**Doctoral Dissertation**

# A New Paradigm in Game Design using Game Refinement Theory and Cross Media

by

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**submitted to**
**Japan Advanced Institute of Science and Technology**
**in partial fulfillment of the requirements**
**for the degree of**
**Doctor of Philosophy**

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September, 2017

# Abstract

Human cannot live without game in this era. A lot of researchers and related workers begin to find a way to make a game more interesting and exciting. In addition a game as Ninth Art has the special humanistic value. With such backgrounds 'game informatics' has been established as a new research area in the field of information and computer science. This thesis focuses on the game refinement theory application and its development. The present contributions can be divided into two parts: natural science and social science. Chapter 2 to Chapter 7 discuss mainly from the viewpoint of the natural science, whereas Chapter 8 and Chapter 9 are studied from the perspective of the social science.

Chapter 1 introduces the background of the study in this thesis. Chapter 2 presents the mathematical model of game refinement. Chapter 3 employs the game refinement theory and its measurement to analyze a new type of sports called electronic sports or e-sports such as StarCraft II and MOBA games. Chapter 4 proposes a novel method to tune the entertainment impact of Role-playing-game (RPG). Chapter 5 focuses on a paradox of the game refinement theory and proposes a new theory called unexpectedness theory. Chapter 6 analyzes the unexpectedness phenomenon in the domain of sports games. Chapter 7 explores possible interpretations for game refinement measure which has been successfully used to quantify the game sophistication of various types of games such as boardgames and sports. Chapter 8 considers another train of thought on how to design a game from the viewpoint of social science. Chapter 9 focuses on the research related with China and Japan game market. Chapter 10 gives the conclusion in which research questions and problem statement in this thesis are answered, and suggests several possible future works.

*Keyword: Game refinement theory, Game design, Mathematical model of game, Cross media and IP, Game market.*

# Acknowledgments

I would like to appreciate my supervisor Professor Hiroyuki Iida. He provided a lot of advices for my study and research. Four years ago, he receive me as his master student, and in past four years Professor Iida was very kind, patience and knowledgeable, he provided many ideas and economy supports to me. Mostly, Professor Iida help me to get the Japan Society for the Promotion of Science(JSPS) foundation DC2, which reduced a lot of pressure in my life and give me the highest honor for the young researcher in Japan. He is not only a good professor, but also an excellent eldership. Without Professor Iida, I cannot receive my achievement.

I would like to appreciate my parents, they give me the life and a happy family. My health is not so good during my Ph.D study, every time while I come to China, my parents provide a warm environment for me and take care of my health. Because of the warm family, I can recover my body quickly and return to Japan to prepare then next research battle. My parents are proud of me, they give me the economy support while I was the research student and master student. Without my parents, I cannot finish my master and Ph.D work.

I would like to appreciate Miss.Ying Peng. She put me in a good mood and give me a lot of happiness. Also she provide some research idea for me and help me to collect the game data.

I would like to appreciate Mr.Chetprayoon Panumate, he is my friend and the master member in our lab. Mr. Panumate is a genius guy and write a lot of interesting papers. He give me two chances to visit Okayama (Japan) for conference ACIT2015 and Trondheim (Norway) for conference IFIP ICEC2015. Specially, that was my first time to visit Europe and left a fantastic memory for me.

I would like to appreciate Professor Kokolo Ikeda. He provide me insightful comments and advices for my research, and he taught me how to be an independent researcher.

I would like to appreciate Professor Akinori Nakamura in Ritsumekan University. He directed me to do the Ph.D minor research, and when I was the research student in Osaka

university, he had given me some advices.

I would like to appreciate JAIST provide the economy support for me then I can travel to U.S.A, Canada, Norway and Netherlands.

I would like to appreciate the member in our lab. Mr.Long Zuo and Mr.Song Zhang are very generous and give me some ideas of DOTA. Mr.Mingyang Wu can cook very delicious Sichuan food and provided some game opinion for me. Mr Zhichao Wang and Mr.Yu in Lim lab always provided car service for me to make our life become more convenient. Mr.He Zhai is a sucker but goodness guy, he have done a lot of work in our daily life.

I would like to appreciate Professor Shungo Kawanishi and Professor William Holden, they give me the chance to USA and promote my English ability, also that is the first time I visited North America.

Finally, I thanks every one who have help me during these four years. Without you, I cannot get the rush graduation.

# Perface

Human cannot live without game in this era. A lot of researchers and related workers begin to find a way to make a game more interesting and exciting. In addition a game as Ninth Art has the special humanistic value. With such backgrounds 'game informatics' has been established as a new research area in the field of information and computer science. This thesis focuses on the game refinement theory application and its development.

Chapter 1 focusing on the history of chess and evolutionary process of video games, we notice that in order to win a game, human created a mathematical branch subject called 'game theory'. However, game theory mainly focuses on solving problems or how to win the game, and it does not show any method for game designers. From the game designer's point of view, Iida et al. [66] [65] proposed a new approach called game refinement theory.

Chapter 2 presents the mathematical model of game refinement. Game refinement idea is a unique theory that focuses on the uncertainty of game outcome. A game refinement measure was derived from a logistic model of game information progress and has been applied in the domain of boardgames with promising results. The following work was to apply the game refinement theory in the domain of different type of games which are continuous movement games such as Pokemon, soccer, crane game and score limited sports to verify if the game refinement idea is useful and correct.

Chapter 3 employs the game refinement theory and its measurement to analyze a new type of sports called electronic sports or e-sports such as StarCraft II and MOBA games. The present challenge is to apply the game refinement theory in the domain of RTS (real time strategy games like StarCraft II), MOBA (multi-player online battle arena like DotA). To do so, we use StarCraft II as a testbed and introduce a concept of strategy tree in order to construct a game tree of a RTS game. Then, game refinement values are calculated and compared with other type of games. It is found that StarCraft II has a zone value of game refinement. This chapter also focuses on the game refinement theory and its application to two MOBA games "Heroes of the Storm" (HotS) and DotA. Furthermore, we evaluate the measurement for different maps of HotS and different version of DotA.

Experimental results show that a game refinement value of HotS is located somewhere between 0.08 and 0.1, whereas the value of DotA is located somewhere between 0.07 and 0.08 for which previous works have confirmed.

Chapter 4 proposes a novel method to tune the entertainment impact of Role-playing-game (RPG). Game refinement measure is employed to assess the degree of game sophistication or player experience like excitement. RPG is a type of games, in which players assume the role of characters in a fictional setting, along with the game process such as kill monster, and the character will level up and get new ability. However, in traditional RPGs, players may feel unchallenged as the adventure becomes predictable. The main problem has been found to be in one of the three game components: level-up system, money and weapon system, and battle system. We utilize the game refinement theory and a mathematical model to design a reliable level up system in RPG to make players feel more exciting and adventurous. The game refinement theory has provided a new insight into the two games selected for this study and suggested a countermeasure for weapon system and battle system. The findings show that scientific method used by utilizing the game refinement theory can resolve issues in the fields of game technology.

Chapter 5 focuses on a paradox of the game refinement theory and proposes a new theory called unexpectedness theory. A mathematical model of game refinement is constructed based on uncertainty of game outcome. A game refinement measure is derived from the game information progress model. This model has been shown to be useful in measuring the entertainment element in the domains such as boardgames and sports games. However, game refinement theory has not been able to reasonably explain about how the popularity of a game can be attached to the game refinement value. This chapter introduces another notion in the study of game entertainment, so-called "unexpectedness". Unexpectedness is an important entertainment aspect of game playing, which makes it possible to extend the early model of game refinement. The extended model enables to reasonably explain the sophistication-popularity paradox of game refinement theory, i.e., on why some games with similar sophistication level would have different population of fans and players. In order to tackle the paradox, we revisited the Newton's classical mechanics to excavate more physical meaning in games and expand a new mathematical model to represent "unexpectedness " and explain the paradox phenomena.

Two applications are presented to demonstrate how this model can be effectively used to measure the part that previously has not been able to explain.

Chapter 6 analyzes the unexpectedness phenomenon in the domain of sports games. Elo-rating system has been widely used to predict the outcomes in various domains such as boardgames and sports games. However, Fdration Internationale de Football Association (FIFA) like other associations use their own ranking system with certain purposes other than ranking accuracy only. This chapter studies four different ranking methods: Elo-rating system, Betting Odds, FIFA rating based on Elo style and FIFA rating based on Davidson Wang's method, with which 36 round-robin matches of UEFA Euro 2016 are analyzed. It then explores entertainment aspects based on uncertainty of outcome prediction that may have occurred by ranking methods. Moreover, the trade-off between the ranking accuracy and popularity promotion is investigated.

Chapter 7 explores possible interpretations for game refinement measure which has been successfully used to quantify the game sophistication of various types of games such as boardgames and sports. It first presents a brief sketch of game refinement theory with a focus on its early works with boardgames, expansion into continuous movement games such as sports, and a bridge between sports and boardgames. It then highlights the bridging idea while considering possible interpretations for game refinement measure, and the meaning of game refinement measure is discussed with a focus on the skill and chance aspects in game playing. Thus, it enables to have a new perspective of game refinement theory. Moreover, an example of interpretation for game refinement measure from boardgames and continuous movement games such as MOBA game is shown. The interpretation is well fitting to our intuition as game players and spectators.

Chapter 8 considers another train of thought on how to design a game from the viewpoint of social science. It analyzes the cross media impact using "Journey to the West", which is a Chinese novel published in the 16th century during the Ming dynasty and attributed to Wu Cheng'en, being one of the Four Great Classical Novels of Chinese literature. In the past 400 years, "Journey to the West" had been recomposed to many different media styles such as Novel, xylograph, comic, animation, drama, Peking opera and game. This chapter explores the reason why "Journey to the West" can be so popular in eastern Asia and has been developed into different media forms, then draws the time

line of cross media evolution and the development process. From the case study using "Journey to the West", we learn how to spread and converge culture what can help game designers understand how to choose their topics, then create a wonderful cross media successfully.

Chapter 9 focuses on the research related with China and Japan game market. In ancient times, classical boardgames have been developed and dispersed throughout the entire world. However, in recent years, the game industry is developing fast in many countries. Japanese games and Chinese games all have similar opportunities and problems in the modern context. The most serious problem both facing is "sakoku which means, in Japanese and Chinese word, seclusion from the outside world. Although the effects of sakoku are very far-reaching, this chapter examines the effects of seclusion from the outside world in the context of game development. The Chinese game industry is still in the development period. If the sakoku problem is not yet solved, the Japanese game industry will decline and fall behind that of the West. For their part, Chinese game developers who fail to address gamers beyond their borders stand to lose the best chance to step into the successful development of the gaming future.

Chapter 10 gives the conclusion in which research questions and problem statement in this thesis are answered, and suggests several possible future works.

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# Chapter 1

# Introduction

Game is a structured form of play, usually undertaken for enjoyment and sometimes used as an educational tool. Chinese people often interpret the word *"game"* as *"Video Game"* or *"Online Game"*. However, the original definition of concept "game" given in the vocabulary in English was quite common. Any competition or something for fun can be attributed to game. In Katie Salen's book, according to Huizinga's idea [113], the definition of play is described as follows.

> *Summing up the formal characteristics of play we might call it a free activity standing quite consciously outside "ordinary" life as being "not serious", but at the same time absorbing the player intensely and utterly. It is an activity connected with on material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner. It promotes the formation of social groupings which tend to surround themselves with secrecy and to stress their difference from the common world by disguise or other means.*

Typically, the academic concept in "game theory" comes from management and business. Sports such as soccer, basketball, table tennis etc. are classified as to physical games. Of course, the boardgames and video games are the standard understanding in people's mind. In recent years, the concept of game has been developed and changed into online games, cellphone games and serious games [49].

Unfortunately, in a huge group of people's mind, game is just for enjoyment or associate chair-warmer, that they think the game is specially for children and teenagers, therefore

in university or academic area, few university or lab do the work related to the game science. In fact, a game called as "Ninth Art" which was a combined name with other 8 different arts – literature, painting, music, dance, sculpture, architecture, theater and film [98] [82]. A fantastic game would need a good story line and background, good structure, mathematical balance and AI algorithm research, complex coding and programming work, and excellent painting and music design, being as complex as operation system. Therefore, this study is dedicated to the development of a new academic research area in "Game Informatics" which has become apparent.

## 1.1 Historical Overview of Game Research and Game Classification

At this moment, millions of people around the world are playing games. One obvious way in which this matters is financial. The game industry is rapidly becoming an economic power. The present contributions may help people to develop better games and help large companies increase profits, and provide a critical perspective on the social functioning and impact of the gaming industry. Either way, the very size of the industry justifies our attention. But it is not just the money that is important. Games warrant attention for their cultural and aesthetic elements. The aesthetic developments of game design are intense, and constant, and thrilling; this explosive evolution of creative possibility is beginning to influence significantly other types of expression [39].

In this era, people begin to use information technology to develop and play games. Games of strategy, such as Chess, couple intellectual activities with competition. We can exercise and improve intellectual skills by playing such games. The competition adds excitement and allow us to compare skills with others. The same motivation accounts for interest in computer game playing as testbed for artificial intelligence. Computer Programs that think better should be able to win more games, and so we can use competitions as an evaluation technique for intelligent system. The idea of game playing can be used as good impact to inspire and evaluate good works in artificial intelligence, that requires shifting more from the design work to the computer itself such as Deep Blue [90].

### 1.1.1 A Brief History of Computer Games Research

Previously, humans used a long time to discover the creation of Deep Blue. Chess is an old game with the long history for centuries since before AD [86]. Early in the chesss long history, the question "whether a machine could really play chess" arose. Overtime, computer chess program is a great example while showing how a humans idea seems to be infeasible from the beginning to a great success until now.

Turk - the worlds first appearance of a chess playing machine was created in 1770 by Baron Wolfgang von Kempelen [36] - a diplomat and inventor. Turk was a large box upon which a chess board sat, the chess pieces moving from some unknown force in response to a human opponent, seemingly by the mysterious machinery hidden in the box beneath the board. Although the mechanism of this machine is simple and needs a human to operate, it inspires a lot of inventors to focus on building an intelligent machine in this field.

In the late 19th century, Charles Babbage [125] originated the idea of programmable computers using punched cards, which marked a point that a machine or a computer is able to think and play chess like a human. Based on the programming languages and Claude Shannon's famous paper "Programming a Computer for Playing Chess" [115], Leonardo Torres y Quevedo [37] built the first chess playing machine. This early machine can only play some simple games such as the endgame of King and Rook vs King, which was demonstrated in Paris in 1914.

Hardware was a major limiting factor at that time, however the algorithm for playing chess was already known by the 1950s, though updates and improvements would follow in coming decades. John von Neumann [89] anticipated the algorithm that would prove the success in playing chess: Min-Max algorithm. Min-Max, so-named because it sought to maximize one player's score while minimizing the opponents score, became the essential tool in the AI scientists toolbox for building chess playing computers. The processing power of computer have increased over time, their capability to overlook further steps also becomes much better than human and making chess programs start to be formidable opponents [80]. Moreover, Shannon proposed that a chess game should be divided into three phases, namely the opening, middle and endgame. The objectives of the three phases are different since we may employ various programs for each phase.

The underlying logic of computer chess is as follows. When a computer decides on

a move, the computer optimizes its move by guessing what move the human player is going to play in response to the computer move. To guess the human player's move, the computer assumes what guess the human player is going to make on the next computer move and so on. To address this problem, the solution of using an opening book like the way chess grandmaster do is added to the computer program. Besides, the endgame database is also implemented for computer chess to avoid any mistakes occurred in these phases [105].

From simple computers such as IBM704 (1959) and DEC PDP-6 computer (1966), the hardware for computer chess are also improved significantly to specialized chess computers like Chess Challenger (1977) and BELLE Chess hardware (1980). As a result of that development, in 1989 DEEP THOUGHT won the match against David Levy, a long time since his bet that a computer can beat him. In 1997, DEEP BLUE beat Gary Kasparov, the world chess champion and since then, there is no chance for a human to win a computer chess [90].

### 1.1.2 A Brief History of Modern Game Development

While we made entrance into the end of 20th century (say 1980s), game also gained entrance into a new age where people were only focus on traditional boardgames because console game machine was created, computer and video games have both fascinated and caused great fear in the politicians, educators, academics, and the public at large [121]. Since its inception in the 1970s, the game console industry has been characterized by a number of significant changes. The industry has witnessed seven generations of video game consoles starting from Magnavoxs Odyssey in the early 1970s to Nintendos Wii, Microsofts Xbox 360 and Sonys PlayStation 3 in the early 2000s. The industry had several other dominant players like Fairchild Semiconductor, Texas Instruments, Mattel, Atari, Sega and NEC. Industry leadership in such a dramatically changing industry can be a transient experience for firms. Nevertheless, Nintendo, an incumbent firm in this industry, occupies a unique and successful position in spite of the fierce competition that it has faced from technologically superior entrants like Sony and Microsoft [122].

The first video games appeared in the 1960s [135]. It were played on massive computers connected to vector displays, not analog televisions. The second generation video console

is the Fairchild Video Entertainment System which was produced in 1976 [52]. While there had been previous game consoles that used cartridges, either the cartridges had no information and served the same function as flipping switches or the console itself was empty and the cartridge contained all of the game components. In 1983, the third generation Family Computer was released, then it became famous all over the world, not only in North America and Europe, but also in China and Southeastern Asia, many knock-off digital products were produced such as Xiaobawang. Twenty years later, Nintendo announced that they stop to produce the Family Computer, it is the most successful console machine in the world, until now many fans still like playing it. Unfortunately Sega's Master System was not so successful. At the same time, Nintendo created the earliest handheld game console – Game Boy (GB) in 1989, it also opened a new era. Three major franchises made their debut on the Game Boy: Tetris, Pokemon and Kirby.

In 1990, Nintendo had created Super Famicom (SFC) and sold it to all over the world. In comparison of FC, SFC has the stronger CPU and graphic function. A feature of the fourth generation is the large number of independent games. [13]. The fifth generation console is a big revolution of game machine and game market. In 1994, the famous electronic device company Sony joined the battle of console market, began the trip to against Nintendo, they made an amazing machine PlayStation, which has the stronger graphic processing ability. Many masterpieces such as Biohazard was created for PlayStation. Nintendo released a fifth generation console – Nintendo 64 (N64) in 1996, Nintendo released several acclaimed games, and the Nintendo 64 was sold over 10 millions units [34]. Together with the handheld console Game Boy Color (GBC).

The sixth-generation era refers to the computer and video games. The sixth-generation platform includes SONY PlayStation 2, Sega Dreamcast, Microsoft's Xbox and Nintendo's GameCube. However, Dreamcast was discontinued in 2001 and in the 21th century the video game machine market made entrance into the age of "Three Kingdom"– Nintendo, Microsoft and Sony. For the hardware technology, Nintendo is weaker than Sony and Microsoft, then they changed the strategy to develop handheld, in this era, Game Boy Advance (GBA) was produced and changed the market of handheld console [45].

The seventh generation consoles was created at the end of year 2005, which includes Nintendo's Wii release, Microsoft's Xbox 360 and SONY PlayStation 3. Each new console

introduces a new technological breakthrough. From this year, game machine have become an important part of the global IT infrastructure [136] [58]. In this era, Sony also joined the handheld market and created PlayStation portable (PSP), Nintendo refused to admit being inferior to the production of the Nintendo DS (NDS).

The eighth generation began from 2012 with the creation of the Nintendo Wii U, Sony PlayStation 4 and Microsoft Xbox One [71]. For video game handhelds, the successor to the Nintendo DSm the Nintendo 3DS was released. PlayStation portable (PSP)'s successor– PlayStation Vita (PSV, was released in December 2011. The eighth generation faced competition from tablets, smartphones and smart TVs [112], and the game informatics and hardware devices are still keeping development and revolution.

### 1.1.3 Game Classification

The modern game technology creates a lot of different game style, therefore, here we will discuss the classification of games.

#### Daily Game

Just like the Chinese revolutionist Mao Zedong [79] said: "To fight with the heavens, earth, and human beings, the enjoyment is boundless." Daily games are existing in our life everyday and around each corner. From business deal to the political compromise, from life planning to interpersonal communication, any strategic behaviour or competitive modes can be described as game. For example, a student graduated from middle school has the opitions to choose between liberal art or science in high school. Then, after three years of study, that student must choose his/her major in university. These process is to be called as *daily game* as described in Figure 1-1.

#### Sports Game

Sports game is another common game style. It is usually organize participation in sports activities or games, maintain or improve physical ability and skills, while providing entertainment for the participants, in some cases, it can provide entertainment for the audience.

The most famous sporting event - the Olympic Games [56] is one of the top international sporting events, including summer and winter sports. Thousands of athletes from

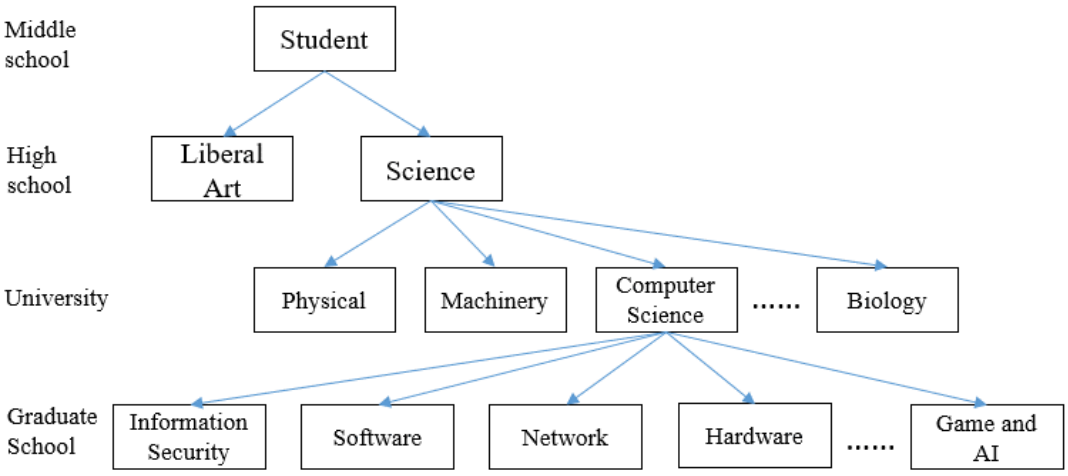


Figure 1-1: An example of daily game in our life

all over the world take part in various competitions. The Olympic Games are considered to be the most important sports events in the world, with more than 200 countries participated. The Olympic Games are held every four years. Ancient Olympic Games [56] was held in Greece. Competition was between several cities in ancient Greek kingdoms. These games are also the main sports such as wrestling, horse and chariot. While we look over the history, we can find the sports game was the form to replace daily game (such as war).

### Boardgame

Boardgame is a tabletop game according to a set of rules, usually play on a "board". It is a typical game when human notice that they need not to fight against each other face to face, they create the game for brain and strategy competition, therefore the wide definition of boardgame can be described as brain game. After that, the game of Go [60] was invented in ancient China for more than 5,500 years ago, which is the oldest boardgame continuously played until now. It is considered as one of the four essential arts of the cultured aristocratic Chinese scholar caste in antiquity. On the other hand, Chaturanga developed in the Gupta Empire, India around the 6th century AD [35]. In 7th century, it was evolved to Chess, Chinese Chess (Xiangqi) and Japanese Chess (Shogi) etc. Also Mahjong and card game such as Poker was to created and classified as boardgame. In modern age, some new boardgames such as *"Catan"*, *"Monopoly"* and new card games such as *"Wolfman"*, *"Three Kingdom Kill"* were developed, people enjoyed and use them

as social utility. In this thesis, many preliminary works were based on boardgames.

### Video Game

Video game is an electronic game. It relies on the video device such as television screen or computer monitor. With the advancement of technology, people begin to use personal computer, console (such as Nintendo FC, Sony PlayStation 3 and MS-XBOX 360), handheld (such as Nintendo 3DS, Sony PlayStation Vita), Cellphone, Arcade and Web-page to play the game. Video games can provide much more exciting screen effect, story and operation feeling for the players. In this thesis, the main research target focuses on this area.

- **ACT.** The ACT means action game. The magnum opus such as: *Series of Assassin's Creed, Series of Dynasty Warriors, Series of Devil May Cry.*
- **AVG.** The Adventure Game (AVG) means the player plays a leading role in interactive story to drive exploration and solving puzzle. The magnum opus such as: *Series of Gyakuten Saiban, Series of Silent Hill, CLANNAD.*
- **CAG.** Card Game (CAG), which means using cards as the device to play game. Different with traditional card game, the CAG almost use electronic device to play them. The magnum opus such as: *Hearthstone: Heroes of Warcraft, Yu-Gi-Oh!.*
- **FPS.** First person shooter (FPS) is a video game genre focused on gun and bullet weapons through the first person perspective. The magnum opus such as: *Series of Call of Duty, Series of of Battlefield, Series of Counter-Strike.*
- **FTG.** Fighting game (FTG) need game players to control the characters on the screen, and fight with their opponent. The magnum opus such as: *Series of Street Fighter, Series of The King of Fighter, Series of Tekken.*
- **MOBA.** Multiplayer online battle arena (MOBA) is a genre of strategy video games, in which a player controls a single character in one of the two teams. The objective is to destroy the opposing team's main structure with the assistance of periodically spawned computer-controlled units that march forward along set paths

[138]. The magnum opus such as: *Defense of the Ancients, League of Legends, Heroes of the Storm.*

- **MSC.** The music game (MSC) is a video game that is almost exclusively around the player's interaction with music scores. The magnum opus such as: *Series of Taiko no Tatsujin, Hatsune Miku: Project DIVA.*

- **PZL.** Puzzle game (PZL) is a type of video game that emphasizes solving problems. The types of puzzles can test many problem-solving skills, including logic, pattern recognition, and sequence resolution. The magnum opus such as: *Candy Crush Saga, Tetris, Jigsaw.*

- **RCG.** Racing game (RCG) is the video game which player partakes in a racing competition. The magnum opus such as: *Series of Need for Speed, Series of Gran Turismo, Series of Dirt.*

- **RPG.** Role-playing game (RPG) is a type of game in which players assume the roles of characters in a fictional setting [21]. Players take responsibility for acting out these roles within a narrative, either through literal acting, a process of structured decision-making or character development. The magnum opus such as: *Series of Diablo, Series of The Legend of Heroes, Series of The Elder Scrolls.*

- **RTS.** Real-time strategy (RTS) is a sub-genre of strategy video games which does not progress incrementally in turns. In an RTS, as in other wargames, the participants position and maneuver units and structures under their control to secure areas of the map and/or destroy their opponents' assets [143]. The magnum opus such as: *Series of StarCraft, Series of WarCraft, Series of Age of Empires.*

- **SLG.** The simulation game (SLG) attempts to replicate various activities in the form of a game of real life. Such as war games and commercial games. The magnum opus such as: *Series of The Sims, Series of Romance of the Three Kingdoms, Series of Civilization.*

- **SPG.** The sports game (SPG) is a video game that simulates the practice of sports. The magnum opus such as: *Series of FIFA, Series of NBA, Series of Winning Eleven.*

- **STG.** Shooting game (STG) is an action game, which often test the player's speed and reaction time. The magnum opus such as: *Series of Contra, Series of Touhou Project, Series of Metal Slug.*

- **TPS.** Third-person shooter (TPS) is a 3D shooter game where the player character is visible on the screen, and the game is primarily shot. These games are closely related to the first person shooter game, however the two types are different. The magnum opus such as: *Series of Resident Evil(Biohazard), Series of Gears of War.*

In order to win a game, or get benefit from the game, human began to search some strategies to become the winner. In the next section, we will introduce the process of "winning".

## 1.2 Game Theory and Game Refinement Theory

Game theory is a fascinating subject [42]. Many entertaining games, such as chess, poker, tic-tac-toe, bridge, baseball and computer games etc. In addition, there is a vast area of economic games, discussed in Myerson (1991) [88] and Kreps (1990) [73], and the related political games, Ordeshook (1986) [93], Shubik (1982) [118], and Taylor (1995) [126]. The competition between firms, the conflict between management and labor, the fight to get bills through congress, the power of the judiciary, war and peace negotiations between countries, that provide examples of games in action. There are also psychological games played on a personal level, where the weapons are words, and the payoffs are good or bad feelings, Berne (1964) [19]. There are biological games, the competition between species, where natural selection can be modeled as a game played between genes, Smith (1982) [119]. There is a connection between game theory and the mathematical areas of logic and computer science. One may view theoretical statistics as a two person game in which nature takes the role of one of the players, as discussed in Blackwell and Girshick (1954) [38] and Ferguson (1968) [20] [42].

Games are characterized by a number of players or decision makers who interact, possibly threaten each other and form coalitions, take actions under uncertain conditions, and finally receive some benefit or reward or possibly some punishment or monetary loss [127] [42].

In gernenal game progress, typically involves several players; a game with only one player is usually called a decision problem. The formal definition lays out the players, their preferences, their information, the strategic actions available to them, and how these influence the outcome. Games can be described formally at various levels of detail [51]. A cooperative game is a high-level description, specifying only what payoffs each potential group, or coalition, can be obtained by the cooperation of its members. What is not made explicit is the process by which the coalition forms. As an example, the players may be several parties in parliament. Each party has a different strength, based upon the number of seats occupied by party members. The game describes which coalitions of parties can form a majority, but does not delineate, for example, the negotiation process through which an agreement to vote en bloc is achieved [51].

Cooperative game theory investigates such coalitions games with respect to the relative amounts of power held by various players, or how a successful coalition should divide its proceeds. This is most naturally applied to situations arising in political science or international relations, where concepts like power are most important. For example, Nash proposed a solution for the division of gains from agreement in a bargaining problem which depends solely on the relative strengths of the two parties bargaining position [131] [42]. The amount of power a side has is determined by the usually inefficient outcome that results when negotiations break down. Nashs model fits within the cooperative framework in that it does not delineate a specific timeline of offers and counteroffers, but rather focuses solely on the outcome of the bargaining process [42]. In contrast, noncooperative game theory is concerned with the analysis of strategic choices. The paradigm of noncooperative game theory is that the details of the ordering and timing of players choices are crucial to determine the outcome of a game. In contrast to Nashs cooperative model, a non cooperative model of bargaining would posit a specific process in which it is prespecified to make an offer at a given time. The term "non cooperative means that this branch of game theory explicitly models the process of players making choices out of their own interest. Cooperation can, and often does, arise in noncooperative models of games, when players find it in their own best interests [51] [131] [42].

Branches of game theory also differ in their assumptions. A central assumption in many variants of game theory is that the players are rational. A rational player is one

who always chooses an action which gives the outcome he most prefers, given what he expects his opponents to do. The goal of game-theoretic analysis in these branches, then, is to predict how the game will be played by rational players, or, relatedly, to give advice on how best to play the game against opponents who are rational [42] [7]. In the following subsection, we will introduce some typical interesting cases.

### 1.2.1 Nash Equilibrium and Prisoner's Dilemma

In game theory, the Nash equilibrium is a non-cooperative game involving two or more than two game players [50]. Each game player should know the concept of equilibrium solutions. While each player choose a strategy, no player can change the strategy, while the other players keep their income unchanged, then the current strategic choices and the corresponding payoffs is a Nash equilibrium. The reality of a game's Nash equilibrium can be tested with an experimental economics approach [42].

Simply to say, $PlayerA$ and $PlayerB$ are in Nash equilibrium if $PlayerA$ is making the best choice what he can, taking into account $PlayerB$'s decision while $PlayerB$'s decision remains unchanged, and $PlayerB$ is making the best decision he can, taking into account $PlayerA$'s decision while $PlayerA$'s decision remains unchanged [42] [51]. For Nash equilibrium, the most typical case is the prisoner's dilemma [42].

The prisoner's dilemma is a standard example of a game analyzed in game theory that shows why two completely "rational" individuals might not cooperate, even if it appears that it is in their best interests to do so. It was originally framed by Merrill Flood and Melvin Dresher working at RAND in 1950. Albert W. Tucker formalized the game with prison sentence rewards and named it [109].

In a finite Prisoner's Dilemma supergame the same game is repeated for a fixed number of times known to both players in advance. It is well known that such games have a definite game theoretical solution which prescribes non-cooperative behavior in all periods of the super game [114].

### 1.2.2 Example in Video Game

In StarCraft II game lobby, a very interesting customized map called "Mafia", which is the wolf man-like game. In Mafia, there are three camps: Mafia, Triad and Town. Mafia

needs to kill all other camps to win the game, Triad and Town follow the same logic. However, Mafia and Triad killer can kill other players in night, and Town only can vote to kill the player whom they suspect as Mafia or Triad.

Now we have an ending game case: 1 Mafia killer, 1 Triad killer and 2 Town members were left, each player already knew others' identity. Now is the daytime, for 2 Town players, how do they choose strategy? If Town players vote Mafia, then next night Triad killer can kill any one of Town members, for last daytime and night, 1 Triad killer must kill the final Town member, then win the game; if Town players vote Triad, following the same logic Mafia must win the game. Therefore, for 2 Town players, they need to choose nothing to do and skip the daytime, that is the only strategy to use Prisoner's Dilemma to win the game. Thus, we are going to analyze the game play.

If the daytime is wasted, in night time, Mafia and Triad killer can choose to kill one player. For Mafia case, if he chooses to kill Town member, then Triad player can kill him or kill another Town member. While he was killed, Mafia camps lost the game, while he was not killed, the final night time, 2 killers will kill each other and no one survive, draw game. For Triad case is the same logic, then we have the Prisoner's Dilemma case as shown in Table 1.1, where $(V_a, V_b)$ means the value for $(Triad, Mafia)$. According to the

Table 1.1: Nash equilibrium and prisoner's dilemma in Mafia game

| Triad \ Mafia | Kill Town | Kill Triad |
|---|---|---|
| Kill Town | $(0, 0)$ | $(-\infty, \infty)$ |
| Kill Mafia | $(\infty, -\infty)$ | $(0, 0)$ |

results in Table 1.1, we find that the best strategy for Triad is "kill Mafia". Similarly the best strategy for Mafia is "kill Triad". Therefore, under the Nash Equilibrium Town can win the game because the next night 2 killers will kill each other. Game theory, specially Nash Equilibrium and Prisoner's Dilemma was widely used in many game process.

### 1.2.3 Game Refinement Theory

Previously, we introduced the concept of game theory. However, game theory only can solve the problem of "how to win the game", it is the mathematical method with focus on the players' side. In order to develop a new game theory from game designer's point

of view, Iida et al. [66] created game refinement theory in 2003.

Game and game refinement theory have played an important role in the development of computer playing game and general games. So what is the difference between game theory and game refinement theory? How could those ideas be applied in our real life? As we have known that von Neumann is one of the man that formed the background for the modern game theory. From his idea of minimax, one of the most effective chess playing algorithm  the minimax game-tree search algorithm  was born. And what we can see in his theory is to find the best outcome in a game no matter what the other player does, also how to ensure the possibility of winning a game based on the understanding of current positions. On the other hand, in game refinement theory, the focus is not on how to win a game but how much attraction of a game to players. In particularly, in game refinement theory, they try to quantify the engagement of players to games and based on that values, games are classified and analyzed to improve the attractiveness of the game itself.

Moreover, game refinement theory could be used to gain more understanding about the development of game history. Therefore, it gives us a more general and reasonable look on the evolution of specific game variants. In another way, game refinement theory provides us with another viewpoint of games from the entertainment aspect while game theory helps us understand about the game's mechanism itself. From that viewpoint, we can extend the idea of game refinement into other domains in human life such as sport games, video games, education or business. The possibility of extension comes from the core idea of game refinement theory that is quantifying the engagement. In many human activities, the engagement is usually used as one of the important standards to evaluate the effectiveness of those activities. In my opinion, we can extend models of game refinement and apply it into many fields as mentioned above.

Although there are differences between game and game refinement theory, both have contributed as a firmed base for the development of computer chess. Moreover, I believe that their potential would not be limited to game informatics field only but could be useful for many other domains as well from scientific research to daily life improvement.

## 1.3 Problem Statement

H.Iida [63] has proposed a model of "Three Masters" about game: *Master of Winning, Master of Playing, Master of Understanding*. Master of Winning focuses on how to win the game, therefore the game theory is very important. From *"Master of Winning"* to *"Master of Playing"*, Iida established a mathematical psychology model "game refinement theory" to evaluate target games.

Three Masters model in game has been mentioned by Iida [63] which demonstrated the inner meaning of games with a focus on solving a game to know its true color, thrilling sense to feel when playing a game and uncertainty to imply the mind state of vanity including in game theory, game refinement theory and game information dynamics. Classical game theory focuses mainly on strategies of players during the game. The goal is to win the game, and its approach is applying algorithms which can generate best moves and optimize latency. This approach, however, will make the game less interesting due to lack of enjoyment and human sense. While in game refinement theory, the focus is to concentrate about the attractiveness and the sophistication of games. It considers properties that are essential for enjoyable games, including outcome uncertainty, game speed, game length, etc. However, game refinement theory is a fairly new model, which need to be solved the follow problems and research questions.

**Problem Statement:** When comparing the game refinement value of Go and soccer, we notice that the game refinement value of Go is greater, which implies that Go is more interesting than soccer. But if we look into the statistics, it can be seen that soccer is a very popular sport and being recognized internationally which has around 1.3 billion fans globally. In contrast to that, there are very few people who follow and play Go.

**Research Question 1:** Can game refinement theory be used in video games, especially in e-sports games? How do we use it and what is the relationship between sports game, boardgame and e-sports game? In Chapter 3, 4 and 6 will solve this research question.

**Research Question 2:** How to improve the defect in game refinement theory and make it become better? Game refinement theory relates to the game outcome and game uncertainty, that will create unexpectedness phenomenon. Therefore, which parameter can show the unexpectedness in game? Also, if the refinement value is out of zone value,

what does it mean? Further, in Chapter 5 and 7, we will discuss more in detail about them

**Society Science** From Chapter 2 to Chapter 7, we will introduce the nature science part of game research. However, in order to design an interesting game and sell the target game well, we also need to analyze the society science impact. Therefore, I write Chapter 8 and Chapter 9 to show the cross media application in game and analyze the China-Japan game market issue.

## 1.4 Structure of The Thesis

In Chapter 2, we introduce the basic idea and model of game refinement theory, and then we show some examples of the preliminary works. In Chapter 3, using game refinement theory we analyze the e-sports games: RTS game and MOBA game. Chapter 4 shows how to use game refinement theory for designing an interesting RPG game. In Chapter 5, with focus on the population paradox and defect point of game refinement theory, we provide a new concept to evaluate target games. In Chapter 6, around population problem we analyze the FIFA ranking system and Elo-rating system, to hack crack the secret of draw game evaluation function. Chapter 7 presents some further works around game refinement theory and explains the meaning of $R$ value in each zone. In Chapter 8, we study some society science works to show some methods to design game by cross media. In Chapter 9, we analyze the issue in Japan and China game market and discuss how to market them successfully.

Chapter 10 gives the final conclusion and future works.

# Chapter 2

# An Overview of Game Refinement Theory

This chapter is an updated and abridged version of the following publications:

- Shuo Xiong, Long Zuo and Hiroyuki Iida. (2014). Quantifying Engagement of Electronic Sports Game. Advances in Social and Behavioral Sciences Vols.5-6, (pp. 37–42). Hongkong, China. Dec. 2014
- Shuo Xiong, Long Zuo, Rachaya Chiewvanichakorn and Hiroyuki Iida. (2014). Quantifying engagement of various games. In The 19th Game Programming Workshop 2014. (pp. 101–106) Information Processing Society of Japan. Hakone, Japan. Nov. 2014

## 2.1 Chapter Introduction

From this chapter, we begin to discuss about the concept of "Master of playing". In our daily life, we always meet such questions: "Which game is more interesting, chess or Go? Which sport is more exciting, basketball or soccer?" While people face these questions, they may answer by their experience then arguing without result. Actually, the concept of interesting or exciting is quite subjective feeling or opinion, just like the great author William Shakespeare said:"There are a thousand Hamlets in a thousand people's eyes." However, we would like to find a mathematical model to evaluate the interesting or exciting by nature science way, then Iida et al. [66] established a new

method what was called *Game Refinement Theory*. Just like the game theory focused on "winning game", game refinement theory focuses on "playing game", therefore Iida et al. [64] defined it as *refinement*. In fact, the game refinement idea is strongly related with Newton mechanism and psychology, we guide from the process of Newton mechanism then get the data to evaluate the feeling in human's mind. In this chapter, we will explain the meaning of game refinement theory, use mathematical derivation process to show how it was born out, also some previous works will be introduced.

However, we need recognize the game refinement theory cannot explain everything of game, just like we judge a lady is beautiful or not, Body Mass Index(BMI, decided by height and weight) only can show some part of the target lady, we also need three size, face, skin and hair style etc. to analyze how beautiful she is. In the other hand, we cannot deny the useful and scientific significance of BMI, therefore, game refinement theory still have strongly positive meaning for game analysis and game design.

## 2.2 Game Refinement Model in Boardgame

The dynamics of decision options in the decision space has been investigated and we observed that this dynamics was a key factor in gauging game entertainment. Then Iida et al. [66] proposed the measure of the refinement in games. The outcome of interesting games is always uncertain until the very end of the game. Thus, the variation in available options stays nearly constant throughout the game. In contrast to this, one player quickly dominates over the other in uninteresting games. Here options are likely to be diminishing quickly from the decision space. Therefore, the refined games are more likely to be seesaw games. We then recall the principle of seesaw games [31].

Based on the principle of seesaw games, Iida et al. [65] proposed a logistic model of game uncertainty. From the players' viewpoint, the information on the game result is an increasing function of time (the number of moves) $t$ . We further define the information on the game result as the amount of solved uncertainty $x(t)$. Game information progress presents how certain is the result of the game in a certain time or steps. Let $B$ and $D$ be the average branching factor and the average number of the depth of game, respectively. If one knows the game information progress, for example after the game, the game progress $x(t)$ will be given as a linear function of time $t$ with $0 \leq t \leq B$ and $0 \leq x(t) \leq B$, as

shown in Equation (2.1).

$$x(t) = \frac{B}{D}\ t \tag{2.1}$$

However, the game information progress given by Equation (2.1) is usually unknown during the in-game period. Hence, the game information progress is reasonably assumed to be exponential. This is because the game outcome is uncertain until the very end of game in many games. Hence, a realistic model of game information progress is given by Equation (2.2).

$$x(t) = B(\frac{t}{D})^n \tag{2.2}$$

Here $n$ stands for a constant parameter which is given based on the perspective of an observer in the game considered. Then acceleration of game information progress is obtained by deriving Equation (2.2) twice. Solving it at $t = T$, the equation becomes:

$$x''(T) = \frac{Bn(n-1)}{D^n}t^{n-2} = \frac{B}{D^2}n(n-1).$$

It is assumed in the current model that the game information progress in any type of games is happening in our minds. We do not know yet about the physics in our minds, but it is likely and we propose that the acceleration of information progress is related to the force in mind. Hence, it is reasonable to expect that the larger the value $\frac{B}{D^2}$ is, the more the game becomes exciting due to the uncertainty of game outcome. Thus, we use its root square, $\frac{\sqrt{B}}{D}$, as a game refinement measure for the game considered [65]. We show, in Table 2.1, a comparison of game refinement measures for traditional boardgames [65].

