for the left. Yet, for the opposite side (the right), it has found that 61.54% of all players happen to perform the left gesture. In average the naturalistic factor of the hand movement turns to be 55.77%.

6.1.2 Wii natural gestures

The Wii motion controller have reduced possibilities of gestures diversity when comparing with the Kinect and that limitation should grant players an easily way to find out the right controls more easily. However, the results diverge a lot. The larger score in this interaction was the ball movement with 91.67% of the players performing it, downsizing to the worst result of 33% of the player for the square movement. This diverge happened because the other 66.67% of the players controlling the square continued to though that the Nunchuk joystick has the one controlling the square instead of motion it (Figure 4.12).

In the action department, both the square transformations and circle grow action performed well with 75% of the players performing it, while the jump action was only performed by 66.67% of them. Although all players did, in fact, the jump action in the natural section, only 66.67% of them did the
6.1.3 Tangible interaction natural gestures

The tangible interaction was perfectly designed for this game so that it could deliver the maximum natural feeling as possible. In fact all actions were performed by all players (100%) during the natural section. The only big downsizing was the square movement, with only 50% of the player performing it. As the collaboration square transformation problem, not all the players did quite understand how to transform the square since the movement is very sensitive, although they were performing "somehow" the right action.

6.1.4 Natural Summary

This sub-chapter summarize and discusses all the natural results. Table 6.1 resume all natural results for all interaction tested.

<table>
<thead>
<tr>
<th>In Game Interactions</th>
<th>Natural Factor</th>
<th>Final Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Movement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Circle</td>
<td>Square</td>
</tr>
<tr>
<td>Hand</td>
<td>55.77%</td>
<td>55.77%</td>
</tr>
<tr>
<td>Full-Body</td>
<td>30.77%</td>
<td>30.77%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>30.77%</td>
<td>30.77%</td>
</tr>
<tr>
<td>Object</td>
<td>100.00%</td>
<td>50.00%</td>
</tr>
<tr>
<td>Wii</td>
<td>91.67%</td>
<td>33.33%</td>
</tr>
<tr>
<td></td>
<td>Circle Actions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>Grow</td>
</tr>
<tr>
<td>Hand</td>
<td>61.54%</td>
<td>46.15%</td>
</tr>
<tr>
<td>Full-Body</td>
<td>80.77%</td>
<td>73.08%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>53.85%</td>
<td>53.85%</td>
</tr>
<tr>
<td>Object</td>
<td>100.00%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Wii</td>
<td>66.67%</td>
<td>75.00%</td>
</tr>
<tr>
<td></td>
<td>Square Deformations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stretch Up</td>
<td>Stretch Downwards</td>
</tr>
<tr>
<td>Hand</td>
<td>46.15%</td>
<td>46.15%</td>
</tr>
<tr>
<td>Full-Body</td>
<td>80.77%</td>
<td>73.08%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>48.08%</td>
<td>48.08%</td>
</tr>
<tr>
<td>Object</td>
<td>100.00%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Wii</td>
<td>83.33%</td>
<td>66.67%</td>
</tr>
</tbody>
</table>

Table 6.1: Summary of all Natural Results

First of all, it is remarkable the leadership of the tangible interaction (yet a 100% has expected here). The Wii interaction highlights when comparing with all Kinect interaction done, however only having a 8% difference from the best scored Kinect interaction (the full-body interaction). This concludes that although the Kinect enhances many natural interactions possibilities, it is very hard to enhances them in a non real-life environment or non-avatar control. Yet, it is remarkable that the full-body interaction has a better overall result in the game actions naturalistic and the Wii interaction only had better results because of the low natural results of the full-body movement.

Comparing with all Kinect interactions, it is remarkable the almost 10% difference from the hand
interaction and the 17% difference from the collaboration interaction when comparing with the full-body interaction. Yet, it is interesting that the hand interaction suppressed in the movement gestures from the body movement gestures and even suppresses all the square movement natural factor of all interactions.

