

# Advantage of Initiative Revisited: A case study using Scrabble AI

Htun Pa Pa Aung  
Entertainment Technology  
School of Information Science  
Japan Advanced Institute of Science and Technology  
Email: htun.pp.aung@jaist.ac.jp

Hiroyuki Iida  
Entertainment Technology  
School of Information Science  
Japan Advanced Institute of Science and Technology  
Email: iida@jaist.ac.jp

**Abstract**—This paper explores the advantage of initiative using Scrabble as a test bed. Recently, a list of solved two-person zero-sum games with perfect information has increased. Among them, most of the games are a win for the first player (i.e., the advantage of initiative), some are draws, and only a few games are a win for the second player. Self-play experiments using Scrabble AIs were performed in this study. The results show that the player who established an advantage in the early opening took higher win expectancy. This implies that the advantage of initiative should be reconsidered to apply for all levels including nearly perfect players. Thus, we meet a new challenge to improve the rules of a game to maintain the fairness. The game of Scrabble gives an interesting example while giving a randomized initial position. This discussion can be extended to other domains when AI becomes much stronger or smarter than before.

**Index Terms**—Artificial Intelligence, Advantage of Initiative, Fairness, Scrabble

## I. INTRODUCTION

Game has been as an ideal test bed for the study of Artificial Intelligence (AI). Until recently, most of the academic works in the area focused on traditional board games and card games, the challenge is to beat expert human players [10]. AI can be applied to most aspects of game development and design including automated content creation, procedural animation, adaptive lighting and intelligent camera control. While most games are developed to be fun to play, there exists a class of games developed as simplified models for the study of economics or social behavior and even for the improvement of the quality of education.

Now AI can utterly dominate humans within the world of gaming. One proof was demonstrated in chess with Deep Blue [5] beating the world champion Garry Kasparov in 1997. AlphaGo [13] showed its significant performance being much better than humans. Moreover, poker AI LIBRATUS convincingly beat four professional players [1]. In this study we have chosen Scrabble as the main test bed. Scrabble [2] is a board scoring game in which players place words with tiles with different scores using own rack onto a board. It is originally played by two or more players on a 15x15 grid of cells. It has been played for decades in various situations, for instance, as a competitive match between professional players or a friendly match among family members or students. Different players have different vocabulary knowledge and

supposed to play to get different experiences.

This paper concerns about “advantage of initiative” in games, which was discussed by Uiterwijk and Van den Herik [16] with respect to Singmaster’s reasoning [14]. The state of the current knowledge is that many games are a win for the first player, some games are draws, and only a few games are a win for the second player. The results indicate that having the initiative is a clear advantage under the condition that the board size is sufficiently large [17]. Van den Herik et al. [18] observed that in relatively many games on small boards the second player is able to draw or even to win. However, these observations were made under the assumption that the performance level is perfect or human-like (beginners to grandmasters). Thus, our research focuses on the level of more than human but not perfect. A question may arise: “What will the game-theoretic value be if both players are stronger than human but not perfect?” Since AI in games becomes (much) stronger than human, it is possible to find the answer.

The present contribution is expected to enhance the completeness of initiative from different perspective. Then, we focus on the advantage of initiative from the perspective of very strong players using Scrabble as a test bed. We conduct self-play experiments using Scrabble AIs of different levels to observe the impact of the initiative. Fairness or equality is another essential aspect of games. Without it, a game would lose its charm and therefore be forgotten in the past. So, it is a serious matter to maintain fairness as well as attractiveness in the history of the games [6]. Another question may arise: “Which factor should be considered to maintain fairness for those who are stronger than human but not perfect?”

The course of the paper is as follows. Section II describes the basic overview of Scrabble and early work of Scrabble. Section III discusses the advantage of initiative from AI’s perspective. Experimental evidence on playing Scrabble by AI is described in Section IV. Finally, Section V gives conclusions and future work.

## II. SCRABBLE AND ITS EARLY WORKS

### A. SCRABBLE

Scrabble is a game with a long history, which still maintains its popularity without major changes in its regulations. Scrabble is an imperfect information game but becomes a

perfect information game during the endgame phase. Scrabble is affected by the chance factor during the draw phase. In general, Scrabble is luck-dependent during the draw phase. Thus, both players cannot predict for a future draw. So, it is more effective to play with a local best move. Each move may lead to a different outcome. However, Scrabble is such a kind of two player scoring game played on the board.