Table 2.1: Measures of game refinement for traditional boardgames

| | B | D | $\frac{\sqrt{B}}{D}$ |
|---|---|---|---|
| Chess | 35 | 80 | 0.074 |
| Xiangqi | 38 | 85 | 0.073 |
| Go | 250 | 208 | 0.076 |
| Shogi | 80 | 115 | 0.078 |

## 2.3 Game Refinement Model in Continuous Movement Game

For the later work [123], we expand the game refinement theory from traditional boardgame to the sports game successfully. Similarly, we consider two parameter $G$ and $T$ what express as the average number of successful shoots and the average number of shoots per game, then refinement value was strongly related with $\frac{\sqrt{G}}{T}$.

Similarly, we give a short sketch of the basic idea of game refinement theory from [123]. The "game progress" is twofold. One is game speed or scoring rate, while another one is game information progress with focus on the game outcome. In sports games such as soccer and basketball, the scoring rate is calculated by two factors: (1) goal, i.e., total score and (2) time or steps to achieve the goal. Thus, the game speed is given by average number of successful shoots divided by average number of shoot attempts. For other score-limited sports games such as Volleyball and Tennis in which the goal (i.e., score to win) is set in advance, the average number of total points per game may correspond to the steps to achieve the goal [69].

Game information progress presents the degree of certainty of a game's results in time or in steps. Let $G$ and $T$ be the average number of successful shots and the average number of shots per game, respectively. Having full information of the game progress, i.e. after its conclusion, game progress $x(t)$ will be given as a linear function of time $t$ with $0 \leq t \leq T$ and $0 \leq x(t) \leq G$, as shown in Equation (2.3).

$$x(t) = \frac{G}{T}\, t \tag{2.3}$$

However, the game information progress given by Equation (2.3) is unknown during the in-game period. The presence of uncertainty during the game, often until the final moments of a game, reasonably renders game progress as exponential. Hence, a realistic model of game information progress is given by Equation (2.4).

$$x(t) = G(\frac{t}{T})^n \tag{2.4}$$

Here $n$ stands for a constant parameter which is given based on the perspective of an observer in the game considered. Then acceleration of game information progress is

obtained by deriving Equation (2.4) twice. Solving it at $t = T$, the equation becomes

$$x''(T) = \frac{Gn(n-1)}{T^n} t^{n-2} = \frac{G}{T^2} n(n-1)$$

It is assumed in the current model that game information progress in any type of game is encoded and transported in our brains. We do not yet know about the physics of information in the brain, but it is likely that the acceleration of information progress is related to the forces and laws of physics. Hence, it is reasonably expected that the larger the value $\frac{G}{T^2}$ is, the more the game becomes exciting due to the uncertainty of game outcome. Thus, we use its root square, $\frac{\sqrt{G}}{T}$, as a game refinement measure for the game under consideration. We can call it $R$ value for short.

Here we consider the gap between boardgames and sports games by deriving a formula to calculate the game information progress of boardgames. Let $B$ and $D$ be average branching factor (number of possible options) and game length (depth of whole game tree), respectively. One round in boardgames can be illustrated as decision tree. At each depth of the game tree, one will choose a move and the game will progress. Figure 2-1 illustrates one level of game tree. The distance $d$, which has been shown in Figure 2-1, can be found by using simple Pythagoras theorem, thus resulting in $d = \sqrt{\Delta l^2 + 1}$.

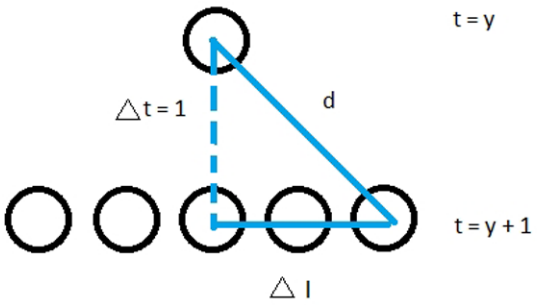


Figure 2-1: Illustration of one level of game tree

Assuming that the approximate value of horizontal difference between nodes is $\frac{B}{2}$, then we can make a substitution and get $d = \sqrt{(\frac{B}{2})^2 + 1}$. The game progress for one game is the total level of game tree times $d$. For the meantime, we do not consider $\Delta t^2$ because the value ($\Delta t^2 = 1$) is assumed to be much smaller compared to $B$. The game length will be normalized by the average game length $D$, then the game progress $x(t)$ is given by $x(t) = \frac{t}{D} \cdot d = \frac{t}{D}\sqrt{(\frac{B}{2})^2} = \frac{Bt}{2D}$. Then, in general we have, $x(t) = c\frac{B}{D}t$, where $c$ is a different

Table 2.2: Measures of game refinement for boardgames and sports games

| Game | B or G | D or T | $R$ |
|---|---|---|---|
| Chess | 35 | 80 | 0.074 |
| Go | 250 | 208 | 0.076 |
| Basketball | 36.38 | 82.01 | 0.073 |
| Soccer | 2.64 | 22 | 0.073 |

constant which depends on the game considered. However, we manage to explain how to obtain the game information progress value itself. The game progress in the domain of boardgames forms a linear graph with the maximum value $x(t)$ of $B$. Assuming $c = 1$, then we have a realistic game progress model for boardgames, which is given by

Then, in general we have Eq. (2.5).

$$x(t) = c\frac{B}{D}t \tag{2.5}$$

where $c$ is a different constant which depends on the game considered. However, we manage to explain how to obtain the game information progress value itself. The game progress in the domain of boardgames forms a linear graph with the maximum value $x(t)$ of $B$. Assuming [1] $c = 1$, then we have a realistic game progress model for boardgames, which is given by

$$x(t) = B(\frac{t}{D})^n. \tag{2.6}$$

Equation (2.6) shows that the game progress in boardgames corresponds to that of sports games as shown in Equation (2.4).

To support the effectiveness of proposed game refinement measures, some data of games such as Chess and Go [66] from boardgames and two sports games [123] are compared. We show, in Table 2.2, a comparison of game refinement measures for various type of games. From Table 2.2, we see that sophisticated games have a common factor (i.e., same degree of acceleration value) to feel engagement or excitement regardless of different type of games.

[1] In this study we concern about this assumption. See Chapter 7.

## 2.4 Applications in Various Games

According to the basic idea of game refinement theory, we have applied the model for different areas. In this section, we show further investigation in the domains of score-limited sports games such as Badminton, Arcade games such as UFO catcher, Fighting games games such as Super Street Fighters 4, and video game such as Pokemon.

### 2.4.1 Score Limit Sports Game

Generally, the sports game can be divided into two types: Score limit game such as tennis and badminton; Time limit game such as basketball and soccer. For previous work, we already got the data and analysis of Time limit game in Table 2.2. In a score-based game, the measure of refinement was proposed based on the information gained from the game and the average game length. Here we choose the previous work that written by Nathan Nossal [91].

The ancients played a game "battledore and shuttlecock" similar to badminton more than 2000 years ago. Badminton was played in India in the 1800s and brought back to England by British officers. The first use of the name badminton in England was around the mid-1800s. There have been numerous changes in rules and equipment. We first explain the current scoring of badminton and compare the results for game refinement, applied to the scoring system used now, and the most recent one. Then, we discuss the relationship between the different scoring systems.

Badmintons official rules are described on the official site of Badminton World Federation [41]. There are two sides of player(s), either singles or doubles. There are five types of events: Mens singles, Womens singles, Mens doubles, Womens doubles, and Mixed doubles. Under the new current scoring system, the side which wins the rally scores the point regardless of which side serves. The information length of game is 21 points, while maintaining a minimum two-point lead. The first side to win two games out of three wins the match. This is the 3 x 21 rally point scoring system.

In the past, a 3 x 15 side-out scoring system was used (3 x 11 for Womens singles). For this side-out scoring system, only the server can score the point. If the service side loses the rally, no point is awarded, and the service passes to the other side. It can be seen that this could, and often did, result in irregularly long match times. The scoring

system was changed in December 2005.

Table 2.3 compares the average score for both sides and the game refinement value between the old scoring system and the current scoring system. Data was collected from BWF world championship [91].

Table 2.3: Measure of game refinement for Badminton

| Scoring system | Winning score (G) | Total score (T) | R |
|---|---|---|---|
| Old | 30.070 | 45.145 | 0.121 |
| Current | 46.336 | 79.344 | 0.086 |

### 2.4.2 Crane Game: UFO Catcher

The crane game, also digger or claw game, is a type of arcade game which has been popular around the world for decades [30].

We use a common Japanese crane game SEGA UFO Catcher (see Figure 2.4.2) to measure game refinement value in the experiment. Potential payoffs are the prizes in the machine box, typically a mix of plush toys, dolls, baubles, cheap electronics, snacks and so forth. The value of prizes is up to each machines operator, but we usually see them between a few hundred yen (a couple hundred Baht) and perhaps as much as a couple thousand yen (several hundred Baht)often the cost of a few to ten or twenty plays. Players get one attempt to guide the claw over their desired prize objective and drop itthis is the skill component. Success also depends on several other factors: the strength of the claw, size and weight of prizes and, perhaps especially, operator settings [30].

From the game characteristic which is coin-operated, the playing cost is one of the factors which affects player's enjoyment in game. We propose $c$ as a cost per each attempt normalized by the average cost per attempt of each country, since the playing costs are varied for different machines. Let P and T be average number of prizes captured, and average number of attempts, respectively [149]. Similarly, we have the function:

$$x(t) = \frac{P}{cT}\, t \tag{2.7}$$

A model of game information progress for crane game is given by Equation (2.8).

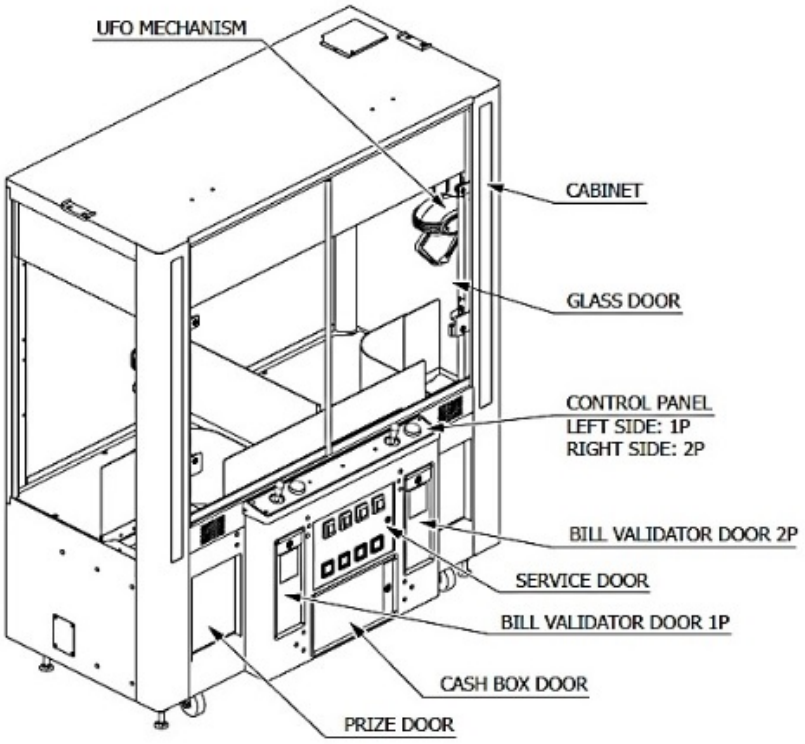


Figure 2-2: A sample of crane game

$$x(t) = P(\frac{t}{cT})^n \tag{2.8}$$

Here $n$ stands for a constant parameter which is given based on the perspective of an observer in the game considered. Then acceleration of game information progress is obtained by deriving Equation (2.8) twice. Solving it at $t = cT$, the equation becomes

$$x''(cT) = \frac{Pn(n-1)}{c^n T^n} t^{n-2} = \frac{P}{c^2 T^2} n(n-1)$$

then expect $\frac{P}{c^2T^2}$ or its root square $\frac{\sqrt{P}}{cT}$ to be a game refinement measure for crane games. Consequently, we suppose that the larger the game refinement value is, the more attractive the game becomes. An experiment has been preliminarily carried out by observing crane game players in amusement centers in different countries. We collected data of 30 and 60 game samples from Japan and Thailand respectively. Then game refinement theory was applied. The results of the experiments are compared in Table 2.4 [149].

Table 2.4: Measures of game refinement for crane game

| country | P | T | R-value |
|---|---|---|---|
| Japan | 0.967 | 13.13 | 0.075 |
| Thailand | 0.367 | 10.65 | 0.057 |

### 2.4.3 Fighting Game

Fighting game is a video game genre in which the player controls an on-screen character and engages in close combat with an opponent. These characters tend to be of equal power and fight matches consisting of several rounds, which take place in an arena. Similar as the football or basketball, for the fighting game, players control the character to attack each other, some attack is valid (hit opponent without defense then make damage successfully). In the other hand, every attack is an attempt no matter it successful or not, so in this condition, G means the average number of successful damage and T means average number of attack per game. As the following Figure 2.4.3 shows.


Figure 2-3: A sample of attempt attack and successful attack

Then three famous games are selected to collect the data and do the corresponding analysis. Generally, according the players' experience and feeling, Super Street Fighter 4 has the slower game rhythm and nice balance between every character, while players attend a match, they need focus on the psychological anticipation; The King of Fighters series has the higher game rhythm and excellent ornamental value, players need focus on the combo. Therefore, these two games refinement value should be different.

According the data and Table 2.5 shows, Super Street Fighter 4 R-value is close to the traditional boardgame and body sports such as soccer, and The King of the Fighters has the exorbitant R-value which means the game is interesting and exciting or we can say

Table 2.5: Measures of game refinement for Fighting games

| version | G | T | R-value |
|---|---|---|---|
| Super Street Fighters 4 | 19.4 | 61.5 | 0.0716 |
| The King of the Fighters 98 | 14.6 | 36.7 | 0.1041 |
| The King of the Fighters 13 | 26.5 | 44.8 | 0.1149 |

this game is good for watching but not so suitable for sports competition. The research result and experiment data fit the players' experience and audiences' feeling.

### 2.4.4 Pokemon

In this section, we present a short history of Pokemon. Then, we focus on catching Pokemon which is our main target to apply game refinement model with consideration on prize cost. Moreover, some essential Pokemon capturing mechanism and equations are described.

Pokemon [16] is a series of games developed by Game Freak and Creatures Inc. and published by Nintendo as part of the Pokemon media franchise. First released in 1996 in Japan for the Game Boy, the main series of role-playing video games (RPG) has continued on each generation of Nintendo's handhelds. Games are commonly released in pairs each with slight variations and then an enhanced remake of the games is released in a few years from the original release. While the main series consists of role-playing games, spin offs encompass other genres such as action role-playing, puzzle and digital pet games. It is the second bestselling video game franchise worldwide, next to Nintendo's own Mario franchise. We show, in Table 2.6, a brief history of Pokemon [96].

The basic goal of Pokemon game [78] is to win the badges of gyms and become the champion of the league. For this purpose, one has to make his/her own team strong enough to win every battle in the game. Hence, in this study, we chiefly focus on the detail in catching Pokemon which is the main means to collect Pokemons and build one's own team [96].

#### Battle of Pokemon

We first consider Pokemon battle as a score limit type sport to find the R-value as $R = \frac{\sqrt{W}}{T}$, where $W$ stands for the winner's score and $T$ total score. HP [85] is an attribute assigned to

Table 2.6: History of Pokemon

| Generation | Number of Pokemons | Year | Version |
|---|---|---|---|
| 1st | 151 | 1996 | Pokemon Red & Green |
| | | 1997 | Pokemon Blue |
| | | 1998 | Pokemon Yellow |
| 2nd | 251 | 1999 | Pokemon Gold & Silver |
| | | 2000 | Pokemon Crystal |
| 3rd | 386 | 2002 | Pokemon Ruby & Sapphire |
| | | 2004 | Pokemon Fire Red & Leaf Green |
| | | | Pokemon Emerald |
| 4th | 493 | 2006 | Pokemon Diamond & Pearl |
| | | 2008 | Pokemon Platinum |
| | | 2009 | Pokemon Heart Gold & Soul Silver |
| 5th | 649 | 2010 | Pokemon Black & White |
| | | 2012 | Pokemon Black2 & White2 |
| 6th | 719 | 2013 | Pokemon X & Y |
| | | 2014 | Pokemon Omega Ruby & Alpha Sapphire |

each entity in game that indicates its state in combat. When the HP of a player character reaches zero, the player may lose a life or their character might become incapacitated or die. Therefore, we can consider HP as a score in score limit type sport [96].

The winner's score ($W$) is equal to the total damages loser received that is constant value 100. This is calculated by percentage because each Pokemon has different full HP. It depends on Pokemon's status, and one player can contain six Pokemons. Then, we assume that full of six Pokemon's HP (= 100) by percentage.

The total score ($T$) stands for the winner's score plus loser's score. The winner's score is constant value 100 mentioned before. However, the loser's score equals to the total damages winner received. The defeat of Pokemon battle is judged based on which player's Pokemon be all lost. By this reason, we can assume score as damage that player made. Next, the damage that winner received can be calculated by $100(fullHP) - remainedHP$. Because normally we can see only the remained HP. So, we can calculate R value as shown in Equation (2.9) [96].

$$R = \frac{\sqrt{W}}{T} = \frac{\sqrt{100}}{100 + RHP} \tag{2.9}$$

where $RHP$ stands for the average winner's lost HP, $RHP = 100 - Average\_winner's\_remained\_HP$.

By this approach, the example results are shown in Table 2.7.

Table 2.7: 30 Samples statistical results of Pokemon battles

| *Percentage* | Remained HP of each Pokemon | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 4.333 | 26 | 0 | 0 | 0 | 0 | 0 |
| 5.667 | 34 | 0 | 0 | 0 | 0 | 0 |
| 20.800 | 4 | 100 | 0 | 0 | 0 | 0 |
| 75.500 | 71 | 69 | 13 | 100 | 100 | 100 |
| 35.867 | 53.5 | 80 | 81.7 | 0 | 0 | 0 |
| 67.983 | 20 | 87.9 | 100 | 100 | 100 | 0 |
| 54.417 | 24 | 100 | 90.4 | 12.1 | 100 | 0 |
| 9.783 | 4 | 23 | 31.7 | 0 | 0 | 0 |
| 14.867 | 29 | 60.2 | 0 | 0 | 0 | 0 |
| 21.183 | 73 | 54.1 | 0 | 0 | 0 | 0 |
| 23.167 | 39 | 100 | 0 | 0 | 0 | 0 |
| 16.167 | 97 | 0 | 0 | 0 | 0 | 0 |
| 66.083 | 6 | 90.5 | 100 | 100 | 100 | 0 |
| 23.00 | 38 | 100 | 0 | 0 | 0 | 0 |
| 6.00 | 36 | 0 | 0 | 0 | 0 | 0 |
| 21.667 | 30 | 100 | 0 | 0 | 0 | 0 |
| 11.367 | 43 | 25.2 | 0 | 0 | 0 | 0 |
| 97.833 | 87 | 100 | 100 | 100 | 100 | 100 |
| 27.000 | 62 | 100 | 0 | 0 | 0 | 0 |
| 26.083 | 6 | 50.5 | 100 | 0 | 0 | 0 |
| 39.517 | 73 | 64.1 | 100 | 0 | 0 | 0 |
| 13.000 | 41 | 37 | 0 | 0 | 0 | 0 |
| 15.000 | 90 | 0 | 0 | 0 | 0 | 0 |
| 10.700 | 6 | 31.4 | 26.8 | 0 | 0 | 0 |
| 83.333 | 100 | 100 | 100 | 100 | 100 | 0 |
| 36.733 | 53 | 67.4 | 100 | 0 | 0 | 0 |
| 6.000 | 36 | 0 | 0 | 0 | 0 | 0 |
| 36.667 | 50 | 70 | 100 | 0 | 0 | 0 |
| 59.883 | 64 | 95.3 | 100 | 100 | 0 | 0 |
| 72.317 | 38 | 58.4 | 37.5 | 100 | 100 | 100 |

Table 2.7 shows the average remained HP for each Pokemon as percentage. Then, we can also find *Percentage* which is the percentage of winner's remained HP by Equation (2.10).

$$Percentage = \frac{1}{6}\sum_{i=1}^{6} Pokemon\_Remained\_HP_i \tag{2.10}$$

Finally, from the samples of 250 games, we obtained $Average\_winner's\_remained\_HP = 34.939$ with a standard deviation $SD\_winner's\_remained\_HP = 25.51$. So we constitute it to Equation (2.11).

$$R = \frac{\sqrt{100}}{100 + (100 - 34.939)} = 0.061 \tag{2.11}$$

Also we can consider about the boardgame apporch such as Section 2.2 shows. Pokemon battle is a turn-based game where each player has to choose what to do at his/her turn, same as boardgames like chess. So we can suppose Pokemon battle as a boardgame. However, there are many important differences between boardgame and Pokemon battle, as described below.

Pokemon battle is one-to-one fighting. This means that each player can control only one Pokemon to fight with opponent's Pokemon. If one wants to use another Pokemon, the player has to change his/her current used Pokemon [2] Chess, typical boardgame, is a kind of war with a lot of pieces in the battlefield. Player can choose which piece that they want to control in his/her turn. Thus, chess game is run by many pieces against many pieces of the opponent.

Chess has a position on a board at each turn. This is a very important factor for boardgame. That's why we call 'board' game. But for Pokemon battle, there is no such position. A game is normally run by one Pokemon per player, i.e., one's Pokemon and opponent's Pokemon. They play what they want to do, whereas no positions are considered.

Turn in chess means the chance that one can do what the player wants. Turn is run by switching system. $A's\,turn \rightarrow B's\,turn \rightarrow A's\,turn \rightarrow B's\,turn \rightarrow ...$, simple like this. In Pokemon battle, one turn means that both players have to choose what they want to do. Then, the speed (one of Pokemon's status) of current used Pokemon is the factor which is decided who will first start this turn. Pokemon with a faster speed can do first in that turn, then Pokemon with a lower speed will do afterward.

To summarize the meaning of turn, one turn in chess is for only one side player's action (one player), whereas Pokemon battle's one turn means simultaneous actions of both players. As for the turn's sequence, it is a simple order in chess but it is ordered in

[2]There are two-to-two or three-to-three Pokemon fighting mode but not so popular.

Pokemon battle by speed of current used Pokemon [96].

Then, game-refinement theory can be applied by using the same idea as another boardgame. Normally, we find $R$ value by using possible options $B$ and game length $D$, with an equation $R(=\frac{\sqrt{B}}{D})$.

For Pokemon battle, possible options are very limited. It can be easily counted as shown in Table 2.8.

Table 2.8: Possible options in Pokemon battle

| | |
|---|---|
| Attack with move | 4 |
| Changing Pokemon | 5 |

Because one Pokemon can remember only four moves and player can change his/her current used Pokemon to the other Pokemons that player possesses. Basically, one can control at most six Pokemons, so player can choose five possible options. In case of using some items such as medicine and potion, it is illegal in Pokemon contests, so we do not consider that case. Therefore, we have possible options $B = 9$.

For game length $D$, we can find by collecting the data and find its average. However, the meaning of one turn in Pokemon battle is both players' simultaneous actions. Hence, there are two actions in one turn. So, we have to multiply 2 to this value. Finally, with this simple method, we can completely find $R$ value as shown in Equation (2.12).

$$R = \frac{\sqrt{B}}{D} = \frac{\sqrt{9}}{Average\_number\_of\_turns \times 2} \tag{2.12}$$

From the samples of 250 games, we obtained $Average\_number\_of\_turns = 25.796$ with a standard deviation $SD\_number\_of\_turns = 11.53$ , the results are given in Equation (2.13).

$$R = \frac{\sqrt{9}}{25.796 \times 2} = 0.058 \tag{2.13}$$

**Catching Pokemon**

At the very initial stage to start a game, a Pokemon is given as a starter Pokemon for the coming adventure. The player may be able to catch other Pokemons by his/her effort, except some Pokemons given automatically due to the story of the game. Importantly,

the final goal of Pokemon game is to catch every Pokemon, a portable device which provides information regarding the diversified species of Pokemon, be completed. Moreover, Table 2.6 shows that the number of Pokemons incessantly increases. We therefore understand that catching Pokemon is one of the most important parts in Pokemon game [97].

Catching Pokemon can be simply described that a player has to reduce the current HP of a target Pokemon as much as possible. HP [85] is an attribute assigned to each entity in game that indicates its state in combat. When HP of a player character reaches zero, the player may lose a life or their character might become incapacitated or die. So, to catch Pokemon, it is reasonable that the more Pokemon's HP is reduced, the weaker the target Pokemon is. Then, the player has to throw a ball, working as a catching device, to the Pokemon. Importantly, if the Pokemon is fainted, the catching attempt is unquestioningly failed. Additionally, using high quality ball or giving bad status to target Pokemon makes it easier to be caught.

According to Table 2.6, Pokemon has six generations to date. Each generation has own different catch rate mechanism except third generation and fourth generation, where these two generations follow the same mechanism. Below we show the detail for each catching mechanism [94].

$$P_1 = \frac{S}{B} + \frac{\min(C+1, B-S)}{B} \times \frac{\min(255, F)+1}{256} \tag{2.14}$$

Where, $F = \left\lfloor \frac{\lfloor \frac{M \cdot 255}{G} \rfloor}{\max(1, \lfloor \frac{H}{4} \rfloor)} \right\rfloor$

$$P_2 = \frac{\max(\frac{(3M-2H)\cdot C}{3M}, 1) + S + 1}{256} \tag{2.15}$$

$$P_{34} = \frac{\frac{(3M-2H)\cdot CB}{3M} \cdot S}{255} \tag{2.16}$$

$$P_5 = \frac{\frac{(3M-2H)\cdot GCB}{3M} \cdot S \cdot \frac{E}{100}}{255} \tag{2.17}$$

$$P_6 = \frac{\frac{(3M-2H)\cdot GCB}{3M} \cdot S \cdot O}{255} \tag{2.18}$$

$P_i$ stands for probability of catching Pokemon at $i$th generation. $S$ is a variable for additional status. Normally, it is easiest to catch a Pokemon when its status is either asleep or frozen. The difficulty increases if the status is poisoned, burned, or paralyzed. The status none is the hardest case because it means that Pokemon is now very strong and ready to break any balls. $C$ is a capture rate. Every Pokemon has its own capture rate status between 3 and 255. The value 3 means that it is very hard to catch that Pokemon, it is for super rare or legendary Pokemon. The value 255 means that it is very easy to catch, it is for common Pokemon which can be found regularly. $B$ is a variable for ball used. There are many kinds of ball in this game. Some balls have special property which fit for some Pokemons whereas it also does not fit for other Pokemons. In this experiment, we focus on three kinds of common balls: Poke Ball, Great Ball and Ultra Ball, which can be bought in mart [97].

$G$ (for $P_1$) represents a variable for Great Ball modifier. Due to some bugs in the first generation, this variable makes Great Ball has a higher average catch rate than Ultra ball even though Ultra Ball is more expensive. $G$ (for $P_5$ and $P_6$) is a variable for grass modifier. It depends on the place where the player meets Pokemon. For example, if the action catching Pokemon takes place in thick grass, it is harder than normal grass. $E$ denotes Entralink power. During normal gameplay this value is not effective. However, by playing Entralink missions with their friends over local wireless, they can receive capturing power from another player, which enables them to increase the chance of catch rate. $O$ stands for O-Power bonus. This value replaces the Entralink modifier of the fifth-generation games to factor in Entralink powers sixth generation analogue, O-Powers . $M$ means maximum HP. It can be exactly calculated by Equation (2.19) for first and second generation, and by Equation (2.20) for third generation onward. $H$ stands for current HP. It is reasonable that the more Pokemon's HP is reduced, the easier target Pokemon is caught. Importantly, if one makes the target Pokemon fainted, the catching attempt is unquestioningly failed [97].

$$HP_{12} = \frac{(IV + BaseHP + \frac{EV}{8} + 50) \times Level}{50} + 10 \tag{2.19}$$

$$HP_{3456} = \frac{(IV + 2 \cdot BaseHP + \frac{EV}{4} + 100) \times Level}{100} + 10 \tag{2.20}$$

$IV$ is an individual value which is randomly generated by the game at the time when one meets that Pokemon first. There are six $IV$ due to each Pokemon has six battle status. To calculate HP, $IV$ of HP is used. $BaseHP$ means initial HP status of Pokemon considered. It depends on what kind of one's Pokemon is. Some Pokemons have outstanding $BaseHP$ while other Pokemons have poor $BaseHP$. Rationally, Pokemon with poor $BaseHP$ should have another great initial status. However, legendary Pokemon may have excellent value in every initial status. $EV$ stands for special value which Pokemon will receive when finishing a battle. It depends on what kind of Pokemon has been defeated. Some Pokemons give $EV$ of HP while other Pokemons give $EV$ of another status. *Level* denotes a level of Pokemon considered. It simply starts from 1 to 100. The more Pokemon's level increase, the stronger Pokemon becomes [97].

Moreover, there are various works which have been carried out with Pokemon, for example, in the domains of mathematics [11] and computer science [27]. In this chapter, we focus on catching Pokemon which is an essential component in Pokemon game. Pokemon Catch Rate Calculator [94] is an application that enables us to calculate Pokemon catch rate in many situations and every generations. We use this tool for calculating the chance of catching Pokemon. In the next section, we show our new model, game refinement model with consideration on prize cost, which is applied to catching Pokemon.

While early work [30] focuses on playing cost, this work focuses on prizing cost. We propose $V$ as a value of each prize captured and $P$ as a probability of successful capturing the prize. Therefore, the game information $x(t_k)$ can be described as an average of $P$ and $V$, as given in Equation (2.21).

$$x(t_k) = \frac{1}{n} \sum_{0<i<n} P_i V_i \tag{2.21}$$

Next, we apply our $x(t_k)$ in game refinement measure $R$ in Equation (2.22). For this case, we have to calculate by percentage as shown in Equation (2.23).

$$R = \frac{\sqrt{x(t_k)}}{t_k} \tag{2.22}$$

$$R = \frac{1}{10} \sqrt{\frac{1}{n} \sum_{0<i<n} P_i V_i} \tag{2.23}$$

In order to apply this model to catching Pokemon, $V$, a value of each prize captured, can be calculated by the degree of rareness of target Pokemon. Normally, each Pokemon has its own capture rate which shows how hard to capture the target Pokemon, which means like a rareness of Pokemon. Therefore, we propose an equation for calculating the rareness of each Pokemon, $V$, as shown in Equation (2.24)

$$V = \frac{Max - Cap + Min}{Max - Avg} \tag{2.24}$$

$Max$ means the maximum of capture rate and $Min$ means the minimum of capture rate. Likewise, $Avg$ means the average of capture rate and $Cap$ means that target Pokemon's capture rate. Generally, the minimum of capture rate in Pokemon game is 3, which means that it is very hard to catch. The maximum of capture rate in Pokemon game is 255 which means that it is very easy to catch this Pokemon. For the average of capture rate, it can be directly calculated which equals 100.25. Therefore, Equation (2.24) can be reduced in Equation (2.25).

$$V = \frac{256 - Cap + 3}{256 - Avg} \tag{2.25}$$

For probability of successful prize capturing, $P$, it can be calculated by Pokemon Catch Rate Calculator [94]. To use this calculator, we reasonably assume some parameters as explained below [97].

- Used Pokemon: We use 110 Pokemon samples which come from the first episode of Pokemon because we cannot use Pokemon from new episode to the first episode Pokemon Catch Rate Calculator. Moreover, the first episode of Pokemon contains 151 Pokemons but some Pokemon can be found from evolution. So we considerably cut some Pokemons which cannot be found as natural one.

- Current HP: We use 50 percent of full HP. It is the middle from 0 to 100.

- Pokemon level: It should be the average level of natural Pokemon in every episode which is approximately calculated by the lowest level and the maximum level of natural Pokemon in every episode. Finally, we already calculated average Pokemon level equals 25.69, approximately 26.

- Ball: There are many kinds of ball in Pokemon game. In this experiment, we focus on three main balls: Poke Ball, Great Ball and Ultra Ball.

- Status: Generally, if a Pokemon is asleep or frozen, it will be easiest to catch. If it is poisoned, burned or paralyzed, it is easier to catch but harder than asleep or frozen status. The hardest status for catching is none status. Hence, we use paralyzed status as an average status.

By this assumption, we obtain average of $P$ for each generation and ball used as shown in Table 2.9

Table 2.9: Average catch rate

| Generation | $R_{PokeBall}$ | $R_{GreatBall}$ | $R_{UltraBall}$ |
|---|---|---|---|
| 1st | 39.14 | 63.98 | 52.55 |
| 2nd | 33.36 | 42.60 | 47.86 |
| 3rd & 4th | 53.33 | 67.12 | 74.85 |
| 5th | 57.03 | 69.54 | 76.50 |
| 6th | 57.07 | 69.51 | 76.50 |

Finally, we apply our new game refinement model with consideration on prize cost to Catching Pokemon. According to Equation (2.23), the result is shown in Table 2.10 [97].

Table 2.10: Measures of game refinement for catching Pokemon with three main balls

| Generation | $R_{PokeBall}$ | $R_{GreatBall}$ | $R_{UltraBall}$ |
|---|---|---|---|
| 1st | 0.047 | 0.062 | 0.059 |
| 2nd | 0.042 | 0.050 | 0.056 |
| 3rd & 4th | 0.054 | 0.064 | 0.071 |
| 5th | 0.058 | 0.067 | 0.072 |
| 6th | 0.058 | 0.067 | 0.072 |

## 2.5 Chapter Summary

This chapter presented the basic idea of game refinement theory, then showed how it works in traditional boardgames. Later we have successfully use game refinement theory to analyze different types of game. It proof game refinement theory not only can be used in original traditional boardgames, but also it can be used in sports game (score limited and time limited), video game (fighting game, Arcade catching game and Pokemon).

Therefore, game refinement theory could be a useful tools to analyze any target game, however we also need to know, game refinement theory do not suitable for every game, it cannot explain every property in game. Some time game refinement model is useful and most of time, the mathematical model was not so effected. In a word, game refinement theory could be seen as the useful tools in some area, in the following chapter, one popular game type– electronic sports game will be evaluate by this measurement.

# Chapter 3

# Analysis of Electronic Sports Game

This chapter is an updated and abridged version of the following publications.

- Shuo Xiong, Hiroyuki Iida (2014). Attractiveness of real time strategy games. In Systems and Informatics (ICSAI), 2014 2nd International Conference on (pp. 271-276). IEEE. Shanghai, China. Nov. 2014
- Shuo Xiong, Long Zuo and Hiroyuki Iida. (2014). Quantifying Engagement of Electronic Sports Game. Advances in Social and Behavioral Sciences Vols.5-6, (pp. 37-42). Hongkong, China. Dec. 2014
- Shuo Xiong, Hiroyuki Iida (2015). Attractiveness of Real Time Strategy Games. Computer Science and Information Systems, Vol. 12, No. 4, (PP. 1217-1234), 2014. Journal. Nov. 2015
- Shuo Xiong, He Zahi, Long Zuo, Mingyang Wu, and Hiroyuki Iida. (2015). Analysis of the "Heroes of the Storm". Advances in Computer Science: an International Journal, 4(6), 79-82. Journal. Dec. 2015

## 3.1 Chapter Introduction

Video games grow more popular every year and Real Time Strategy (RTS) is a sub-genre of strategy video games which does not progress incrementally in turns [29] [25]. Our research interest is to know a theoretical aspect of attractiveness of such popular video games. However, any method or approach to quantify the engagement of target games

is strictly limited. In other words, no mathematical theory has been established in this direction. The present study is the first attempt to explore the attractiveness of RTS using a new game theory which focuses on the game sophistication.

Many efforts have been devoted to the study of strategic decision making in the framework of game theory with focus on mathematical models of conflict and cooperation between intelligent rational decision-makers or game-players. Game theory originated in the idea regarding the existence of mixed-strategy equilibrium in two-person zero-sum games [89], which has been widely recognized as a useful tool in many fields such as economics, political science, psychology, logic and biology [8].

However, little is known about mathematical theory from the game creator's point of view. An early work in this direction has been done by Iida *et al.* [66] [65], in which a measure of game refinement was proposed based on the concept of game outcome uncertainty. A logistic model was constructed in the framework of game-refinement theory and applied to many boardgames including chess variants. Recently a general model of game refinement was proposed based on the concept of game progress and game information progress [123]. It bridges a gap between boardgames such as chess and sports games such as soccer. The next challenge is to apply the game refinement theory to RTS games.

In this chapter we have chosen the domain of StarCraft II, which is one of the most popular RTS games [106]. We analyze the attractiveness of StarCraft II based on the game refinement theory. In typical RTS games like StarCraft II, players build armies and vie for control of the battlefield. The armies in play can be as small as a single squad of Marines or as large as a full-blown planetary invasion force. As a commander, one observes the battlefield from a top-down perspective and issues orders to one's own units in real time. Strategic thinking is key to success. Players need to gather information about the opponents, anticipate their moves, outflank their attacks, and formulate a winning strategy [74]. StarCraft II features three distinct races whose armies comprise entirely unique units and structures. Each race has its own strengths and weaknesses, and knowing their tactical profiles can mean the difference between glorious victory or crushing defeat [9].

To our best knowledge, no one published any successful application of the game refinement theory to RTS games. The main reason is that a RTS game is basically time-

continuous [25], so any method to determine the game progress has not yet been established. In this chapter we propose an idea to determine the game progress of RTS games bases on a concept of strategy tree.

In Section 2.2 we present the game refinement theory and in Section 3.2 we will introduce the concept of Real Time Strategy Game. Then, a concept of strategy tree will be described in Section 3.3 while showing how to apply the strategy tree to StarCraft II. Section 3.4 presents an application of game refinement theory to StarCraft II. Finally, concluding remarks are given in Section 3.7.

## 3.2 Real Time Strategy Game

Real-time strategy (RTS) is a sub-genre of strategy video games which does not progress incrementally in turns. In an RTS, as in other wargames, the participants position and maneuver units and structures under their control to secure areas of the map and/or destroy their opponents' assets. In a typical RTS, it is possible to create additional units and structures during the course of a game. This is generally limited by a requirement to expend accumulated resources. These resources are in turn garnered by controlling special points on the map and/or possessing certain types of units and structures devoted to this purpose. More specifically, the typical game of the RTS genre features resource gathering, base building, in-game technological development and indirect control of units [25].

The tasks a player must perform to succeed at an RTS can be very demanding, and complex user interfaces have evolved to cope with the challenge. Some features have been borrowed from desktop environments; for example, the technique of "clicking and dragging" to select all units under a given area.

Though some game genres share conceptual and gameplay similarities with the RTS template, recognized genres are generally not subsumed as RTS games. For instance, city-building games, construction and management simulations, and games of the real-time tactics variety are generally not considered to be "real-time strategy".

In a typical real-time strategy game, the screen is divided into a map area displaying the game world and terrain, units, and buildings, and an interface overlay containing command and production controls and often a "radar" or "minimap" overview of the

entire map. The player is usually given an isometric perspective of the world, or a free-roaming camera from an aerial viewpoint for modern 3D games. Players mainly scroll the screen and issue commands with the mouse, and may also use keyboard shortcuts.

In most real-time strategy games, especially the earliest ones, the gameplay is generally fast-paced and requires very quick reflexes. For this reason, the amount of violence in some games makes RTS games close to action games in terms of gameplay.

Gameplay generally consists of the player being positioned somewhere in the map with a few units or a building that is capable of building other units/buildings. Often, but not always, the player must build specific structures to unlock more advanced units in the tech tree. Often, but not always, RTS games require the player to build an army (ranging from small squads of no more than 2 units, to literally hundreds of units) and using them to either defend themselves from a virtual form of Human wave attack or to eliminate enemies who possess bases with unit production capacities of their own. Occasionally, RTS games will have a preset number of units for the player to control and do not allow building of additional ones.

Resource gathering is commonly the main focus of the RTS games, but other titles of the genre place higher gameplay significance to the how units are used in combat, the extreme example of which are games of the real-time tactical genre. Some titles impose a ceiling on the number simultaneous troops, which becomes a key gameplay consideration, a significant example being StarCraft, while other titles have no such unit cap [25].

### 3.2.1 Micromanagement and Macromanagement

Micromanagement refers to when a player's attention is directed more toward the management and maintenance of his or her own individual units and resources. This creates an atmosphere in which the interaction of the player is constantly needed. On the other hand, macromanagement refers to when a player's focus is directed more toward economic development and large-scale strategic maneuvering, allowing time to think and consider possible solutions. Micromanagement frequently involves the use of combat tactics. Macromanagement tends to look to the future of the game whereas Micromanagement tends to the present [25].

### 3.2.2 Criticism of Gameplay

Because of their generally faster-paced nature (and in some cases a smaller learning curve), real-time strategy games have surpassed the popularity of turn-based strategy computer games. In the past, a common criticism was to regard real-time strategy games as "cheap imitations" of turn-based strategy games, arguing that real-time strategy games had a tendency to devolve into "click-fests" in which the player who was faster with the mouse generally won, because they could give orders to their units at a faster rate. The common retort is that success involves not just fast clicking, but also the ability to make sound decisions under time pressure. The "click-fests" argument is also often voiced alongside a "button babysitting" criticism, which pointed out that a great deal of game time is spent either waiting and watching for the next time a production button could be clicked, or rapidly alternating between different units and buildings, clicking their respective button [25].