6.2 Playability results

In this subsection it will be described how accurate the Kinect has when tracking the players gestures. As said before, this playability factor does not entirely represents only the Kinect accuracy, but the players perspective and evaluations about different expect namely some question-answering results. Not to forgot that these question-answering results regard gesture difficulty, gesture exhaustion and the environment physical space issues in which the game has played. It is to indicate that the room in which all Kinect tests were performed had no problems with space, since it had no obstacles around the players and the room had about 10x10 meters of free space. Finally and since each interaction used different gestures, each interaction results will be described separately in this subsection.

6.2.1 Hand interaction playability factor

The hand interaction revealed a 97,73% of accuracy when recognizing the gestures of the player that controlled the circle and a perfect 100% of recognition accuracy of the player controlling the square. However, the players did not sense a so well recognition and the overall result of the players perspective has 46,67% (SD = 21,08% (SD: Standard Deviation)). This negative value (under 50%) is due that players were somehow doing the gestures wrong and thinking it was the Kinect that was failing to recognize. The results about the gesture difficulty and gesture exhaustion in this interaction reveled to be quiet disastrous too. The results indicates a nearly positive 55% (SD = 21,88%) of gesture difficulty “happiness” and a 60% (SD = 51,64%) for the gesture exhaustion factor. The others 40% “unhappy” players left proclaimed arms exhaustion. Finally for the environment physical space issues, the answers percentage meter indicates a rather gratifying result with 75% (SD = 19,66%).

6.2.2 Full-Body interaction playability factor

The full-body interaction revealed a 97,75% of accuracy when recognizing the gestures of the player that controlled the circle and a nearly same 97,40% of recognition accuracy of the player controlling the square. But again, the players did not sense a so well recognition and the overall result ends up with a 47,22% (SD = 15,84%) negative value. In the other hand, the results about the gesture difficulty and gesture exhaustion in this interaction out-stands higher values. The results indicates a 65,97% (SD = 19,32%) of gesture difficulty “happiness” and an 70,83% (SD = 45,02%) for the gesture exhaustion factor. The others 29,17% “unhappy” players left proclaimed arms exhaustion again and back exhaustion too. Finally, the answers percentage meter for the environment physical space issues is 64,17% (SD = 25,35%).
6.2.3 Collaboration interaction playability factor

The collaboration interaction end up with an overall 97.01% of gesture recognition accuracy, and with a surprising positive recognition sense value of 55.56% (SD = 12.31%). However, the results about the gesture difficulty were negative with a 48.61% (SD = 20.82%) value, yet surprising because it has expected a lot worst percentage (since the players had to control both polygons, instead of just one). The gesture exhaustion and space problem happened to have the exactly same value of 62.5% (SD = 48.27%; 24.80%). Players proclaimed many distinguished body-part exhaustion for this interactions, such as arms, trunk and shoulders.

6.2.4 Tangible interaction playability factor

The tangible interaction is the downsizing one in this factor, since it has encountered many difficulty in getting the Kinect system to recognize the tangible objects perfectly. While the ball had a 100% recognition ratio, for the square action, only a 73.33% recognition accuracy was achieved. This meaningful difference relates to the fact that the interaction has designed in relatives depth values, not in absolute depth values. This means that if a players moves to much from the detect area where the Kinect is suppose to recognize the objects, it would fail to recognize. It would only work with static, or nearly static, players. And as expected, the players punished severely in the questionnaire, because of this bad recognition. The recognition sense of players end up with a 33.33% (SD = 0%) value. Furthermore, the gesture difficulty and the gesture exhaustion had downsizing percentages too, with 41.67% (SD = 12.50%) and 50% (SD = 70.72%) respectively. Yet, the space problems is a highlight in this interaction with a 83.33% (SD = 14.43%) ratio.

6.2.5 Wii playability factor

All Wii motion controls have been successfully recognize as expect, yet the player felt very disappointing, giving an only 37.5% (SD = 20.86%) recognition sense to the interaction. This was surely the consequence of the left and right motion movement control, as it was find out that in all of the tests sequences players were sometimes performing the wrong bend that it is suppose to do (i.e. a 90% rotation is needed, not only pointing to the designated direction). This resulted in a poor 50% (SD = 18.26%) value for the gesture difficulty too. Yet, the gesture exhaustion and space problem have gratifying results with a 87.5% (SD = 23.15%) and a 70.83% (SD = 22.13%) values respectively.