### B. Early works with Scrabble

Scrabble has been an interesting target for search algorithm to develop the fastest one. Among many works, for example, see [4]. Another direction is to explore the entertaining aspect of playing Scrabble. Scrabble was analyzed using game refinement measurement. For example, the sophistication of Scrabble was assessed from the viewpoint of entertainment [8]. The results indicate that the game refinement value of Scrabble is slightly higher than the zone of well sophisticated games such as chess. We show, in Table I, the measures of game refinement for several games.

TABLE I  
MEASURES OF GAME REFINEMENT FOR VARIOUS GAMES

Game	GR
Scrabble [8]	0.083
Chess [7]	0.074
Go [7]	0.076
Basketball [15]	0.073
Soccer [15]	0.073

The swing model, a derivation of the game progress model, is defined to solve the nonidentical scoring system in Scrabble [8]. Swing denotes a notion of phase transition in mind from advantage to disadvantage and vice versa. In previous work [8], a computer program was built to simulate multiple Scrabble matches to estimate the game refinement value.

### III. ADVANTAGE OF INITIATIVE AND GAME-THEORETIC VALUE

A two player game with a turn to move would not be enjoyable if it cannot keep fairness of the winning ratio [6]. It is observed in the previous work [7] that it is more interesting for players to play a game in which the information about the game outcome is not clear at the very end of the game than to play a game where the outcome is already determined after a few rounds or stages. An important factor is that all players must feel fair in the game so that the game can maintain its attractiveness besides keeping some degree of competitiveness.

#### A. Advantage of the initiative

During the last decade, several two-person zero-sum games with perfect information have been solved [16] [18]. The state of current knowledge is that many games are a win for the first player, some games are draws, and only a few games are a win for the second player. Uiterwijk and Van den Herik [16] distinguished two main concepts valid for any two players games, namely initiative and zugzwang. The initiative was defined as an action of the first player. The results from their

experiments show that having the initiative is a clear advantage under the condition that the board size is sufficiently large. With respect to Singmaster’s reasoning [14] Van den Herik et al. [18] observed that in relatively many games on small boards the second player is able to draw or even to win. Thus, it can be assumed that Singmaster’s reasoning has limited value when the board size is small.

On the other hands, Kita and Iida [9] studied a link between the initiative and the game-theoretic value with a focus on the mobility in the initial position. The results of the exhaustive analysis of possible initial positions and game-theoretic values in the domain of 4x4 reversi show that the game-theoretic value is positively correlated with the mobility in the initial position.

Of all games solved, many are the first-player win [16]. These games show that having the initiative is an advantage. Therefore, it is worth investigating what happens if the initiative fails. In Table II, we have collected the main results known today [16] [18], in which 0 stands for the draw, 1 for a first player win, and 2 for a second player win.

TABLE II  
SOME GAME-THEORETIC VALUES OF GAMES KNOWN TODAY

Game	Result
Connect-Four	1
Qubic	1
Nine Men’s Morris	0
1xm Go (m =1,2,5)	0
1x3, 1x4, 2x4, 3x3, 3x4 Go	1
6x6 Othello	2
mnk-games(k=1,2)	1
333-game(TicTacToe)	0
mn3-games(m ≥ 4, n ≥ 3)	1
m44-games(m ≤ 8)	0
mn4-games(m ≤ 5, n ≤ 5)	0
mn4-games(m ≥ 6, n ≥ 5)	1
mn4-games(m ≤ 5, n ≤ 5)	0
mn5-games(m ≤ 6, n ≤ 6)	0
19, 19,5-game (Go Moku)	1
mnk-games(k ≥ 8)	0
mxm Domineering (m=1,5)	2
mxm Domineering (m=2,3,4,6,7,8)	1

#### B. Initiative in Scrabble

Scrabble is a scoring game played on the board which is slightly different from standard board games. According to its basic regulations and history, there is no fixed initial position in Scrabble. Letters are randomly distributed to each player in the initial stage of the game. In this paper, we investigate the impact of the advantage of early stages in Scrabble under the condition that the level of players are more than human but not perfect. In Scrabble, the initiative is defined as the action of each player in the first stage. To investigate the impact of the initiative in Scrabble, we set up experiments on Scrabble AI to collect data as well as from Scrabble human tournaments.

## IV. EXPERIMENTS AND RESULTS

### A. Human expert Scrabble players

1) *Human Scrabble strategy*: Human Scrabble strategy can roughly be defined according to the following four phases:

- 1) search for a bingo
- 2) search for hot spots
- 3) try to improve upon the results found, and
- 4) consider the rack leave

First, the player should always try to find a bingo by looking for either a 7-letter word using the entire rack or an 8-letter word that uses one tile from the board. Second, he can look for hot spots including premium squares which are different types, e.g., doubling and tripling the score of a letter and also doubling and tripling the score of a word. Third, he tries to get much advantage upon the previous result of the board. Finally, the player should consider the remaining rack leave for future steps because sometimes the current highest scoring move is not the best option and it can leave bad tiles in the rack for next move.