A third common criticism is that real-time gameplay often degenerates into "rushes" where the players try to gain the advantage and subsequently defeat the opponent as quickly in the game as possible, preferably before the opposition is capable of successfully reacting. For example, the original Command & Conquer gave birth to the now-common "tank rush" tactic, where the game outcome is often decided very early on by one player gaining an initial advantage in resources and producing large amounts of a relatively powerful but still quite cheap unitwhich is thrown at the opposition before they have had time to establish defenses or production. Although this strategy has been criticized for encouraging overwhelming force over strategy and tactics, defenders of the strategy argue that they are simply taking advantage of the strategies utilized, and some argue that it is a realistic representation of warfare. One of the most infamous versions of a rush is the "zergling rush" from the real-time strategy game StarCraft; in fact, the term "zerging" has become synonymous with rushing [25] [144].

### 3.2.3 Tactics vs. Strategy

Real-time strategy games have been criticized for an overabundance of tactical considerations when compared to the amount of strategic gameplay found in such games. In general terms, military strategy refers to the use of a broad arsenal of weapons including

diplomatic, informational, military, and economic resources, whereas military tactics is more concerned with short-term goals such as winning an individual battle. In the context of strategy video games, however, the difference is often reduced to the more limited criteria of either a presence or absence of base building and unit production [25].

### 3.2.4 StarCraft II

Our research mainly focus on StarCraft II: Heart of the Swarm(A expansion of StarCraft II). It is a most outstanding and popular real time strategy game where the players' goal is to destroy their enemy's base by developing their own base and an army. Players can choose from three different races (Terran, Zerg, Protoss) to play, each of which plays very differently. To construct buildings and produce army units, a player needs minerals and gas. During the game, players unlock new options by constructing particular buildings [144].

The game revolves around three species: the Terrans, human exiles from Earth; the Zerg, a super-species of assimilated life forms; and the Protoss, a technologically advanced species with vast mental powers. In macroscopic view, three races are the same strength, however in microcosmic view every race has their own advantage and disadvantage what is quietly related with game refinement. In the Table 3.1 have introduced the character of three races [106].

## 3.3 Strategy Tree in RTS

Our present study focuses on StarCraft II which is a RTS game where the player's goal is to destroy their enemy's base by developing their own base and an army. In StarCraft II players cannot see their opponent's situation and they have the same power, StarCraft II does not rely on any chance. Therefore, in a sense this game is similar with boardgames such as chess. It means that we can use some similar tools or methods to analyze the game of StarCraft II.

Table 3.1: Features of three races

| Race | Features |
|---|---|
| Terran | 1. Excellent defensive ability in Opening<br>2. The are many strategies in Opening, however with the time past, that will decline<br>3. Endurance is weak<br>4. From quantitative change to qualitative change<br>5. Observe weakly in Opening, however with the time past, that will develop |
| Zerg | 1. Strength in numbers<br>2. The opening strategy is less than Terran and Protoss, but with the time past, that will develop fast<br>3. Endurance is strong<br>4. Observe is normal in any time |
| Protoss | 1. High quality of soldiers<br>2. The are many strategies in Opening, however with the time past, the number of strategy will decline<br>3. Observe is very weak in Opening, however with the time past, that will develop up to normal level<br>4. Endurance is normal |

### 3.3.1 Basic Idea of Strategy Tree

Minimax strategy is a decision rule used in decision theory, game theory, statistics and philosophy for minimizing the possible loss for a worst case (maximum loss) scenario [107]. Alternatively, it can be thought of as maximizing the minimum gain (maximin or MaxMin). Originally formulated for two-player zero-sum game theory, covering both the cases where players take alternate moves and those where they make simultaneous moves. It has also been extended to more complex games and to general decision making in the presence of uncertainty. The traditional minimax tree is illustrated in Figure 3-1.

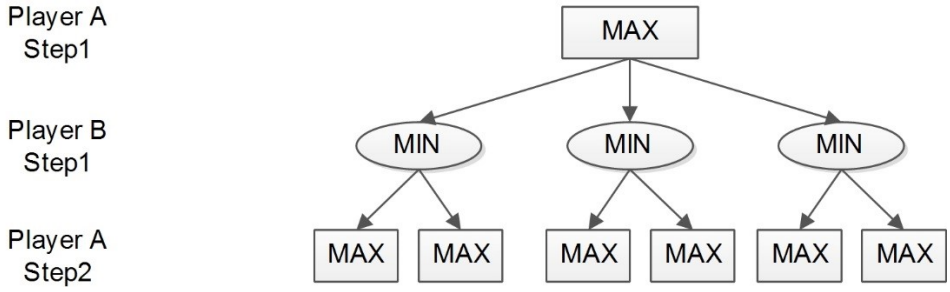


Figure 3-1: Traditional minimax tree

As we know, while players want to execute one strategy, some premises are needed.

For any graph structure as Shogi(Japanese Chess) shown in Figure 3-2 are all defined as **strategy tree**. While player choose node1.1 , the next strategy must execute follow

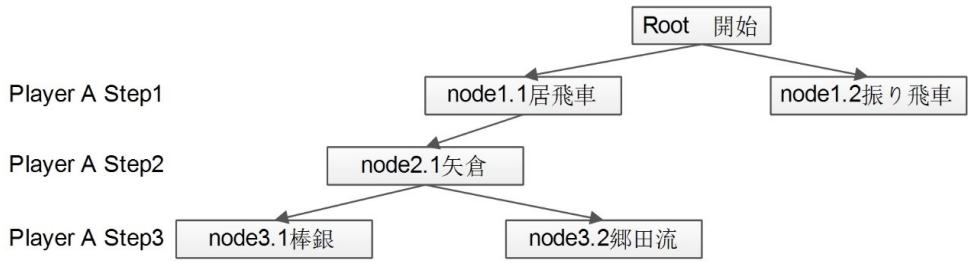


Figure 3-2: Basic strategy tree in Shogi(Japanese Chess)

node1.1 and player hardly go back to choose node1.2 again. Structurally analyze, node2.1 "Yagura" is one child node of node1.1 "Ibisha", also it is the premise of node 3.1 and node3.2.

Because StarCraft II is an incomplete information game, neither player A nor player B do not know opponent's condition, so they only consider about their own tree. the player A $step_i$ and player B $step_i$ should be happened in the same time and shown in Figure 3-3.

Our idea is to combine the search tree of both players. Then we can establish a strategy tree of StarCraft II.

### 3.3.2 Strategy Tree of StarCraft II

StarCraft II is a RTS game where players have the goal to destroy their enemy by building a base and an army. Players can choose 1 out of 3 races to play with. These races are: Terran, Protoss, and Zerg. Terran are humans, Protoss are alien humanoids with highly advanced technology, and Zerg are a collection of assimilated creatures who use biological adaptation instead of technology [15].

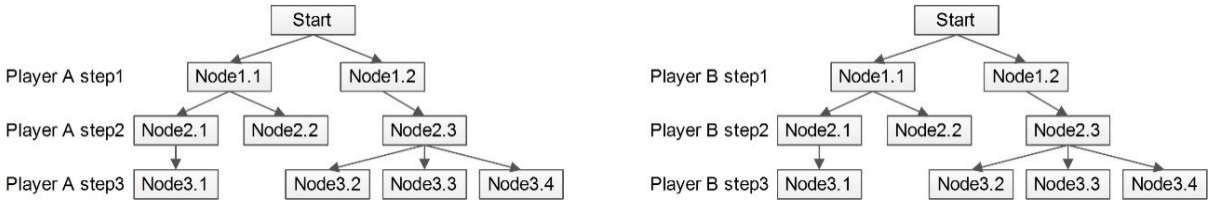


Figure 3-3: Strategy tree model for two players

For anything a player builds, he needs to gather 2 types of resources: minerals and gas. These resources are used to construct buildings which in turn can be used to produce units. At the start of the game, not all units and buildings are available. New construction options can be unlocked by making certain buildings. This means that some units and buildings are available at the start of the game while others become available later in the game. This is also called tier: the point in time that certain units and buildings become available.

In order to play the game well, one must engage in strategy, macro-management and micro-operation. Strategy determines whether player can establish the strategic superiority. Macro-management determines the economic strength of a player. This is determined by the construction of buildings, the gathering of resources and the composition of units. Micro-operation determines how well a player is able to locally control small groups and individual units. It includes movements and attacks that are issued by the player [106].

Macro-management of a player heavily depends on the strategy the player has chosen to follow. For example, if a player chooses to rush his opponent by making fighting units at the very early stage in the game, his economy will suffer. On the other hand, if a player chooses to focus on having a strong economy before building an adequate-size army, he would take the risk of being overrun by his opponent.

### Opening stage of StarCraft II

According to the game features of StarCraft II, we should divide the game into four parts: Opening, Mid-prophase, Mid-anaphase and Endgame. The game could finish in any time domain. For example, while players choose supervise attack or extremely rush strategy, the game must finish in 7 or 8 minutes or before; Normally, the average game time is 15 to 20 minutes (it means that most games will not enter into Mid-anaphase or Endgame time domain). As our experience, we find the game in different time domain, the **main elements** are completely disparate.

In the opening, the StarCraft II is similar to real war or traditional boardgames. In other words, only in the opening time domain, StarCraft II is an intellectual game. While a game enters into Mid-prophase or Mid-anaphase, the main elements are economy, management and operation. It means that in mid-game, the StarCraft II is similar to the

Table 3.2: Feature of Starcraft II in every process

| Domain | Timing | Character |
|---|---|---|
| Opening | 0 to 10 minutes | Strategy |
| Mid-prophase | 10 to 20 minutes | Economy and Management |
| Mid-anaphase | 20 to 30 minutes | Economy and Operation |
| Endgame | Over 30 minutes | operation |

simulation game. As we know, a good chess player can not always be a good manager, a strategy genius does not mean that he could be a nice executive.

For the endgame, the operation element will be more and more important, even occupy all the StarCraft II process. It means that on that time StarCraft II is similar to Super Mario. When we watch somebody playing Super Mario, we only focus on whether or not his operation skill is proficient. In this situation, StarCraft II is like sports games such as soccer and basketball.


Figure 3-4: Feature of StarCraft II

According to the above, only in the opening stage, we have the strategy tree, and then find the $B$ and $D$. Also in the opening stage, the game is highly similar to traditional boardgames or brain sports, we can take example by game tree model to establish new mathematical model. If we want to research mid-game or end game, we must find other model or method. At least, the meaning of $B$ and $D$ must be changed. Actually, the completion between profession players, the most exciting and wonderful part is mid-game. It is likely that body sports are more suitable than brain sports to watch. However for AI research, apparently opening part seems more valuable. Also the opening stage is worth to establish opening book or do other related research in the future. So these are the reasons why we only focus on the opening stage.

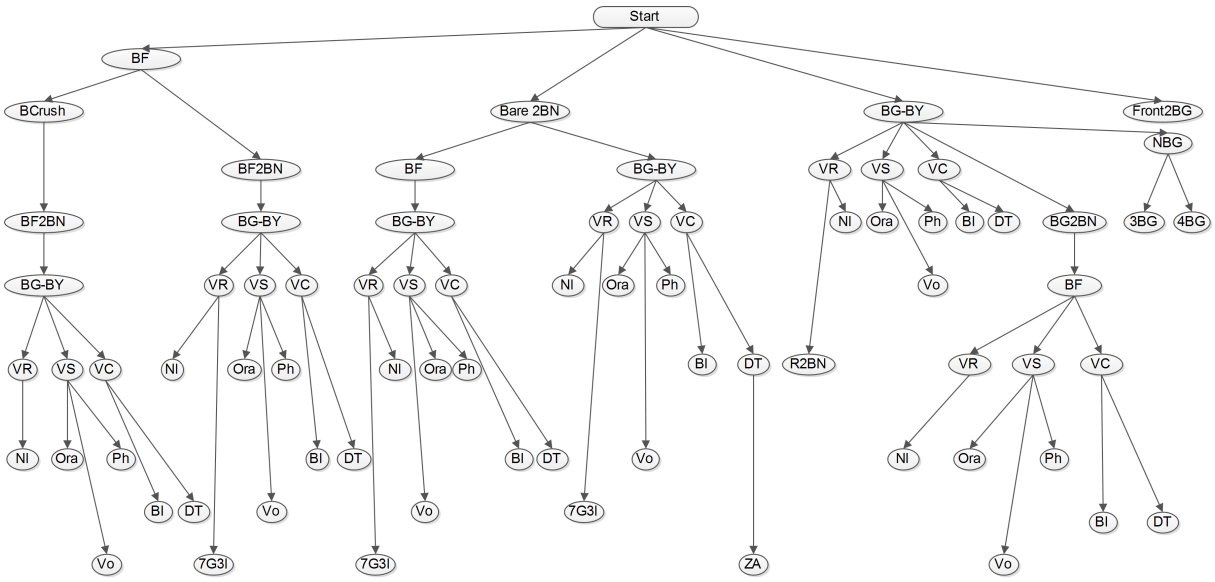


Figure 3-5: Opening strategy tree of Protoss

**Strategy Tree – The Tree with Unbalanced Children Nodes**

In StarCraft II, there are three races. Every race has their own particular strategy tree. Here we analyze the Protoss strategy tree. We enumerate all the opening strategies existed, which are commonly used in High Ladder system. Professional players have validated their rationality through experience and experiments.

In the following strategy tree, the content is denoted as "4BG" or "BF" which means a strategy name or code name. These strategies would be used in the opening stage, i.e., within 10 minutes after starting a game. Then we get the strategy tree as shown in Figure 3-5.

In traditional turn-base boardgame, any length of one depth should always equal to 1. Since StarCraft II is a RTS game, its minimax tree cannot be built in a normal way. For example, the depth of tree is defined by each step or turn, while in StarCraft II, the depth might be given by time evolution. In Figure 3-6, we notice that the child node "BCrush" and "BF 2BN" have the different depth. This situation would never happen in traditional boardgames to build a minimax search tree. So we consider one method to solve it, while changing an unbalance depth tree into a balance tree.

Here is an interesting example in our life. Now we assume a professor X who have two conference in the same day, one will be held in Tokyo and other will be held in Shanghai.

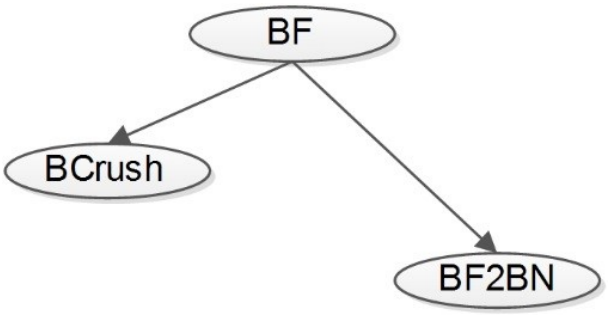


Figure 3-6: An example of strategy tree with two unbalanced child nodes

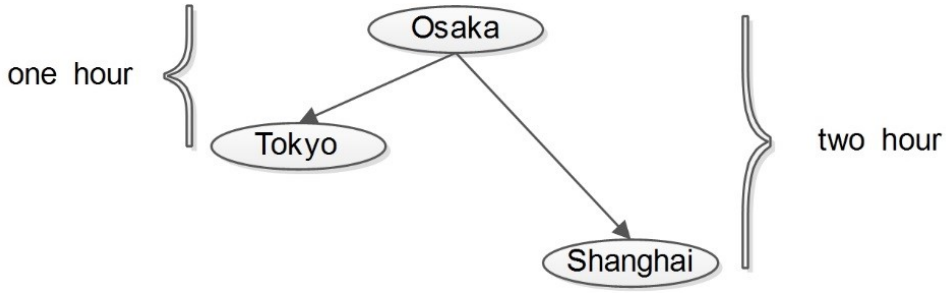


Figure 3-7: A Travel strategy tree of Prof.X

Prof. X live in Osaka, of course he only can attend one conference on that day. From Osaka to Tokyo will cost 1 hour, and From Osaka to Shanghai will cost 2 hours, then he has a strategy tree with time as Figure 3-7 shows.

From Osaka to Shanghai, just consider about one thing. After one hour past, the airplane will arrive Fukuoka. However, Prof. X cannot leave the airplane or airport to enter in Fukuoka city (he must go to Shanghai, and he cannot order aircraft commander to stop the airplane), so the strategy tree will completely equal to Figure 3-8. We call Fukuoka is a **temporary node**!

According to this method, while adding the temporary node, then we get another strategy tree of Protoss as shown in Figure 3-9.

## 3.4 Analysis of Attractiveness of StarCraft II

### 3.4.1 Applying Game Refinement Measure

The game of StarCraft II can be divided into four parts. For the artificial intelligence, the most important part is the opening domain where players have to focus on their strategies.

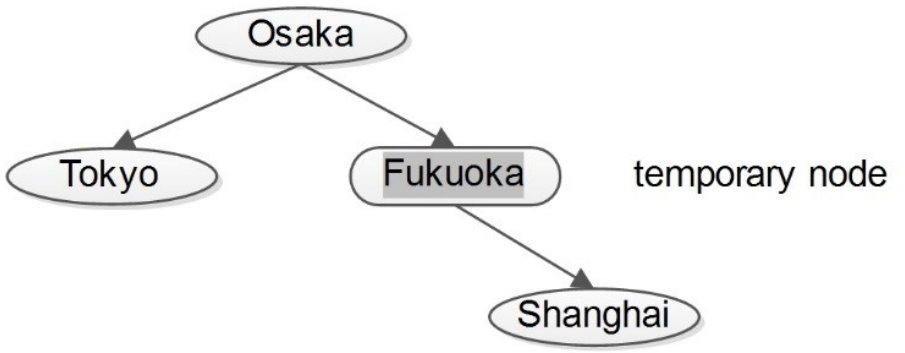


Figure 3-8: Temporary node in unbalance strategy tree

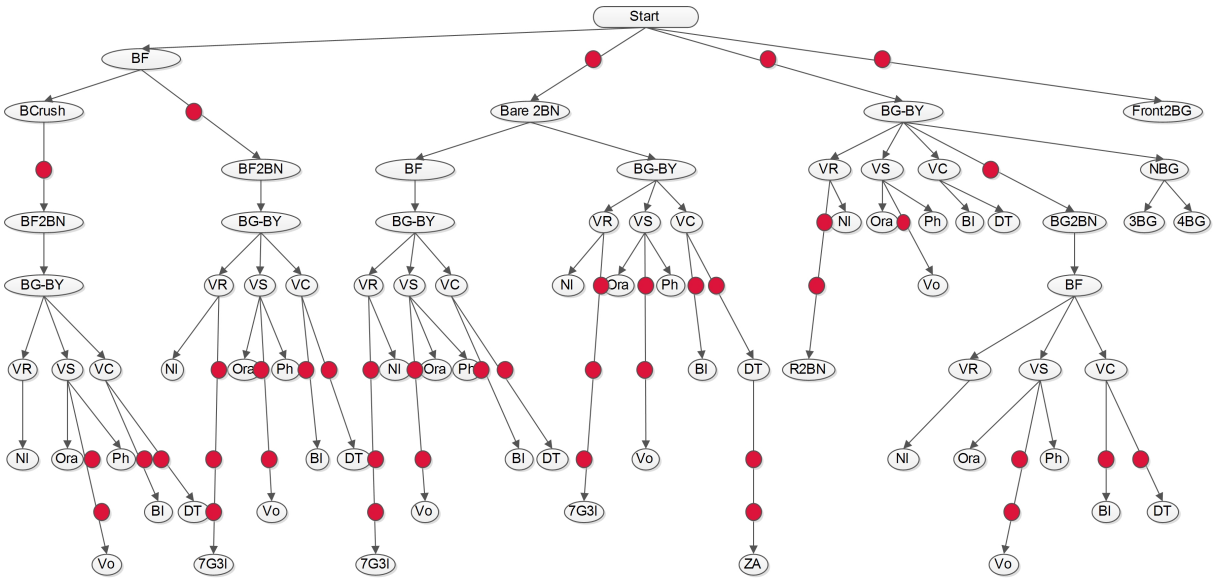


Figure 3-9: New opening strategy tree of Protoss with temporary node

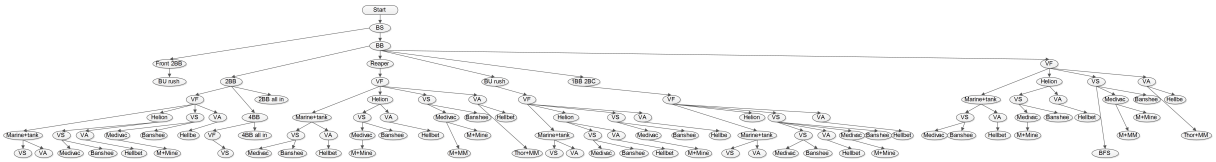

Figure 3-10: Opening strategy tree of Terran

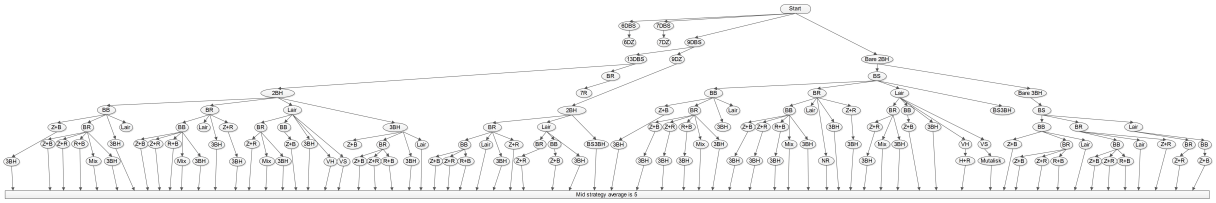

Figure 3-11: Opening strategy tree of Zerg

In this area, the weaker player would have a little chance to win. Now we can draw the figure of Terran and Zerg as follows.

In Figure 3-9, the Protoss tree's depth is 9. In this tree, the total branching factor is 116 and we have 74 parent nodes, so average branching factor is $B = \frac{116}{74} = 1.57$. However, until now we cannot calculate the game refinement value directly. Because in the real game, two players cannot maintain playing game independently at anytime. Sometimes, they will use spy and predict their opponent's choice to modify their strategy. So we can combine two trees into one tree, as shown in the following figure.

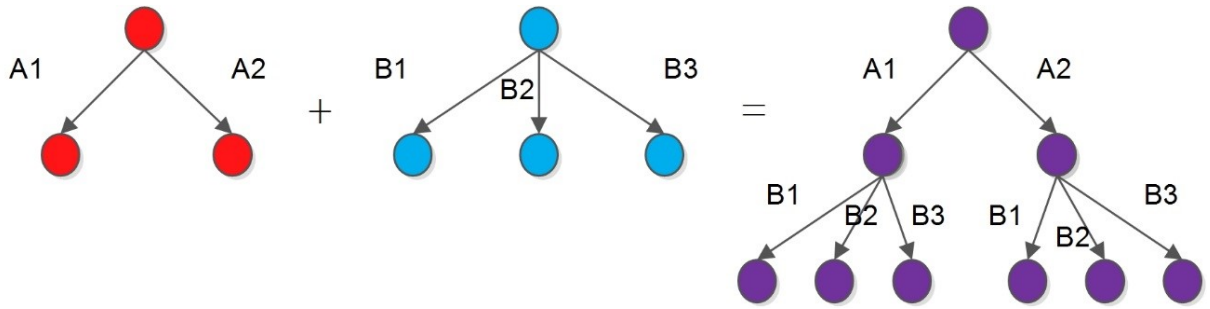


Figure 3-12: Combination of two strategy trees

For the combined strategy tree, player A's choice and Player B's choice are all happened in the same time. No matter player A choose A1 or A2, it will not affect player B to decide B1, B2 or B3, combine the two trees together, can analyze the game refinement value more accurately. While player A uses spy then realize player B will choose "some

strategy", he can modify his next path based on player B's parent node.

In minimax tree, the whole tree size is estimated by $B^D$, and the game refinement formula equal to $\frac{\sqrt{B}}{D}$, while in the combined strategy tree, the tree size is $(B^2)^D$, so the game refinement value should be given by $\frac{\sqrt{B}}{2D}$. Then the game refinement value of Protoss in the opening time domain is given by

$$R = \frac{\sqrt{B}}{2D} = \frac{\sqrt{1.57}}{2 * 9} = 0.0695.$$

Similarly, race Terran and Zerg also have their own strategy tree, then the game refinement value is calculated, as shown in Table 3.3. In this table, we notice that Zerg has two game refinement values.

Table 3.3: Measure of game refinement for three races in StarCraft II

| Race | all nodes | all parent nodes | B | D | R-value |
|---|---|---|---|---|---|
| Terran | 126 | 76 | 1.64 | 16 | 0.0805 |
| Zerg | 219 | 141 | 1.54 | 18 | 0.0692 |
| Zerg* | 564 | 210 | 1.61 | 20 | 0.0819 |
| Protoss | 116 | 74 | 1.55 | 18 | 0.0691 |

The R-value not only means the property of every race, but also means the competition between same race such as Terran versus Terran or Zerg versus Zerg. We evolve the mathematical formula in Equation (3.1).

$$R = \frac{\sqrt[4]{\frac{AllBranchFact_1}{AllFatherNode_1} * \frac{AllBranchFact_2}{AllFatherNode_2}}}{\log_{Avg.depth}(depth_1 * depth_2) * Avg.depth} \tag{3.1}$$

Then we have the full data of every race's competition in Table 3.4:

Table 3.4: Measure of game refinement for every competition in Starcraft II

| | Terran | Zerg | Zerg* | Protoss | Average |
|---|---|---|---|---|---|
| Terran | 0.0805 | 0.0746 | 0.0809 | 0.0747 | 0.07675 |
| Zerg | 0.0746 | 0.0692 | None | 0.0694 | 0.07107 |
| Zerg* | 0.0809 | None | 0.0819 | 0.0754 | 0.07940 |
| Protoss | 0.0747 | 0.0694 | 0.0754 | 0.0691 | 0.72150 |

Compared with other traditional boardgames, the result are closed, as Table 3.5 shows:

Table 3.5: Game refinement values for StarCraft II and boardgames

| Game | $\frac{\sqrt{B}}{D}$ |
|---|---|
| Chess | 0.074 |
| Go | 0.076 |
| Terran | 0.07675 |
| Zerg | 0.07107 to 0.07940 |
| Protoss | 0.72150 |

### 3.4.2 Discussion

As shown in Figure 3-10 and Figure 3-11, strategy trees of Terran and Zerg are more complex than Protoss. In particular Zerg's strategy tree has critical points, as shown in Figure 3-11. This means that game refinement value will change after crossing the critical point [106].

Below we show the illustration of tech tree structures of three different races. Figure 3-13 shows that Protoss tech tree is a branch tree. Terran tech tree is basic divergence linear, as shown in Figure 3-14. Moreover, Zerg tech tree is a disperse tree, as shown in Figure 3-15. Thus the different structures determine that Zerg has a strategy critical point in the opening stage, but Terran and Protoss have no such point.

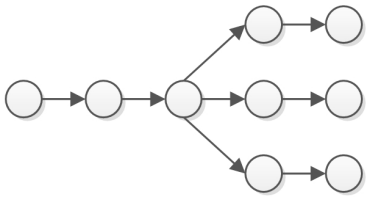

Figure 3-13: Protoss's tech tree structure

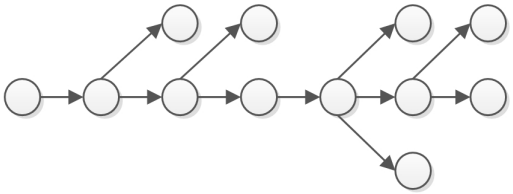

Figure 3-14: Terran's tech tree structure

Compared with the StarCraft II ladder race ratio in Table 3.6, it is found that the race Zerg has been selected with highest percentage in every local server. Behind that, the second popular race is Protoss. Consider the operation difficulty, the results mainly

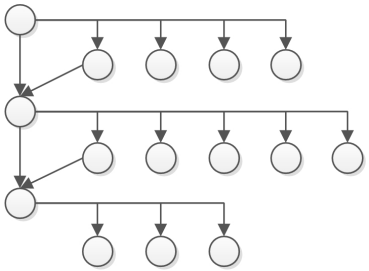

Figure 3-15: Zerg's tech tree structure

Table 3.6: StarCraft II ladder race ratio of grandmaster group

| Server | Terran | Zerg | Protoss | Random |
|---|---|---|---|---|
| US | 23.5% | 38% | 36.5% | 2% |
| EU | 23.8% | 40.5% | 34.7% | 1% |
| China | 25.5% | 35.8% | 34.3% | 4.4% |
| Korea & Taiwan | 30.1% | 32.5% | 32.5% | 4.9% |

fit the research result. In addition, as shown in Figure 3-16 [3], we notice that the wining percentage of Terran is lower than Protoss. Actually, Protoss is much easier to control, while Terran and Protoss's player has the same APM(Actions Per Minute), Terran's player has less chance to win. According to the nature of StarCraft II, many players play the game not only for fun, but also for winning the competition, even though Terran is more interesting than Protoss, they prefer to choose the latter.

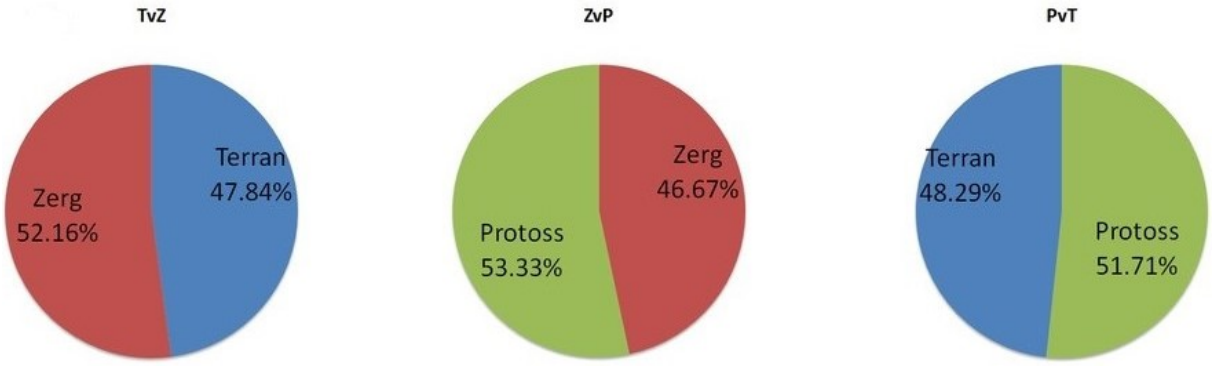


Figure 3-16: Wining percentage of three races

## 3.5 Economy Model Approach in StarCraft II

In the premise sections, we use traditional boardgames model to analyze the strategy element in StarCraft II, the application seems beautiful and successful, however some limitation was existed. For example, in the version of Heart of the Swarm, the shortest strategy time is 1 minutes, therefore, we can divide the 2 minutes strategy length into 2 parts, now we change the situation– just like in the version of Legacy of the void, the shortest strategy time maybe change. If the shortest strategy time is 30 seconds, that will be easy, we can divide the 2 minutes strategy length into 4 part, if the shortest strategy time is 50 seconds, 120 seconds is not the integral multiple for 50 seconds, establish strategy tree and add temporary node will be very tough. Of course we can choose the "greatest common divisor", in this case, 10 seconds as the time unit. We set a example as Figure 3.5 shows.

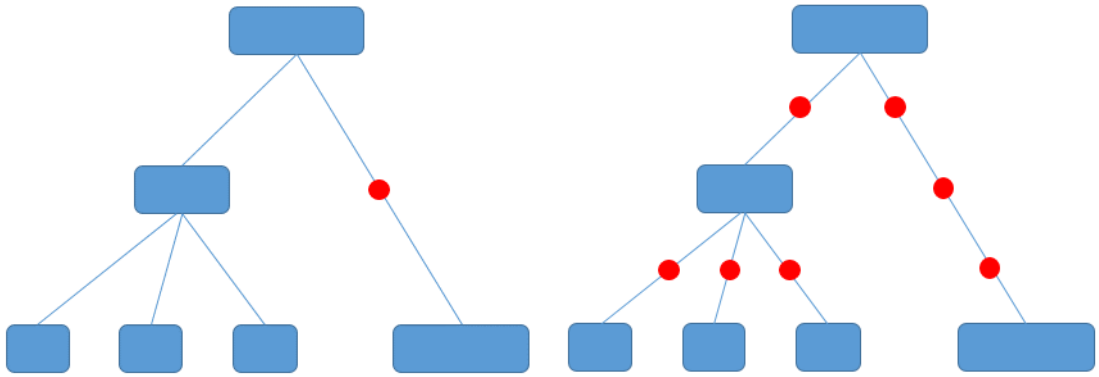

Figure 3-17: Different temporary nodes setting issue

For the left side, we consider the temporary node as 30 seconds; and the temporary node is 15 seconds in right side. Then, the average branch factor of left side is 2 and right side is 1.33; In the same time, the depth of game also was changed, left side equal to 2 and right side equal to 4, therefore the refinement value will be largely changed.

In the other hand, the elder method just focus on the opening part of StarCraft II, past work cannot judge how interesting or how exciting the full game they are. In order to solve these problems, we decide to use sports like game approach to analyze StarCraft II.

### 3.5.1 Game Process and Driving Force

We recognize the game refinement theory measurement is quite useful and reasonable, however the reasonable need base on the precondition that we need make clear the driving force and game process of target game. Except strategy, another driving force in StarCraft II is economy. Players use work to collect item and money to establish a well economy, then they use economy power to produce building and soldiers, also they use economy develop the science and technology, update their equipment. The player who have favourable economic condition can win the game easier. Therefore, the game process by economy model approach can be described as below.

Base on economy element, we consider StarCraft II game progress. It can be measured by two factors: economic aggregate and real physical time. Let E and T be the average number of economic aggregate, and the average physical time per game, respectively. If one knows the game information progress, for example after the game, the game progress x(t) will be given by Equation 3.2.

$$x(t) = \frac{E}{T}\, t \tag{3.2}$$

However, the game information progress given by Equation (3.2) is unknown during the in-game period. The presence of uncertainty during the game, often until the final moments of a game, reasonably renders game progress as exponential. Hence, a realistic model of game information progress is given by Equation (2.4).

$$x(t) = E(\frac{t}{T})^n \tag{3.3}$$

Here $n$ stands for a constant parameter which is given based on the perspective of an observer in the game considered. Then acceleration of game information progress is obtained by deriving Equation (2.4) twice. Solving it at $t = T$, the equation becomes

$$x''(T) = \frac{En(n-1)}{T^n} t^{n-2} = \frac{E}{T^2} n(n-1)$$

Similarly, we have the game refinement formula

$$R = \frac{\sqrt{E}}{T} \tag{3.4}$$


Figure 3-18: Ccreen Shot of StarCraft II Replay

### 3.5.2 Data and Analysis

We have a very useful and convenient replay tool In StarCraft II, player and researcher can access easily to get all the data in past matches. Figure 3-18 is the screen shot of StarCraft II.

The top left corner show the economy data of income, technology and military for two players; the bottom right corner shows the current time. Then we choose analyze 8 target– AI game in Heart of Swarm version, human game in Heart of Swarm version (short, medium, long), AI game in Legacy of the Void version, human game in Legacy of the Void version (short, medium, long). Then we collect the data to analyze the refinement value for each case.

In StarCraft II, we need notice a phenomenon, every time the work always collect 5 mines or 5 gases. Therefore, if the whole economy of a game is 5000, the actual economy $E'$ equal to $\frac{5000}{5} = 1000$, and time $T$ we use second as the unit, then we have the refinement as Table 3.7 shows.

We here summarize the feature of game refinement application in StarCraft II.

- It is very clear to notice that, the Refinement value of "Version: Legacy of the

Table 3.7: Economy Approch in StarCraft II for Each Version

| Version | E' | T | R |
|---|---|---|---|
| AI, HoS | 11220 | 1304 | 0.0812 |
| Human, HoS, short | 1865 | 478 | 0.0904 |
| Human, HoS, medium | 3650 | 804 | 0.0751 |
| Human, HoS, long | 6011 | 1237 | 0.0627 |
| AI, LotV | 11762 | 939 | 0.1154 |
| Human, LotV, short | 2150 | 352 | 0.1317 |
| Human, LotV, medium | 6515 | 635 | 0.1271 |
| Human, LotV, long | 12919 | 1311 | 0.0866 |

Void" is much higher than the "Version: Heart of the Swarm", not matter the AI testing or human competition (short, medium, long). However, the higher R value does not mean the more interesting the game it is. While R value is much higher than comfortable zone value, it means the game with high entertainment, lower competition, the larger R value also means the game deviate the strategy element further away. Therefore, the "Version: Legacy of the Void" is a failing version update. Until now, the medium length competition in HoS version is the most suitable.

- No matter the HoS version or LotV version, it is very clear to notice the R value in StarCraft II has some common principle phenomena. For the short game, the R value is the highest, according to the time past, R value will decrease gradually, which means too long game is not so interesting. The current AI in StarCraft II is not so perfect, so the game length almost equal to the medium length of human player.

- Compared with the strategy tree approach, economy approach can not only analyze the opening game, but also can analyze the whole game, no matter when the time was game finished. On the other hand, economy approach can avoid the defeat in strategy tree approach, we need not to consider about the reasonable strategy or unbalance tree problem, and we can get the data without any self-fish work.

## 3.6 MOBA Game

Multi-player Online Battle Arena (MOBA) [46], also known as Action Real-Time Strategy (ARTS), in which a player controls a single character at one of two teams. The objective is to destroy the opponent team's main structure with the assistance of periodically spawned computer controlled units. Player characters typically have various abilities and advantages that improve over the course of a game and that contribute to a team's overall strategy. A fusion of action games and RTS games, players do not construct either buildings or units. The genre traces its roots to Aeon of Strife (AOS), a custom map for StarCraft where four players each controlling a single powerful unit and aided by weak computer-controlled units were put against a stronger computer-controlled faction. Defense of the Ancients or "DOTA", a map based on Aeon of Strife for Warcraft III: Reign of Chaos and The Frozen Throne, was one of the first major titles of its genre and the first MOBA for which has been kept sponsored tournaments. It was followed by two spiritual successors: "League of Legends" (LOL) and "DOTA 2". Generally, the Original MOBA game map is shown in Figure 3-19. From the Figure 3-20, we can see that MOBA game has developed over 17 years. However, DOTA 2 and LOL are very hard to learn that makes a lot of new players jump away from the game. This situation greatly limits the development of the MOBA game. In this case, a subversive game called Heroes of Storm came out in 2015.

### 3.6.1 Analysis of DOTA

DOTA pits two teams of players against each other: the Sentinel and the Scurge. Players on the Sentinel team are based at the southwest corner of the map, and those on the Scourge team are based at the northeast corner. Each base is defended by towers and waves of units which guard the main paths leading to their base. In the center of each base is the "Ancient", a building that must be destroyed to win the game [150].

Each human player controls one Hero, a powerful unit with unique abilities. In Allstars, players on each side choose one of over one hundred different heroes, each with different abilities and tactical advantages over other heroes. The scenario is highly team-oriented; it is difficult for one player to carry the team to victory alone. Nevertheless, some heroes, given enough time, can change the outcome single-handedly, while countering the opposing

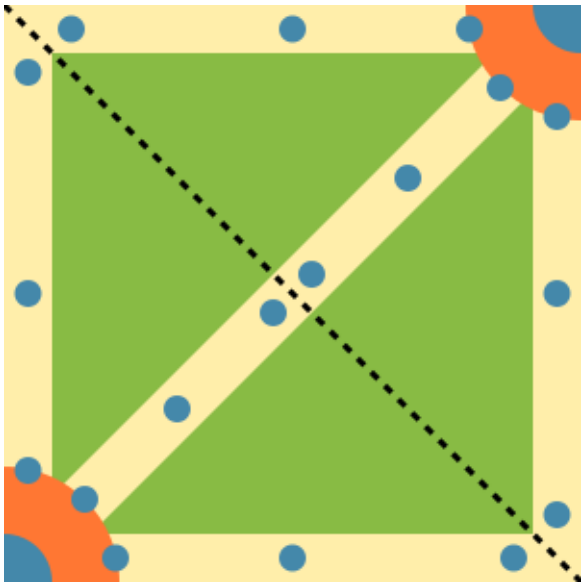

Figure 3-19: Map of MOBA

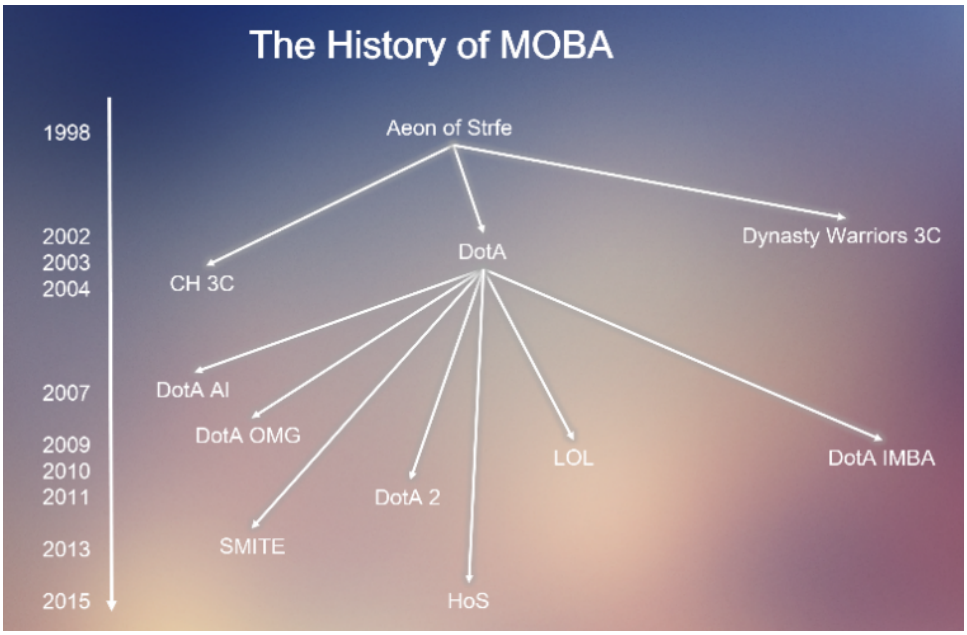


Figure 3-20: History of MOBA

team's heroes. Defense of the Ancients allows up to ten players in a five versus five format and an additional two slots for referees or observers, often with an equal number of players on each side [150].