6.2.6 Playability Summary

This sub-chapter summarize and discusses all the playability results. Table 6.2 resume all playability results for all interaction tested.

In the playability factor, the difference did not happened to be so largely diverge as the natural factor. It is noticeable the very small difference between the best scored Kinect interaction and the Wii interaction (0.23% difference). It was although disappointing that the tangible interaction resulted in the
worst result here, in which it could be the best with some more future work. It is remarkable the space problem metric although it would always have a downside in the gesture exhaustion metric, because the players are "forced" to hold the tangible objects all the game time (unless small/light/comfortable objects are made). Comparing with the Wii interaction, the gesture exhaustion metric was very gratifying and glorious, having a 17% difference from the second better score.

Within the Kinect interactions, all gesture recognition and recognition senses from players are similar, but the full-body interaction wins in terms of gesture difficulty and exhaustion, having a downside in space issues. As expected, the less body parts the players have to use, the less space problems appear when interacting. In the other hand, the less body parts the players have to use, the more exhaustion the interaction becomes (as expected too).

### 6.3 Collaboration Sense results

This subsection will describe the rest of all question-answering results, namely the ones that regards the collaboration sense. As said before, the collaboration sense factor was evaluated though different measures like the pleasure of winning, the repeatability of the game, the feeling of being losing, the need of playing alone and finally direct questions about the collaboration feeling. Equally to the playability subsection, each interaction collaboration sense results was evaluated separately in this subsection.

#### 6.3.1 Hand interaction collaboration sense

Beginning with the players sense of playing alone, the results reveals that only 20% (SD = 41,04%) of the players felt that playing alone in some part of the level was the way to go. About the feeling of losing, a surprisingly 30% (SD = 48,30%) of the player felt that they were losing because they were taking to much time to accomplish the levels (even knowing that there is no time limit for any level). Other 20% (SD = 34,86%) of the player regarded that it did not felt so much winning pleasure and some of them

<table>
<thead>
<tr>
<th>In Game Interactions</th>
<th>Playability Factor</th>
<th>Final Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gesture Recognition + Sense</td>
<td>Gesture Difficulty</td>
</tr>
<tr>
<td>Hand</td>
<td>72,67%</td>
<td>55,00%</td>
</tr>
<tr>
<td>Full-Body</td>
<td>72,45%</td>
<td>65,97%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>76,73%</td>
<td>48,61%</td>
</tr>
<tr>
<td>Object</td>
<td>60,61%</td>
<td>41,67%</td>
</tr>
<tr>
<td>Wii</td>
<td>68,75%</td>
<td>50,00%</td>
</tr>
</tbody>
</table>

Table 6.2: Summary of all Playability Results
said it has because the game was to hard. Continuing with the repeatability feeling about the game, the metric indicates to a 73,33\% (SD = 45,00\%) evaluation. Finally, integrating all the remaining direct questions about the collaboration sense, the results indicates a good 75.67\% value.

### 6.3.2 Full-Body interaction collaboration sense

Starting again with the players sense of playing alone, the results of the full-body interaction reveals that only 4,17\% (SD = 20,41\%) of the players felt that playing alone in some part of the level was needed. About the feeling of losing, only 8,34\% (SD = 28,87\%) of the player felt that they were losing, as the issue was again the extended time past in one particular level. Yet, all player felt satisfied to the please of winning and none contested against it. Continuing with the repeatability feeling about the game, the metric indicates to a 79,17\% (SD = 27,40\%) value. Finally, integrating all the remaining direct questions about the collaboration sense, the results indicates a strong 83,19\% value.

### 6.3.3 Collaboration interaction collaboration sense

The collaboration interaction had the better results in this factor as expect, but had a downside in the losing feel with 31,82\% (SD = 46,22\%) of player proclaiming this feeling. Yet, in the other hand, all players felt pleased when winning. 16,7\% (SD = 38,07\%) of the player felt like playing alone in some part of the level was needed. Only 14,59\% (SD = 14,74\%) of the players felt that the game has repeatable. Integrating all the remaining direct questions about the collaboration sense, the results indicates again a strong 85,69\% value.

