Attractiveness of Real Time Strategy Games

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Abstract. Game refinement idea is a unique theory that has been proposed based on the uncertainty of game outcome. A game refinement measure was derived from the game information progress model and has been applied in the domains such as board games and sports games. The present challenge is to apply the game refinement theory in the domain of RTS games. 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.

Keywords: game refinement theory, StarCraft II, real time strategy game, game progress, strategy tree.

1. 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 [3][2]. 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 [6], which has been widely recognized as a useful tool in many fields such as economics, political science, psychology, logic and biology[10].

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.* [4][5], 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 board games including chess variants. Recently a general model of game refinement was proposed based on the concept of game progress and game information progress [8]. It bridges a gap between board games such as chess and sports games such as soccer. The next challenge is to apply the game refinement theory to RTS games.

In this study we have chosen the domain of StarCraft II, which is one of the most popular RTS games[13]. 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[12]. 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[11].

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

In Section 3 we present the game refinement theory and in Section 2 we will introduce the concept of Real Time Strategy Game. Then, a concept of strategy tree will be described in Section 4 while showing how to apply the strategy tree to StarCraft II. Section 5 presents an application of game refinement theory to StarCraft II. Finally, concluding remarks are given in Section 6.

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.[15]

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.[15]

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.[15]

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.[15]

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 unitłwhich 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.[15]

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.[15]

2.4.   The introduction of research object– 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 enemys 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.

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 1 have introduced the character of three races.[13]

3.   Game Refinement Theory

We give a short sketch of the basic idea of game refinement theory from [8]. 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

Table 1. The features of three races

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

in advance, the average number of total points per game may correspond to the steps to achieve the goal [9].

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 (1).

$$x(t) = \frac{G}{T}\, t \qquad (1)$$

However, the game information progress given by Equation (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 Equation (2).

$$x(t) = G(\frac{t}{T})^n \qquad (2)$$

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

Fig. 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 Δt^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 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 board games forms a linear graph with the maximum value $x(t)$ of B. Assuming $c = 1$, then we have a realistic game progress model for board games, which is given by

$$x(t) = B(\frac{t}{D})^n. \tag{3}$$

Equation (3) shows that the game progress in board games corresponds to that of sports games as shown in Equation (2).

To support the effectiveness of proposed game refinement measures, some data of games such as Chess and Go [4] from board games and two sports games [8] are compared. We show, in Table 2, a comparison of game refinement measures for various type

of games. From Table 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.

Table 2. Measures of game refinement for board games 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

4.   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 board games such as chess. It means that we can use some similar tools or methods to analyze the game of StarCraft II.

4.1.   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 [7]. 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 2.
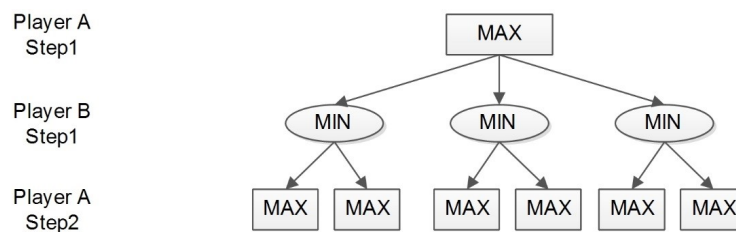

Fig. 2. The traditional minimax tree

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 are all defined

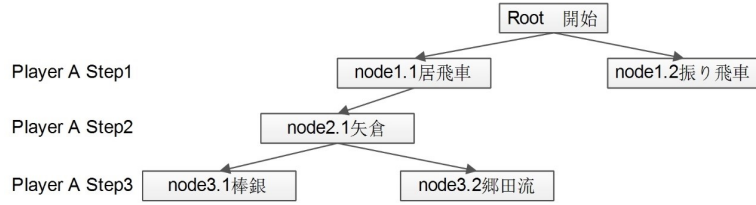as **strategy tree**. While player choose node1.1 , the next strategy must execute follow

Fig. 3. The 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 4.

Fig. 4. Strategy tree model for two players

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

4.2.   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 [1].

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 [13].

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.

Table 3. 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

In the opening, the StarCraft II is similar to real war or traditional board games. 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 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.

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 board games 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

Fig. 5. Feature of StarCraft II

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.