Because the gameplay revolves around strengthening individual heroes, it does not require one to focus on resource management and base-building, as in most traditional real-time strategy games. Killing computer-controlled or neutral units earns the player experience points; when enough experience is accumulated, the player gains a level. Leveling up improves the hero's toughness and the damage it can inflict, and allows players to upgrade their spells or skills. In addition to accumulating experience, players also manage a single resource: gold. The typical resource gathering of Warcraft III is replaced by a combat-oriented money system; in addition to a small periodic income, heroes earn gold by killing hostile units, base structures, and enemy heroes. Using gold, players buy items to strengthen their hero and gain abilities. Certain items can be combined with recipes to create more powerful items. Buying items that suit one's hero is an important tactical element of the scenario [150].

Allstars offers a variety of game modes, selected by the game host at the beginning of the match. The game modes dictate the difficulty of the scenario, as well as whether people can choose their hero or are assigned one randomly. Many game modes can be combined (for example, an easy difficulty level and a random hero pick), allowing more flexible options [55].

We consider DotA's game progress. Although DotA or LOL belong to e-sports game, essentially access the body game, so we also can simulate the $\frac{\sqrt{G}}{T}$. It can be measured by two factors: to kill heroes and to destroy towers. Let K and A be the average number of successful killing heroes and destroying towers, and the average number of attempts per game, respectively. If one knows the game information progress, for example after the game, the game progress x(t) will be given by Equation 4 [123].

$$x(t) = \frac{K}{A}\, t \tag{3.5}$$

Similarly, we have the game refinement formula

$$R = \frac{\sqrt{K}}{A} \tag{3.6}$$

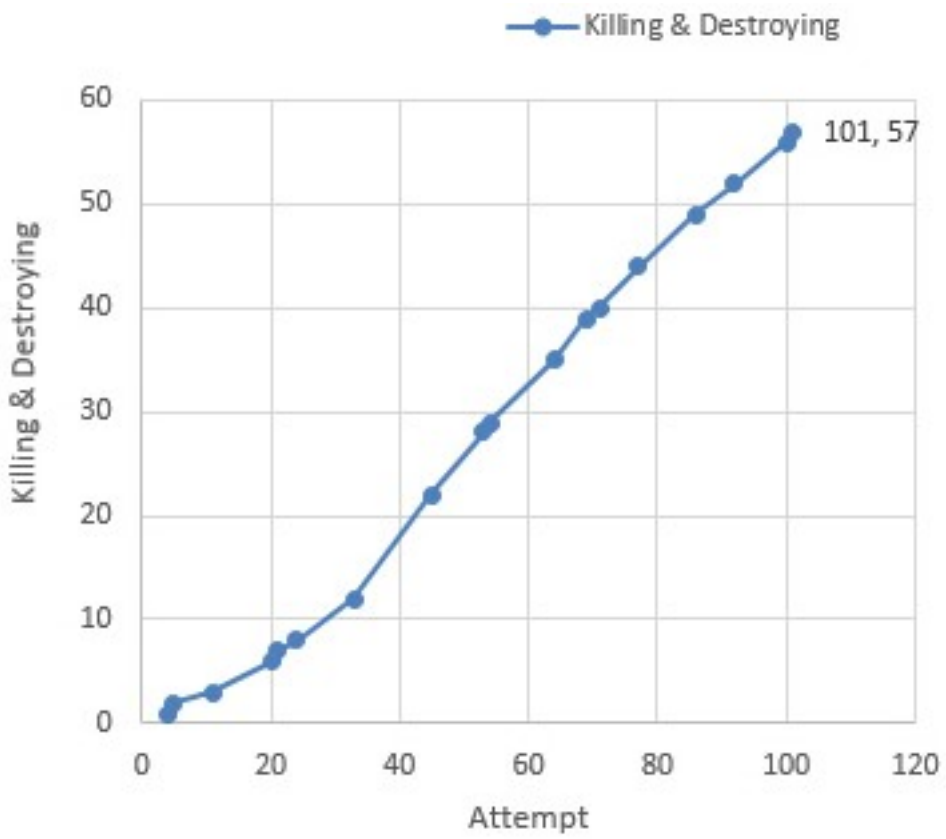


Figure 3-21: Game progress of a replay on DotA ver. 6.74

According some auxiliary software, we can correct the data of DotA as Figure 3-21 shows

We download five replays of each version on website. The players in the game are all expert players in order to make the data more objective and reasonable. A software called replay manager is used for this study to collect the data of killing and the destroyed towers of each game. The attempt is counted by watching replays. We show, in Table 3.8, the results of different DotA versions using game refinement measure by computer system. We played the related versions with other players on platform and collected five replays of each related version [150].

### 3.6.2 Analysis of HotS

Heroes of the Storm (originally titled Blizzard DOTA and later changed to Blizzard All-Stars) is a multiplayer online battle arena video game which has been developed by Blizzard Entertainment. The game features heroes from Blizzard's franchises including

Table 3.8: Measures of game refinement for historical versions of DotA

| version | released | K & D | A | R-value |
|---|---|---|---|---|
| 6.48 | Aug 2007 | 69.2 | 110.8 | 0.075 |
| 6.51 | Mar 2008 | 68.4 | 110.2 | 0.074 |
| 6.59 | Jan 2009 | 69.8 | 110.0 | 0.076 |
| 6.61 | Aug 2009 | 70.0 | 111.6 | 0.075 |
| 6.64 | Oct 2009 | 68.4 | 110.4 | 0.075 |
| 6.69 | Oct 2010 | 67.8 | 108.4 | 0.076 |
| 6.74 | Mar 2012 | 62.4 | 102.6 | 0.077 |
| 6.77 | Dec 2012 | 62.8 | 102.8 | 0.077 |
| 6.80 | Mar 2014 | 68.6 | 106.2 | 0.078 |

Series of Warcraft, Diablo, and StarCraft. In order to develop the game rhythm and make more interest for players, Blizzard has revised a lot of mechanisms to modify the traditional MOBA game. Heroes of the Storm revolves around online 5-versus-5 matches, operated through Blizzard's online gaming service Battle.net. Players can choose one among three game modes, which make the players play with/against computer-controlled heroes or other players. When players first start the game, they may play five heroes provided by the free hero rotation, a methodically selected list that changes weekly, but by using gold, the in-game source of wealth, or through micro transactions, they can gain permanent access to a hero. Two additional heroes are available to players who have reached level 15. As of July 2015, there are currently 39 heroes in the game divided into 4 separate roles. Of the currently released maps, 6 of the 8 have the standard 3 main lanes where players can fight, while the others have only two main lanes, but a separate objective-based area. Killing enemy/neutral units and the opposing side's heroes grants experience points, which are shared with the entire team. When a certain experience threshold is reached for a team, each hero on that team levels up, acquiring slightly amplified status and gaining a talent point upon reaching levels 1, 4, 7, 10, 13, 16, and 20. Talent points allow players to customize their hero's abilities and generally result in large increase in power, especially for levels 10 and 20. This level-up system emphasizes the importance of teamwork, since a player's action can affect the whole team. Minions at neutral camps can be defeated to gain mercenaries that fight for the player. Each map has a different side-objective that will help either team deal significant damage to the other.

There are many different maps existed in the Heroes of the Storm. For each map,

Figure 3-22: Map name in HotS: Tomb of The Spider Queen

Table 3.9: Measures of game refinement for each map in Heroes of the Storm

| Map name | K | D | A | K' | R-value |
|---|---|---|---|---|---|
| Blackheart's bay | 31 | 7.5 | 67.5 | 61 | 0.1157 |
| Sky temple | 44.1 | 11.25 | 85.5 | 89.1 | 0.1104 |
| Dragon Shire | 41.6 | 6.25 | 98.8 | 66.6 | 0.0826 |
| Tomb of the Spider queen | 48 | 7 | 101.3 | 76 | 0.0861 |
| Infernal shrines | 48.5 | 6.5 | 102 | 74.5 | 0.0846 |
| Cursed hollow | 40.6 | 6.8 | 94.8 | 67.8 | 0.0869 |
| Battlefield of eternity | 71.5 | 6.7 | 134 | 98.3 | 0.0740 |
| Garden of terror | 37 | 7.5 | 51.5 | 67 | 0.0741 |
| Haunted mines | 25.5 | 3.5 | 51.5 | 39.5 | 0.1220 |

players can choose the corresponding strategy to fight against each other, also the same hero can choose the different talent to fit the map environments as shown in Figure 3-22 and 3-23.

As game players, the first thing they care about is how to develop themselves and limit the development of the enemy. Each player have different role in the game, therefore players have to choose the different kinds of heroes and their talent base on the corresponding map. In order to make the data more objective and reasonable, we choose the expert players' video to analyze data. The statistics was collected the data of killing and the destroyed fortress of each replay. As the Table 3.9 shows, the results of different map using game refinement measure by computer system, and one fortress equal to four defense force, then we have $K' = K + 4 * D$.

Figure 3-23: Map name in HotS: Garden of Terror

We collected data of Heroes of the Storm (HotS) for each map. Then, we applied game refinement theory application in Section II and Section III. In the previous studies, it is found that sophisticated R-value in each game between 0.07 ? 0.08. However, we see that the results show much higher values for HotS battle. It means this game will be too excited which is suitable for especial viewer such as boxing which is extremely exciting sport. Compared with other MOBA game such as DOTA, we can summarize the conclusion as below:

- As a new game, HotS still has some insufficient aspects. In fact, until our research was done, only 43 heroes can be chosen, however, there are 112 heroes in DOTA. Many new heroes should be added and the current heroes' parameter should be changed.

- Generally, the R-value in HotS is too high even approach 0.1, and DOTA almost in the window value which between 0.07 and 0.08. It means DOTA fit to set as an e-sports competition item, but HotS is fit to do entertainment. DOTA has powerful skill and more visual impact for each hero, what cares more about management and running. Players need to make a stable and safe environment for carry and develop. Gank usually happens during the whole game. However in the HotS, the most important thing is large-scale team combat, therefore, the game rhythm is much higher than DOTA. Generally, a DOTA game may spend about 40 minutes

but HotS usually within 20 minutes. HotS offers game players a new style of MOBA game that spends less time of each game and form a fast rhythm.

- According to the Table 2, the most interesting and exciting map are Sky temple and Blackheart's bay. Battlefield of eternity and Garden of terror are suitable for e-sports competition. In fact, DOTA can consider make more maps in the future to improve the fun level. The higher refinement value will be tenderer to the freshman players. DOTA is very unamiable to the new players.

- For the mechanism, DOTA focus on the anaphase period during the game, but the core mechanism in HotS is wild monster. For this reason, the game depth of HotS is less than DOTA and gets a larger R-value. Therefore, HotS cares more about teamwork not personal operation and game awareness.

Nevertheless, the fun of HotS is not derived only from battle. The various heroes and their talent can provide a lot of enjoyment for Blizzard fans. In addition, they can design maps that are more interesting. For example, control the map mechanism to keep the R-value between 0.07 and 0.08, what suitable for held e-sports use.

## 3.7 Chapter Summary

This chapter presented the game refinement measure has been calculated for three different races in the opening game of StarCraft II. Thus, it is possible to compare the degree of game refinement or engagement of RTS games with other type of gamers such as boardgames and sports games. We conclude that the resulting game refinement values of StarCraft II, as measured by game refinement theory, support the previous assumptions of a balanced window of game sophistication around 0.07-0.08. Particularly, our research was based on the July, 2014 year. After that, some parameter in StarCraft II had been changed and player's tactics had been updated. However, base on our achievements, game refinement theory can successfully be used in various of Real Time Strategy game, it can be a good tool to help game designer to make rules or set the game parameter.

Also in this chapter we have extended game refinement theory to the field of MOBA game. The results of computer analysis confirmed MOBA game has the similarity of game entertainment impact like sports games and boardgames. It means that multi-player game

also follow the principle of seesaw games. Compared with DOTA, the game rhythm of HotS is much higher, it means player can feel more enjoyable from this game, on the other hand it shows HotS has lacked serious competition. HotS is trying to increase the amount of team play involved; this will absolutely lead to more fun than ever before. However, we need further investigation in collecting data and apply game refinement theory to another famous MOBA game such as LOL. Finally, further work may be considered the comparison of three popular MOBA games (DOTA, LOL and HotS), this content will be analyzed in Chapter 7.

Until now we just use game refinement theory to analyze the target game, the current new question is "Can we inverse using the game refinement theory to design game to make it more interesting?" In the next chapter, we will solve this issue.

# Chapter 4

# An RPG Tuning Way using Game Refinement Measurement

This chapter is an updated and abridged version of the following publication.

- Shuo Xiong, Ying Peng, Hiroyuki Iida and Nordin Abu-Bakar. (2016). An Approach to Entertainment Tuning in RPGs: Case Study Using Diablo III and Trails of Cold Steel. In Games and Learning Alliance (pp. 385-394). Springer International Publishing. Utrecht, Netherlands. Dec. 2016

## 4.1 Chapter Introduction

In this Chapter, we will show how to use game refinement theory to help game related worker to design a RPG game. Role-playing game (RPG) is a type of game in which players assume the roles of characters in a fictional setting [21]. Players take responsibility for acting out these roles within a narrative, either through literal acting, a process of structured decision-making or character development. The actions taken within many games deem successful or not according to a formal system of rules and guidelines.

There are several forms of RPG [21]. The original form, sometimes called the tabletop RPG, is conducted through discussion, whereas in live action role-playing games (ARPG) players physically perform their characters actions. In both of these forms, an arranger called a game master (GM) usually decides on the rules and setting to be used and acts as a referee, while each of the other players plays the role of a single character.

Several varieties of RPG [26] also exist in electronic media, such as multi-player text-based MUDs(Multiple User Domain) and their graphics-based successors, massively multiplayer online role-playing games (MMORPGs). Role-playing games may also include single-player off-line role-playing video games in which players control a character or team who undertake quests, and may include capabilities that advance using statistical mechanics. These games often share settings and rules with tabletop RPGs, but emphasize character advancement more than collaborative storytelling. Despite the variety of forms, some game forms such as trading card games and war games that are related to role playing games may not be included. Role-playing activity may sometimes be present in such games, but it is not the primary focus. The term is also sometimes used to describe role play simulation games and exercises used in teaching, training, and academic research [145].

Up until now, role-playing game has been produced in many companies with great quantity and popular around the world. In Console Game area, generally we classify all the RPG into three types [116] [70]: Japanese-style RPG, such as series of Final Fantasy and series of the Legend of Heroes, which focus on the weltanschauung, scenario and character setting; Chinese-style RPG, such as series of The Legend of Sword and Fairy, which focus on the love, tragedy and Chinese culture; Western-style RPG, such as series of Diablo and series of The Elder Scrolls, which focus on the operation and play system. A lot of people are addicted to play RPG, according to the game company Blizzard report about Diablo III, 20 million copies were sold worldwide. So how to make or design an excellent role-playing game with high playability and quality is worthy of research [21].

## 4.2 Problem Statement in RPGs

Ideally all games must be extremely attractive, continuously challenging the mind and offer infinite excitement at every turn of events to remain relevant. However, compared with some other types of game such as FPS(First Person Shooting) or ACT(Action Game); the system and game rhythm of traditional RPGs are not as interesting and exciting. Game designer always pay a lot of attention on the story background or characterization, but the battle system and weapon system are ignored; after a player finishes the game and know the scenario they do not want to play it again. Therefore, this study will

explore, using a scientific approach, how to improve the quality of RPG by making the game to become much more exciting and interestingly long. In this chapter, we mainly put emphasis on the video role-playing game which was designed on the PC or console, and lay emphasis on how to develop the quality of current eastern role-playing game by utilizing Game Refinement Theory(GRT). In the end, this chapter will answer the following question: can entertainment be assessed numerically and produced a threshold for excitement? Ultimately, the results of this study will help game designer to improve the quality of games and prolong the excitement period for the gamers to enjoy the game.

A role-playing game(RPG) is divided into two major categories [26] [21] in the mainstream market: action role-playing game (ARPG) and Turn-base/Half Turn-base role-playing game. In ARPG, a player need not break the game process as all the events and battle scenes will happen in the Big Map; which is very similar to real time strategy or MOBA game. For Turnbase/Half Turn-base Role-playing game, the characters move on the Big Map only and the battle will change the stage. It means the game process will be broken and from the macro view it seems like the Chess and Go. It is very difficult to determine which model is better; Action Role-playing game allows the player to get more pleasure or Turn-base/Half Turn-base Role-playing game that provides more strategic element to allow the players to easily enjoy the story and scenario [26].

## 4.3 Three Bottlenecks of Current RPGs

However, there are serious limitations to the RPGs that have hindered players to play the games. These limitations are categorised into three different themes, they are: Weapon System, Battle System and Game Rhythm and Time. In this section, we will analyse them one by one in greater details.

### 4.3.1 Weapon Trading System Issue

For the current system of weapons, players need to constantly hunt monsters to get the money, then purchase the appropriate equipment and weapons from the scene shops. However in this way, it will have an irrational phenomenon: players can only ever buy the lower equipment from shop in stage A, after that players will be able to buy higher

level weapons from shop in stage B.

For each section, in order to replace the lower level equipment, players will feel trapped in an unnecessary obligation because they have to repeat buying and selling in different scene stores. Also consider about the story background, it is very difficult to explain why all the equipment sold in stage B are much more expensive than stage A. Moreover, even in the same city, the weapons and equipment in store can actually develop with chapter change. Therefore, the current weapon system phenomenon not only conform to common logic and make player waste a lot of time, but also lack the personality of weapons. The traditional money and weapon system are shown in Figure 4-1.

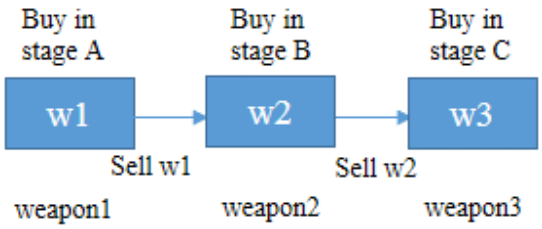


Figure 4-1: Trading weapon system

In this weapon system, the branching factor always equal to 1, also lacking of tree structure will make the replace system become boring and disjointed. We will explain the related concept detailed in following section.

### 4.3.2 Linear Turn-Based Battle System

The battle system in many traditional role-playing game such as "Pokemon" used "linear turn-based", as shown in Figure 4-2. In Figure 4-2, our characters are marked as $C1$, $C2$ and $C3$, and the enemies are marked as $E1$ to $E4$. Each character and enemy unit can attack, assist or hinder any other unit directly without movement. This system is commonly used in *"Final Fantasy (From I to X)"* and many Chinese RPG such as series of *"Chinese Paladin"*.

The completely turn-based battle systems, however, have a lot of limitation and as a result, lack of enjoyment. According to the research by C.Panumate [96], the game has low excitement value and the battle system is only fit for children. In following section, a developed system will be introduced and a new design method will be provided.

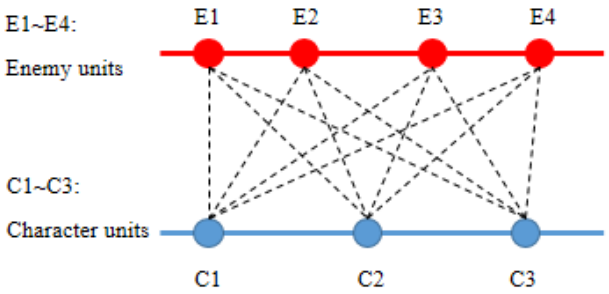


Figure 4-2: Linear turn-based battle system

### 4.3.3 Level Up System

Compared with the other types of game, especially the Action game or RTS (Real Time Strategy) game [143], role-playing games lack processing fluency. For example, all the story, non player character(NPC) communication and script triggers are defined in the "Big map stage", the monster and the enemies also move on the "Big map", while players' character hit these enemies, the "Big map" stage will break and change into the "Battle stage" [77] and this is generally called "scene translation". , as the Figure 3 shows.


Figure 4-3: An sample of big map stage and battle stage in "The Trail of Blue"

The problem with this game is that the player needs to break the stage for hundreds of times while they move on the big map. This frequent "times breaks" will make the player feels interrupted and destroy the rhythm of the game; however, fewer breaks will deem the game too easy and worthless.So the current issue is that how many times of break for one level up is the best or the most fitting value. In following section, we will resolve this issue.

## 4.4 Methodology

In order to solve the three bottlenecks, we guide a mathematical method which called "Game refinement theory"(GRT) to show some countermeasures. Game refinement is a unique idea that has been proposed based on the uncertainty of game outcome. This idea was commonly used in various games to judge how interesting and how exciting they are. Therefore, we reverse the use of GRT and utilize it to analyze or design an interesting game model.

## 4.5 Evaluating RPG using Game Refinement Theory Enhancement

### 4.5.1 Forging Weapon System

In this chapter, a reliable countermeasure is proposed to solve the issue which is called "Forging System". In fact, the "Forging System" are commonly used in many games, such as Diablo III and Monster Hunters. Specifically, in forging system, players only need to buy one or a small number of original equipment. With the game progress past and hunting monsters, players can get a certain amount of "material", after that a player will use these materials and original weapons to forge stronger and more advanced equipment, rather than use money to replace the older. At least there are four benefits of doing so as Figure 4-4 shows:

- 1. Avoiding unnecessary duplication of operation.
- 2. Players can decide the direction to evolute their weapons and equipments with highlight personality.
- 3. Enhancing the life of role-playing game. Players want to experience the different weapon systems, so they will try the "New Game Plus" after clear the story.
- 4. Improving Battle System, for example while player forge a weapon with "Water Property", it will have much more effect to the monster with "Fire Property" and less effect to the enemy with "Earth Property".

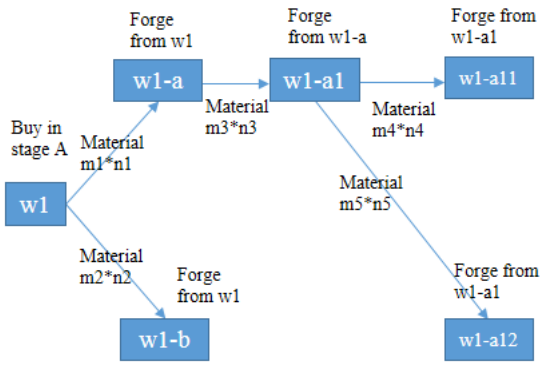


Figure 4-4: Progress of forging system

The parameter $D$ is defined from default equipment to the final equipment, in traditional trade weapon system which was shown in Figure 4-1, the Branching Factor $B$ equal to 1. Therefore, the refinement value of traditional trade weapon system should be $R = \frac{\sqrt{B}}{D} = \frac{\sqrt{1}}{D}$. While we improve trade system into forging system, branching factor should be larger than 1, then refinement value of weapon system will be developed.

### 4.5.2 Half Turn-Based and Hexagon Battle System

Some game companies established a new system which called "Half turn-based" such as "The Legend of Heroes VI: Trails in the Sky" which was produced by Falcom company [92]. "Half turn-based" can simulate further the interest and fairness of real-time system, and at the same time can keep high strategic factor of turn-based mode, which draw lessons from SLG(Simulation game) and absorbs the advantages of "Military Simulation". Figure 4-5 is a typical hexagon battle system map of "Half turn-based" which commonly used in the series of "Civilization" [110]. In Figure 4-5, from $C1$ to $C3$ is our character and enemies are marked as $E1$ to $E4$, this is similar to the pieces in Chess or Shogi. For example $C1$ can move to its left, right or forward, $E4$ has four direction to choose. Now we combine half turn-based system (from traditional RPG) and hexagon map (from SLG) together.

This game does not imitate the system of boardgame, but also we will guide a "time concept" into the battle system. It is called "Half-Turn-Based" what can ultimately simulate the real time game as each unit will be assigned a speed value. Now only consider three parameters $C1$, $E1$, $E2$. $C1$ is the fastest which speed value is 3, so every movement

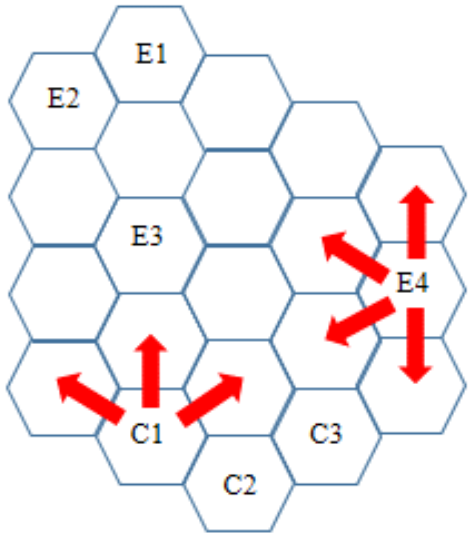


Figure 4-5: Boardgame like battle grand system

Table 4.1: Time concept in half turn-based battle system

| C1 | E1 | E2 | Move Piece |
|---|---|---|---|
| 3 | 4 | 5 | C1 |
| minimum+3 | | | |
| 6 | 4 | 5 | E1 |
| | minimum+4 | 5 | |
| 6 | 8 | 5 | E2 |
| | | minimum+5 | |
| 6 | 8 | 10 | C1 |
| minimum+3 | | 5 | |
| 9 | 8 | 10 | E1 |
| | minimum+4 | 10 | |
| 9 | 12 | 10 | C1 |
| minimum+3 | | 10 | |
| ..... | ..... | ..... | ..... |

cost 3 time units. $E1$ and $E2$ are defined in a similar way as shown by Table 4.1. This system had been commonly used in several RPGs game such as the series of "The Legend of Heroes" or "Chinese Paladin" [92].

As shown in the table above, the most previous six movement sequence follow as "$C1 - E1 - E2 - C1 - E1 - C1''$, where $C1$ is in the front because it can move for three times in six rounds and provide more role properties and features that can also can keep the game in balance. The most important thing is after analysing the half turn-based battle system, we can design and set the game parameters much more easily and accurately by using the game refinement theory.

In our early work, the refinement value can assess how interesting a game is. In fact, the full formula of boardgame is as follows

$$R\ value = C_b * \frac{\sqrt{B}}{D}$$

$C_b$ is the parameter which can express the skill of player. Usually in boardgame or strategy game, the higher a player's skill is. The lower the $C_b$ value is. For intelligent player the c value should be around 0.1. Generally, an interesting game progress have the refinement value between 0.07 to 0.08. Therefore, we have the formula as devised below:

$$B^2 = 0.64 * D. \tag{4.1}$$

According to Equation 4.1, we can easily design the large of battle checkerboard and evaluate the various of parameter in game. Based on the game environment and AI strength, constant front of D can float between 0.5 to 1. Based on this mathematics model, the refinement value should be much larger than traditional battle system in Pokemon.

### 4.5.3 Improving Game's Level-up System

We consider RPG level-up progress. It can be measured by two factors: to kill monster then get the experience and go one level up [149]. Let $\Delta L$ and $U$ be the Level n+1 minus Level n, and the average number of battle time "Unit", respectively. If one knows the game information progress, for example after the game, the game progress $x(t)$ will be given by Equation 4.2.

$$x(t) = \frac{\Delta L}{U}\ t \tag{4.2}$$

A model of RPG information progress is given by Equation 4.3.

$$x(t) = \Delta L(\frac{t}{U})^n \tag{4.3}$$

Here $n$ stands for a constant parameter which is given based on the perspective of an observer in the game considered. Then acceleration of game information progress is

obtained by deriving Equation (4.3) twice. Solving it at $t = U$, the equation becomes

$$x''(T) = \frac{\Delta L n(n-1)}{U^n} t^{n-2} = \frac{\Delta L}{U^2} n(n-1) \tag{4.4}$$

Similarly, then we have the game refinement formula$R = \frac{\sqrt{\Delta L}}{U}$. Let us use the score limited game approach. In RPG, players need to hunt monster to get experience and level up, therefore, each battle is one round. And players can not lose the battle (if they lose, then game over), so need to win all the battle. Base on this idea, $\Delta L$ always equal to 1, so now we can analyze the question: "How many battle time units for one level up will make players feel interesting and comfortable". Then the Equation (4.4) can be changed as the following formula$U = \frac{\sqrt{1}}{R}$.

We define a new concept which is called "Battle Time Units", for the word "Time" has two meanings namely: first, is duration regarded as belonging to the present life as distinct from the life to come or from eternity; second, the current period or previously present era. We selected two excellent representative games as research subjects– *"The Legend of Heroes: Trails of Cold Steel"* and *"Diablo III"* [44]. For the turn-based or half-turn-based RPG such as *"The Legend of Heroes: Trails of Cold Steel"*, the battle will break the big map and change stage, therefore time means frequency. Figure 4-6 and Table 4.2 show the statistic of how many times break from level 3 to level 65 and corresponding refinement value.

In Trails of Cold Steel, all the battle and experience are embedded into the scenario, hence only one statistic is sufficient. Based on the game refinement function, the refinement value of every level can be calculated.

In Figure 4-7, we notice that almost refined value are around the dotted line which falls in the range of 0.08 to 0.09. There are six wave crests existed and very 10 levels there is a crest. It means that in each chapter of the "Final boss battle" , the boss can provide plenty of experience to give players a sense of accomplishment.

For the Action RPG (ARPG) such as *"Diablo III"*, because all the scenes and battle all happened in the same big map without any break, the game progress is clearly defined. In order to describe the concept of "time", we select physics Time as the parameter. Figure 4-7 show the statistic of how long consumption for each level. Consider Diablo III has a high degree of freedom, hence our statistic is taken from three sample then choose

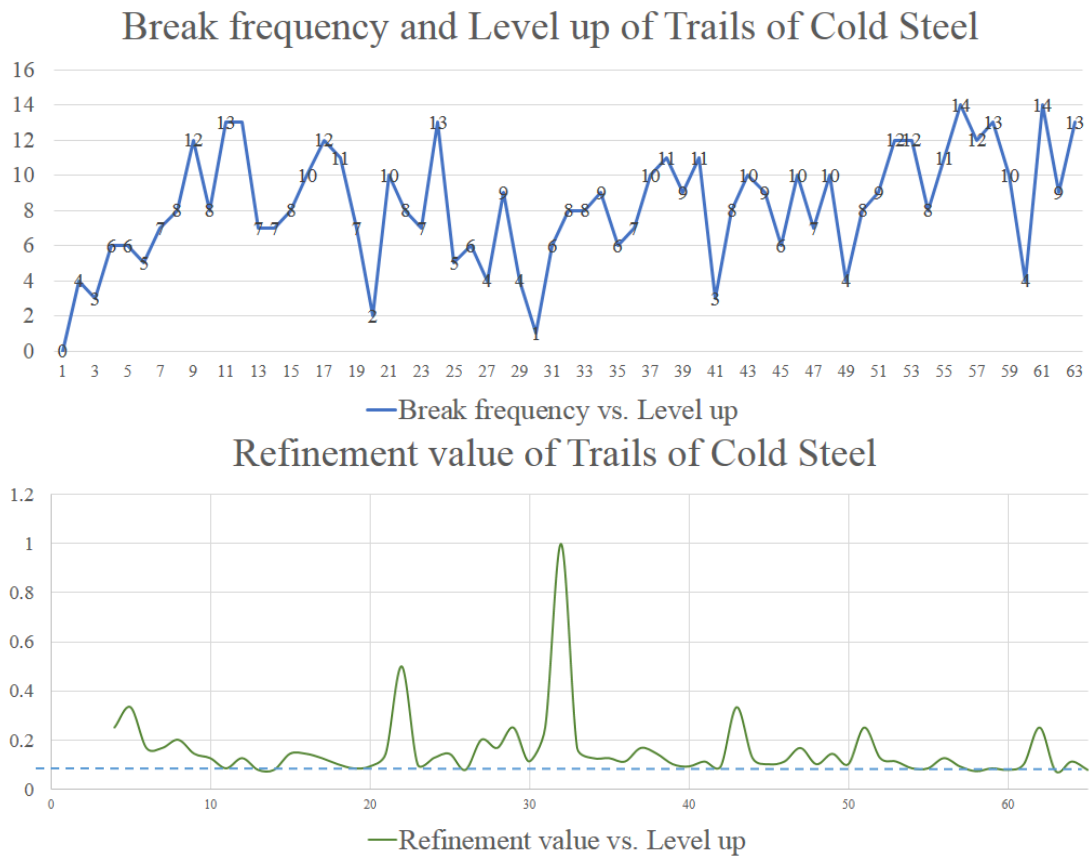


Figure 4-6: Statistic of level up and refinement value tendency in “Trails of Cold Steel”

Table 4.2: Statistic of level up in Trails of Cold Steel

| Level | Time | Level | Time | Level | Time | Level | Time |
|---|---|---|---|---|---|---|---|
| 3 | 0 | 19 | 12 | 35 | 8 | 51 | 4 |
| 4 | 4 | 20 | 11 | 36 | 9 | 52 | 8 |
| 5 | 3 | 21 | 7 | 37 | 6 | 53 | 9 |
| 6 | 6 | 22 | 2 | 38 | 7 | 54 | 12 |
| 7 | 6 | 23 | 10 | 39 | 10 | 55 | 12 |
| 8 | 5 | 24 | 8 | 40 | 11 | 56 | 8 |
| 9 | 7 | 25 | 7 | 41 | 9 | 57 | 11 |
| 10 | 8 | 26 | 13 | 42 | 11 | 58 | 14 |
| l1 | 12 | 27 | 5 | 43 | 3 | 59 | 12 |
| 12 | 8 | 28 | 6 | 44 | 8 | 60 | 13 |
| 13 | 13 | 29 | 4 | 45 | 10 | 61 | 10 |
| 14 | 13 | 30 | 9 | 46 | 9 | 62 | 4 |
| 15 | 7 | 31 | 4 | 47 | 6 | 63 | 14 |
| 16 | 7 | 32 | 1 | 48 | 10 | 64 | 9 |
| 17 | 8 | 33 | 6 | 49 | 7 | 65 | 13 |
| 18 | 10 | 34 | 8 | 50 | 10 | | |

the average time for each level-up.

Table 4.3: Statistic of level up in Diablo III

| Level | Time | Level | Time | Level | Time | Level | Time |
|---|---|---|---|---|---|---|---|
| 2 | 0:02 | 20 | 0:08 | 38 | 0:21 | 56 | 0:29 |
| 3 | 0:03 | 21 | 0:08 | 39 | 0:24 | 57 | 0:30 |
| 4 | 0:03 | 22 | 0:10 | 40 | 0:15 | 58 | 0:30 |
| 5 | 0:03 | 23 | 0:10 | 41 | 0:21 | 59 | 0:30 |
| 6 | 0:05 | 24 | 0:10 | 42 | 0:22 | 60 | 0:36 |
| 7 | 0:05 | 25 | 0:10 | 43 | 0:24 | 61 | 0:2 |
| 8 | 0:05 | 26 | 0:10 | 44 | 0:24 | 62 | 0:24 |
| 9 | 0:08 | 27 | 0:15 | 45 | 0:26 | 63 | 0:27 |
| l0 | 0:13 | 28 | 0:15 | 46 | 0:30 | 64 | 0:27 |
| 11 | 0:07 | 29 | 0:19 | 47 | 0:32 | 65 | 0:36 |
| 12 | 0:07 | 30 | 0:10 | 48 | 0:32 | 66 | 0:39 |
| 13 | 0:07 | 31 | 0:12 | 49 | 0:33 | 67 | 0:48 |
| 14 | 0:08 | 32 | 0:18 | 50 | 0:29 | 68 | 0:51 |
| 15 | 0:08 | 33 | 0:18 | 51 | 0:30 | 69 | 0:57 |
| 16 | 0:08 | 34 | 0:20 | 52 | 0:32 | 70 | 1:00 |
| 17 | 0:10 | 35 | 0:21 | 53 | 0:32 | | |
| 18 | 0:10 | 36 | 0:21 | 54 | 0:36 | | |
| 19 | 0:16 | 37 | 0:21 | 55 | 0:24 | | |

Next, we need to analyse the concept called “battle time unit”. At the beginning of each game, designers have to provide some incentives to the new players to keep them

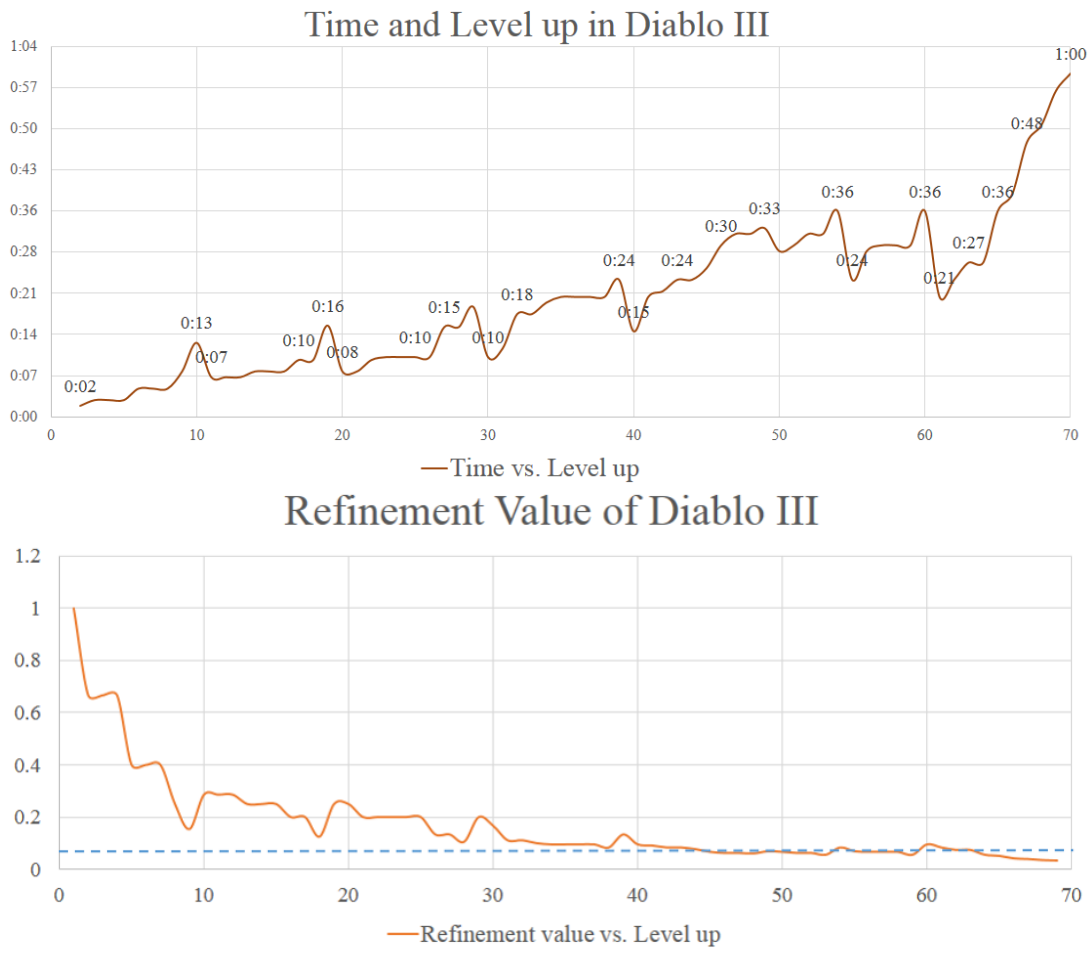


Figure 4-7: Statistic of level up and refinement value tendency in Diablo III

playing the game; thus the character can advance the next level very easily. In Figure 4-7, from level 1 to level 2, it only costs 2 minutes, so the whole game will follow the same rhythm to adapt the parameter. While 2 minutes is "1 unit", then 3 minutes will equal to "1.5 unit", therefore, the refinement value of level 2 to level 3 equal to $R = \frac{\sqrt{\Delta L}}{U} = R = \frac{\sqrt{1}}{1.5} = 0.67$. Similarly, we can get all the R values of each level as Figure 4-7 shows.

From Figure 4-7 we are aware at the beginning of the game, the refinement values are very high than regular ones,however,over the time, R value will decrease very quickly and remains stable at a particular value. After level 35, R values are all around the dotted line within the range of 0.07 to 0.08. Upon reviewing the whole equation curve, there are eight wave crests existed. It means after the challenging "Boss battle" or game progress, the character can get new skill or ability, designer also will provide some more incentives and players can level up very quickly. Then by adjusting parameters to make the time period back to normal and make the game become more challenging, the game time progress will be shown as spiral.

## 4.6 Results and Discussion

This work is an attempt to find a scientific method to design an interesting role-play game. We focused on three bottleneck in current RPG and provide the countermeasures. Using forging system to replace trading system; use half-turn-based boardgame like battle system to replace linear turn-based system.

The game refinement theory has also been applied with three game progress modeling approaches; one from traditional boardgame to change the simple battle system into half-turn-based boardgame like battle system such as chess and Shogi, Based boardgame like battle system such as chess and Shogi and two from sports game to design an attractive and challenging level up system. We used Diablo III and The Legend of Heroes: Trails of Cold Steel as the analysis object in this research. The results were shown in Figure 4-6 and Figure 4-7. We used Diablo III and The Legend of Heroes: Trails of Cold Steel as the analysis object in this research. For the analysis of two masterpiece games, the R value are around 0.08. We conclude that this slightly high $R$ means that it attracts player and they can feel extreme excitement after a challenging battle.

Moreover, we can propose some method to increase or decrease $R$ value in RPG level up system such as reduce the number of monster, for each monster could be more difficult to fight but they will provide times of experience point. Thus, each battle will become more challenging and player will have minimum interruption or progress break. We can design or set some reward monster in stage, lower skill players can continue their game normally with a lot of easy battle break, however, more experienced players can choose hunt the reward monster in a lesser time. Generally, the work presented here is very fundamental in gaming and would require further studies . Future work may include various data in another turn-based RPG or Action RPG. However, the enjoyment and attractiveness of turn-based RPG do not come from only the battle system, level up or weapon system. It should come from a good story, interesting background and attractive scenario. Therefore, further research will be initiated to look into game refinement theory in RPG by other point of view.