### 6.3.4 Tangible interaction collaboration sense

The tangible interaction had some up and downs in this factor. For the up percentage, the results shows that all players felt satisfied on winning and the same 100\% did not felt playing alone has needed. However, only 50\% (SD = 70,72\%) felt like they were losing in some part of the game and 33,33\% (SD = 28,87\%) of the players though that the game was repeatable. Finally, integrating all the remaining direct questions about the collaboration sense, the results indicates again a 79,17\% value.

### 6.3.5 Wii playability collaboration sense

Finally, in the Wii interaction, 18,75\% (SD = 40,31\%) of the player felt that playing alone in some part of the level was the way to go. With the feeling of losing, only 6,25\% (SD = 17,68\%) of the player felt that they were losing, yet again all player regarded to be pleased when winning. Continuing with the repeatability feeling about the game, the metric indicates to a 89,58\% (SD = 15,05\%) evaluation. Finally, integrating all the remaining direct questions about the collaboration sense, the results indicates a 75.65\% evaluation.
6.3.6 Collaboration Sense Summary

This sub-chapter summarizes and discusses all the collaboration sense results. Table 6.3 resumes all the results of the collaboration sense in all interactions tested.

<table>
<thead>
<tr>
<th>In Game Interactions</th>
<th>Collaboration Factor</th>
<th>Game Collaboration Sense</th>
<th>Interaction Collaboration Sense</th>
<th>Final Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Losing Feeling</td>
<td>Winning Pleasure</td>
<td>Need of playing alone</td>
</tr>
<tr>
<td>Hand</td>
<td>70.00%</td>
<td>80.00%</td>
<td>80.00%</td>
<td>73.33%</td>
</tr>
<tr>
<td>Full-Body</td>
<td>91.67%</td>
<td>100.00%</td>
<td>95.83%</td>
<td>79.17%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>68.18%</td>
<td>100.00%</td>
<td>83.33%</td>
<td>85.51%</td>
</tr>
<tr>
<td>Object</td>
<td>50.00%</td>
<td>100.00%</td>
<td>100.00%</td>
<td>66.67%</td>
</tr>
<tr>
<td>Wii</td>
<td>93.75%</td>
<td>100.00%</td>
<td>81.25%</td>
<td>89.58%</td>
</tr>
</tbody>
</table>

Table 6.3: Summary of all Collaboration Sense Results

Analyzing these results, it can be reviewed that two of the Kinect interactions have better collaboration sense than the Wii and the tangible interaction. In the other hand, the other Kinect interaction (the hand) was evaluated has the worst interaction for the collaboration sense. It is remarkable that although the full-body had a better best final result, the collaboration interaction had the best score in interaction collaboration sense. The disappointing 68.18% evaluation of the losing feeling of the collaboration interaction surely hurt the interaction final result. This can be the consequence of the hard (or different) control gestures that this interaction has. Finally, it is evident that it has found players that did not feel so victorious on winning only in the hand interaction.

6.4 Menus Interaction results

Away from the in-game experience, this subsection describes the results of the menus experience. As earlier explained in this document, this experience was not count with a natural factor and only one question was done to evaluate the collaboration sense factor. What is to be more judge here is the playability factor, which gathers the Kinect fidelity to recognize gestures and the gesture difficulty relatively this last one with the time spent to complete the task, the number of errors committed and finally some few question answering results. For last, it is to note that the hand interaction and the full-body interaction used the same menu interaction which then was evaluated together. Table 6.4 resumes all the main menu interaction results that were tested.

Comparing the different menus interaction, the one that achieve the most collaboration sense factor was the collaboration gesture with a 83.33% (SD = 13.06%) value. This value was expected since this
interaction is the only one that needs a second players to navigate through the menus. Apart from this menu interaction, all others revealed distinguishable values, almost in 10% intervals, with 70.83% (SD = 24.76%), 62.88% (SD = 26.71%) and 50% (SD = 17.68%) corresponding respectively to the Wii interaction, the hand/full-body interaction and the tangible interaction.