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 6.
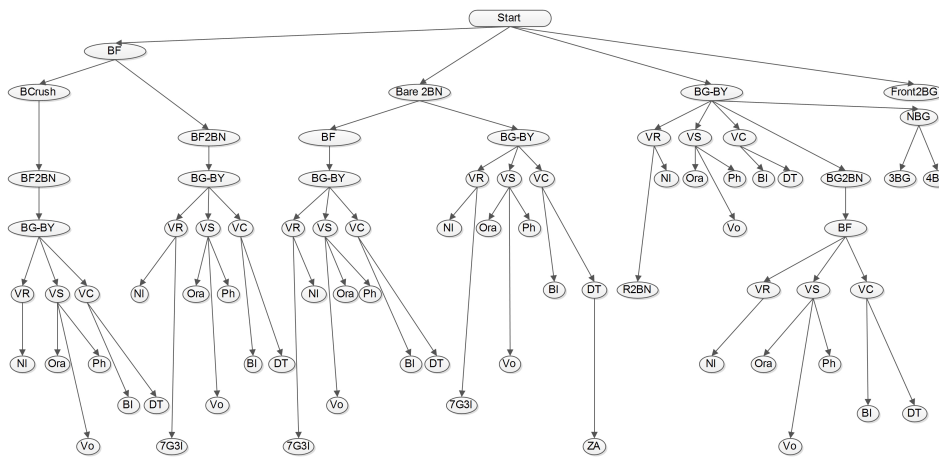

Fig. 6. The opening strategy tree of Protoss

In traditional turn-base board game, 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 7, we notice that the child node "BCrush" and "BF 2BN" have the different depth. This situation would never happen in traditional board games to build a minimax search tree. So we consider one method to solve it, while changing an unbalance depth tree into a balance tree.
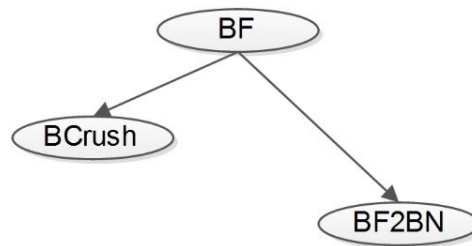

Fig. 7. An example of strategy tree with two unbalanced child nodes

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. 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 8 shows.
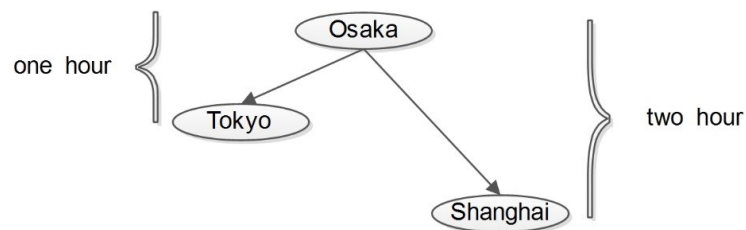

Fig. 8. The travel strategy tree of Prof.X

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 9. 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 10.
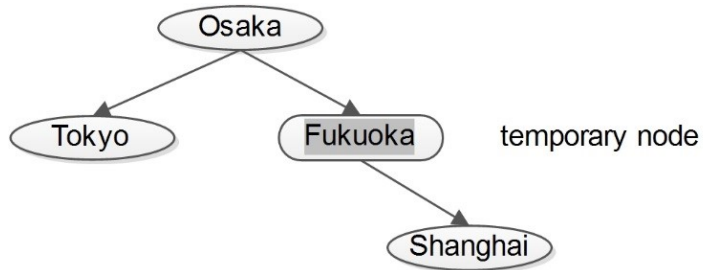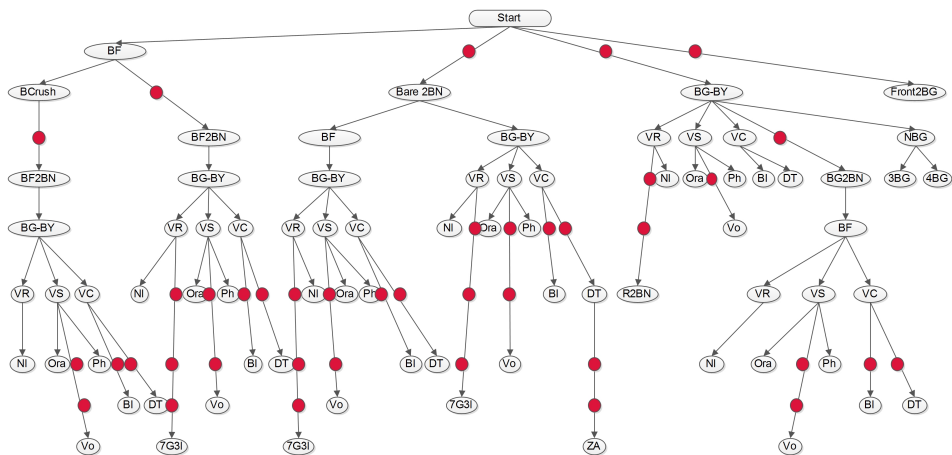
Fig. 9. Temporary node in unbalance strategy tree

Fig. 10. The new opening strategy tree of Protoss with temporary node

5.   Analysis of Attractiveness of StarCraft II

5.1.   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. 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.