## 4.7 Chapter Summary

This chapter presented the game refinement theory has been effectively used in the selected RPGs, with an appropriate model of game information progress. The experimental results have shown that entertainment level of a game can be assessed numerically and produced a threshold for excitement. The level-up system in the game was found to be the key factor that has varied the game refinement values. By enhancing it,the level of excitement,as defined by the game refinement value, will fall within the stipulated range. The game refinement theory has taken into consideration all aspects of human entertainment and intelligence components to evaluate each portfolio of the game. A good and interesting storyline with out-of-the-world characters and scenarios will be the main points that will keep a player in the game and return to play it all over again. Incessant greed of wealth and power could be laid underneath the battle to pacify serious game players into strategic thinking to win the battle and advance to the next level. Ultimately, game designers could refer to the game refinement values to ensure the level of excitement remains high towards the end of the game and improve the quality of the game. However, the issue "whether a game is interesting or not" has no direct relationship with "whether a game is attractiveness or not". Some games have the similar even same game refinement value,

however the fans population are completely different, therefore we need find another property of game to explain the issue. In the following chapter, we will analyze this problem.

# Chapter 5

# Sophistication-Population Paradox of Game Refinement Theory

This chapter is an updated and abridged version of the following publication.

- Shuo Xiong, Parth Pankaj Tiwary, and Hiroyuki Iida. (2016). Solving the Sophistication-Population Paradox of Game Refinement Theory. In International Conference on Entertainment Computing (pp. 266-271). Springer International Publishing. Vienna, Austria. Sep. 2016

## 5.1 Chapter Introduction

In Chapter 2, we have introduced the basic model of game refinement theory, after that we have show a lot of application in various of game. Hiroyuki Iida believe [65], for game refinement theory, game information progress in any type of games is happening in our minds. We do not know yet about the physics in our minds, but it is likely that the acceleration of information progress is related to the force in mind. Hence, it is reasonably expected that the larger the value $\frac{B}{D^2}$ is, the more the game becomes exciting due to the uncertainty of game outcome. Thus, we use its root square, $\frac{\sqrt{B}}{D}$, as a game refinement measure for the game considered.

For the later work, Arie Sutiono [123] provide a new mathematical method to establish a channel between boardgame and sports game. Similarly, we consider two parameter $G$ and $T$ what express as the average number of successful shoots and the average number of

Table 5.1: Measures of game refinement for various of game

| Game | B or G | D or T | $\frac{\sqrt{B}}{D}$ or $\frac{\sqrt{G}}{T}$ |
|---|---|---|---|
| Chess | 35 | 80 | 0.074 |
| Go | 250 | 208 | 0.076 |
| Basketball | 36.38 | 82.01 | 0.073 |
| Soccer | 2.64 | 22 | 0.073 |
| Badminton | 46.336 | 79.344 | 0.086 |
| Table tennis | 54.863 | 96.465 | 0.077 |
| DotA ver 6.80 | 68.6 | 106.2 | 0.078 |
| StarCraft II Terran | 1.64 | 16 | 0.081 |
| The king of the fighters 98 | 14.6 | 36.7 | 0.104 |
| The king of the fighters 13 | 26.5 | 44.8 | 0.115 |

shoots per game, then refinement value was strongly related with $\frac{\sqrt{G}}{T}$. According to this idea, in Table 5.1, a comparison of game refinement measures for various type of games.

However, some paradox was exsited in Table 5.1 and game refinement theory need to be evaluted again, also Hiroyuki Iida have said **"We do not know yet about the physics in our minds, but it is likely that the acceleration of information progress is related to the force in mind"**. Therefore, the following section reviews the Newton's law of motion and discusses the notion of mass and force in game process alongside with complexity issues in games.

## 5.2 Physical Meaning in Game Process

### 5.2.1 Newton's Laws of Motion

According to preamble of this Chapter, the game information outcome is analogous to distance in physical meaning. Then, the physical concept in game and motion can be described as in Table 5.2.

Table 5.2: Physical concept in motion and game compared

| Mathematical notation | Motion | Game |
|---|---|---|
| $x(t)$ | Distance | Information of outcome |
| First derivative of $x(t)$ | Speed | Information speed |
| Second derivative of $x(t)$ | Acceleration | Information acceleration |

The Newton's first law [14] said

> *"In every material universe, the motion of a particle in a preferential reference frame $\Phi$ is determined by the action of forces whose total vanished for all times when and only when the velocity of the particle is constant in $\Phi$. That is, a particle initially at rest or in uniform motion in the preferential frame $\Phi$ continues in that state* ***unless compelled by forces to change it****."*

Therefore, if a game has a certain refinement value, it means that some force should exist and its affect on the game then generates game acceleration.

### 5.2.2 Mass and Force in Game Process

We consider the Newton's 2nd law [14], i.e., we have $F = ma$, where $F$ stands for the resultant force, $m$ for mass and $a$ for acceleration, respectively. In the physical world, mass is a property of a physical body which determines the strength of its mutual gravitational attraction to other bodies. While one deterministic item is not changed or destroyed, the mass of item will not be changed. In the game world using the same analogy, mass should be a property of game, while the game has pre-determined rules and mechanism, mass will remain constant unless the rules and mechanism are modified.

So the question is "What is the unit of mass in the game world?". In Newtonian Mechanics, while Force ($F$) acts on an item that has a determined mass, as a result it produces acceleration and change in speed. Similarly, in the game world the Force ($F$) will produce an acceleration in game progress information and will change the game speed. In other words, if we want to accelerate two objects with same acceleration in same environment, we need to apply more force on the object with the greater mass.

In the game refinement theory, R-value is determined as game acceleration. On comparing tic-tac-toe with Go, if we want to get the same excitement of these two games, it is obvious that Go should be much more difficult. Thought is a mind force, even children can play tic-tac-toe very well but Go needs higher intelligence quotient. ***Therefore, the mass of game is related to the decision complexity of a game with rules and mechanism and force is the elaborative faculty***. Some related work can prove the theory [81]. For example, the mass of Go is $10^{172}$ or decision complexity with rules and mechanism. In Table 5.3, we can notice the comparison of physical concepts in motion and game.

Table 5.3: Newton's 2nd law in motion and game compared

| Symbol | Physical concept in motion | Physical concept in game |
|---|---|---|
| F | Force | Elaborative faculty |
| m | Mass | Decision complexity |
| a | Acceleration | Related to game refinement value |

As an example of four complex games: Chess, Xiang Qi, Shogi and Go. Two types of complexity were considered:

**State-space complexity** [81]: This is the search space that can be expected in a game, based on the average branching factor and average game length in plies. For four games the game tree complexity [130] is as follows.

- Chess: $10^{46}$, based on a branching factor of 35 and an average game length of 80 ply.
- Xiang Qi: $10^{48}$, based on a branching factor of 38 and an average game length of 95 ply.
- Shogi: $10^{71}$, based on a branching factor of 80 and an average game length of 115 ply.
- Go: $10^{172}$, based on a branching factor of 250 and an average game length of 150 ply.

**Decision complexity** [81]: This is the complexity of the problem to find the optimal move in a given situation. It is easy to make an artificial example of a game with high game-tree complexity but low decision complexity. An example for Go can be found in [10]. It is difficult to quantitatively measure decision complexity. The fact that all four games are being played on a large scale and that only a small percentage of the player's population can be considered experts (i.e. professionals) is in our view sufficient evidence of a high decision complexity. For Shogi, more evidence of decision complexity can be found in [64].

## 5.3 Unexpectedness of Boardgames

This section concerns about the limit of game refinement theory and then proposes a notion of so-called unexpectedness in game playing. A mathematical model of unexpect-

edness is given.

### 5.3.1 Limitation of Game Refinement Theory

There is a paradox which we meet in game refinement theory and need to solve. According to the Table 2.1, if someone poses a question as to "Which game is more interesting or exciting between Soccer and Basketball?", we can safely conclude by basing our analysis criteria as game refinement value that both the games generate same level of interest and excitement. However, if we compare the game refinement value of Go and Soccer, we notice that the game refinement value of Go is greater, which implies that Go is more interesting than Soccer. But if we look into the statistics, everyone knows that soccer is a very popular and internationally recognised sport which has around 1.3 billion fans globally, and on the other hand in contrast to that there are very few people who follow and play Go, the population is mostly concentrated in Eastern Asia.

According to the common sense that goes into this phenomenon, the more interesting a game more the number of fans it should have. Game refinement value is just one property of a game, which in fact leads to the conclusion that using game refinement theory we can only judge the sophistication of a game, for example, game refinement value of almost all popular games lies between 0.07 to 0.08. Even if a game has a reasonable refinement value, it does not mean that the game will be accepted by players and will have a large fan following, so in order to solve the paradox we need to consider another property of games.

### 5.3.2 Definition of Unexpectedness

When people ask football fans "Why are there so many people enthusiastic about soccer?" The answer would be "Football is uncertain and exciting, we never know the result until the final second of the game". In this conversation, the high uncertainty of game process and unexpected result attracts a lot of players and fans towards soccer. For the artificial intelligence research area, human players have no chance of defeating the top AI such as deep blue, chess fans also have no interest in watching the competition between a human and deep blue because even before the game they know what the final result will be. So the definition of unexpectedness is "the chance and uncontrollable event in an unbalanced

game", the element of unexpectedness can drive a game towards uncertain and surprising endings which in result will attract more rookies and fans towards the game.

Game refinement theory has expressed the relationship between uncertainty of outcome and game progress, a game outcome can be considered two folds as shown in Figure 5-1. In the balance, the game outcome is decided by players' skill and "chance" which

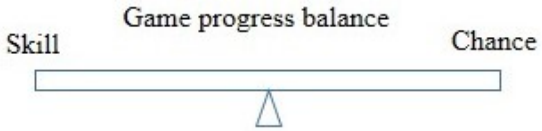


Figure 5-1: Game outcome balance

incorporates some stochastic events, which cannot be controlled or predicted. For chess, in the ideal situation, the top player or AI can always select the best moves at any time in the game, and all of players choices or branching factor are decided by players consideration, while we calculate game refinement value by the formula $R = \frac{\sqrt{B}}{D}$. Now we propose a derivative of chess and in this game the moves are decided by the roll of a dice, for example, when a player gets 2 on the die , he must move pawn. In this derivative of chess the branching factor cannot be controlled by the players consideration. The roll of a die is a stochastic event which may cause some chance for each player in this game.

Similar to the branching factor, we introduce a new concept known as "unexpectedness Branching Factor". If there is an element in the game which can neither be controlled or predicted by audience as well as the players, we call that element as the element of unexpectedness. Generally, there are three situations which will develop the game uncertainty as shown in Figure 5-2. Incomplete information — in this the players are not aware of their opponents situation, which means that their opponent can choose any of the extreme or special strategies against them; Stochastic event — people are enthusiastic about Poker or Mahjong because in these games on every iteration there is a new gambling party to compete with, every round is a new game and players freshness can be maintained for a long time, and the luck element provides chance for the weaker players to win too. The final situation is the players status. This factor becomes important in the games which involve physical strength or skills that can only be gained through experience, taking football as an example, a normal person without any physical training for football will not be able to compete for the whole 90 minutes, and it is most likely that some of

them will make a lot of errors during the whole game.

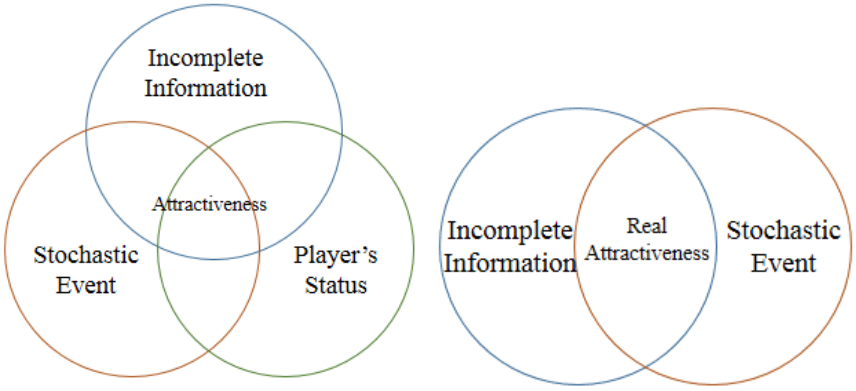


Figure 5-2: unexpectedness elements

However, looking at it from the audience perspective, they do not want to watch a game in which a strong player or a player with a lot of fans following commits a lot of mistakes; on the other hand, as far as the strategic games or brain games like chess and shogi are concerned, we assume that in an ideal situation, a genius player can always select the best move possible at any point in the game. Chess engines like Deep Blue can always traverse its minimax tree and choose the best move at anytime in the game, so humans have no chance of defeating artificial intelligence. In situations like these we remove the players status element and define unexpectedness in a much narrower sense and we call it the "Real unexpectedness". In this chapter our main idea and objective is to focus on the incomplete information and stochastic events.

### 5.3.3 Physical Model of Unexpectedness in Boardgame

We take in consideration the human thinking process in the traditional boardgames, players always follow such a process as shown in Figure 5-3 [62]. For example in chess,

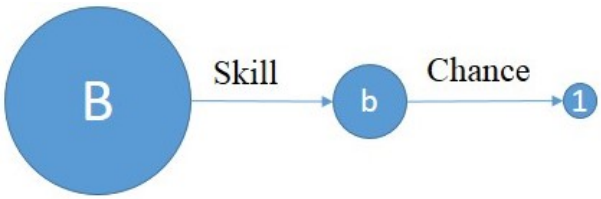


Figure 5-3: Thinking process in traditional boardgame

the average branching factor $B$ is 35, but out of these 35 choices, some moves are not

reasonable, after filtering out some of the existing options based on players' skill, we will be left with a smaller set of plausible options or available moves which we define as "b". Generally, a player is not always aware of the best choice available in $b$ where $b \geq 2$, so he takes a chance which then introduces the "chance element" into the game. By taking a chance and introducing a "chance element" into the game, a player decides his final move.

Almost all traditional boardgames fall in the category of strategic games, and a predominant way of approaching or playing these games is using the concept of **Convergence**. It is a very integral aspect of human thinking process, everyday humans are faced with situations where they have a lot of possible options which can be pursued, but somehow these options are narrowed down or converged to a smaller set based on the existing laws and morality because not all options are plausible. boardgames are the same, in order to win the game players need thought to filter their strategy, this thought process is a typical convergence process.

To make this analogy clear we consider an example of driving a car: when a car is in motion and we change its gear from 'N' to 'D', the car will continue to move in its previous speed if we refrain ourselves from using the accelerator and brake. We refer to this constant speed of the car as "Idle Speed". While driving stepping on the break is analogous to the thought process, we step on the break when we need to think about the different routes possible and which one to take or some similar situation. When we step on the break the speed will decrease, therefore we refer to the thought process as the resistance force in game process and we redefine the formula for force as follows.

$$\mathbf{F\text{-}f = ma} \tag{5.1}$$

In Equation (5.1), $F = m{*}R^2$, $a = {r_0}^2 = (\frac{1}{D})^2$. Consider chance element and skill element, while $B = b$ in Figure 5-3, we have $a_b = r^2 = (\frac{b}{D})^2$. Then we have Equation (5.2).

$$\begin{cases} f_s = F_s - m * r^2 = m * R^2 - m * r^2 \\ f_c = F_c - m * {r_0}^2 = m * r^2 - m * {r_0}^2 \end{cases} \tag{5.2}$$

Therefore, resistance force should be described as $f = F - m{*}a = f_c + f_s$. By the theorem

of impulse, we have the following formula.

$$J = \int_{t1}^{t2} f dt = f\Delta t = mv$$

For game refinement theory we have $v = \frac{f\Delta t}{m}$, while the $F$ is replaced by $F_s$ (the force by skill) and $F_c$ (the force by chance), the formula will be changed as follows.

$$f\Delta t = (f_s + f_c)\Delta t = mv$$

In anytime for one deterministic game, "mass" will not be changed, therefore in any timing $\Delta t$, we have

$$v = \frac{(f_s + f_c)\Delta t}{m} = \frac{f_s \Delta t}{m} + \frac{f_c \Delta t}{m} = v_s + v_c$$

Then according to Figure 5-4, for the $v_c$ part, the "unexpectedness theory" will be

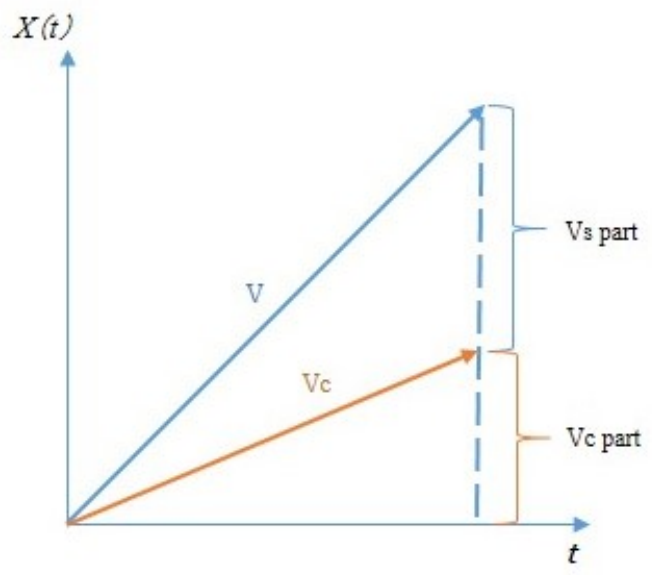


Figure 5-4: Speed of chance and skill

founded. In game refinement theory, the $v$ is $\frac{B}{D}$; while $v$ replaced by $v_c + v_s$, the refinement theory will be $\frac{B}{D} = \frac{B_c + B_s}{D} = \frac{B_c}{D} + \frac{B_s}{D}$. $B_c$ means the branching factor which was controlled by chance element in game and $B_s$ means the branching factor which was controlled by player's skill. Then we call the $B_c$ as a new parameter character $B' + 1$, which changes the "branching factor" into "the branching factor which players cannot control or predict", "1"

means the final determined movement. Then we can apply the likeness game refinement theory as shown in Equation (5.3). In Equation (5.3), $B'$ means "unexpected branching factor", $D$ means "Depth" of game.

$$U = \frac{\sqrt{B'}}{D} = \frac{\sqrt{B_c - 1}}{D} = \frac{\sqrt{b-1}}{D} \tag{5.3}$$

## 5.4 Application of Unexpectedness Theory

We consider three situations: the traditional boardgames; information cannot be observed in-game time (non-stochastic incomplete information game); only stochastic events occur always (stochastic complete information game), then we choose traditional boardgame, StarCraft II HoS version and Monopoly as the benchmark.

### 5.4.1 Application in Traditional Board Game

From H.Iida's view, the Sophisticated games would have possibility in boardgame should equal to $\log_3 B$, generally we have the Table 5.4. According to the Table 5.4, under

Table 5.4: Game refinement for boardgames

| Game | Chess | Shogi | Go |
|---|---|---|---|
| Branch Fact | 35 | 80 | 250 |
| Complexity | $3^3$ | $3^4$ | $3^5$ |
| Reasonable Branch | 3 | 4 | 5 |

the assumption that a good player can always choose the several best moves, given his expertise and control, using this assumption we have the following conclusion. As the case of Shogi, it means that a good player always have a high chance of not being able to find the best possible move in Shogi. Then the game unexpectedness value equals to $U = \frac{\sqrt{B_c-1}}{D} = \frac{\sqrt{4-1}}{115} = 0.015$, whereas the game refinement value is 0.078. Of course, for grandmaster players, while he face the several four moves, the possibility for four choices are different, here we only consider about the normal good players.

The unexpectedness scaling factor of any game is given by Equation (5.4)

$$P_{usf} = \frac{Game\ unexpectedness\ value}{Game\ refinement\ value} \tag{5.4}$$

So, the unexpectedness scaling factor of Shogi is 19.3%. Follow this logic, we can easily get the $U\ value$ and $P_{usf}$ of each traditional boardgame.

### 5.4.2 Application in StarCtaft II with Strategy Tree Approach

We suppose a strategy tree as shown in Figure 5-5 [143].

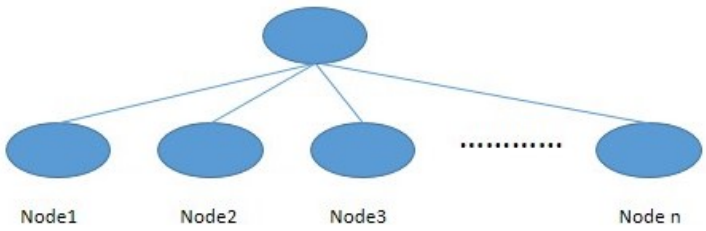


Figure 5-5: Strategy tree model in StarCraft II

While player A does not use spy to observe his opponent Player B, the probable strategy node for player B could be any node from node 1 to node N, in other words, the probability of Player A to be able to successfully predict Player B's strategy in order to make a corresponding counter measure is $\frac{1}{n}$, and player A has a probability of $\frac{(n-1)}{n}$ of not being able to control or predict the strategy of player B. So the Real Leaf $L$ should be

$$L = \frac{n-1}{n} \times n = n - 1 \tag{5.5}$$

However, in the actual game, no matter the StarCraft II HOS version or other video game even the real warfare, all the players should use spy, otherwise they will lose the game. Under this assumption we have the following situation. While branching factor at some point in time can be 1, in that situation the spy will be easily able to observe the strategy successfully and hence $L = 0$. While branching factor at some point in time can be 2, node 1 and node 2, the player will be able to control the strategy node if the opponent chooses strategy node 1 and spy also gets node 1, even if the spy chooses node 2 in this situation the player will be able to notice that the opponent has chosen node 2, the node which was left, so in this situation too the $L$ still equals 0.

While the branching factor is larger than 2, the spy has a probability of $\frac{1}{n}$ for getting the correct information, if the player A could not observe successfully, he will predict the opponent's choice, player A will have a probability of $\frac{1}{(n-1)}$ for predicting the current

strategy which player B is executing. So we have:

$$Prediction\_success\_rate = \frac{1}{n} + \frac{n-1}{n} \times \frac{1}{n-1} = \frac{2}{n} \tag{5.6}$$

In other words, the unexpected probability is $\frac{n-2}{n}(n > 2)$. Above all, the L for each node is given by:

$$L = \begin{cases} 0 & n < 2 \\ n-2 & n \geq 2 \end{cases}$$

For example, in the the strategy tree as shown in Figure 3-9.

From start to first timing, branching factor is 4, so the L is 2. According to the method and model the average attract Branching Factor is $B' = \frac{17}{74} = 0.230$, so the unexpectedness value will be given by

$$A = \frac{\sqrt{B'}}{D} = 0.0266. \tag{5.7}$$

Sometimes player cannot use spy, in this situation we get the unexpected value is 0.0423, it means the unexpectedness scaling factor of StarCraft II HoS version (Protoss) between $38.27\% \sim 60.86\%$.

### 5.4.3 Application in Monopoly Game

Monopoly is an American-originated board game Players move around the game board buying or trading properties, developing their properties with houses and hotels, and collecting rent from their opponents, with the goal being to drive them into bankruptcy.

Players take turns in order, with the initial player determined by chance before the game. A typical turn begins with the rolling of the dice and advancing their piece clockwise around the board the corresponding number of squares. If a player rolls doubles, they roll again after completing their turn. If a player rolls three consecutive sets of doubles on one turn, the player has been "caught speeding", and the player is immediately sent to jail instead of moving the amount shown on the dice for the third roll, ending the player's turn. The Figure 5-6 is the original map of Monopoly.

In this research, we only focus on the unexpectedness of move which decided by dice, Chance Card just a small effect element so do not consider it. According to the mathematical proof, while players use two dices, they have 17% probability get the double

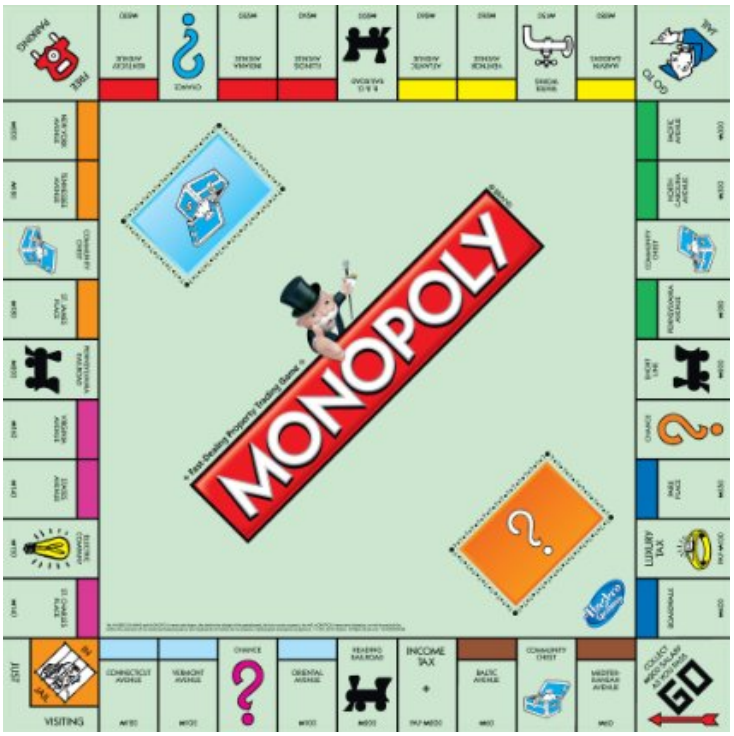


Figure 5-6: Monopoly Map

number[83], the branch fact decided by dice is $UB = 11*+11*0.17+11*0.17^2 = 13.1879$ First, we need calculate the game refinement value of Monopoly, under the rule of "3 players, 1500 original capital, 4 house can change into 1 hotel". The average game depth is 40 rounds. While player have been decided their movement by dice, average have 25 times they can choose buy the lands or not, also the deal in game are control by players, average times of deal in one game is 35. Finally, players can decide to build their house or hotel while they have enough money, the average choices for one Monopoly area is 5 and average Monopoly area in one game is 7. So the game refinement value should be

$$R = \frac{\sqrt{B}}{nD} = \frac{\sqrt{\frac{13.1879*(120-25)+13.1879*2*25}{120} + 30 + 7*5}}{3*40} = 0.075 \tag{5.8}$$

As the same method, the game unexpectedness value should be

$$U = \frac{\sqrt{UB}}{nD} = \frac{\sqrt{13.1879}}{3*40} = 0.0326 \tag{5.9}$$

Then the unexpectedness scaling factor is

$$F = \frac{Game\ unexpectedness\ value}{Game\ refinement\ value} = \frac{0.0326}{0.075} = 40.4\% \tag{5.10}$$

Iida et al. [66] [65] has established the game refinement theory which can be used to conclude on the sophistication of a game. As a property of game, game refinement value represents the quality of game, however some paradox and limitation had existed. Under this condition, the unexpectedness theory has been proposed. Also as one property of game, unexpectedness value can judge how unexpected a game is for the players and fans, the higher unexpectedness value, the more fans and players prefer to enjoy it. Table 5.5 has shown the each property value in Shogi and StarCraft II HOS version.

Table 5.5: Three properties of different game

| Game | $R$ value | $U$ value | $P_{usf}$ |
|---|---|---|---|
| Shogi | 0.078 | 0.0151 | 19.36% |
| Chess | 0.074 | 0.0177 | 23.92% |
| Xiangqi | 0.073 | 0.0166 | 22.74% |
| Go | 0.076 | 0.0096 | 12.63% |
| StarCtaft II HoS Protoss | 0.0691 | $0.0266 \sim 0.0423$ | $38.49\% \sim 61.22\%$ |
| StarCtaft II HoS Terran | 0.0805 | $0.0392 \sim 0.0507$ | $48.70\% \sim 62.98\%$ |
| StarCtaft II HoS Zerg | 0.0692 | $0.0317 \sim 0.0405$ | $45.80\% \sim 58.53\%$ |
| StarCtaft II HoS Zerg* | 0.0819 | $0.0549 \sim 0.0646$ | $67.03\% \sim 78.88\%$ |
| Monopoly | 0.075 | 0.0326 | 40.4% |

## 5.5 Xiong's Practical Conjecture

No matter in the competition game or real world warfare, people always takes delight in talking about "The weaker player defeat the stronger side". While the weak overcame the strong, it will make the game process seems much more interesting and exciting. In the long history we have several example, such as "The Battle of Okehazama" or "The Battle of Red Clift". So now we have a question is "How the weaker player can defeat stronger player successfully, are there any chance?"

As the example of Shogi in Figure 5-3, the parameter $B$ is 80 and for each player they should choose the final movement 1. We assume two players $X$ and $Y$, the $X$ is the weaker one, because his skill is not strong enough, so parameter $b_x$ should larger than $b_y$. Then we have relativity execution advantage rate in each step for the weaker player will be equal to

$$Advantage\ Rate_n = \frac{A_y}{A_x} = \sqrt{\frac{b_y - 1}{b_x - 1}}$$

, n means the step number. So for the weaker player $X$, at the end of game, the benefit rate which he get will be

$$Benifit = \prod_{n=1}^{N} Advantage\ Rate_n$$

In Shogi, the N equal to 115. While a fresh man against the super strong player, the benefit of him is $19.3\%^{115} = 6.9^{-83} \approx 0.00$. Combined with the view of Elo-rating system [40], the winning possibility for weaker player $P_x$ will be equal to

$$E_x = \frac{1}{1 + 10^{(Rate_y - Rate_x)/400}}$$

While $rate_y \gg rate_x$, $X$ has no chance to win.

However, while $N$ is small, weaker player could have some chance. Generally, in Non-random incomplete information game such as StarCraft II, some extreme strategies can finish the game less than three steps. Conclusively, three elements make the Practical Conjecture could be found:

- Incomplete information can hide the extreme strategies to get a quite small step parameter $N$
- Commonly, the unexpectedness scaling factor in incomplete information game is much higher than complete information game
- Non-random power can help the weaker player to draw up a plan easily.

Base on the theorem of unexpectedness, we can prove a practical conjecture as below ***"In Non-random incomplete information game, if the much weaker player wants to win, he must choose the extreme strategy or surprise attack strategy and finish the game in opening stage. Otherwise, he must lose the game."***. Also we will analyze the related work in Chapter 6.

## 5.6 Chapter Summary

This chapter presented the unexpectedness theory model. According to the Newton's classical mechanics we have found the meaning of Mass and Force in game. Then based

on the theorem of impulse, we educed the property concept and value of "unexpectedness" to patch the game refinement value. For the concept "unexpectedness scaling factor", it can show whether a game is friendly to the freshman or weaker player. The higher unexpectedness scaling factor, the weaker player will have more chance to win in the game (or we can say that the different level player can play the game together happily), the lower value means that the game is unfriendly to weaker side (or we can say that the different level player cannot play the game together happily). Usually, a high unexpectedness scaling factor game will gather more fans population, then we understand the reason why Go or Shogi have really high game refinement value and high game quality but few people prefer to play it. However, this chapter only focus on the boardgame model, for sports game this mathematical method cannot be used well, therefore we need choose another way to analyze the popularity promotion in next chapter.

# Chapter 6

# Ranking Accuracy and Popularity Promotion

This chapter is an updated and abridged version of the following publication.

- Shuo Xiong, Liang Yang, Nor Azan Mat Zin, and Hiroyuki Iida. (2016). Ranking Accuracy and Popularity Promotion: case study using UEFA Euro 2016. 3rd International Conference on Systems and Informatics. Shanghai, China. Nov. 2016

## 6.1 Chapter Introduction

Elo rating system has been widely used to predict the outcome in various domains such as boardgames and sports games [40]. This is because Elo rating system is statistically accurate and stable. Note that the phrase "Elo rating" is often used to mean a player's chess rating as calculated by the World Chess Federation (FIDE). However, this usage is confusing and misleading, because Elo's general ideas have been adopted by many organizations such as Federation Iternationale de Football Association (FIFA). Interestingly each organization has a unique implementation, and none of them follows Elo's original suggestions precisely. This study concerns about the difference between Elo rating system and other ranking systems from the viewpoint of ranking accuracy and popularity promotion. In fact, little is known about its potential effect to popularity promotion. To the best of our knowledge, this study is the first serious observation in this direction.

Elo rating system was initially developed for assessing the strength of chess players

[40], but has been widely adopted in various sports including association football [24], then the Elo style method has been used to predict the outcome of the Premier League [59]. On the other hands, a certain ranking system has been established in a community or association. For example, FIFA like other associations established their own ranking system.

Moreover, Dan ranking system is used by many Japanese organizations and Korean martial arts to indicate the level of one's ability within a certain subject matter. As a ranking system, it was originally used at a Go school during the Edo period [57]. It is now also used in modern fine arts and martial arts. The system was applied to martial arts in Japan by Kano Jigoro, the founder of Judo, in 1883, and later introduced to other East Asian countries. In the modern Japanese martial arts, holder of Dan ranks often wear a black belt. Dan ranks are also given for boardgames such as Go, Japanese chess (Shogi), and Renju, as well as for cultural arts such as flower arrangement (Ikebana), Japanese calligraphy (Shodo) and team ceremony (Sado).

These examples may suggest the importance of a good balance between ranking accuracy and popularity promotion in the domain considered. In this chapter we study four different ranking methods: Elo-rating system, Betting Odds, FIFA rating base on Elo style and FIFA rating base on Davidson Wang's method. Using these ranking methods, 36 Round-Robin matches of UEFA Euro 2016 are analyzed. It then explores entertainment aspects based on uncertainty of outcome prediction that may be occurred by ranking methods. What is Soccer? Soccer is a sport played between two teams of eleven players with a spherical ball [22]. It is played by 250 million players in over 200 nations, making it the world's most popular sport. The game is played on a rectangular field with a goal at each end. The objective of the game is to score by getting the ball into the opponent's goal. A regular soccer game consists of two 45-minute halves. It ends after the regular time of 90 minutes for almost all A-International friendly matches, unofficial championship matches, and qualifier matches of official tournaments. In the final round of the FIFA World Cup or continental championship tournaments, a group stage game ends after 90 minutes regardless of whether there is a goal difference or not. In the knockout stage, a game ends after regular playing time if there is a goal difference. Otherwise a 30-minute extra time will be added. If after the extra time there is still no goal difference,

a penalty shootout will be played.

In this chapter, soccer or association football was chosen as a benchmark , in particular with a focus on "UEFA Euro 2016". The UEFA European Championship is the primary association football competition contested by the senior men's national teams of the members of the Union of European Football Associations (UEFA) [134], determining the continental champion of Europe. Held every four years since 1960, in the even-numbered year between World Cup tournaments, it was originally called the UEFA European Nations Cup, changing to the current name in 1968 [76]. Prior to entering the tournament, all teams other than the host nations compete in a qualifying process. The championship winners earn the opportunity to compete in the following FIFA Confederations Cup, but are not obliged to do so [134]. The 14 European Championship tournaments have been won by nine different national teams: Germany and Spain each have won three titles, France has two titles, and Soviet Union, Italy, Czechoslovakia, Netherlands, Denmark and Greece have won one title each. To date, Spain is the only side in history to have won consecutive titles, doing so in 2008 and 2012 [76]. UEFA Euro is the 2nd most watched football tournament in the world after the FIFA World Cup. The Euro 2012 final was watched by a global audience of around 300 millions [75] [134]. The UEFA Euro 2016 tournament is hosted by France, where 24 teams play in this tournament. For these 24 teams, we analyze the winning percentage for each match in round-robin using different ranking methods: Elo rating system, Betting Odds, FIFA rating based Elo style and FIFA rating based Davidson Wang's method. We then discuss the ranking accuracy and its potential influence to popularity promotion.

In this chapter we investigate the use of Elo and FIFA ratings to create co-variates for match result prediction models. The Elo-rating system was initially developed for assessing the strength of chess players [40], but has been widely adopted in various sports, including association football [24], then the Elo style method has been used to predict the outcome of the Premier League [59].

The structure of this chapter is as follows. Section 6.2 presents four different outcome prediction methods. Section 6.3 explains the detail of each method and compares. Section 6.4 discusses the results of our analysis. Section 6.5 gives concluding remarks.

## 6.2 Outcome Prediction Models

In this section, four types of mathematical models for the outcome prediction are presented, and the winning probability outcomes are compared.

### 6.2.1 Official FIFA Ranking System

FIFA World Ranking is a ranking system for men's national teams in association football. The teams of the member nations of FIFA are ranked based on their game results with the most successful teams being ranked highest [23]. This rankings was introduced in December 1992 and most recently revamped after 2006 World Cup, with the first edition of the new series of rankings issued on 12 July 2006. In FIFA ranking system, each team has its own rating point, which is used to determine the ranking position in the full team list.

The rating point refers to the last 48 months scores with weightage of 0.2, 0.3, 0.5 and 1 for every 12 months. For a chosen team the formula for the calculation of points $P$ awarded after a single game is given by Equation (6.1).

$$P = M * I * T * C * 100 \tag{6.1}$$

Where each parameter has the following meaning.

- $M$: the outcome (win=3, draw=1 and lose=0)
- $I$: the match importance (see Table 6.1)
- $T$: the strength of opposition (see Equation (6.2))
- $C$: the confederation strengths (see Table 6.2)

Table 6.1: Meaning of $I$: Match importance multipliers

| Competition | $I$ |
|---|---|
| World Cup final competition | 4.0 |
| Continental final competition and FIFA Confederations Cup | 3.0 |
| World Cup qualifier and continental-level qualifier | 2.5 |
| Friendly match (including small tournaments) | 1.0 |

Strength of opposition $T$ is calculated according to the following formula.

$$T = \frac{200 - r}{100} \tag{6.2}$$

Where $r$ stands for the ranking position of the opposing team. Only the team at the top of the ranking is assigned the value near 2.00 (when $r = 1$), teams ranked 150th and below are assigned the minimum weightage of $T = 0.5$.

The confederation strength $C$ is a dynamic parameter calculated on the basis of the number of victories by confederation at the last FIFA World Cup competitions. The new values are shown in Table 6.2. Once we calculate the points that a team earned in one

Table 6.2: Meaning of $C$: Confederation values

| Confederation | $C$ |
|---|---|
| Confederacin Sudamericana de Ftbol | 1.00 |
| Union of European Football Associations | 0.99 |
| Asian Football Confederation | 0.85 |
| Confederation of African Football | 0.85 |
| Oceania Football Confederation | 0.85 |
| CONCACAF | 0.85 |

match, we can obtain the whole points over a period of 4 years (48 months). In the consecutive years the mean of the accumulated points is computed, then the 4 yearly averages are summed up with weights 0.2, 0.3, 0.5 and 1. Finally, FIFA can compute each teams' scores and publish the new FIFA rating. In fact, until now there is no good mathematical model to predict the game outcome by FIFA ranking system. Therefore, in Section 6.3, we introduce two measurements to calculate the winning probability based on FIFA rating [117].

### 6.2.2 Elo Rating System in Soccer

Elo rating system is a method for calculating the relative skill levels of players. It was created by Arpad E. Elo in 1960 originally for chess rating system and was approved at USCF (United States Chess Federation) in that year. Later, In 1970 it was agreed by FIDE [40]. The World Football Elo Ratings [40] is based on the Elo rating system but modified to take various football-specific variables into account. The rating points are

calculated by the following formula.

$$R_n = R_o + KG(W - W_e) \tag{6.3}$$

Where $R_n$ and $R_o$ is the new and old team rating point, respectively. $K$ is a dynamic weightage index regarding the tournament of the match. Similar to the FIFA rating system, the different tournament level has different $K$ value, as shown in Table 6.3.

Table 6.3: Meaning of $K$: Tournament or match type

| Tournament or Match type | $K$ |
|---|---|
| World Cup | 60 |
| Continental Championship and Intercontinental Tournaments | 50 |
| World Cup and Continental qualifiers and major tournaments | 40 |
| All other tournaments | 30 |
| Friendly Matches | 20 |

$G$ denotes the number of goals. If the game is a draw or is won by one goal then $G = 1$. If the game is won by two goals then $G = 1.5$. If the game is won by three or more goals the formula $G = \frac{11+N}{8}$ is applied.
$W$ and $W_e$ represents the match outcome ($W = 1$ for win, $W = 0.5$ for draw, and $W = 0$ for lose) and the winning expectation, respectively. While two teams have a competition, the winning expectation of team $a$ (say $W_{ea}$) is given by Equation (6.4).

$$W_{ea} = \frac{1}{1 + 10^{\frac{-dr}{400}}} \tag{6.4}$$

Where $dr$ stands for the difference in ratings (add 80 points for the home team).

We show, in Figure 6-1, the distribution of expected results. The upper (lower) line shows the expected result when the opponent is in lower (higher) ranking by Elo rating measurement. When two teams are in the same ranking, the expect result is 0.5 (draw). When two teams have a little gap in ranking, the excepted result will increase or decrease rapidly. But when two teams have a big gap in ranking, the excepted result will increase or decrease slowly. This means that the changing values of expected result get smaller per gap which is opposite to realities.

The original Elo rating measurement was used to analyze the winning percentage of boardgame that have rare draw games, however for soccer there are a lot of draw out-

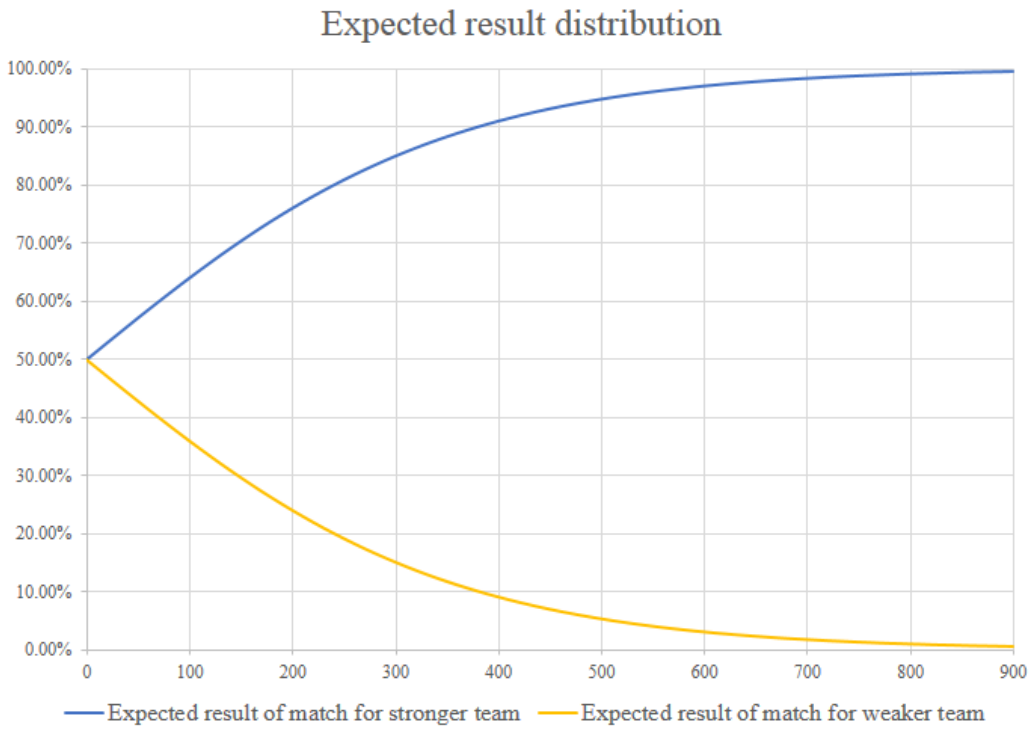


Figure 6-1: Distribution of expected results $W_e$ by Elo rating measurement

comes. Therefore, we need to evaluate and infer the function in [59], the draw probability $P(draw\ elo)$ which fits the normal distribution as shown in Equation (6.5).

$$P(draw\ elo) = f(x) = \frac{1}{\sqrt{2\pi}e} exp(-\frac{(\frac{dr}{200})^2}{2e^2}) \tag{6.5}$$

Where $e$ is Euler's number. Then, the probability of win and lose is given by Equations (6.6) and (6.7), respectively.

$$P(win\ elo) = \frac{1}{1+10^{\frac{-dr}{400}}} - \frac{1}{2}P(draw\ elo) \tag{6.6}$$

$$P(lose\ elo) = \frac{1}{1+10^{\frac{dr}{400}}} - \frac{1}{2}P(draw\ elo) \tag{6.7}$$

Then, the game outcomes are depicted in Figure 6-2.