Considering now the playability factor, the Kinect accuracy revealed a perfectly 100% gesture recognition from the collaboration menu interaction, and a 98% for the hand/full-body menu interaction. For the gesture difficulty metric, only the hand/full-body menu interaction revealed some side downs for some players indicating that most players understand and used this interaction perfectly, but some of them (mostly, the female players) had some hardship to fully pass the menu navigation. Yet, it it to remark that this only happened in the main menu interaction, since all different interactions revealed a perfectly and remarkable 100% value for the level select menus (the reason why Table 6.4 only gather the main menu results). With all downsides from the hand/full-body main menu interaction, the gesture difficulty meter estimate a 49.01% evaluation. The tangible interaction has only tested by female players, and thus reveals a very disappointing evaluation. This may not be because of the sex factor, but it clearly reveals that was the worst main menu interaction, since even the hand/full-body interaction had better result. The collaboration interaction was the best scored here with a 81.94% evaluation, winning the 76.39% evaluation of the Wii interaction.

With an overview of all menu interaction results, it clearly highlight the collaboration main menu interaction with an outstanding 87.15% evaluation, winning against the Wii interaction with a 7% difference. The hand/full-body and the tangible interaction reflected a rather bad interaction to choose with many playability problems. Nevertheless, it is not to forget that if the main menu interface has changed to a big buttons interface like the level select menus, all interactions are evaluated equally in playability (all have 100%). This would put the hand/body, tangible and Wii interaction in closer terms. Yet, the collaboration interaction would always have the trophy here, because of the outstanding difference in the collaboration sense.

<table>
<thead>
<tr>
<th>Main menu Interactions</th>
<th>Collaboration Sense Factor</th>
<th>Playability Factor</th>
<th>Final Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Gesture Difficulty</td>
<td>Gesture Recognition</td>
</tr>
<tr>
<td>Hand/Full-Body</td>
<td>62.88%</td>
<td>49.01%</td>
<td>98.00%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>83.33%</td>
<td>81.94%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Object</td>
<td>50.00%</td>
<td>11.11%</td>
<td>76.92%</td>
</tr>
<tr>
<td>Wii</td>
<td>70.83%</td>
<td>76.39%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Table 6.4: Summary of all Main Menu Results
6.5 Fun Factor and Final Results

This subsection will finalize the results section with an overall fun factor results gathered from every results indicated in the past subsections. To make things clearly and understandable, table 6.5 relates all overall results for every factor evaluated. The fun factor has separated from the three main factors of this dissertation (natural, playability and collaboration sense) so that is does not influence the dissertation objective, making it clear the final percentage results without the fun factor.

Table 6.5: Summary of all Factor Results

<table>
<thead>
<tr>
<th>In Game Interactions</th>
<th>Natural Factor</th>
<th>Playability Factor</th>
<th>Collaboration Sense Factor</th>
<th>Final Result</th>
<th>Fun Factor</th>
<th>Final Result With Fun Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>51.92%</td>
<td>65.67%</td>
<td>75.75%</td>
<td>64.45%</td>
<td>34.44%</td>
<td>61.95%</td>
</tr>
<tr>
<td>Full-Body</td>
<td>61.54%</td>
<td>69.50%</td>
<td>87.43%</td>
<td>72.82%</td>
<td>68.52%</td>
<td>71.75%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>44.23%</td>
<td>62.59%</td>
<td>84.98%</td>
<td>63.93%</td>
<td>84.26%</td>
<td>69.01%</td>
</tr>
<tr>
<td>Object</td>
<td>91.67%</td>
<td>58.90%</td>
<td>79.17%</td>
<td>76.58%</td>
<td>88.89%</td>
<td>79.66%</td>
</tr>
<tr>
<td>Wii</td>
<td>69.45%</td>
<td>69.27%</td>
<td>83.40%</td>
<td>74.04%</td>
<td>84.72%</td>
<td>76.71%</td>
</tr>
</tbody>
</table>

From this table, it can be seen that the tangible interaction has the better final result with or without the fun factor. This was expected since this interaction is especially designed for only this game particularly. Yet, without the fun factor, the difference is not so great as expected, since only a 2.54% difference from the Wii interaction and a 3.76% difference from the full-body interaction is detected. It fact, the tangible interaction only wins here, because of the high natural factor, since the playability factor is the worst between all interaction and the collaboration sense is the second worst. In the same theory, the Wii interaction achieves the second place though the good natural factor too.