2) *Tournaments results of human expert players*: Normally, human players use a very common strategy to open the board with high scores. Such players would always want to keep the board open since they are more able to utilize the board's openness than their opponent. On the other hand, most human players use several strategies simultaneously. According to human tournament results, even the human experts have higher chance to be winner of the game when he took higher score as much as possible than his opponent in the first turn of the game.

TABLE III  
EARLY STAGE ADVANTAGE AND DISADVANTAGE COMPARED IN HUMAN EXPERT TOURNAMENTS (N=6000)

	Advantage	Disadvantage
Win ratio	4200 (70%)	1800 (30%)

### B. Scrabble AI – QUACKLE

Almost all of the improvements were driven by breakthroughs in artificial intelligence growing ability to understand complex nuances of the world around it. QUACKLE is not only a Scrabble Game but also an artificial intelligence and analysis tool. There are three key features in this AI from the perspective of artificial intelligence and analysis [11]. First, all the playable moves from the game current position. Second, QUACKLE can run a simulation, by playing itself hundreds of times, and tell the player how often each of these moves ends up winning. Third, the player can find out how many other mistakes the player made during the game.

1) *How QUACKLE works*: Computer Scrabble QUACKLE was used to simulate multiple scrabble matches with two AI players. The results with essential data with individual scores and total scores are collected. The database of estimated win probabilities was implemented by analyzing the distribution of

wins over many QUACKLE self-play games. This kind of win-percentage-based analysis is critical in a Scrabble AI when we need to erase a large deficit or protect a lead.

2) *Experiment results on Quackle*: In this section, the results of the experiment performed with QUACKLE are discussed. Although Player A and Player B have the same strength and they are almost perfect players, the player who got the advantage in the initial stage of the game has the higher probability to be a winner of the game. As shown in Figure ??, there are two QUACKLE AI with the same strength and Player B got an advantage at the early stage, so Player A has very low probability to win the game. At the final stage, Player A won the game because of the advantage in the first stage. We made Scrabble match simulation with QUACKLE. The players are almost perfect. The results are shown in Figure 1. No matter who got played first in Scrabble, the result in the first stage can guess the probability of winning fraction of scrabble. In Figure 1, there are total 60 matches by QUACKLE and from the results, the probability of winning fraction of the match can be estimated as shown in Table IV.

TABLE IV  
EARLY STAGE ADVANTAGE AND DISADVANTAGE COMPARED IN 6000 GAMES PLAYED BY QUACKLE

	Advantage	Disadvantage
Win ratio	4400 (73.3%)	1600 (26.7%)

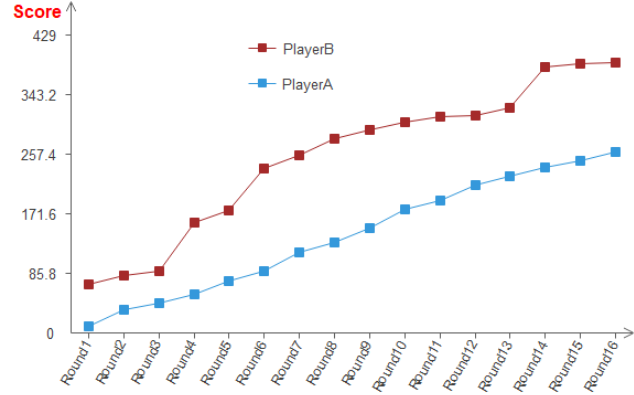


Fig. 1. A self-play experiment using QUACKLE: score at each turn

According to the experiment, only 11 out of 2566 games were tied (0.4 %), player 1 won 1404 games compared to Player 2s 1151 games. We can test if this is a significant difference using a binomial test.

### C. Scrabble AI – MAVEN

Maven [12] is another Scrabble AI, created by Brian Sheppard. It has been used in official licensed Hasbro Scrabble games. In 1983, Maven's first version was better than anything, but it was nothing special. By 1998, Maven had very good methods of controlling CPU utilization so that it could play at interactive speeds. This was the first commercial product that a

Perfect level. And then Maven Champion level was developed, it is probably stronger than human champions by seeing the statistics of tournaments' results.

1) *How Maven plays*: Maven is divided into three sub-phases: mid-game phase, pre-endgame, and endgame. Maven performs three basic operations to make the best move: move generation, rack evaluation and search and evaluation and simulation. Maven uses different search engines, each specializing in one phase of the game. One of the challenges of programming Maven was to produce the realistic play at the weak levels. Maven has a common-word dictionary that it employs at levels below Champion, and move generation strategies that result in low average scores without resorting to frequent exchanges.