### 6.2.3 Betting Odds System

Another useful prediction method is Betting Odds [111]. Odds are a numerical expression, usually expressed as a pair of numbers, used in both gambling and statistics [104]. In

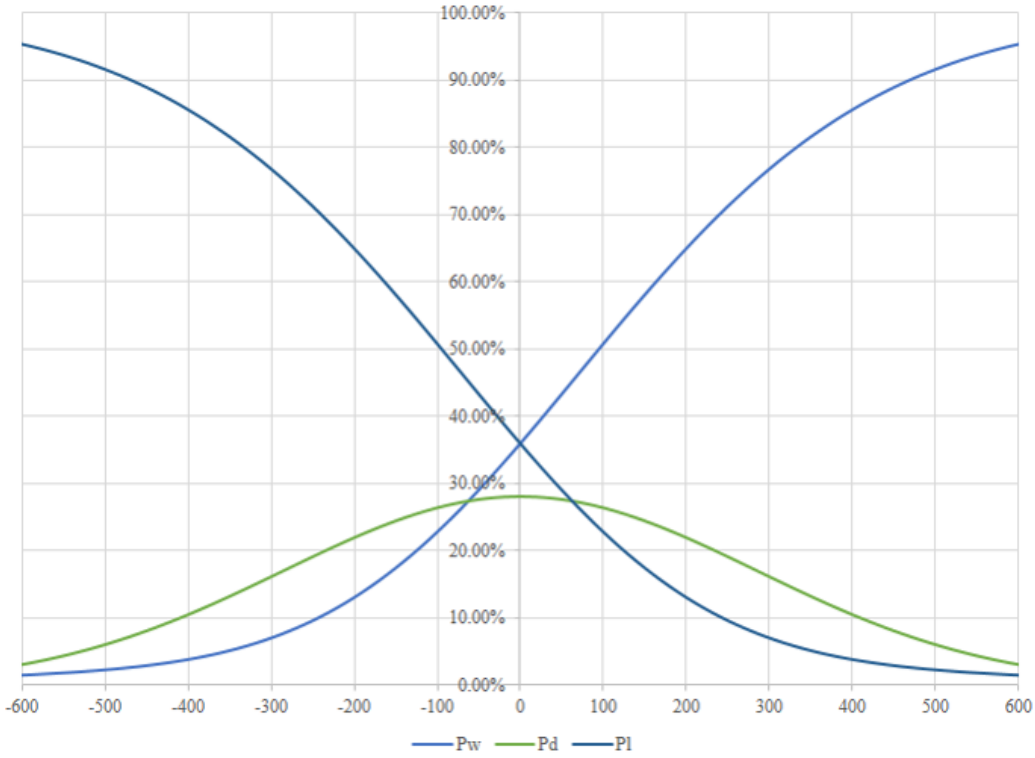


Figure 6-2: Probability distributions of win, draw and lose by Elo rating measurement

statistics, the odds for or odds of some event reflect the likelihood that the event will take place. Odds against reflect the likelihood that a particular event will not take place. In gambling, the odds are the ratio of payoff to stake, and do not necessarily reflect the exact probabilities. Odds are expressed in several ways, and sometimes the term is used incorrectly to mean simply the probability of an event. Conventionally, gambling odds are expressed in the form "X to Y", where X and Y are numbers, and it is implied that the odds are odds against the event on which the gambler is considering wagering.

In both gambling and statistics, the 'odds' are a numerical expression of the likelihood of some possible event. In gambling, odds represent the ratio between the amounts staked by parties to a wager or bet. Thus, odds of 6 to 1 mean that the first party stakes six times the amount staked by the second party. We can get an easy example to explain how betting odds comes: while $Team\ A$ vs. $Team\ B$, 1,000 audience predict the result and 900 audience choose $Team\ A$ win; 90 audience choose draw game and 10 audience choose $Team\ B$ win. Then we have odds for $Team\ A$ as $O(w) = \frac{1000}{900} = 1.11$, $O(d) = \frac{1000}{90} = 11.1$ and $O(l) = \frac{1000}{10} = 100$. In order to earn money, betting company will decrease the odds by revising as (1.06, 10.3, 90).

In this study, we focus on the individual match of UEFA Euro 2016 round-robin tournament and employ betting odds data to generate a measure of uncertainty of outcome by Ladbrokes company [6]. Based on the odds $(O(w), O(d), O(l))$ we can obtain the probability [104] by Equations (6.8) - (6.10).

$$P(win\ bet) = \frac{1}{\frac{1}{O(w)} + \frac{1}{O(d)} + \frac{1}{O(l)}} * \frac{1}{O(w)} \tag{6.8}$$

$$P(draw\ bet) = \frac{1}{\frac{1}{O(w)} + \frac{1}{O(d)} + \frac{1}{O(l)}} * \frac{1}{O(d)} \tag{6.9}$$

$$P(lose\ bet) = \frac{1}{\frac{1}{O(w)} + \frac{1}{O(d)} + \frac{1}{O(l)}} * \frac{1}{O(l)} \tag{6.10}$$

## 6.3 Explanation and Comparison

In this section, Wang's [132] and Davidson's [33] model-based ideas are introduced. As mentioned previously, we need to model the probability of ties in a soccer match which is not available in the standard Bradley-Terry model. There are various ways for constructing an extended Bradley-Terry model in the literature. Then in Wang's work [132] models the tie probability similarly to Davidson [33]. The basic idea is derived from regularly occurring patterns in the football world. The closer in strength the two playing teams are, the more likely is a draw [124].

In contrast, if there is a relatively huge strength difference between the two playing teams, it is very likely that the stronger team will win the game. With this in mind, $P(win\ Davidson)$ which means the probability that team 1 wins; $P(draw\ Davidson)$, the probability that game ends with a tie and $P(lose\ Davidson)$, the probability that team 2 wins game can be calculated by the following Equations (6.11) - (6.13).

$$P(win\ Davidson) = \frac{\beta_1}{\beta_1 + \beta_2 + K\sqrt{\beta_1\beta_2}} \tag{6.11}$$

$$P(draw\ Davidson) = \frac{K\sqrt{\beta_1\beta_2}}{\beta_1 + \beta_2 + K\sqrt{\beta_1\beta_2}} \tag{6.12}$$

$$P(lose\ Davidson) = \frac{\beta_2}{\beta_1 + \beta_2 + K\sqrt{\beta_1\beta_2}} \tag{6.13}$$

Where $\beta_1$ and $\beta_2$ denote the strength parameters of the first and second team in game respectively. $K$ is the tie effect to be estimated as 0.905 [132].

We use the FIFA rating to present the strength for each team. Another measurement is "Elo Style"; use the same functions as Equations (6.5) - (6.7), just replace the Elo rating to FIFA rating. The FIFA rating data of UEFA Euro 2016 is shown in Table 6.4 *(Data from date: 2nd May, 2016)* [2]. Similarly, we have the Elo rating data of UEFA

Table 6.4: FIFA rating of UEFA Euro 2016

| Group A & B | Rating | Group C & D | Rating | Group E & F | Rating |
|---|---|---|---|---|---|
| France | 1007 | Poland | 821 | Ireland | 792 |
| Albania | 632 | Germany | 1309 | Belgium | 1352 |
| Romania | 922 | Ukraine | 880 | Italy | 959 |
| Switzerland | 974 | Northern Ireland | 825 | Sweden | 713 |
| Wales | 839 | Turkey | 983 | Austria | 1067 |
| England | 1069 | Spain | 1277 | Portugal | 1184 |
| Russia | 821 | Czech | 810 | Iceland | 724 |
| Slovakia | 784 | Croatia | 856 | Hungary | 925 |

Euro 2016 as shown in Table 6.5, since France is the host, we add 80 points to France *(Data from date: 2nd, May, 2016)* [5].

Table 6.5: Elo rating of UEFA Euro 2016

| Group A & B | Rating | Group C & D | Rating | Group E & F | Rating |
|---|---|---|---|---|---|
| France | 1947+80 | Poland | 1762 | Ireland | 1751 |
| Albania | 1578 | Germany | 2037 | Belgium | 1896 |
| Romania | 1738 | Ukraine | 1797 | Italy | 1844 |
| Switzerland | 1753 | Northern Ireland | 1578 | Sweden | 1735 |
| Wales | 1638 | Turkey | 1797 | Austria | 1766 |
| England | 1934 | Spain | 1977 | Portugal | 1885 |
| Russia | 1747 | Czech | 1728 | Iceland | 1647 |
| Slovakia | 1715 | Croatia | 1794 | Hungary | 1671 |

Then we calculate the round-robin match of UEFA Euro 2016, for each match a number was given. We show, in Table 6.6, the 36 rounds of game prediction for win, draw and lose. Using Equations (6.8) - (6.10), we obtain Table 6.7 and Table 6.8 which shows the 36 rounds of game prediction for win, draw and lose. The data comes from company Ladbrokes on 2nd-May-2016 [6].

Finally, based on FIFA rating, we use David-Wang and "Elo Style" methods according to Equations (6.5) - (6.7) and Equations (6.11) - (6.13) to obtain Table 6.9 and Table 6.10.

Table 6.6: Elo rating and wining probability of UEFA Euro 2016

| No. | Home Team | Away Team | dr | P(w-elo) | P(d-elo) | P(l-elo) |
|---|---|---|---|---|---|---|
| 1 | France | Romania | 289 | 75.70% | 16.74% | 7.56% |
| 2 | Albania | Switzerland | -166 | 15.96% | 23.63% | 60.41% |
| 3 | Romania | Switzerland | -15 | 33.86% | 27.96% | 38.18% |
| 4 | France | Alabania | 440 | 88.39% | 8.50% | 3.11% |
| 5 | Switzerland | France | -274 | 8.30% | 17.64% | 74.06% |
| 6 | Romania | Albania | 151 | 58.29% | 24.33% | 17.38% |
| 7 | Wales | Slovakia | -77 | 25.60% | 27.00% | 47.41% |
| 8 | England | Russia | 187 | 63.29% | 22.58% | 14.13% |
| 9 | Russia | Slovakia | 32 | 40.68% | 27.82% | 31.50% |
| 10 | England | Wales | 296 | 76.44% | 16.33% | 7.23% |
| 11 | Slovakia | England | -219 | 11.67% | 20.84% | 67.49% |
| 12 | Russia | Wales | 109 | 52.18% | 26.02% | 21.80% |
| 13 | Poland | Northern Ireland | 184 | 62.89% | 22.73% | 14.38% |
| 14 | Germany | Ukraine | 240 | 70.10% | 19.64% | 10.26% |
| 15 | Ukraine | Northern Ireland | 219 | 67.49% | 20.84% | 11.67% |
| 16 | Germany | Poland | 275 | 74.18% | 17.58% | 8.25% |
| 17 | Northern Ireland | Germany | -459 | 2.82% | 7.65% | 89.53% |
| 18 | Ukraine | Poland | 35 | 41.13% | 27.79% | 31.09% |
| 19 | Turkey | Croatia | 3 | 36.43% | 28.00% | 35.57% |
| 20 | Spain | Czech | 249 | 71.19% | 19.11% | 9.70% |
| 21 | Czech | Croatia | -66 | 26.99% | 27.26% | 45.76% |
| 22 | Spain | Turkey | 180 | 62.34% | 22.94% | 14.72% |
| 23 | Croatia | Spain | -183 | 14.47% | 22.78% | 62.75% |
| 24 | Czech | Turkey | -69 | 26.60% | 27.19% | 46.21% |
| 25 | Ireland | Sweden | 16 | 38.32% | 27.96% | 33.72% |
| 26 | Belgium | Italy | 52 | 43.66% | 27.54% | 28.80% |
| 27 | Italy | Sweden | 109 | 52.18% | 26.02% | 21.80% |
| 28 | Belgium | Ireland | 145 | 57.43% | 24.60% | 17.97% |
| 29 | Sweden | Belgium | -161 | 16.42% | 23.87% | 59.71% |
| 30 | Italy | Ireland | 93 | 49.80% | 26.55% | 23.65% |
| 31 | Austria | Hungary | 95 | 50.10% | 26.49% | 23.42% |
| 32 | Portugal | Iceland | 211 | 66.47% | 21.29% | 12.25% |
| 33 | Iceland | Hungary | 3 | 36.43% | 28.00% | 35.57% |
| 34 | Portugal | Austria | 119 | 53.65% | 25.66% | 20.68% |
| 35 | Iceland | Austria | -92 | 23.77% | 26.58% | 49.65% |
| 36 | Hungary | Portugal | -214 | 12.03% | 21.12% | 66.85% |

In order to analyze the data, we put the outcomes of winning probability by four prediction methods together to draw the poly-line in Figure 6-3. Similarly, we show, in Figure 6-4 and Figure 6-5, draw and losing probability by using the four prediction methods, respectively.

Table 6.7: Betting odds of UEFA Euro 2016

| No. | Home Team | Away Team | Odd(w) | Odd(d) | Odd(l) |
|---|---|---|---|---|---|
| 1 | France | Romania | 1.36 | 4.2 | 10 |
| 2 | Albania | Switzerland | 6 | 3.6 | 1.62 |
| 3 | Romania | Switzerland | 3.85 | 3.4 | 2 |
| 4 | France | Alabania | 1.27 | 5.8 | 10.5 |
| 5 | Switzerland | France | 3.85 | 3.4 | 2 |
| 6 | Romania | Albania | 1.9 | 3.5 | 4.1 |
| 7 | Wales | Slovakia | 2.5 | 3 | 3 |
| 8 | England | Russia | 2.15 | 3.1 | 3.6 |
| 9 | Russia | Slovakia | 1.8 | 3.6 | 4.5 |
| 10 | England | Wales | 1.75 | 3.5 | 4.25 |
| 11 | Slovakia | England | 6.7 | 4.2 | 1.5 |
| 12 | Russia | Wales | 2.3 | 3.3 | 3.15 |
| 13 | Poland | Northern Ireland | 1.85 | 3.2 | 4.5 |
| 14 | Germany | Ukraine | 1.55 | 3.8 | 6.5 |
| 15 | Ukraine | Northern Ireland | 2 | 3.4 | 3.85 |
| 16 | Germany | Poland | 1.55 | 4 | 6.3 |
| 17 | Northern Ireland | Germany | 11.5 | 6 | 1.25 |
| 18 | Ukraine | Poland | 2.7 | 3.2 | 2.7 |
| 19 | Turkey | Croatia | 3.4 | 3.2 | 2.15 |
| 20 | Spain | Czech | 1.55 | 3.8 | 6 |
| 21 | Czech | Croatia | 2.85 | 3.3 | 2.5 |
| 22 | Spain | Turkey | 1.6 | 3.9 | 5.7 |
| 23 | Croatia | Spain | 3.55 | 3.35 | 2.1 |
| 24 | Czech | Turkey | 2.6 | 3.25 | 2.75 |
| 25 | Ireland | Sweden | 2.9 | 3 | 2.5 |
| 26 | Belgium | Italy | 2.4 | 3 | 3 |
| 27 | Italy | Sweden | 1.9 | 3.5 | 4.1 |
| 28 | Belgium | Ireland | 1.65 | 3.8 | |
| 29 | Sweden | Belgium | 4.8 | 3.6 | 1.75 |
| 30 | Italy | Ireland | 1.7 | 3.7 | 5.1 |
| 31 | Austria | Hungary | 1.83 | 3.3 | 4.5 |
| 32 | Portugal | Iceland | 1.62 | 3.5 | 6 |
| 33 | Iceland | Hungary | 2.5 | 3.3 | 2.85 |
| 34 | Portugal | Austria | 2.3 | 3.3 | 3.15 |
| 35 | Iceland | Austria | 3.85 | 3.4 | 2 |
| 36 | Hungary | Portugal | 5.7 | 3.9 | 1.6 |

## 6.4 Discussion

In this section we focus on ranking accuracy and its potential influence to popularity promotion to be discussed based on the data analysis described previously. Figures 6-3 - 6-5 clearly show that Elo rating system is better than FIFA ranking system from the

Table 6.8: Wining probability of UEFA Euro 2016 by Betting odds

| No. | Home Team | Away Team | P(w-bet) | P(d-bet) | P(l-bet) |
|---|---|---|---|---|---|
| 1 | France | Romania | 68.50% | 22.18% | 9.32% |
| 2 | Albania | Switzerland | 15.70% | 26.16% | 58.14% |
| 3 | Romania | Switzerland | 24.65% | 27.91% | 47.44% |
| 4 | France | Alabania | 74.63% | 16.34% | 9.03% |
| 5 | Switzerland | France | 24.65% | 27.91% | 47.44% |
| 6 | Romania | Albania | 49.84% | 27.06% | 23.10% |
| 7 | Wales | Slovakia | 37.50% | 31.25% | 31.25% |
| 8 | England | Russia | 43.65% | 30.28% | 26.07% |
| 9 | Russia | Slovakia | 52.63% | 26.32% | 21.05% |
| 10 | England | Wales | 52.31% | 26.15% | 21.54% |
| 11 | Slovakia | England | 14.16% | 22.59% | 63.25% |
| 12 | Russia | Wales | 41.20% | 28.72% | 30.08% |
| 13 | Poland | Northern Ireland | 50.27% | 29.06% | 20.67% |
| 14 | Germany | Ukraine | 60.74% | 24.78% | 14.48% |
| 15 | Ukraine | Northern Ireland | 47.44% | 27.91% | 24.65% |
| 16 | Germany | Poland | 61.22% | 23.72% | 15.06% |
| 17 | Northern Ireland | Germany | 8.25% | 15.82% | 75.93% |
| 18 | Ukraine | Poland | 35.16% | 29.67% | 35.16% |
| 19 | Turkey | Croatia | 27.44% | 29.16% | 43.40% |
| 20 | Spain | Czech | 60.02% | 24.48% | 15.50% |
| 21 | Czech | Croatia | 33.29% | 28.75% | 37.95% |
| 22 | Spain | Turkey | 59.14% | 24.26% | 16.60% |
| 23 | Croatia | Spain | 26.67% | 28.26% | 45.08% |
| 24 | Czech | Turkey | 36.42% | 29.14% | 34.44% |
| 25 | Ireland | Sweden | 31.98% | 30.92% | 37.10% |
| 26 | Belgium | Italy | 38.46% | 30.77% | 30.77% |
| 27 | Italy | Sweden | 49.84% | 27.06% | 23.10% |
| 28 | Belgium | Ireland | 57.48% | 24.96% | 17.56% |
| 29 | Sweden | Belgium | 19.70% | 26.27% | 54.03% |
| 30 | Italy | Ireland | 55.78% | 25.63% | 18.59% |
| 31 | Austria | Hungary | 50.99% | 28.28% | 20.74% |
| 32 | Portugal | Iceland | 57.71% | 26.71% | 15.58% |
| 33 | Iceland | Hungary | 37.95% | 28.75% | 33.29% |
| 34 | Portugal | Austria | 41.20% | 28.72% | 30.08% |
| 35 | Iceland | Austria | 24.65% | 27.91% | 47.44% |
| 36 | Hungary | Portugal | 16.60% | 24.26% | 59.14% |

viewpoint of ranking accuracy. Hence we focus on the other aspects to be considered.

Table 6.9: FIFA rating, wining probability by Davidson method and Elo rating style of UEFA Euro 2016

| No. | Home Team | Away Team | P(w-dav) | P(d-dav) | P(l-dav) |
|---|---|---|---|---|---|
| 1 | France | Romania | 35.95% | 34.40% | 32.92% |
| 2 | Albania | Switzerland | 27.29% | 33.88% | 42.05% |
| 3 | Romania | Switzerland | 33.48% | 34.41% | 35.37% |
| 4 | France | Alabania | 42.65% | 33.79% | 26.77% |
| 5 | Switzerland | France | 33.85% | 34.42% | 35.00% |
| 6 | Romania | Albania | 41.07% | 34.00% | 28.15% |
| 7 | Wales | Slovakia | 35.60% | 34.41% | 33.26% |
| 8 | England | Russia | 39.05% | 34.22% | 29.99% |
| 9 | Russia | Slovakia | 35.22% | 34.42% | 33.63% |
| 10 | England | Wales | 38.66% | 34.25% | 30.34% |
| 11 | Slovakia | England | 29.24% | 34.14% | 39.87% |
| 12 | Russia | Wales | 36.04% | 34.40% | 32.83% |
| 13 | Poland | Northern Ireland | 34.34% | 34.42% | 34.51% |
| 14 | Germany | Ukraine | 41.42% | 33.96% | 27.85% |
| 15 | Ukraine | Northern Ireland | 35.54% | 34.41% | 33.32% |
| 16 | Germany | Poland | 42.66% | 33.79% | 26.76% |
| 17 | Northern Ireland | Germany | 26.83% | 33.80% | 42.58% |
| 18 | Ukraine | Poland | 35.62% | 34.41% | 33.24% |
| 19 | Turkey | Croatia | 36.83% | 34.37% | 32.07% |
| 20 | Spain | Czech | 42.46% | 33.82% | 26.93% |
| 21 | Czech | Croatia | 33.48% | 34.41% | 35.38% |
| 22 | Spain | Turkey | 39.00% | 34.22% | 30.02% |
| 23 | Croatia | Spain | 27.80% | 33.95% | 41.47% |
| 24 | Czech | Turkey | 31.15% | 34.31% | 37.80% |
| 25 | Ireland | Sweden | 36.25% | 34.39% | 32.63% |
| 26 | Belgium | Italy | 40.46% | 34.08% | 28.70% |
| 27 | Italy | Sweden | 39.62% | 34.16% | 29.46% |
| 28 | Belgium | Ireland | 43.89% | 33.59% | 25.71% |
| 29 | Sweden | Belgium | 24.14% | 33.24% | 45.78% |
| 30 | Italy | Ireland | 37.76% | 34.32% | 31.18% |
| 31 | Austria | Hungary | 36.91% | 34.36% | 31.99% |
| 32 | Portugal | Iceland | 43.12% | 33.72% | 26.37% |
| 33 | Iceland | Hungary | 30.30% | 34.25% | 38.71% |
| 34 | Portugal | Austria | 36.23% | 34.39% | 32.65% |
| 35 | Iceland | Austria | 27.99% | 33.98% | 41.25% |
| 36 | Hungary | Portugal | 30.27% | 34.24% | 38.74% |

### 6.4.1 Benefits and Drawbacks of FIFA Ranking System

FIFA ranking does not only evaluate the relative strength of all 209 international teams, but is also useful when categorizing the teams within a continent into different points. This is especially helpful for the draws in the FIFA World Cup qualifiers or continental

Table 6.10: FIFA rating, wining probability by Davidson method and Elo rating style of UEFA Euro 2016

| No. | Home Team | Away Team | P(w-elos) | P(d-elos) | P(l-elos) |
|---|---|---|---|---|---|
| 1 | France | Romania | 48.60% | 26.78% | 24.62% |
| 2 | Albania | Switzerland | 5.44% | 13.63% | 80.93% |
| 3 | Romania | Switzerland | 28.80% | 27.54% | 43.66% |
| 4 | France | Alabania | 83.76% | 11.78% | 4.46% |
| 5 | Switzerland | France | 31.36% | 27.81% | 40.83% |
| 6 | Romania | Albania | 75.81% | 16.68% | 7.51% |
| 7 | Wales | Slovakia | 44.11% | 27.48% | 28.41% |
| 8 | England | Russia | 71.07% | 19.17% | 9.76% |
| 9 | Russia | Slovakia | 41.42% | 27.76% | 30.81% |
| 10 | England | Wales | 68.88% | 20.22% | 10.91% |
| 11 | Slovakia | England | 7.75% | 16.98% | 75.27% |
| 12 | Russia | Wales | 48.15% | 26.86% | 24.98% |
| 13 | Poland | Northern Ireland | 35.43% | 28.00% | 36.58% |
| 14 | Germany | Ukraine | 87.69% | 9.02% | 3.29% |
| 15 | Ukraine | Northern Ireland | 44.11% | 27.48% | 28.41% |
| 16 | Germany | Poland | 91.09% | 6.46% | 2.45% |
| 17 | Northern Ireland | Germany | 2.50% | 6.62% | 90.88% |
| 18 | Ukraine | Poland | 44.71% | 27.41% | 27.89% |
| 19 | Turkey | Croatia | 54.83% | 25.35% | 19.82% |
| 20 | Spain | Czech | 89.98% | 7.31% | 2.71% |
| 21 | Czech | Croatia | 29.60% | 27.64% | 42.76% |
| 22 | Spain | Turkey | 76.23% | 16.44% | 7.32% |
| 23 | Croatia | Spain | 3.44% | 9.40% | 87.16% |
| 24 | Czech | Turkey | 15.33% | 23.29% | 61.38% |
| 25 | Ireland | Sweden | 47.70% | 26.94% | 25.35% |
| 26 | Belgium | Italy | 85.16% | 10.82% | 4.02% |
| 27 | Italy | Sweden | 70.83% | 19.29% | 9.88% |
| 28 | Belgium | Ireland | 94.14% | 4.06% | 1.80% |
| 29 | Sweden | Belgium | 1.33% | 2.27% | 96.40% |
| 30 | Italy | Ireland | 60.55% | 23.58% | 15.87% |
| 31 | Austria | Hungary | 57.00% | 24.73% | 18.27% |
| 32 | Portugal | Iceland | 89.58% | 7.61% | 2.81% |
| 33 | Iceland | Hungary | 13.00% | 21.83% | 65.16% |
| 34 | Portugal | Austria | 53.36% | 25.74% | 20.90% |
| 35 | Iceland | Austria | 5.41% | 13.57% | 81.02% |
| 36 | Hungary | Portugal | 9.12% | 18.53% | 72.36% |

championships [132].

FIFA ranking system is a points-earning system. Theoretically, two teams both ranked 150th or below can always benefit from playing a large number of friendly games against each other and negotiate to win half of these games each [75]. They can apply this strategy

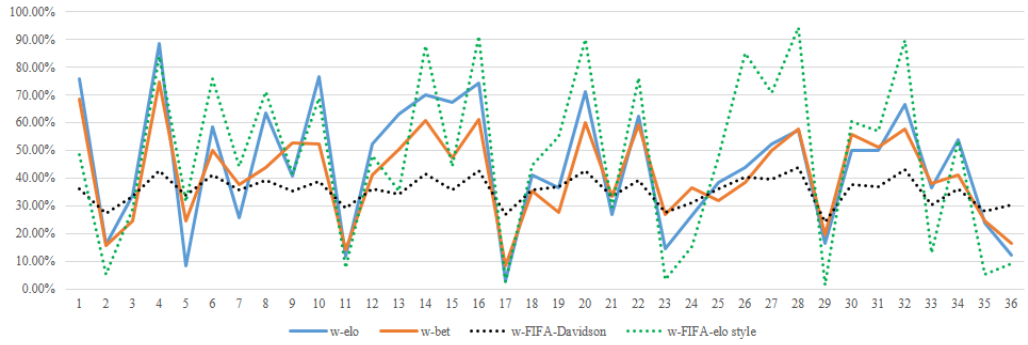


Figure 6-3: Winning probability by four prediction methods

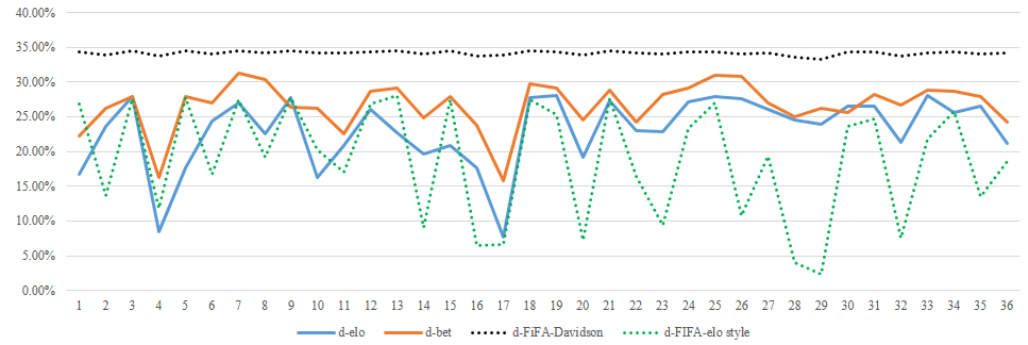


Figure 6-4: Draw probability by four prediction methods

without any cost.

Although the points-based FIFA ranking is easy to operate and modify, it is not obvious how the points should be used to predict the 3 possible outcomes in a game. As the average performance difference between home and away games for almost all football teams has been revealed by various researchers, a team can benefit more from playing a higher percentage of its games at home. A more realistic method should take the home effect into account such that the ranking can be determined by the pure strength parameters of the Elo rating system [132].

FIFA ranking currently assigns a fixed depreciation weight for all games played within a 12-month period. Although the basic idea is that the older the game is, the lower the weight should be assigned to it, its depreciation function is piecewise with 3 discontinuous points, which seems not very reasonable [75].

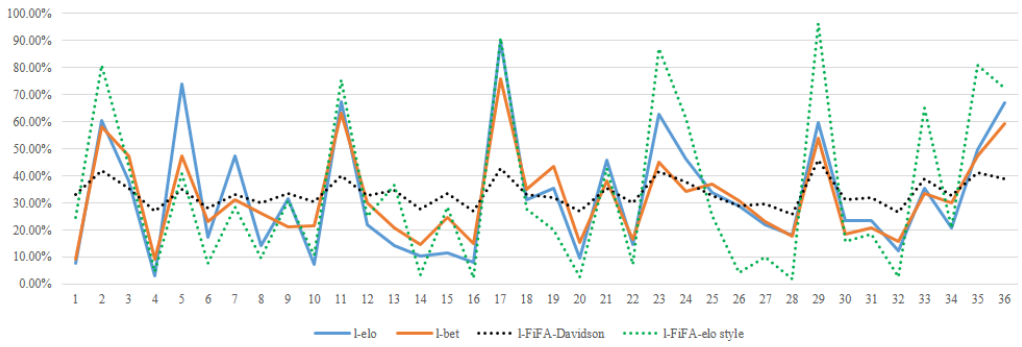


Figure 6-5: Losing probability by four prediction methods

### 6.4.2 Potential Influence to Popularity Promotion

When introducing a ranking system in a target domain, what is the most important aspect to be considered? Ranking accuracy should be important to maintain fairness, but may be not the most, or it depends on the domain or the current situation. In a sense, having an accurate ranking system may imply that only few people (winners) would be happy while many others are not so. It would affect the popularity promotion in the domain considered. FIFA ranking system also follows this way, increasing uncertainty of outcome prediction and entertaining more people are two significant ways to promote the popularity of football.

FIFA ranking is used to choose the seeds teams in World Cup qualification in each confederation according to their scores. So it is very important to increase the uncertainty in ranking to attract more people. A significant approach is to use the strength of opposite "$T$" instead of expected results "$W$" in Equation (6.1). For example, the minimum score condition when one team wins one match is: Friendly Match; The strength of opposite $T$ is 0.5; Confederation score is 0.85. So the minimum score one team wins the match can obtain $3 * 1 * 0.5 * 0.85 * 100 = 127.5$ points. But when using the Elo rating system, when two teams have big strength gap the minimum score of winning is close to 0. Therefore, the official FIFA rating can speed up the changing of rating and create more uncertainty to attract fans to pay more attention to football game.

Figure 6-6 shows that FIFA ranking of Belgium Men's National Football Team is No.71 in 2007, whereas after 7 years Belgium has raised to No.1 in 2015 (October 15th). However, the Elo ranking seems more smooth and provides less excitement for audiences.

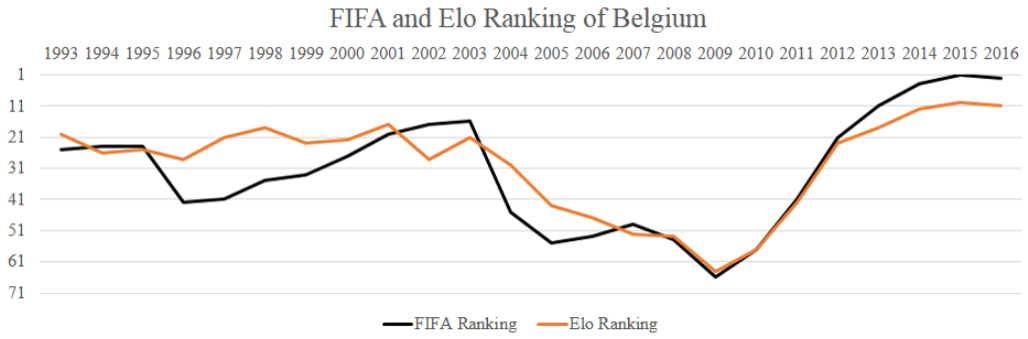


Figure 6-6: Belgium's FIFA ranking and Elo-rating-based ranking compared

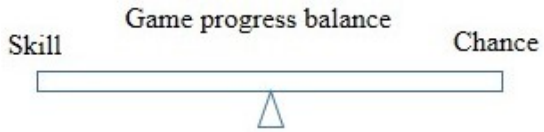


Figure 6-7: Illustration to show a balance between skill and chance in games

On the other hand, the FIFA rating has a higher possibility of draw for two teams with a wider gap. It can attract more people in disadvantaged national team's fans to make perceive that their team will not lose the game. Therefore, the population of football fans increase rapidly, especially in the disadvantaged nation area.

### 6.4.3 Balance between Skill and Chance

The balance between skill and chance is an important issue from the entertainment's point of view. An interesting game should not depend too much on skill or chance, but should have a harmonic balance which provides comfortable uncertainty of game outcome prediction (See Figure 6-7). This idea has been studied in the framework of game refinement theory [66]. A measurement to quantify game sophistication (i.e., balance between skill and chance) has been proposed based on the game outcome uncertainty in the sense that the game outcome should be uncertain until the very end of game.

Assuming that ranking system is a kind of game playing (from the organizer's point of view), a good balance between skill and chance should be examined. In the domain of ranking system, ranking accuracy may correspond to the skill part, whereas uncertainty of ranking may correspond to the chance part. Roughly speaking, Elo rating system is a very skill player, while FIFA ranking system is located in the level somewhere between skill and chance.

Table 6.11 shows the main different points between two ranking systems. From the

Table 6.11: Main different points of FIFA and Elo ranking

| | FIFA ranking | Elo ranking |
|---|---|---|
| 1 | Only used in FIFA soccer | Commonly used in variety of games |
| 2 | Have no effective math model to predict result | Predict game outcome accurately |
| 3 | Mutability | Stable |
| 4 | Big gap rating | Small gap rating |

table we know FIFA ranking system can provide more unexpected results for audience to attract more population attend the game. On the other hand, Elo rating system always can show the actual ranking what means that the system is too skillful and lack of chance, then FIFA refuse to use it.

In fact, not only FIFA, but also shogi and Go professional communities do not use Elo rating system. Instead they use "Dan System", in which, while a player gets 9 dan in 30 years old, he will keep the status forever. However, in Elo rating system, all players must change their rankings by their records and strength. Therefore, in order to protect player's self-respect and attract more people prefer to enjoy the game, Elo rating system was not employed. It means that if we want to make a game become more popular, Elo rating system is not a good choice, at least it better not show in surface. Elo rating system just focus on the real strength and no other things to be covered, therefore if we want to promote the target game, Elo rating system is not a good choice.

Interestingly, FIFA uses Elo rating system for Women's football. We notice that FIFA chooses the different popularity promotion strategies for Men and Women games. Therefore, FIFA also understands that Elo rating system is quite useful and accurate. For the phenomenon, compared with Men's football, Women's football is currently not so popular, FIFA can perform an experiment of Elo rating system application on commerce.

### 6.4.4 Game Refinement Theory and Ranking System

In this section, we will guide game refinement theory to analyze two ranking system by mathematical way [123]. Game information progress presents how certain is the result of the game in a certain time or steps. Let $F$ and $T$ be the average number of ranking float and the time period, respectively. If one knows the game information progress, for

example after the game, the game progress $x(t)$ will be given as a linear function of time $t$ with $0 \leq t \leq T$ and $0 \leq x(t) \leq F$, as shown in Equation (6.14).

$$x(t) = \frac{F}{T}\, t \tag{6.14}$$

However, the game information progress given by Equation (6.14) is usually unknown during the in-game period. Hence, the game information progress is reasonably assumed to be exponential. This is because the game outcome is uncertain until the very end of game in many games. Hence, a realistic model of game information progress is given by Equation (6.15).

$$x(t) = F(\frac{t}{T})^n \tag{6.15}$$

Here $n$ stands for a constant parameter which is given based on the perspective of an observer in the game considered. Then acceleration of game information progress is obtained by deriving Equation (6.15) twice. Solving it at $t = T$, the equation becomes

$$x''(T) = \frac{Fn(n-1)}{T^n} t^{n-2} = \frac{F}{T^2} n(n-1)$$

It is assumed in the current model that the game information progress in any type of games is happening in our minds. We do not know yet about the physics in our minds, but it is likely that the acceleration of information progress is related to the force in mind. Hence, it is reasonably expected that the larger the value $\frac{F}{T^2}$ is, the more the game becomes exciting due to the uncertainty of game outcome. Thus, we use its root square, $\frac{\sqrt{F}}{T}$, as a game refinement measure for the game considered.

According to the Figure 6-6, we can know the ranking position in each year of Belgium. First we calculate the average ranking range for two ranking systems. The data from 1993 year to 2016 year and define the ranking position in 1993 is $R_0$ and ranking position in 2016 is $R_{23}$, then the average ranking range should be

$$R_{avg} = \frac{\sum_{i=0}^{22} |R_{i+1} - R_i|}{23}$$

Then we calculate the parameter F, the average ranking float is

$$F = \frac{\sum_{i=0}^{22} ||R_{i+1} - R_i| - R_{avg}|}{23}$$

Final we get $F_{fifa}$=5.55 and $F_{elo}$=3.60 to calculate $R_{FIFA} = \frac{\sqrt{F}}{T} = 0.102$ and $R_{Elo} = \frac{\sqrt{F}}{T} = 0.082$. In game refinement theory, the higher R value means the higher entertainment with low competition. Therefore, FIFA ranking system can attract more people to join it.

## 6.5 Chapter Summary

In this chapter, comparing between the four mathematical models (Elo rating system, betting odds system, FIFA rating base on Davidson Wang's method, and FIFA rating base on Elo rating style) we have found the advantages of each measurement. FIFA ranking system can provide more chance and interesting points for the supporter or fans. The most accurate measurement is Elo rating system, however many associations and organizations refuse to use it although it is accurate. Thus FIFA ranking is very useful to attract more people to join the game and keep the enthusiasm of fans. In addition, we now know how to attract more people who prefer to play the target game. Also in this paper, we have inferred and cracked the draw probability function in Elo rating system [147]. Until now, we use game refinement theory to analyze and solve a lot of research question. However, still some leftover problem in game refinement theory was ignored. In the following chapter, we will revisit the game refinement theory and evolve the detailed questions more.

# Chapter 7

# Possible Interpretations for Game Refinement Measure

This chapter is an updated and abridged version of the following publication.

- Shuo Xiong, Long Zuo, and Hiroyuki Iida. (2017). Possible Interpretations for Game Refinement Measure. In International Conference on Entertainment Computing . Springer International Publishing. Tsukuba, Japan. Sep. 2017

Game refinement theory is a mathematical measurement to judge whether a game is interesting or exciting, it has been widely used in many different types of game successfully. However, while we revisit the game refinement theory, we notice the boardgame model and sports game model have different information progress. Also some detailed omission existed in current mathematical model, the explanation and definition of refinement zone value are not clear. In this chapter, we will revisit the game information progress and develop the game refinement theory and analyze the omission issue and explain the meaning of game refinement value again. We try to find the difference between boardgame model and sports game model, then redefine the meaning of game refinement value.

## 7.1 Chapter Introduction

In previous Chapter, we noticed that the game refinement values defined excitement using the breadth and depth of a game; or game information progress by taking into consid-

eration the average good shots and number of shots in the game. These measurements have been applied in the domains such as boardgames and sports games. In both type of games, some circumstances are not defined in game information progress. This leads to the emerging of a tunable parameter (called 'c') to describe the missing game information progress. The meaning and importance of parameter $c$ will be described in detail. Combined with other parameters, the parameter $c$ is able to describe diverse players' skills for both sports and boards games. The data have shown that when parameter $c$ transformed the values in the game refinement formula, its resulting measurement fits well to describe the game information progress, and most importantly strengthens our previous results. This finding makes a vital contribution to complete game refinement theory and increase its ability to scientifically analyse games from both domains: sports and boards games.