Comparing between the different Kinect interactions tested, the full-body interaction is clearly the winner in here. Yet, with the fun factor the full-body interaction became very close to the collaboration interaction (1.74% difference). The lost in the collaboration sense (not expected) reveals less reasons why this interaction should be highlighted, since it has expected with the collaboration need of the interaction gestures, the collaboration interaction would come up with a better collaboration sense. The hand interaction was expected to achieve a better playability factor too, however it reveals a lost when comparing with the full-body interaction as the collaboration interaction lost in the collaboration sense factor. Furthermore, the full-body interaction revealed a much better natural than the other two Kinect interactions. It is also remarkable that the full-body interaction has the better playability and collaboration sense evaluation from all interaction tested.

In overall, the tangible and the Wii interaction revealed a good and better natural factor than all Kinect interaction done, and as concluded in the natural sub-chapter, the Kinect reinforcement of many natural interactions possibilities are hard (yet, surely not impossible) to enhance in a non real-life environment or non-avatar control. Yet, only an nearly 8% difference differs from the full-body interaction and the Wii.
interaction. If a natural factor was not evaluated here, the Kinect full-body interaction would have the best score here, and even the tangible interaction would be surpassed by all other interactions. However, with the fun factor appreciation, the full-body interaction have a clearly downside here to the collaboration, tangible and Wii interactions which both had superior evaluation. Finally, it is clear in table 6.5 that the hand had the worst collaboration sense factor and fun factor of all interactions.
Chapter 7

Conclusions

To make a good structure of a collaboration game is not an easy task. Even if the objective of the game is for everyone to win, it does not mean that a collaboration feeling is achieved. It has revealed that the Geometry Friends can achieve true collaboration sense and this sense can vary with an interaction change. However, it was not found a direct correlation between the playability and the collaboration sense of the different interactions, meaning that problems like gesture recognition and gesture exhaustion does not have a directly correlation with collaboration sense of the players, neither have a true correlation with fun too. Playability is a factor to surely be taken seriously it the gestural and motion control industry, but not the only important feature. For example, the insertion of the second player for the menus navigation surely has helped the navigation, since the players greatly evaluated the gesture difficulty metric (Chapter 6.3.6). It can not be forgotten that the idea of collaboration or cooperation modes in games are to reach a better performance than in a single-player mode, not equal or worst.

A change of the interaction can truly change the perspective about the game. Yet, participants proclaimed difference problem issues about the game, such as being to hard, taking to much time to complete a level, repeatability, etc. It was also acknowledged that players needed more time to accustom to the Geometry Friends physics and overall gameplay with the Kinect interactions. This means a proper change in the game interaction should come with a change of the game itself. If the game is non real-life environment or non-avatar control, players tend to have difficulties to get used to the virtual game. This relationship can be seen when comparing the natural results with the gesture difficulty of the three Kinect skeleton interactions. This concludes that some more tutorials and difficulty changes should be evaluated to be changed when changing the game interaction to a gestural interaction.
Chapter 8

Future Work

Beginning with the 'in game' interactions, the tangible interaction has not so widely explored. Many difficulties had been found through many forms of color based algorithms that have been tested with the Kinect color frame data. Yet none were really successful. The environment illumination has an enormous influence in the Kinect RGB camera and color frame data. Playing at day or at night always had a severe impact on the color recognition, even if the colors were clearly different from the rest of the room. This incapability turned to be impossible for recognizing the big black dot in the middle of the yellow ball tangible object. With the use of the Kinect depth data this happened to be more easily, but still only a 'find nearest point' algorithm has achieved, having the burden that with a two players game and with three tangible objects to detect individually, the task was rather hard. Only with relational measures it was really possible to make things running, still having the consequence of the players mobility as major problem. With this said, maybe with a larger time investment and future work in other absolute recognition methods and some alternative interactions options (with some other tangible objects maybe) could make an impact on the results outcome. It could also be used as an algorithm to transform any real-life objects into the video games (or applications).

Apart from the tangible interaction, the distribution and size of the participant tests can be further studied. If an larger group evaluation and a good group distribution like sex, age, experience evaluation would be studied, it could lead to a better result examinations and conclusions. Sex, age and experience measures were extracted from the participants in this dissertation, but since the participants size was small with no specific group distribution, no further conclusions could be gathered.
Bibliography