As the primary goal of heuristic is to find the best matching solution of the original answer, Maven uses four main heuristics to select the most promising moves for a player [3]. The first one is called Vowel-Consonant for balanced rack management to examine if the rack has a right mix of Vowels and Consonants. The second is known as U-with-Q-Unseen to give a priority to play the words that contain a combination of Q and U. The third heuristic is called Hot-Spot Block where the board-square near the premium squares are blocked by the player in the current turn. The fourth one is First-Turn-Open that implies the importance of playing the first turn with a few tiles.

2) *Maven tournament statistics*: Maven plays better than the human experts [12], as shown in Table V. According to [12], Maven's total matches and tournament record is 3500 wins and 1500 losses against an average rating of 1975. Finally, what qualities of MAVEN make it such a very strong player? The reason is that MAVEN knows all the words, it evaluates the moves well, it plays fast that makes the other player into time trouble, it never loses a challenge and it plays endgames perfectly. MAVEN is a machine, so it never gets tired and inattentive. That is one of the significant factors in game play. Because of these skills, it becomes a formidable opponent for human players.

The biggest challenge in the world of Scrabble AI is met because no one disputes that MAVEN is better than any human seeing the statistics in Figure V.

TABLE V  
MAVEN AND HUMAN EXPERTS COMPARED [12]

	MAVEN	Human expert
Average Bingo per game	1.9	1.5
Average tiles played per game	4.762	4.348
Average turns per game	10.5	11.5
Chance to play Bingo if exists	100%	85%

TABLE VI  
EARLY STAGE ADVANTAGE AND DISADVANTAGE COMPARED IN MAVEN SCRABBLE TOURNAMENTS (N=5000)

	Advantage	Disadvantage
Win ratio	3500 (70%)	1500 (30%)

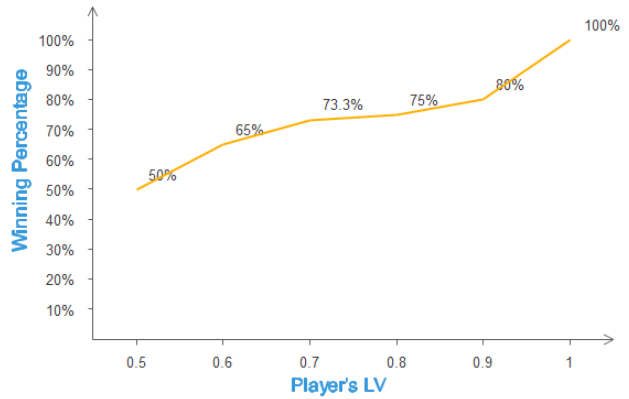


Fig. 2. Impact of Player's Strength on Winning Percentage

## V. CONCLUSION AND FUTURE WORK

Scrabble is the main test-bed of this study. We used our AI intelligent player, MAVEN, QUACKLE and human tournament statistics to deeply comprehend its special characteristics. The notion of initiative introduced by Singmaster [14] can be considered for players of normal level from beginners to grandmasters. While AI is becoming stronger than human and even at nearly perfect level, we revised the earlier model from the perspective of different player's level (from intermediate to perfect) in Scrabble game. Singmaster (1981; 1982) showed a reasoning of why first-player wins should abound over second-player wins. However, Van den Herik et al. (2002) observed through the exhaustive computer analysis that in relatively many games on small boards the second player is able to draw or even to win [18]. Hence, it is assumed that the Singmasters reasoning has limited value when the board size is small.

From an investigation of solved games the concept of initiative seems to be a predominant. Thus, in our study, we observed that if the player got advantage in the first stage of the game, the initial position of a given game would take an advantage of the initiative and he has also higher winning percentage. The higher the player's level is, the greater winning percentage he takes. However, it is supposed that although real match between novice players is difficult to obtain if the level of players are not very strong and they have different strength, we could say that they probably have equal chance to win the game. Moreover, the decision complexity of both of human players is almost the same. But for AI players, the decision complexity of winner is slightly higher than that of a loser.

There is still an important issue, i.e., all participants must feel fair in the game. The next step is to consider fairness issue for AI players in Scrabble game. Moreover, one possible way is to enhance the original rules of Scrabble which would make both AI players to get fairness. Clearly, it will be more interesting for players to play a game in which the information about the game outcome is not clear until the very end of the game. For future work, fairness needs to be considered not only in Scrabble but also in other domains as well. It is an

important factor not only for games but also in society. Further verification and investigation are also left for future work.

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