Here we describe game refinement theory by a common way. The game progress is twofold. One is game speed, while another one is game information progress with a focus on the game outcome. Game information progress presents the degree of certainty of a game's result in time or in steps. Having full information of the game progress, i.e. after its conclusion, game progress $x(t)$ will be given as a linear function of time $t$ with $0 \leq t \leq t_k$ and $0 \leq x(t) \leq x(t_k)$, as shown in Eq. (7.1).

$$x(t) = \frac{x(t_k)}{t_k}\ t \tag{7.1}$$

However, the game information progress given by Eq. (7.1) is unknown during the in-game period. The presence of uncertainty during the game, often until the final moments of a game, reasonably renders game progress as exponential. Hence, a realistic model of game information progress is given by Eq. (7.2).

$$x(t) = x(t_k)(\frac{t}{t_k})^n \tag{7.2}$$

Here $n$ stands for a constant parameter which is given based on the perspective of an observer of the game considered. Only a very boring game would progress in a linear function however, and most of course do not. Therefore, it is reasonable to assume a parameter $n$, based on the perception of game progress prior to completion. If the information of the game is completely known (i.e., after the end of the game) and the

value of $n$ is 1, the game progress curve appears as a straight line. In most games, especially in competitive ones, much of the information is incomplete, the value of $n$ cannot be assumed, and therefore game progress is a steep curve until its completion, along with $x(t_k)$, $t_k$, $x(t)$ and $t$, just prior to game's end.

Then acceleration of game information progress is obtained by deriving Eq. (7.2) twice. Solving it at $t = t_k$, we have Eq. (7.3).

$$x''(t_k) = \frac{x(t_k)}{(t_k)^n}(t_k)^{n-2}\ n(n-1) = \frac{x(t_k)}{(t_k)^2}\ n(n-1) \tag{7.3}$$

It is assumed in the current model that game information progress in any type of game is encoded and transported in our brains. We do not yet know about the physics of information in the brain, but it is likely that the acceleration of information progress is subject to the forces and laws of physics. Too little game information acceleration may be easy for human observers and players to compute, and becomes boring. In contrast, too much game information acceleration surpasses the entertaining range and will be frustration, and at some points beyond that could become overwhelming and incomprehensible.

Therefore, we expect that the larger the value $\frac{x(t_k)}{(t_k)^2}$ is, the more the game becomes exciting, due in part to the uncertainty of game outcome. Thus, we use its root square, $\frac{\sqrt{x(t_k)}}{t_k}$, as a game refinement measure for the game under consideration. We call it $R$ value for short shown in Eq. (7.4).

$$R = \frac{\sqrt{x(t_k)}}{t_k}\sqrt{n(n-1)} = C\frac{\sqrt{x(t_k)}}{t_k} \tag{7.4}$$

In Chapter 2 or this common description, we found a sentence was described as **Here** $n$ **stands for a constant parameter which is given based on the perspective of an observer in the game considered.** or **In most games, especially in competitive ones, much of the information is incomplete, the value of** $n$ **cannot be assumed.**, all of thses description, the parameter $n$ was ignored.

## 7.2 Game Refinement Measure Revisited

It seems that the bridge between boardgame and continuous movement game was successfully built. However, we claim that it is not yet completed. For this purpose we detail the problem while considering the meaning of parameter $c$ in Eq. (2.5).

### 7.2.1 The Meaning of Game Refinement Measure

For the sports games such as soccer, all the attempted shots or successful shots (goal) are parts of the strategy to win the match, so they are an integral part of the game. In the domain of video games such as StarCraft II, the branching factor was calculated only by reasonable strategies to be considered as part of the winning [143]. This suggests that parameter $c$ in Eq. (2.5) is a key factor when considering the gap between boardgames and continuous movement games. It also indicates that the parameter $c$ can be replaced with $\sqrt{n(n-1)}$ in Eq. (7.3).

From Eq. (2.5) we obtain the measure of game refinement for boardgame as shown in Eq. (7.5).

$$R = \frac{\sqrt{cB}}{D} \qquad (\frac{1}{B} \leq c \leq 1) \tag{7.5}$$

Where we have $cB = B$ when $c = 1$, and $cB = 1$ when $c = \frac{1}{B}$. Hence, the assumption $c = 1$ means that we focus on a specific level of players or a certain property of the game under consideration. When we focus on a certain level of players like masters in boardgames, the crucial factor is the game property. If a game is skillful, the parameter $c$ will decrease, whereas if the game is stochastic, $c$ will increase. This is because it is usually hard in such a stochastic game to distinguish only fewer good candidates among all possible moves. On the other hands, it would be possible in boardgames like chess for masters to identify a few plausible moves. Note that continuous movement games such as sports games are basically stochastic if compared with boardgames.

*Remark 1* The parameter $c = 1$ in Eq. (2.5) means that the game under consideration is assumed to be insufficiently deterministic to identify plausible candidates.

We show from [61], in Figure 7-1, a model of move candidate selection based on skill and chance. This illustration shows that skillful players would consider a set (say $b$) of fewer plausible candidates among all possible moves (say $B$) to find a move to play. For

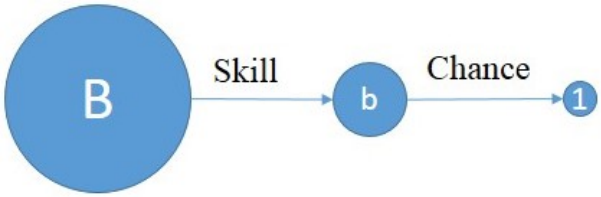


Figure 7-1: A model of candidate move selection based on skill and chance [61]

example, in chess where $B = 35$ and $D = 80$, when assuming $c = 1$, then $R = 0.074$. An estimation of the number of plausible candidates as a function of the strength of players (say $s$) may be given by Eq. (7.6) [66]).

$$b = B^{\frac{1}{s}} \qquad (1 \leq s \in \mathbb{N}) \tag{7.6}$$

For sports game, the mechanism is different with boardgame model. We have done the experiment to collect the data as shown in Table 7.1. *England Premier League (EPL), Primera division de Liga (LIGA)* and *Serie A* are high skill league, and Chinese Football Association Super League (CSL) is the low skill league [120]. Then notice an interesting phenomenon, while two players have the similar skill, the $R$ *value* almost same. Thus, currently we consider $C_s$ always equal to 1.

Table 7.1: Game refinement value for each league football match

| Game | $G$ | $T$ | $R$ |
|---|---|---|---|
| EPL Averge (2016) | 2.84 | 25.6 | 0.066 |
| LIGA Averge (2016) | 2.75 | 23.62 | 0.070 |
| Serie A Averge (2016) | 2.77 | 25.44 | 0.065 |
| CSL Averge (2014) | 2.75 | 24.6 | 0.067 |
| CSL Averge (2015) | 2.80 | 24.6 | 0.068 |
| CSL Averge (2016) | 2.67 | 24.6 | 0.066 |

We show, in Figure 7-2, the relationship between the parameter $c$ and chance-and-skill aspect. Note that we assume the estimation of the plausible candidates as shown in Eq. (7.6).

From Figure 7-2 we conjecture that the parameter $c$ relates to the strength of players or the difficulty of a game, as stated in Remark 2. *Remark 2* The value of parameter $c$ should be lower in the case where the game under consideration is simple to identify fewer plausible candidates or the case where players are very skillful like grandmasters.

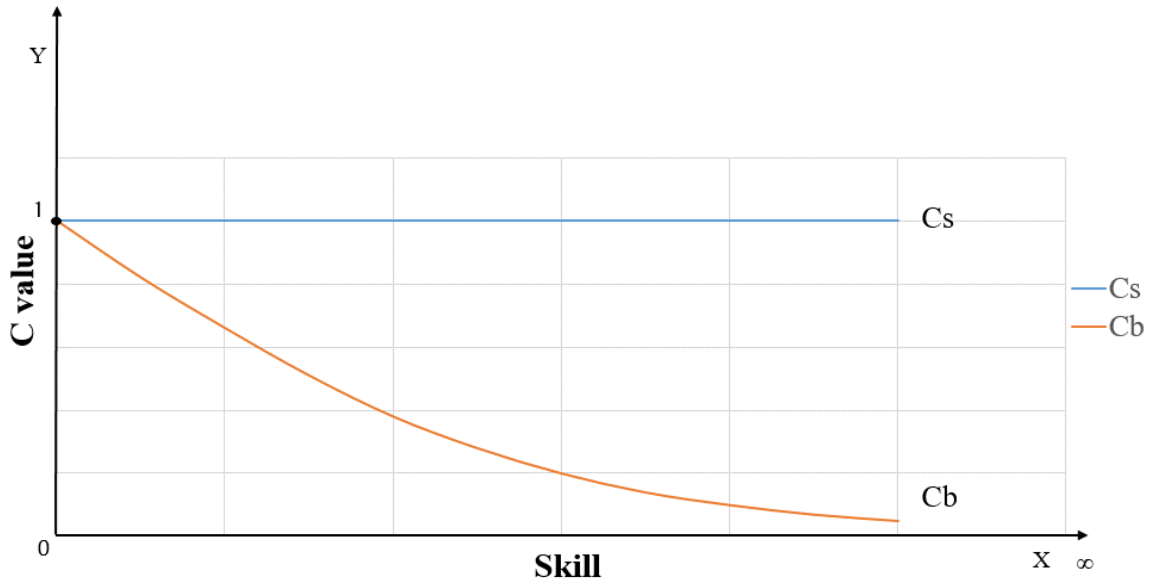


Figure 7-2: The parameter $c$ and chance-and-skill aspect of games

Using the estimation of plausible candidates as shown in Eq. (7.6), we obtain game refinement measures as described in Table 7.2.

Table 7.2: Measures of game refinement for boardgames with different parameters

| | R ($c = 1$) | R ($cB = b, s = 2$) |
|---|---|---|
| Chess | 0.074 | 0.030 |
| Shogi | 0.078 | 0.026 |
| Go | 0.076 | 0.019 |

We here summarize the meaning of game refinement measure.

- In a game where its game refinement measure is higher than the zone value (0.07-0.08), people may feel more entertaining. This is because the game is too stochastic or players are too weak to identify fewer plausible candidates.

- The game with a zone value of game refinement measure has a good balance between chance and skill, in which people may feel comfortable and then the game is sophisticated or fascinating.

- In a game where its game refinement measure is smaller than the zone value, people may feel less entertaining. This is because the game is too simple or players are too strong to experience harmonic uncertainty during the game playing. In this situation the game tends to be competitive [146].

### 7.2.2 Relative Game Refinement Measure

The game refinement theory is basically used to evaluate the property (sophistication) of games with a focus on the game outcome uncertainty. Let us consider the individual match analysis using game refinement measure [102] [95]. Since each match has an independent game process, game refinement measure can be applied.

According to the theory in Chapter 5, human's thinking (Force) can drive the target game (Mass) to move (Acceleration). In physical concept, the force and acceleration not only have value, but also the direction exist. Base on this idea, we can analyze each player in game individually. Game refinement value is related with acceleration. While we throw something front of us, it will move as parabolic motion– one acceleration from earth, another acceleration from our hand. Therefore, for game refinement value, we also can divide them into different parts. While we analyze the relationship between each player then get the related data, we call it relative refinement value.

Here, relative game refinement model is not a new concept or new model, it just a catalyst and pure mathematical tool to analyze the meaning of game refinement value.

We demonstrate an analysis of two extreme conditions and special cases. The first example is The 2014 World Cup semi-final [53]: Germany vs. Brazil, where the number of goals $G = 8$ and the number of shot attempts $T = 31$. When focusing on this match, $R$ value is given by Eq. (7.7).

$$R = \frac{\sqrt{G}}{T} = \frac{\sqrt{8}}{31} = 0.091 \tag{7.7}$$

In fact, this match was not a well balanced. Brazil had 1 goals, whereas Germany had 7 goals. Individually, game refinement measure for Brazil (say $R_B$) and Germany (say $R_G$) is given in Eq. (7.8) and Eq. (7.9), respectively.

$$R_B = \frac{\sqrt{1}}{31} = 0.032 \tag{7.8}$$

$$R_G = \frac{\sqrt{7}}{31} = 0.085 \tag{7.9}$$

In Figure 7-3 shows the acceleration direction relationship during the entire game. Apparently, the $R$ value of Germany is higher than Brazil, which means that Germany

had better playing skill. Even more we need to know the psychological meaning of game refinement value for each team's perception.

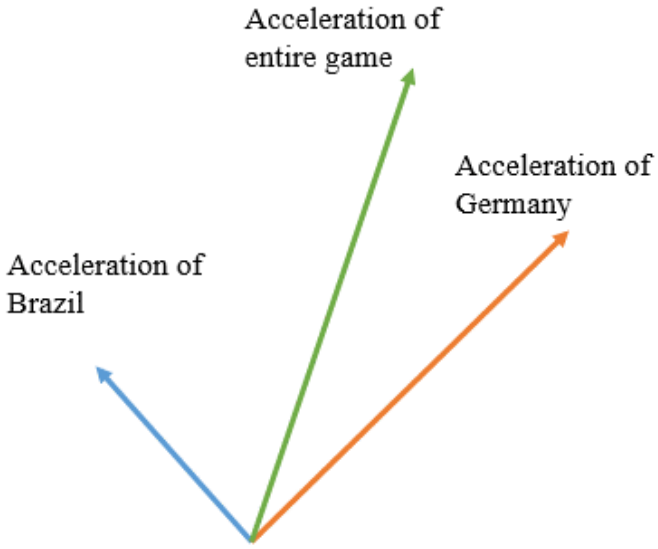


Figure 7-3: Individual game refinement value and direction

In order to understand the power for each player clearly, here we ignore the direction just focus the numerical value. Base on the Newton's second law $F = ma$, the force of Brazil in this game is contained in Germany $\frac{0.085}{0.032} = 2.66$ times. Therefore, during the game progress, the psychological feeling for Germany could be described as $Acceleration\frac{0.085}{0.032}$, we call it relative game refinement measure. Then the relative game refinement measure for Brazil (say $R_r$) is given by Eq. (7.10).

$$R_r = R \times \frac{R_B}{R_G} = 0.091 \times \frac{0.032}{0.085} = 0.034 \tag{7.10}$$

Similarly, the relative game refinement measure for Germany is given by Eq. (7.11).

$$R_r = R \times \frac{R_G}{R_B} = 0.091 \times \frac{0.085}{0.032} = 0.242 \tag{7.11}$$

From Eq. (7.10) and Eq. (7.11) we see that from Germany's perspective, people can enjoy the game for fun. Meanwhile from Brazil's perspective, people may feel very tough and they must seriously face the game progress. Larger $R$ value means higher fun, whereas smaller $R$ value means more serious or competitiveness. Illustration in Figure 7-4 the relation between $R$ value and balance between skill and chance in boardgames as well as

continuous movement games.

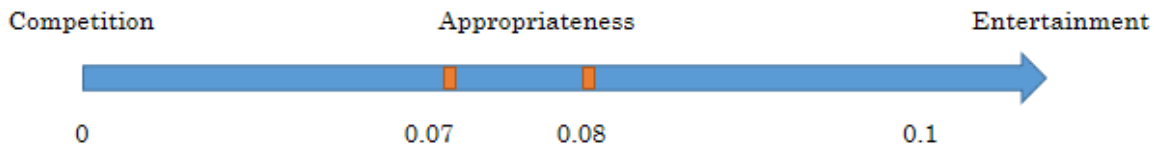


Figure 7-4: An illustration of the meaning of game refinement measure

### 7.2.3 Analysis of MOBA Games

Multi-player On-line Battle Arena (MOBA) [68] is the most popular game type, in which a player controls a single character at one of two teams. MOBA game is a typical continuous movement game. The objective is to destroy the opponent team's main structure with the assistance of periodically spawned computer controlled units. Player characters typically have various abilities and advantages that improve over the course of a game and that contribute to a team's overall strategy. Mainly in the world market, it was followed by three spiritual successors: "League of Legends" (LOL), "Defense of the Ancients" (DotA) and "Heroes of the Storm" (HotS) [148].

The game progress model of MOBA is given by the average number of successful killing heroes and destroying fortress (say $K$) over the average number of attempts per game (say $A$) [149]. Hence, the game refinement measure of MOBA is given by Eq. (7.12).

$$R = \frac{\sqrt{K}}{A} \tag{7.12}$$

The measures of game refinement for various MOBA games are shown in Table 7.3. Because of the game battle system and macro mechanism, in DotA and LOL one tower equals to 1 kill, and in HotS one castle equals to 4 kills [148]. For killing tendency $A$, any tower or castle as 1 attempt is calculated. It is found that R-value of sophisticated games is located somewhere between 0.07 to 0.08 [65] [123]. Distinctly, we notice that the game refinement value in LOL battle is so high. It means that LOL will be too excited with high entertainment and low competitiveness.

Below we summarize the entertaining and competitiveness aspect of MOBA games based on the game refinement values.

Table 7.3: Measures of game refinement for each MOBA Game

| game | map or version | K | A | R-value |
|---|---|---|---|---|
| HotS | Blackheart's bay | 70.90 | 80.10 | 0.105 |
| | Sky temple | 77.68 | 79.90 | 0.110 |
| | Dragon Shire | 63.90 | 88.80 | 0.090 |
| | Tomb of the SQ | 75.00 | 98.00 | 0.088 |
| | Infernal shrines | 63.08 | 93.00 | 0.085 |
| | Cursed hollow | 69.55 | 100.70 | 0.083 |
| | Battlefield of eternity | 99.30 | 168.8 | 0.082 |
| | Garden of terror | 68.83 | 88.90 | 0.093 |
| | Haunted mines | 55.68 | 78.10 | 0.096 |
| DotA | Version 6.48 | 69.2 | 110.8 | 0.075 |
| | Version 6.51 | 68.4 | 110.2 | 0.074 |
| | Version 6.59 | 69.8 | 110.0 | 0.076 |
| | Version 6.61 | 70.0 | 111.6 | 0.075 |
| | Version 6.64 | 68.4 | 110.4 | 0.075 |
| | Version 6.69 | 67.8 | 108.4 | 0.076 |
| | Version 6.74 | 62.4 | 102.6 | 0.077 |
| | Version 6.77 | 62.8 | 102.8 | 0.077 |
| | Version 6.80 | 68.6 | 106.2 | 0.078 |
| LOL | Version 6.6 | 37.65 | 44.26 | 0.138 |

**DotA:**

DotA is a very stable game, also it is a typical "G-T Model" (continuous movement games), for each version $R$-values are all seated between 0.07 to 0.08. Therefore, DotA is a well designed game with a good balance between entertainment and competitiveness, which is suited for competitions. For the activity population, DotA2 has 7.9 million per month all over the world [84]. The measure of game refinement indicates that that DotA is the most successful and well balanced MOBA game in the world.

**LOL:**

Generally, $R$-value in LOL is too high, whereas DotA is almost in the window value. It means that DotA fits for setting as e-sports competition, but LOL is suited to enjoy for entertainment. DotA has powerful skill and more visual impact for each hero, which cares more about management and running. Players need to make a stable and safe environment to carry and develop. Gank usually happens during the whole game. Generally, a DotA game may spend about 50 minutes but LOL usually takes around 30 minutes. LOL provides players with a new style of MOBA game that spends less time for each game

and forms a fast rhythm. For the activity population, LOL has 67 million per month all over the world [84]. The rhythm and game refinement value of LOL is faster and larger than DotA or HotS, **so that is the reason why LOL can attract more children, female or beginners prefer to play it** because of the higher entertainment property in LOL [48].

**HotS:**

For HotS, the most important point is large-scale team combat and the game rhythm is much higher than DotA or LOL. As a new game, HotS still has some insufficient aspects. According to Table 7.3, the most interesting and exciting map is 'Sky temple'. 'Battlefield of eternity' and 'Cursed hollow' have the highest level competitiveness. However, the game refinement measures of HotS are higher than 0.08, which means that compared with DotA, HotS is not so suitable for e-sports competition. Also some serious mechanism issue existed in HotS, DotA focuses on the ana-phase period during the game, but the core mechanism in HotS is wild monster. For this reason, the game depth of HotS is less than DotA and gets a larger R-value. Therefore, HotS cares more about teamwork than personal operation and game awareness, then we can only find valid data about the population of HotS in US server is 0.13 million, the expected number all over the world will not be larger than DotA 2. Nevertheless, the fun of HotS is not derived only from the battle. The various heroes and their talents can provide a lot of enjoyment for Blizzard fans. In addition, they can design maps which become more interesting and well balanced. Also the design group of HotS needs to revise the game mechanism.

All property of these three MOBA games can be shown as Figure 7-5.

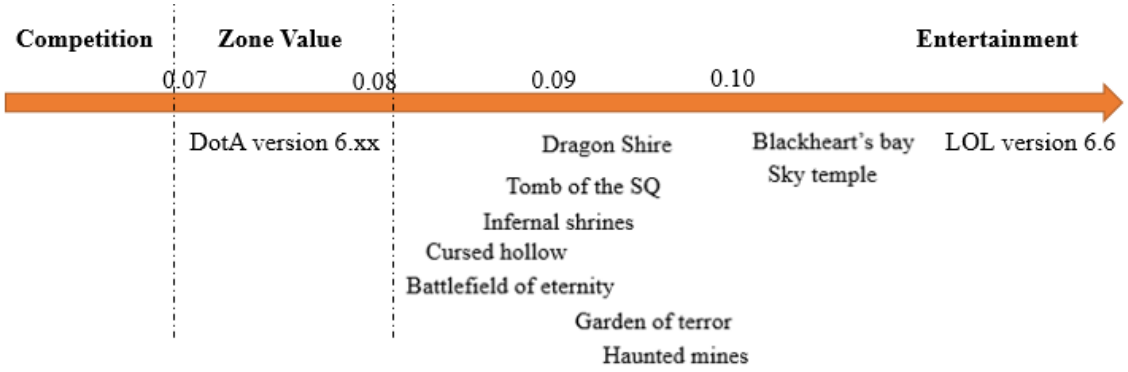


Figure 7-5: Entertainment and Competition Property of 3 MOBA Games

## 7.3 Chapter Summary

This chapter revisited the game refinement model, and presented the meaning of paramter $c$ and refinement value. The notion of game progress and game information progress model for continuous movement games was introduced in the development of game refinement measure. It seemed to be a successful bridge between continuous movement games like sports and boardgames. However, this chapter claimed with a focus on the parameter $c$ in the game progress model for boardgames.

The parameter $c$ relates to the game balance. The condition $c = 1$ corresponds to the case where the game is more chance-based one. If the parameter $c$ becomes lower, the game will be more skill-based one. Moreover, a new perspective of game refinement measure was obtained. Higher (lower) $R$ value means more entertaining (competitive), whereas 0.07-0.08 should be a comfortable zone due to its good balance between skill and chance in game playing. The analysis of popular MOBA games using game refinement measure supports the observation. The concept of relative game refinement measure was proposed to focus on individual team performance in two team sports such as soccer. The game refinement measure has been used to quantify the game sophistication for the game under consideration. However, we considered the possibility of quantifying the game sophistication from the viewpoint of individual team.

Above all, the game design by game refinement theory was finished. However, for game design we cannot only focus on one method or just focus on nature science way such as mathematical or physical, another channel is use society science method to develop the game design, in the following two chapters, we will analyze the IP (Intellectual Property) sharing, cross media and Eastern Asian game market to understand more issue in game development work.

# Chapter 8

# Game Design by Cross Media: case study use *Journey to the West*

Game was called "Ninth Art" in this century. Compared with the other eight art form– Painting, Sculpture, Architecture, Music, Literature, Dance, Film and Television, game is quite young however it has the strongest life and widest influence what can act on human's brain directly. Game is not only a new form of art, but also it was a most successful new media form, in 2015 year the global game market income was 61 billion dollars, and you can see many people no matter gentleman or lady, young or elder they sit front of PC, console machine to play games. After smart phone was popularized, people can use cellphone to play game and kill time in subway even in office. However, there are so many companies, designer, programmers and media professionals had joined into the game industry, what lead game market became the most competitive industry. Some game or intellectual property(IP) can survival for a long time 20 years(such as WarCraft, Mario, Pokemon) even hundreds of years(Three Kingdom, Journey to the West, Mid age of European, Senkoku of Japan), some other only could survival for several months then disappear soon. Why the result and vitality of each game is so different, of course one element is game quality, in my opinion another important element is whether game practitioner can use cross-media to keep expand and enhance their IP into different media corner. Therefore, in this chapter we will analyze the research case of cross-media.

## 8.1 Chapter Introduction

Cross-media is the publishing process topics planning, prepress editing and printing process, the content can be published in a digital form, in order to accommodate different carrier media, so that all media can share the same information resources and with the characteristics of each media publicity sales, it also absorbed other media forms of communication and features a three-dimensional business model. Cross-media publishing is the idea that cultural products are interchangeable in different media paper dielectric, electronics, networking and the like. For example, text can be converted to images, sounds and other symbolic form; if it is the image of nature, plot content, can also be converted to film, television, theme parks, cartoons and other cultural products.

Cross-media has the strong power, in the book "Convergence culture where old and new media collide" which was written by Henry Jenkins has shown an example [67]. The story circulated in the fall of 2001: Dino Ignacio, a Filipino-American high school student created a Photoshop collage of Sesame Street's (1970) Bert interacting with terrorist leader Osama Bin Laden as part of a series of "Bert is Evil" images he posted on his homepage. Others depicted Bert as a Klansman, cavorting with Adolph Hitler, dressed as the Unabomber, or having sex with Pamela Anderson. It was all in good fun. In the wake of September 11, a Bangladesh-based publisher scanned the Web for Bin Laden images to print on anti-American signs, posters, and T-shirts. Sesame Street is available in Pakistan in a localized format; the Arab world, thus, had no exposure to Bert and Ernie. The publisher may not have recognized Bert, but he must have thought the image was a good likeness of the al-Qaeda leader. The image ended up in a collage of similar images that was printed on thousands of posters and distributed across the Middle East [67]. CNN reporters recorded the unlikely sight of a mob of angry protestors marching through the streets chanting anti-American slogans and waving signs depicting Bert and Bin Laden. Representatives from the Children's Television Workshop, creators of the Sesame Street series, spotted the CNN footage and threatened to take legal action: "We are outraged that our characters would be used in this unfortunate and distasteful manner. The people responsible for this should be ashamed of themselves [67]. We are exploring all legal options to stop this abuse and any similar abuses in the future." It was not altogether clear who they planned to sic their intellectual property attorneys onthe young man who

had initially appropriated their images, or the terrorist supporters who deployed them. Coming full circle, amused fans produced a number of new sites, linking various Sesame Street characters with terrorists. From his bedroom, Ignacio sparked an international controversy. His images crisscrossed the world, sometimes on the backs of commercial media, sometimes via grassroots media. In addition, in the end he inspired his own cult following [67]. Of course, it was not a good case, however according to the case we can recognize the power of cross-media. In this chapter, we use Journey to the West as the research target and analyze the cross-media effect of it. From the Ming dynasty to the present world, public and media have corresponding respond about it.

## 8.2 Journey to the West

First of all, we need make clear the question– what is Journey to the West. Journey to the West is a Chinese novel published in the 16th century during the Ming dynasty and attributed to *Wu Cheng'en (1500 - 1582).* It is one of the Four Great Classical Novels of Chinese literature. In English-speaking countries, the work is widely known as Monkey [137].

This novel is an extension to the legendary pilgrimage to the Tang Dynasty monk Xuanzang who traveled to the "the West" where is the current Central Asia and India, he suffer many trials and pain to obtain Buddhist scriptures . Gautama Buddha provides three protectors for Xuanzang– Sun Wukong, Zhu Wuneng and Sha Wujing, together with a Dragon Prince– a White Horse. Journey to the West have the strong effect in the Chinese folk religion such as Chinese mythology, Taoism and Buddhist philosophy. Until now, many Taoist immortal and Buddhist temple still reflects the attitude today. Enduringly popular, the tale is at once a comic adventure story, a spring of spiritual insight, and an extended allegory in which the group of pilgrims journeys towards enlightenment by the power and virtue of cooperation [133].

Wu Chengen has been worked in Ming dynasty as a junior officer when he was 50 years old, before that he joined the imperial competitive examination for several times however were all failed. Unfortunately, when Wu was 58 years old, someone framed Wu up, then he lose the official position and source of finance. Then Wu noticed the gloomy side of officialdom and society in China Ming dynasty, he decided to write a novel to disclose

and metaphorize the political struggle of royal court.

### 8.2.1 History Background

The novel Journey to the West was based on historical events [133].*Xuanzang (602 - 664)* was a real monk at Jingtu Temple (Chang'an) in the end-Sui Dynasty to early-Tang Dynasty. Because of the poor quality of the translation of Buddhist scriptures in that time, Xuan Zang decide to leave Changan in 629 with illegel way (Illegal emigration). He went on a trip from Gansu and Qinghai with the help of Buddhist monks, and then from the Tianshan Mountains to Turpan. After that he crossed the route what is today's Kyrgyzstan, Uzbekistan, Afghanistan, into Gandhara, finally arrived India in 630. He stay in India for 13 years to visit important Buddhist pilgrimage sites, study at the ancient university at Nalanda, and debate the rivals of Buddhism.

*Xuanzang* left India in 643 and back to Chang'an in 646. Although he had violated the Tang Emperor's law while he left, *Xuanzang* still received a warm welcome from Emperor Taizong. The emperor provided money and support for *Xuanzang's* translation projects. He recorded his journey in the book Great Tang Records on the Western Regions [133]. With the support of the emperor, he set up a research institute in the Yuhua temple, dedicated to translating the scriptures. His translation and commentary work made him as the founder of the Buddhist law school *Xuanzang* died on March 7, 664. The Xingjiao Monastery was established in 669 to house his ashes [133] [54].

### 8.2.2 The Main Story of Journey to the West

The novel has 100 chapters that can be divided into four unequal parts. The first part is the introduction of main story. It deals entirely with the earlier exploits of Sun Wukong, commonly known as "Monkey King" or Qitian Dasheng [100] [133].

The second part introduces another main character– Xuanzang (Tang Sanzang), the story tell about his early biography and the background before journey. Part of the story here also relates to how Xuanzang becomes a monk [100].

The third and longest section of the work. An episodic adventure story in which Xuanzang sets out to bring back Buddhist scriptures from Leiyin Temple on Vulture Peak in India, but encounters various evils along the way. The section is set in the sparsely popu-

lated lands along the Silk Road between China and India, including Xinjiang, Turkestan, and Afghanistan. The geography described in the book is, however, almost entirely fantasy; once Xuanzang departs Chang'an, the Tang capital, and crosses the frontier, he finds himself in a wilderness of deep gorges and tall mountains, inhabited by demons and animal spirits, who regard him as a potential meal, with the occasional hidden monastery or royal city-state amidst the harsh setting [137] [133].

It is strongly suggested that most of these calamities are engineered by fate and/or the Buddha, as, while the monsters who attack are vast in power and many in number, no real harm ever comes to the four travelers. Some of the monsters turn out to be escaped celestial beasts belonging to bodhisattvas or Taoist sages and deities. Towards the end of the book there is a scene where the Buddha literally commands the fulfillment of the last disaster, because Xuanzang is one short of the 81 tribulations he needs to face before attaining Buddhahood [137] [133].

Last parts quickly describes the return journey to the Tang Empire, and the aftermath in which each traveller receives a reward in the form of posts in the bureaucracy of the heavens [151] [133].

Except Xuanzang, other characters described as below:

- The first is Sun Wukong, appearing in chapter 1. He is one of the famous mythological characters in China. By the creation of the world since the birth of the stone, the monkey king has entered the cave and led a group of monkeys, known as "monkey king". Sun Wukong is smart, lively, loyal, Fear No Evil, in Chinese folk culture has become a witty and brave incarnation, Chinese him as a deity [137].

- The second is Zhu Bajie, appearing in chapter 19, in English translated as Pigsy. He was previously the Marshal of the Heavenly Canopy, a commander of Heaven's naval forces, and was banished to the mortal realm for flirting with the moon goddess Chang'e. A reliable fighter, he is characterised by his insatiable appetites for food and sex, and is constantly looking for a way out of his duties, which causes significant conflict with Sun Wukong [54] [133].

- The third is Sha Wujing, appearing in chapter 22. In English also translated as Friar Sand or Sandy. He was previously the celestial Curtain Lifting General, and

was banished to the mortal realm for dropping a crystal goblet of the Queen Mother of the West. He is a quiet but generally dependable character, who serves as the straight foil to the comic relief of Sun and Zhu [129] [133].

- The fourth is Bai Long, he is the son of the West Sea Dragon King. He appears first in chapter 15, but has almost no speaking role, as throughout the story he mainly appears as a horse that Xuanzang rides on [137] [133].

Because of the interesting story and characters, public have enthusiasm on this intellectual property.

## 8.3 Cross Media and Intellectual Property Impacts

The United States and Japan have the successful experience on cross-media work, here are two typical cases: Disney and Pokemon. Disney is an American diversified multinational mass media and entertainment conglomerate headquartered [32]. It is the world's second largest media conglomerate in terms of revenue, and it expanded its existing operations and also started divisions focused upon theater, radio, music, publishing, and online media. In addition, Disney has since created corporate divisions in order to market more mature content than is typically associated with its flagship family-oriented brands [32]. People can enter into Disney Land theme park to play different rides and interact with the characters in Disney series. Pokemon is a media franchise owned by The Pokemon Company, and created by Satoshi Tajiri in 1995 [17]. It is centered on fictional creatures called "Pokemon", which humans known as Pokemon Trainers catch and train to battle each other for sport. The franchise began as a pair of video games for the original Game Boy, developed by Game Freak and published by Nintendo. The franchise now spans video games, trading card games, animated television shows and movies, comic books, and toys. Pokemon is the second-most successful and lucrative video game-based media franchise in the world [17]. Recently, Pokemon Go was added in Apple store and blow a frenzied agitation of Pokemon. Therefore, Chinese related media industry need learn the experience and paradigm to expand the effect of their IP, specially in game design area.

### 8.3.1 Evolutionary Process of Journey to the West

Journey to the West is a classic Intellectual Property(IP) in China. After it was written and published in Ming dynasty, Journey to the West have been recomposed into different media form and achieve a huge success. Every year in China, while winter and summer vacation come, you can find the varies of media such as drama, film in TV program related Journey to the West. Table 8.1 shows the cross-media evolution process of Journey to the West. Before 1911 year, only few traditional media form existed such as novel and Peking Opera, however after 1949 year, cross-media domino effect become very strong.

### 8.3.2 Response of Public and Media

When Journey to the West was born in Ming dynasty, it was caused some responses from royal court– it was forbidden, because Journey to the West insinuate too much political struggle and gloomy side of Ming dynasty, so emperor did not want people infer them from the novel then banned the book. However, people still would like to find some illegal means to achieve the novel and read it, discuss political struggle after dinner or in the party. Because of the policy and piracy version, Wu Cheng'en cannot get money from his work and his daily life was quite rough. However, since the excellent content of novel, Journey to the West received the comment "Four Big Wonderful Novels" of Ming dynasty (Other three are "Romance of the Three Kingdoms", "Water Margin" and "The Golden Lotus"). After the era enter into Qing dynasty, the new emperor does not care to show the gloomy side of former royal court, then Journey to the West was published by public channel, not only intellectual, but also more normal citizens can access this book. Opera or storytelling also can provide the interest for illiteracy population. At the late period of Qing dynasty, Journey to the West received the comment "Four Great Classical Novels" (Other three are "Romance of the Three Kingdoms", "Water Margin" and "A Dream in Red Mansions"). Also in Qing dynasty, Journey to the West was introduced to Korea and Japan.

In early 20th century, the Revolution of 1911 was happened. Qing dynasty was overthrown and Republic of China was established, however after the strong power central government was crashed, China lost into the situation of warlord dogfight, Second Sino-Japanese War and Kuomintang-Communist Civil War, only few media opus was created

in this era. Just in Shanghai, a film company took two movies. Unfortunately, almost Chinese people have no money, no channel and no energy to watch them, and few comments left.

In 1949 year, People Republic of China was established. Under the stable regime, people begin to reconsider to develop art and literature. In 1961 year, Shanghai Animation Film Studio, which was a part of Shanghai Film Group Corporation was founded in April 1957 in Shanghai, which is one of the oldest animation studio in China, create a amazing opus– *Havoc in Heaven*. Although before 1961 year, China already have two animation opuses about Journey to the West, Havoc in Heaven is the earliest animation film in Asia. The film was created at the height of the Chinese animation industry in the 1960s, and received numerous awards. It earned the brothers domestic and international recognition. The famous Japanese animation director Miyazaki Hayao had said because of Havoc in Heaven, he decided to choose animation as his career of life. Without the modern information technology, the painters just use pen and painting tools to achieve this film, which was earlier than Astro Boy in Japan. Unfortunately, from 1966 year China lost into *Cultural Revolution*, the disastrous populist movement and political struggle stop almost literary and artistic activity, of course Havoc in Heaven also cannot display in China Mainland. During this period, some Journey to the West related opus was created by Hong Kong and Taiwan, however not so famous. While Cultural Revolution finished, Havoc in Heaven has been displayed again then acquire a lot of rewards again– however, the most important significance is to show the possibility of future of Journey to the West. The Chinese people in new era begin to consider how to make the classic IP great again by modern media technology.

In 1980s year, China Central Television decide to use nation power to make a drama of Journey to the West, it is a huge project on that time. Director Yang Jie use 6 years to find actors, scenes and shooting tools, the footsteps of cast and staff cross all over the China mainland. It is the first drama with full story of Journey to the West, until now the opus still has a huge influence– from elder to children, no matter city or village, for every summer or winter vacation each TV station in China will scroll to broadcast the *86 version Journey to the West*. Almost all Chinese people have watched the epic. In the industry, related media worker and audiences believe some element in *86 version Journey*

*to the West* cannot be surpassed such as Monkey King acted by Liu Xiao Ling Tong. The classic music in *86 version Journey to the West* also commonly used in later opus in 21th century. From *86 version Journey to the West*, China media worker begin to recognize the IP power then, also *86 version Journey to the West* spread to Hong Kong and Taiwan region, then to the Korea, Japan and over the East Asia.

After the success of *86 version Journey to the West*, the related opuses were created as blowout. Public and media understand how to use the IP power to gain benefit or achieve their dream. In 1995 year, the great Hong Kong comedian Stephen Chow acted the Monkey King in movie– A Chinese Odyssey, also in film area, A Chinese Odyssey become as the classic range pole. Thousands teenagers, young men and university students enthusiastic about this movie. Further more, media related worker understand recompose the classic story also can make the new culture value. Specially, the Chinese title of *A Chinese Odyssey* is "Da Hua Xi You", had been used to create the game by company NetEase in 2008 year.

Before design the "Da Hua Xi You", NetEase make another game– NetEase's Fantasy Westward Journey, based on the company's classic PC title, has already surpassed sky-high expectations, sweeping to the top of App charts and creating waves across the entire mobile gaming industry [101]. As a major Internet technology company in China, NetEase has continually maintained its leading position in domestic markets by the development of Internet applications, services and other technologies. The company's achievements in research and development are well demonstrated by the many Best Game accolades Fantasy Westward Journey has received since launch. NetEase's Fantasy Westward Journey PC client game continues to be a titan in the online gaming industry in China. The game boasts 310 million registered users, with a record of peak concurrent users standing at 2.71 million (In August 5, 2012) [101].

Through these constant refinements, Fantasy Westward Journey has become the immortal titan of PC gaming in China. But a legend was born again on March 26 earlier this year, when the Fantasy Westward Journey mobile game was officially launched on all major platforms [101]. Within a mere two hours, it reached the number one spot on the top free games chart, and another eight hours later it landed first place on the top free Apps chart. The "Fantasy Westward Craze" followed on the iPad, gaining the honor of

the highest rank on both the top free Apps and top grossing Apps charts [101].

Specially about another case, in 2015 year summer, as the main character Sun Wukong became a huge hit in China. The Chinese 3D animated film called Monkey King: Hero is Back was released on July 10 and in just over three weeks grossed some 800 million RMB (approximately 120 million dollars), breaking the records for box office profits for an animated film in China. The movie is still showing in theatres, so ultimately it is projected to gross more than 1 billion yuan, generating huge media buzz. Critics claim that this single movie has restored the confidence of the Chinese animation industry, which had been in stagnation for quite some time [47]. Global Times and Xinhua News Agency comment that **Monkey King a milestone for Chinese animation** [4]. The animated film inspired by a classical epic is a bold creation, said Tong Gang, deputy head of the State Administration of Press, Publication, Radio, Film and Television, when attending a seminar on the film. Tong said the work was a real tribute to the classic epic story. The animation has pulled in about 800 million yuan ($130 million dollars) since its release on July 10, the highest grossing animated film in Chinese film history. Critic Zhong Chengxiang stated that he felt the domestic production has blazed a trail for domestic animators. While the production has been criticized, with some saying its characters were not well drawn and the ending was abrupt, encouraged by favorable criticism and box-office success, the film's director, Tian Xiaopeng, said plans to promote the film overseas were underway and that the producers were already planning a sequel. Before Monkey King: Hero is Back, most Chinese animated films found it difficult to reach the 100 million yuan box-office benchmark [4] [47]. In 2016 year, Monkey King: Hero is Back was displayed in Japan, and received a lot of comments with high value, it means the IP has been successfully stand in oversea market.

## 8.4 Discussion

Why Journey to the West can be so success in China and other countries? In our opinion, there four main reasons.

- *Free Copyright.* Journey to the West was born in Ming dynasty when was published 400 years ago, according to the copyright law, fans and journalists can create the

related opus freely, similarly another famous classic Chinese novel Three Kingdoms also have been recomposed into different forms. On the contrary, Jin Yong's Wuxia novel(Chinese Ranger Story) also famous all over the China even Southeastern Asia, you also can find some drama, comic even game media related Jin Yong's work, however Jin Yong still alive and any recomposing work need pay a lot copyright fee to him. Therefore, compared with the IP similar as Wuxia novel, Journey to the West can be spread wider.

- *Modern Media Technology.* According to the Internet and science development, Chinese fans can touch a lot of media contents and entertainment forms. In China, people would like join digital media directly with public area, not only just receive the information, but also they like "Second Creation" and get together to communicate to each other then finish their work. Also from Table 8.1, we noticed that before 1949, few cross-media work was born out and recent years, so many new opuses have been created easily with high quality. Network and smart phone can help fans to change the world.

- *Depth of IP.* Journey to the West is a very interesting opus. From the main story, in children and teenager' minds, Journey to the West is a typical Role-Playing Game(RPG) or Adventure Game(AVG): Tang Monk, Monkey, Pigsy and Sandy face the suffering and kill monsters, then level up, fight with strong boss, finally they get the Buddhism scripture. However, in adults' minds, Journey to the West is political struggle story of Ming imperial court, they can find many reality prototype [108]. For example, Jade Emperor in novel is the Jiajing Emperor in reality. Also, Journey to the West is a cult novel and tragedy story which about conflict between Buddhism and Taoism, in the end of the story, Monkey king lost freedom and become a hatchet man of Buddhism. Therefore, Journey to the West is a excellent opus with depth philosophy, different readers or audiences can find their own understanding then create a lot of different derivatives.