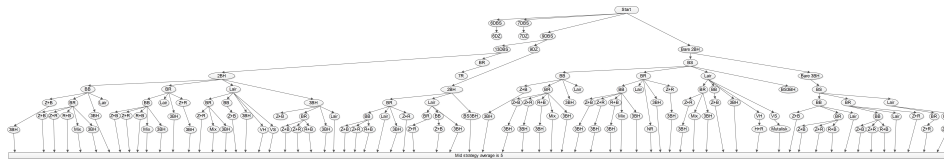
Fig. 11. The opening strategy tree of Terran

Fig. 12. The opening strategy tree of Zerg

In Figure 10, 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.

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

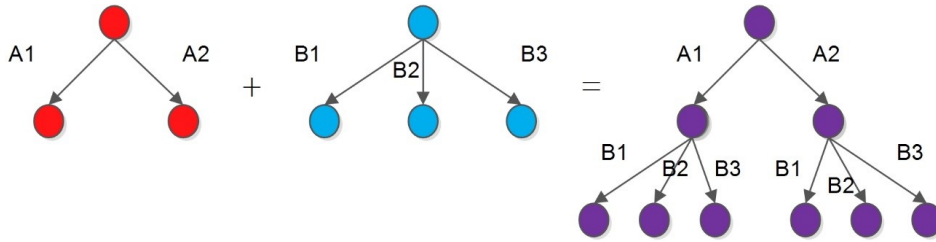$$R = \frac{\sqrt{B}}{2D} = \frac{\sqrt{1.57}}{2*9} = 0.0695.$$

Fig. 13. Combination of two strategy trees

Similarly, race Terran and Zerg also have their own strategy tree, then the game refinement value is calculated, as shown in Table 4. In this table, we notice that Zerg has two game refinement values.

Table 4. 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 (4).

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

Then we have the full data of every race's competition in Table 5:

Table 5. 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 board games, the result are closed, as Table 6 shows:

Table 6. Game refinement values for StarCraft II and board games

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

5.2. Discussion

As shown in Figure 11 and Figure 12, strategy trees of Terran and Zerg are more complex than Protoss. In particular Zerg's strategy tree has critical points, as shown in Figure 12. This means that game refinement value will change after crossing the critical point [13].

Below we show the illustration of tech tree structures of three different races. Figure 14 shows that Protoss tech tree is a branch tree. Terran tech tree is basic divergence linear, as shown in Figure 15. Moreover, Zerg tech tree is a disperse tree, as shown in Figure 16. Thus the different structures determine that Zerg has a strategy critical point in the opening stage, but Terran and Protoss have no such point.
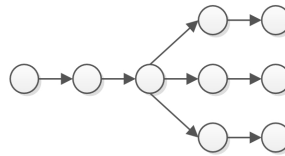

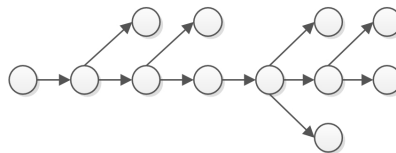**Fig. 14.** Protoss's tech tree structure

Fig. 15. Terran's tech tree structure

Compared with the StarCraft II ladder race ratio in Table 7, 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 fit the research result. In addition, as shown in Figure 17 [14], 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
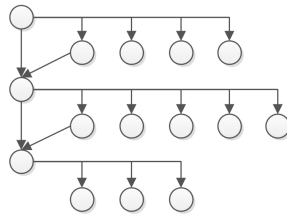
Fig. 16. Zerg's tech tree structure

Table 7. 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%

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.
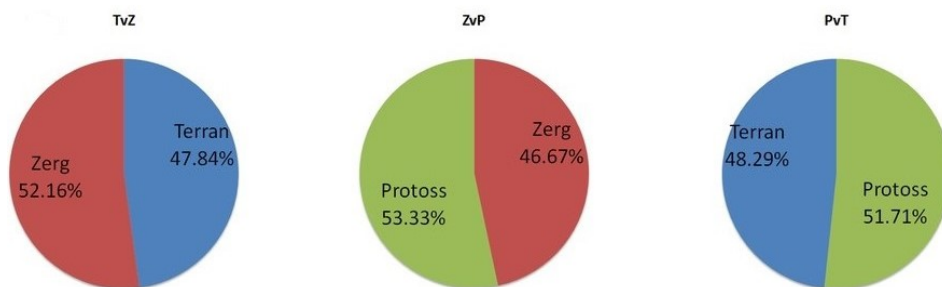

Fig. 17. wining percentage of three races

6.   Conclusion

While introducing the concept of strategy tree, 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 board games 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 model.

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