- *National Soft Power.* Actually, national soft power and cross-media culture supple for each other. cultural originality is a new driving force of cultural development, plays a pioneering role in the enhancement of the soft strength of culture. With the

deepening of globalization, non-material cultural heritage in national soft strength strategy of status is also becoming increasingly important. People have interested in Mid-age because European is strong, similar people have interested in Japan Sengoku Age. The nation with weak soft power will not attract fans easily, people also have no interest about a opus with a weak culture background. Therefore, China soft power is another important element to spread Journey to the West [99].

## 8.5 Chapter Summary

This chapter presented the investigation in the domains of Journey to the West. We analyze the related cross-media work, such as novel, comic, film and game to draw the history and develop process of Journey to the West as Table 8.1 shows, later we know the reason about why Journey to the West can be so success in China and East Asia. We see that the successful cross-media case need have common four factors: free copyright, modern media technology, depth of intellectual property and national soft power. According to this chapter, media worker could understand how to choose the topic to design a game, and recognize the method to spread their game intellectual property widely.

Table 8.1: Cross-Media process of Journey to the West

| Age | Year | Traditional Media | New Media |
|---|---|---|---|
| Ming | 1592 | Journey to the West(Novel) | |
| | 1641 | A Supplement to the Journey to the West (Novel) | |
| Qing | 1644 to 1911 | Peking Opera for chapter short story(Peking Opera) | |
| ROC | 1927 | | The Cave of the Silken Web(Film) |
| | 1941 | | Princess Iron Fan(Animation) |
| PRC | 1958 | | Pigsy Eats Watermelon(Animation) |
| | 1958 | | Flaming Mountains(Animation) |
| | 1961 | | Havoc in Heaven(Animation) |
| | 1966 | | Journey to the West(Film) |
| | 1968 | | The Cave of the Silken Web (Film, Hong Kong) |
| | 1968 | | Country of Women(Film, Hong Kong) |
| | 1976 | | Monkey King With Seventy Two Magic(Film, Taiwan) |
| | 1980 | | Dingding vs. Monkey King(Animation) |
| | 1980s | Lianhuanhua of Journey to the West(Comic) | |
| | 1981 | | Solanum muricatum(Animation) |
| | 1983 | | Pigsy(Animation) |
| | 1985 | | Monkey King defeat Monster(Animation) |
| | 1986 | | Journey to the West(Drama) |
| | 1991 | | Go West to Subdue Demons(Film, Hong Kong) |
| | 1994 | | A Chinese Odyssey Part One: Pandora's Box(Film, Hong Kong) |
| | 1995 | | A Chinese Odyssey Part Two: Cinderella(Film, Hong Kong) |
| | 1996 | | Journey to the West(Drama, Hong Kong) |
| | 1997 | | Oriental Legend(Game, Taiwan) |
| | 1998 | | Journey to the West 2(Drama, Hong Kong) |
| | 1998 | | Journey to the West (Animation) |
| | 2000 | | Journey to the West Extension(Drama) |
| | 2000 | | Sequel of Journey to the West(Drama) |
| | 2000 | Decoding A Biography of Wukong(Novel) | |
| | 2002 | | The Monkey King: Quest for the Sutra(Drama, Hong Kong) |
| | 2003 | | Fantasy Westward Journey(Game) |
| | 2005 | | A Chinese Tall Story(Film) |
| | 2005 | | Pigsy From Sky(Animation) |
| | 2008 | | The Forbidden Kingdom(Film) |
| | 2008 | | A Chinese Odyssey(Game) |
| | 2008 | BuddhaLand(Comic) | |
| | 2009 | | QQ: Journey to the West(Game) |
| | 2010 | | Kabuxiyou(Game) |
| | 2010 | | Kabu Xiyou(Game) |
| | 2010 | | Wu Chengen and Journey to the West(Drama) |
| | 2010 | | Journey to the West(Drama) |
| | 2010 | | Journey to the West (Animation) |
| | 2010 | | Monkey King (Animation) |
| | 2010 | | ASURA(Game) |
| | 2011 | | Chuangshi Xiyou(Game) |
| | 2011 | | Zaomeng Xiyou(Game) |
| | 2012 | | Journey to the West(Drama) |
| | 2012 | Monkey King(Comic, Hong Kong) | |
| | 2012 | Diary of Journey to the West(Novel) | |
| | 2013 | | Journey to the West (Animation) |
| | 2013 | | Dark Journey to the West(Game) |
| | 2013 | | Journey to the West: Conquering the Demons(Film) |
| | 2014 | | The Monkey King(Film) |
| | 2015 | | Westward Journey(Game) |
| | 2015 | | Monkey King: Hero Is Back(Animation Film) |
| | 2015 | Prequel of Journey to the West(Novel) | |
| | 2016 | | The Monkey King 2 (Film) |

# Chapter 9

# The China and Japan Game Market Issue and its Countermeasure

This chapter is an updated and abridged version of the following publications:

- Shuo Xiong (2014). The Problems With Modern Japanese and Chinese Game Seclusion From the Outside World and In-depth Analysis of the Countermeasures. Journal of US-China Public Administration, 11(4): (PP. 334-344), 2014. Journal. Sep. 2014

## 9.1 Chapter Introduction

Games are a part of our lives. Games came into the world together with the advent of tools. Over 5,500 years ago, Senet was played in Pre-dynastic Egypt, as evidenced by its inclusion in burial sites [43]. Until now, the four most popular classic boardgames have been Go, Chess, Xiangqi, and Shogi [28]. Excepting Go, these games share some remarkable similarities, even down the shape and movement of the pieces. In Chess, Xiangqi, and Shogi, for example, the knights (horse) all move in an L shaped fashion. According to some researches, the Indian game Chaturanga is identified as the ancestor of Xiangqi, Shogi, and Chess [72].

The game of Go or Weiqi in Chinese enjoys a special place in boardgame history. Not only it is one of the oldest games known, it has kept essentially the same rules for longer than any other boardgame. After its origins in China perhaps as far back as 2300 B.C.,

Go spread into Korea in the 2nd century, and finally traveled to Japan via trade routes sometime around the year 700 A.D..

The idea of the boardgame can be defined in a more generalized concept, not only boardgames but also including card games like Mahjong. Mahjong originates from the Tang Dynasty in China [43]. Whether its original form was paper and it later moved onto tiles, or whether it began as tiles and cards later developed from it, most of the length of its early history has been recorded as being limited to the aristocracy. The rules were kept secret until China became a republic early in the last century. It is very likely that the earliest versions of the game would bear little resemblance to the game as played today [87].

Only in 1920 did Mahjong step outside the country and spread, first to the United States, then Japan, and around the world [43]. An interesting development was recently shown in the news reports of an international Mahjong competition where French players took home the top prizes, with the Chinese teams only managing to come the fourth and seventh [142].

Cleverly, marketed boardgames can gain worldwide popularity. Chinese designers developed a game called Three-Kingdoms Kill, this game's principle is based on Bang [128].

## 9.2 The Meaning of "Sakoku" and Sakoku Model in Modern Asian Game

In the 19th century, both China and Japan had policies of seclusion from the outside world. On the surface, they were similar government policies. Both of them restricted international travel, both countries prohibited Catholicism, and both strictly regulated international trade. However, the deep-seated reasons have many different points. Limited to its only window to the outside world, the designated international port of Nagasaki, Japanese leadership could remain somewhat informed of the day's global technology. The Chinese of the day considered Chinese culture as superior, and refused all knowledge of the West, thereby missing hundreds of years of science, medicine, and philosophical advancement. The arrogance of Chinese national character in that age retarded China's

growth, while Japan's fears retarded hers. According to this history, sakoku can be viewed on its relation with two elements: government policy and national character.

Compared with the success of the traditional and fashion boardgame, the new media games seem unfortunate. Chinese and American games are hardly keeping a foothold in the Japan market [142]. Few Japanese players know the Starcraft II or Diablo III which are famous and popular all over the world. On the other hand, except some light games which face to light user, many Japanese games are hardly to make the success in Western and China market, such as Monster Hunter [140] [141].

The writer calls this phenomenon with a Japanese word Game Sakoku. There are four points at the root of this problem: government policies, economy, national mind, and poor marketing. Some genius Japanese game designers such as Kojima Hideo and Keji Inafune also have already said as much [142].

First, to illuminate the concept of Game sakoku in detail, a brief discussion and the results of research were began. A note on the word sakokuthere is some difference in meaning between Chinese and Japanese with this word. Japanese seems to have a more emotionally charged connotation to the word phrase meaning "seclusion from the outside world" when it is written in Chinese characters. In Japanese, sakoku is strongly related with government behavior, such as the historic Tokugawa Bakufu. However, this word in Chinese (suoguo) is more generalized, connoting not only government behavior, but extending to the economy, company behavior, and national character or mind [18]. The Chinese game industry is in the development period and the Japanese game hardware industry is in its heyday. If the sakoku problem is not solved, the Japanese game industry will decline and fall behind that of the West. For their part, Chinese developers who fail to address gamers beyond their borders stand to lose the best chance to step into the development of the gaming future [12].

## 9.3 Methodology

Field investigations were begun when the writer resided among the crowded arcade lines streets of Osaka, Japan. The similar e-novels games are sold at premium prices within Japan, even higher than masterpieces such as "Assassin's Creed" or "Call of Duty". If it is any indication of their popularity, Japanese game shops are full of these new assembly

line production games. Japanese gamers' customs and interests can also be observed, which shall be compared with Chinese and other customs [141].

A questionnaire of the gaming public in three languages was undertaken in order to highlight some of the opinions, habits, or feelings of the gaming public. The questionnaire has 59 questions in the Japanese version (answer n = 22), 60 questions in the Chinese version (n = 615), and 58 questions in the English version (n = 17). According to the research data, the Japanese game sakoku problem will be shown with four points: the irrational game price and excessive commercialization, opposite phenomenon, weak innovative ability in recent years, and weak adaptability in overseas market.

The following four points will then be made concerning the Chinese game market: public policy, law and review mechanism, rampant piracy version, and players' economic capability and customs. These points are closely connected to the Japanese four points. They are the main reasons for low sales of Japanese games in the Chinese market [140] [141].

## 9.4 Japan Part

### 9.4.1 The Excessive Commercialization and Game Price

The price of the Japanese game is higher than the other countries. For example, the average price of an "Adventure Game (AVG)" is 6,500 yen, even with games which are simply electronic novels. The game programming required for such a production is very easy, and any student who has begun to study the C language can also write the source code of electronic novel AVGs. On the other hand, with a masterpiece of the West such as "Call of Duty 9", the resources are millions of times harder than the electronic novel games. However, the price of this game is $59 US dollars, which is cheaper than the electronic novel AVG.

Compare the graphics, the AVG games may only need some 2D pictures to be the background, but "Call of Duty 9" or "Assassin's Creed III" contains very complicated 3D effects and modeling. Comparing with the game play, an AVG like Ace Attorney is the most famous AVG, which is often played only once, and never touched again, once the plot is known. Games such as Warcraft or Starcraft, however, are different each time, and

can be enjoyed repeatedly, just like GO.

Not only the high price, but also the excessive commercialization make much worse with that. Because of excessive commercialization, many games are made by assembly lines.

More serious is when company and game design get value from assembly lines, they will rely on that.

### 9.4.2 Opposite Phenomenon

Considering the "Opposite Phenomenon", games such as Warcraft III, Starcraft II, Diablo III, Dota (Defense of the Ancients), LOL (League of Legends), and Counter-Strike are very famous games anywhere in the world; people play them in America, Europe, China, Korea, and other Asia counties, but in Japan, these games are hardly played. On the contrary, few Japanese know them at all.

Every year, there are many electronic competitions such as "WCG" (World Cyber Games) held all over the worldattendance will reveal almost no Japanese player joining in these competitions. There are two questionnaire data to show that(see Figure 9-1, Figure 9-2, Figure 9-3 and Figure 9-4). Sample name recongnition of three games by Japanese, Chinese, and Western players follows for "DotA, LOL, and StarCraft".

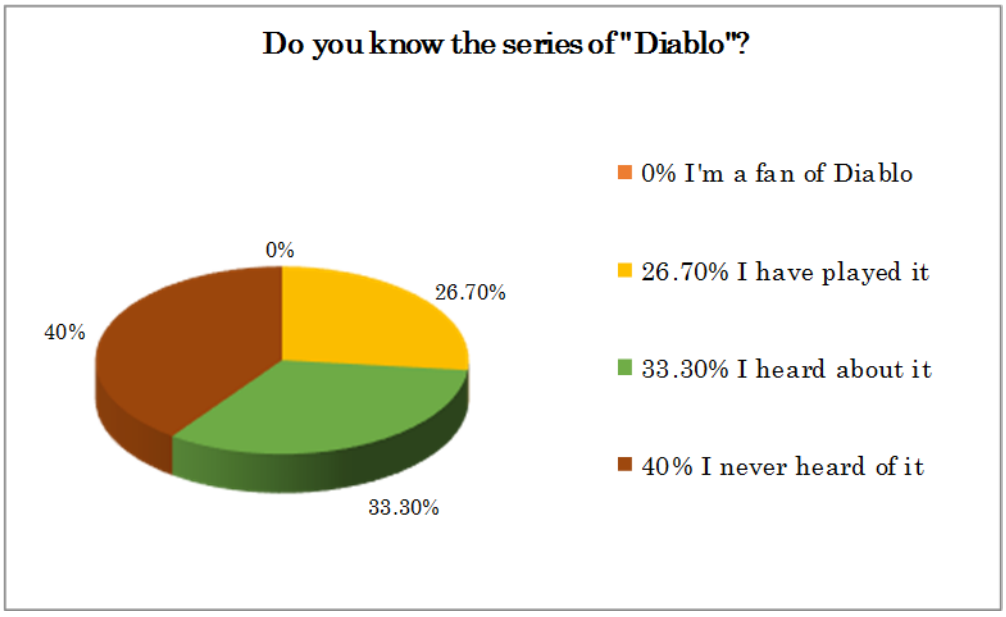


Figure 9-1: Recognition of Diablo in Japan

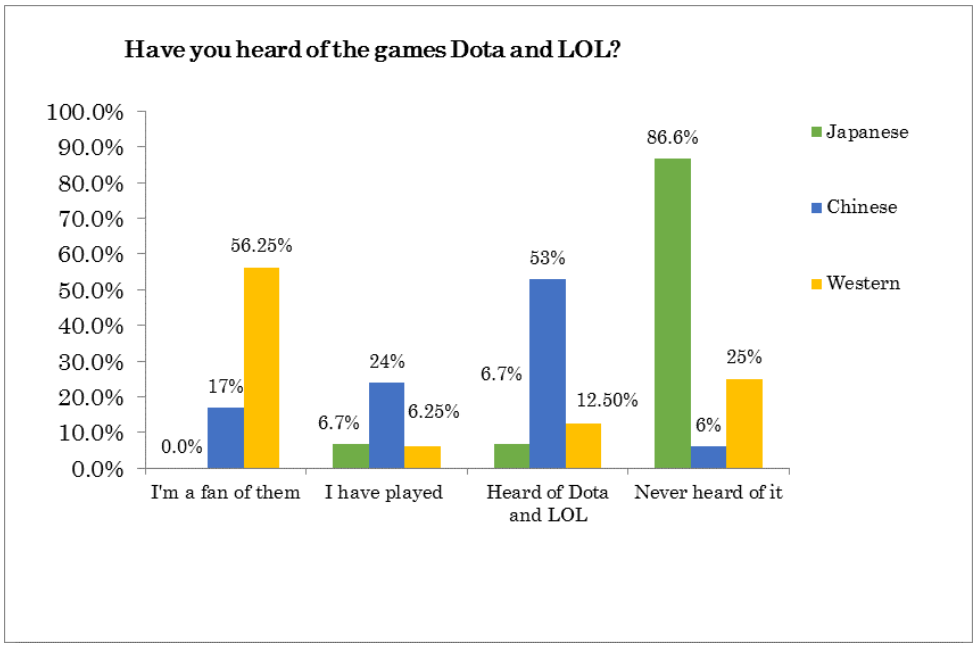


Figure 9-2: Recognition of Dota&LOL

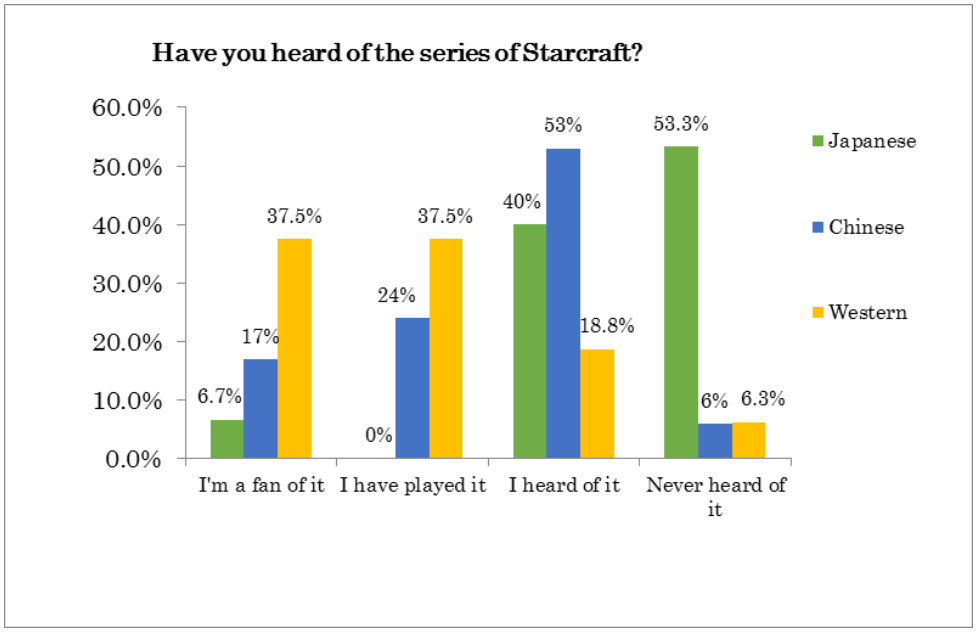


Figure 9-3: Recognition of Starcraft

The opposite phenomenon affects the competitiveness of Japanese gamers, and likewise some famous Japanese game makers cannot get out of the country. In terms of the following anecdotal evidences, we take Monster Hunter as one example. In Japan, Monster Hunter is a nationally recognized Japanese game. People can often be seen playing

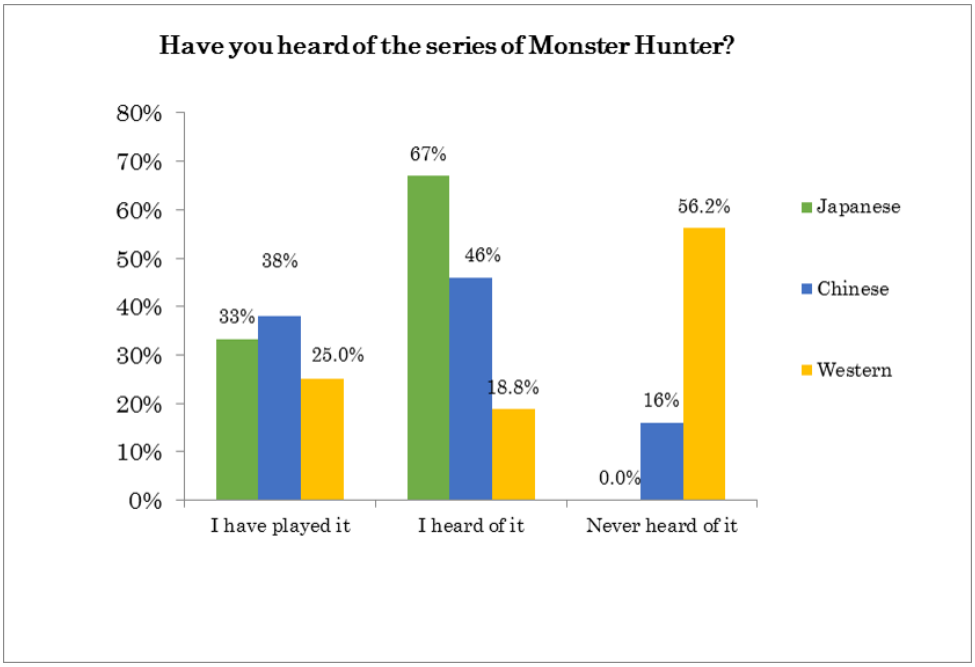


Figure 9-4: Recognition of Monster Hunter

Monster Hunter on PSP in the bus, in the subway station, and most public places. Certainly, Monster Hunter is an interesting and playable game that appeals to many people. Probably Monster Hunter could be received well among society members, just like the "WOW (World of Warcraft)" in other countries. However, while Japanese players are crazy about this game, Western player do not even know what Monster Hunter is.

Monster Hunter is a game that could be translated and marketed effectively to the West. At least the game is easier to understand than "Nobunaga's Ambition". Moreover, even "Dynasty Warriors" and "Samurai Warriors" have an English version [1]. In respect to games like Warcraft III and Monster Hunter, this puzzling situation is the opposite phenomenona sense that Japanese and other countries' players are living in different worlds.

Obviously, the causes of the opposite phenomenon could be culturally, historically, and idiosyncratically complex among all the various players, developers, and marketers of games. Surely one reason is national personality. As it can be seen, this result came from the "Digital Game Textbook" [103].

In Table 9.1, the result of the number of overseas game in Japan top 100-titlelist is shocking.

Table 9.1: The number of overseas game in Japan Top 100 Title List

| Year | Make by overseas title |
|---|---|
| 2005 | 1 |
| 2006 | 0 |
| 2007 | 2 |
| 2008 | 1 |
| 2009 | 0 |

### 9.4.3 Innovative Ability Is Weak in Recent Years

Some Japanese games are the same as those which are famous anywhere else in the world, such as Biohazard 6, Final Fantasy 13, and Devil May Cry 5. However, the other games have a later suffix name, and their origins are all before the PS3 and XBOX 360 age. In other words, 88.6% of the games on this list are Japanese games that are based on their famous first installments. Biohazard first appeared in 1998, and Final Fantasy was made in 1987. The fact that these games are dependent upon 15 to 25 years old ideas is a strong indication of flagging innovation in Japanese game production.

Comparing the Western titles with such games as Need for Speed 17, Tomb Raider 8, and The Elder Scrolls V: Skyrim, based on their classic tags, still there are also a lot of new series created after 2006 such as Assassin's Creed, Mass Effect, and Alan Wake.

Perhaps the best instance of "Call of Duty" best explains the self-revolution ability of Western companies. The series of "Call of Duty" was initially based on the theme about the Second World War [actually the "Call of Duty" is really one of the excellent FPS (First-Personal Shooting) games at that time, and along with such competitors as "Medal of Honor" and "Battlefield 1942"]. In 2007, FPS players around the Game-o-Sphere were jolted by the Activision self-revolution: Call of Duty 4. This version changed the theme from a Second World War game to a modern age game. With a Hollywood movie effect, Call of Duty 4: Modern warfare truly took the gaming world by surprise. Subsequently, Modern Warfare 2 and Modern Warfare 3 sold out in 2009 and 2011. Apparently, the massive changes were a success, Call of Duty: Modern Warfare 3 had earned 775 million dollars just in five days. Game companies ought to have the self-revolution spirit, not only with heritage classics, but also to reclaim new areas.

### 9.4.4 Weak Adaptability in Overseas Market

Whether they even make an attempt to do so, it seems that the products of Japanese game company do not appear widely out of the Japanese market, especially in China. In fact, one would be very hard pressed to find a copyrighted Japanese game in China. Of course, some of the blame for this falls on the Chinese Government and players themselves, as will be discussed in the next section. If Japanese game companies would like to penetrate into Chinese market space, however, they will first need to face the piracy problem and the absence of a review mechanism. While these are indeed serious issues, piracy and review mechanics do not seem sufficient deterrents in and of themselves to cause failure. Western companies such as Blizzard have been successful in China because they could adapt to the environment, and many South Korean companies could also keep their foothold. As long as they are willing to address these concerns, Japanese companies can thrive in the Chinese game market, too.

## 9.5 China Part

### 9.5.1 Policy, Law, and Review Mechanism

Most countries have a ratings system for mass media. Unfortunately, China has no standard ratings system. That means that every player, regardless of age, should play under the same draconian restrictions. The reason for this and many other deficiencies of Chinese culture politic are complicated. The effect is apparent: Any game which contains bloody, erotic, violent, profane or sensitive political or historical content is basically forbidden. Modern game designs that are in high demand can hardly avoid at least some of these elements. In the Mainland China server version of Starcraft II, all the effects of death are censored, and the red blood becomes black like petroleum. Game companies should produce Chinese market versions of their games.

This review mechanism in the absence of any standardized ratings system serves the mainland Chinese game and movie industry and Chinese consumers very poorly. Furthermore, as a student determined to become a game designer, the writer would like to create a game about the Republic of China age someday. This age provides the richest part of Chinas history, and many exciting elements provide potential subject matter for

game designs: frequent wars and cataclysmic world events, thousands of civil servants, generals and heroes, and the crossroads of many different forces.

It is a pity that the game would like not make it out of the review process in China because the Republic of China Age is a too sensitive historical topic. This simple reason kills many excellent game ideas and plans. Additionally, this is the main reason why foreign games cannot access the Chinese market.

Other laws also hinder the Chinese game industry. For example, game machines themselves are unlawful in China for a long time (until 2013). Game machines cannot come into Chinese market by any legal means. This results in not only the great masses of players who are deprived of PS3s or PSVs, but also Chinese game companies are unable to make games on these platforms because they do not know the kernel information about these machines. Ironically, though, game machines can be found for purchase anywhere in China through unconventional means. In addition, game information and strategies are discussed openly on the internet, and video game magazines are sold in every bookshop. It belongs to the gray area. However, this situation has been changed, China Government just modifies the policy in 2014. Accompanying Shanghai FTA (Free Trade Agreement) being established, the game machine can now be sold legally. It is a big and good chance for all the game hardware company.

### 9.5.2 Rampant Piracy Version and Players' Economic Capability and Customs

Piracy is a global problem, but it is more serious in China. The following circular graph explains the detrimental cycle. Figure 9-5 is the model about forever endless vicious circle of piracy version.

That is the present situation. Rampant piracy is the biggest problem which is hindering the Chinese game industry and isolates the Chinese game industry from the outside world. Piracy damages the game industry all over the world. For the Chinese market, native companies and Japanese companies are deeply damaged. Online games are the most important part of the game industry in China, but the video game is nearing a state of collapse [103]. This is easily explained by the fable of the "Warm Boiled Frog". The frog will feel pain if thrown into hot water, but if thrown into cold water, then gently

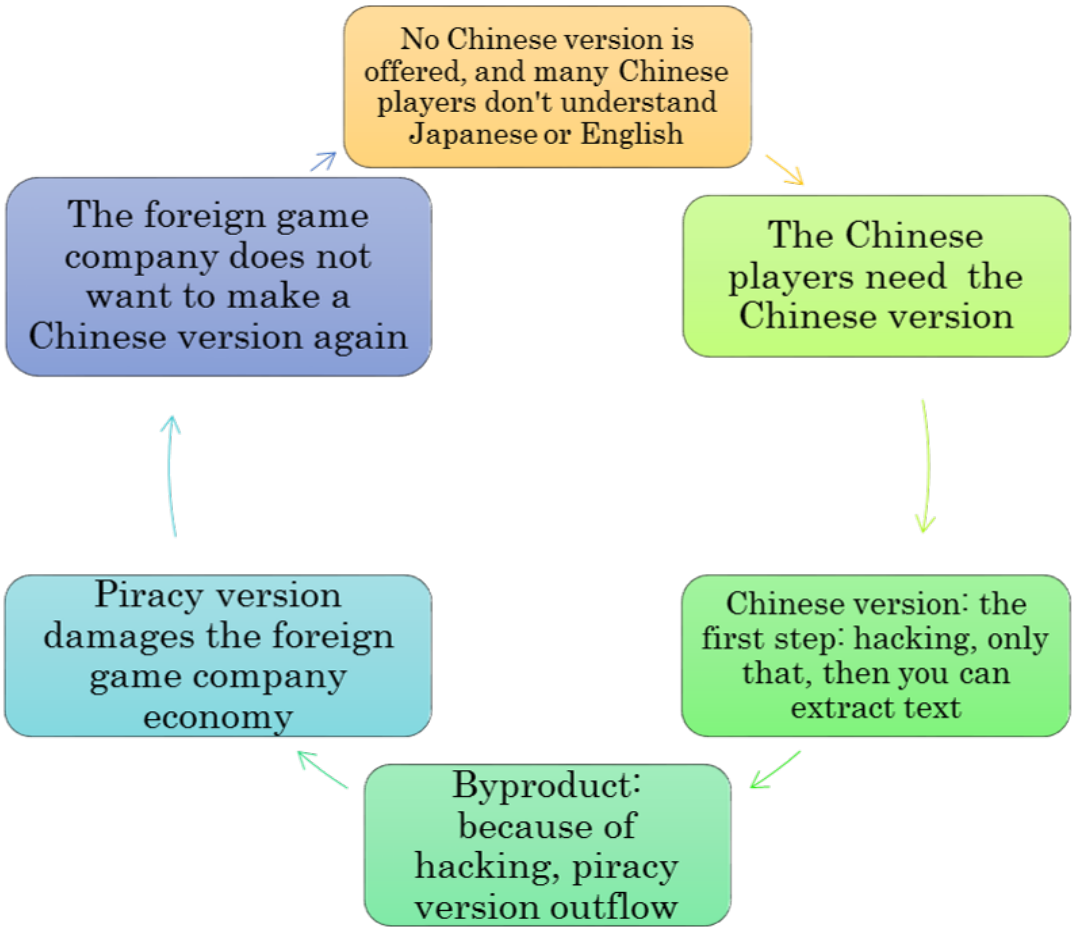


Figure 9-5: Forever-endless Vicious Circle

raising the temperature, the frog will face death quietly and joyfully. This anecdote makes a quirky image perhaps, but there is a very real implication for anyone wishing to sell a product in China. Japanese companies lose a lot of their potential market share to this phenomenon, because Chinese gamers even if they may ultimately spend the same amount or more, will choose the cheaper per-pay game almost every time. Considering that the average Chinese per capita income is only one-tenth of that of Japanese in 2014 [139]. Chinese players are more reluctant to part with their scant money for a game which cannot be eaten, keep a person warm, or contribute to the running of a business.

Blizzard used the "Warm Boiled Frog" method, such as with the marketing of WOW and earned decent profits in China market [103]. Some other South Korean and Chinese game companies have had success with this model. The game is free but equipment must be bought at a premium. Global gaming marketers absolutely must accurately address Chinese players' vanity and psychological treatment to succeed in China.

As is well known, China is a developing country whose citizens have considerably less economic wherewithal than those of more economically developed countries. Secondly, though, the law and review mechanism ban many games; Chinese players wishing to experience them must choose between pirated and smuggled game versions. These are the two main causes of rampant game piracy in China.

## 9.6 Countermeasures and Summary

This research arrives at an uncomfortable question: How is it that traditional boardgames can cross the geographical and cultural chasm in the pre-industrial age, but digital games cannot do so even in the information age? With the development of internet, players should acquire the game information easily. It is a serious and sad condition. In order to improve these conditions, several solutions are now proposed that, if implemented, will grow the sustainable development capacity of the modern game industry. East-Asia cultural stock is well positioned to provide good influence all over the world. Japanese companies can earn handsome profits in China, and improved communication and understanding among Japan, China, and the world can be achieved with better business and enjoyment of games.

Summing up this analysis is a presentation of countermeasures for ending Japanese and Chinese game industry sakoku. Perhaps the best way for Japanese game companies is to secure agent representation in China, or cooperate with an existing Chinese firm. Actually, many Western game companies (Blizzard, Riot games, and Smile Gate) [142] and Japanese manufacturing firms (Honda, Nissan, and Toyota) are known to have had a big success in the Chinese market.

While this method also comes with its own problems, it has many advantages. As would be expected, the Chinese Government is much more amenable to permitting Chinese companies in the review process. In addition, the Chinese Government protects domestic copyrights. The power of the Chinese Government in China is a strong deterrent to hackers. In practice, China holds itself to a separate standard for independent overseas capital or company.

Other main countermeasures contain these four points: First, the presence of overseas branches is helpful to creating a more local image preferable to Chinese Government and

consumers. Especially, considering the price of production, just as for iPhone or so many other products, "Made in China" reduces development cost significantly. Second, modify pricing for the Chinese market, following the logic of the "Warm Boiled Frog". Third, modify game authentication mode. A game company could use the network authentication just like the Diablo III and SimCity 5. Fourth, producers must strongly consider where to strike their balance between projected sales and per-unit profits. Starcraft II in America has an MSRP (Manufacturers Suggested Retail Price) of $59.90, but in China mainland only sells for $14.60. Japanese game company also could follow that example for the opportunity to sell games to millions of Chinese.

Finally, gamers themselves have some measure of power over the world gaming culture. The game associations should encourage Japanese players to participate in the world, for example, by joining in the E-sports such as WCG. Additionally, personnel exchanges among various corporate, NGO (Non-Governmental Organization), and educational entities have helped bridge many cultural gaps and could do much for global gaming culture. Game developers, the media, players, and businesspersons should encourage game designers to open up and innovate. In the future, Japanese game companies could enjoy wonderful success in the Chinese and world market. The Asian modern game contains elements of a vast and ancient past, and values which are strongly desired and respected in the West. This writer believes that Asian digital games can become as popular as the classic boardgames have been. Moreover, if world players and developers can make communication more freely, the effects of modern day de facto sakoku can be dispelled. Future research of both Japanese and Chinese gaming markets will be undertaken with this noble purpose.

## 9.7 Chapter Summary

This chapter presented the Japan and China game market problems. According to the contents, Japanese game designers could understand their weak points and imperfections, for the Japanese game companies, they will notice the method to enter into overseas market especial enter into China market then stand firm, obtain perhaps profits. For China side, government and relevant practitioners may introspect the policy, realize the sakoku problems (policy, law, review mechanism, and rampant piracy version), limit and

hinder China game industry and economic development, establish the regular view system in the future, and strengthen the protection of copyright. Actually, it is glad to see China Government is changing, in September, 2014, Xbox one will be sold in China by regular pathway.

However, there are some limitations and deficiencies existed in this chapter. First, the rootedness of Japanese national character seems so difficult to alter, on the other hand, China Government is powerful and rigid, and it will cost a long period to establish the classifying system. Second, in the section "Opposite phenomenon", the questionnaire data of Japanese and Western are not enough. Third, this chapter just shows some surface phenomenon and lack of deep analysis about why Japanese do not accept other country's game. Fourth, only formulating a reasonable price may not effectively improve the rampant piracy version, game industry personnel need more economy knowledge to make countermeasure.

In the future, researchers should expand the investigation sample to refine the survey result, then dig the deep reasons about Japan sakoku phenomenon to develop effective strategies to solve them. Finally, they should continue this research to find the culture common points and analyze how to sell games successfully in the global market.

# Chapter 10

# Conclusion and Future Work

In this chapter, we give the conclusion in this thesis. We answer our research questions and problem statement. Then, some future works are discussed.

## 10.1 Summary

We summarize our research result of each chapter as below:

- **Chapter 2: Basics of Game Refinement Theory**
  In this chapter, we retrospect the past work of game refinement theory. First, we present the physical model in human mind and infer the mathematical process to get the refinement value. Then, we present the several applications of game refinement theory within various games were analyzed which includes traditional boardgame, sports game and some modern video game. According to the analysis, we noticed that game refinement theory can be successfully utilized in each game domain to evaluate their excitement level. Therefore, game refinement theory is a reliable mathematical tool.

- **Chapter 3: The Application of Electronic Sports Game**
  We have successfully extend the game refinement theory application into Electronic sports game in this chapter. Consider the relationship between StarCraft II and Chess like game, we establish the strategy tree in StarCraft II and analyze the refinement value for three races. Besides, we consider the relationship between DOTA, HOS and basketball, we get the refinement value in different version of

DOTA and in different map of HOS. This means, we can use game refinement theory as a tool to judge and revise the parameter or mechanism in e-sports game.

- **Chapter 4: Comprehensive Application: Enhancing Level-up System in RPG Using Game Refinement Measurement**

  In this chapter, we solve a question: Game refinement theory not only can be the mathematical tool to judge how interesting and exciting a game is, but also using game refinement method to develop their projects where game refinement theory as a good inverse system. According to this idea, we provide three development comments and countermeasures for RPG game by using game refinement method.

- **Chapter 5: Solving the Sophistication Population Paradox of Game Refinement Theory**

  In this chapter we face the paradox of game refinement theory: Go and Soccer have similar game refinement value, but statistics show that soccer is more popular than Go. To solve the problem, we have found the meaning of Mass and Force in game refinement theory according to the Newtons classical mechanics. Based on the theorem of impulse, we educed the property concept and value of "unexpectedness" to patch the game refinement value. The concept of "unexpectedness scaling factor" can show whether a game is friendly to the freshman or weaker player .Usually, a high unexpectedness scaling factor game will gather more fans

- **Chapter 6: Mathematical Model of Ranking Accuracy and Popularity Promotion**

  In Chapter 5, we analyze the popularity issue by game refinement idea in board like game domain while in this chapter we analyze the popularity phenomena by ranking system in sports game. Comparing between the four mathematical models, we have found the advantages of each measurement. FIFA ranking system can provide more chance and interesting points for the supporter or fans and the most accurate measurement is Elo rating system.

- **Chapter 7: Possible Interpretations for Game Refinement Measure**

  This chapter focus on the parameter $c$ in the game progress model which has been ingored in Chapter 2. The parameter $c$ relates to the game balance. The condition

$c = 1$ corresponds to the case where the game is more chance-based. If the parameter $c$ becomes lower, the game will be more skill-based. Moreover, a new perspective of game refinement measure was obtained. Higher (lower) $R$ value means more entertaining (competitive), whereas 0.07-0.08 should be a comfortable zone due to its good balance between skill and chance in game playing. The analysis of popular MOBA games using game refinement measure supports the observation.

- **Chapter 8: Society Science Impact 1: Game Design by Cross Media**
  In this chapter, the society impact about game design, cross-media and Intellectual Property were analyzed. The investigation in the domains of Journey to the West such as novel, comic, film and game to draw the history and develop process, later the reason about why Journey to the West can be so success in China and East Asia was known. The successful cross-media case need have common four factors: free copyright, modern media technology, depth of IP and national soft power. According to this chapter, media worker could understand how to choose the topic to design a game, and recognize the method to spread their game IP widely.

- **Chapter 9: Society Science Impact 2: China and Japan Game Market Issue and Countermeasure**
  In this chapter, Japan and China game market problems have been shown. According to the contents, Japanese game designers could understand their weak points and imperfections, for the Japanese game companies, they will notice the method to enter into overseas market especial enter into China market then stand firm, obtain perhaps profits. For China side, government and relevant practitioners may introspect the policy, realize the *Sakoku* problems (policy, review mechanism, and rampant piracy version), limit and hinder China game industry and economic development, establish the regular view system in the future, and strengthen the protection of copyright.

## 10.2 Answer to RQ1 and RQ2

Above all of the contents in this thesis, thus we answer our research questions as below.

- **Research Question 1**

From Chapter 3, we know that game refinement theory can be successfully used in StarCraft II, DOTA, Heroes of the Storm. Using game refinement method, we can analyze each macro parameter, data and system in e-sports game. From Chapter 4, game refinement theory can be used as a tool to help developers to design a better game that makes players feel more exciting and interesting. Further, from Chapter 6, it is found that the game refinement theory even can judge whether each ranking system is reliable or not, then reveal the relationship between popularity and ranking system.

- **Research Question 2**

  From Chapter 5, we have found another property namely which known as "Unexpectedness Value" to judge whether a game can attract players or not, as game refinement theory just can judge whether a game is interesting, exciting or not. From Chapter 7, we notice that the meaning and function curve of board like game and sports like game are absolutely different. Moreover, the parameter "c" means the skill of players, regardless of the different game refinement value even it is out of zone, the value still have positive meaning.

## 10.3 Answer to Problem Statement

No matter the game refinement value or unexpectedness value, they are just the one parameter or property of the target game. Therefore, game refinement theory only can judge how exciting and how interesting a game is. However, high interesting level does not mean that it can attract more population to enjoy the game. In this case, we need to use unexpectedness value to judge the target game and show the friendly level of a game to the weaker player. StarCraft II and Go have the similar refinement value. However, the unexpectedness scaling factor and unexpectedness value of StarCraft II are higher than Go. Therefore, StarCraft II is more popular than Go.

## 10.4 Future Works

Future works are given below.

- **Game IP and Game Development**

  Until now, our game research only focus on the "research" or "Science". In my point of view, game needs to be played more important research target in the future. In Chapter 8, we have done the research about cross media and intellectual property sharing, I am always interested in explorer of China history and China culture, to make related theme game. The current Chinese game almost concentrated upon Three Kingdom or Journey to the West, however we have many subjects could be developed.

- **Serious Game**

  Serious game industry is the bright future in the world especially in China. In several conferences what I had participated, I have seen a lot of applications and researches about serious game. Serious games can be used in many domain such as education, health care, scientific research, emergency management, city planning, engineering, politics and war. China is following Japan entering into a population ageing society. Health care game can help the elder to have a heathen. Futhermore, educational serious game can change the stereotype images in teachers' and parents' mind, a good educational serious game can help children and students learn more efficiently. Therefore, no matter make project or do research, I am strongly believe that serious game should have a bright future and huge economic potential.

- **Game Future in China: The Combination of Industry, Official and University**

  China game market excessively leant into free market economy, Unfortunately, the players average quality is not so good. In this situation, China game market was inundated with online game, webgame and mobile game; at the same time, the console great opuses cannot be produced. Game designers and developers also only consider how to establish the mathematical model for money collection, free market, company competition, China game environment and profit push meanwhile ignoring the game quality. Therefore, from my point of view the aid of non-profit organizations such as government and university, which was defined as "Sankangaku Renkei" in Japanese. If we can make the project under combination of industry, official and university, game developers can focus their energy to consider how to make an inter-

esting and fantastic game. Future work will focus on establishing the "Sankangaku Renkei" mechanism in China.

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