Informatical Analysis of Go, Part 1: Evolutionary Changes of Board Size

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***Abstract*—This paper explores the nature of the Go game. Go has been played on different size of the board in its long history where it was born in 2356 BC and played on 9×9 board, and later played on 13×13, 15×15, 17×17, 19×19, and 21×21 board. Self-play experiments using an open-source implementation of AlphaZero, namely LeelaZero, as the artificial intelligence (AI) player, are conducted for data collection, whereas game refinement (GR) measures had been employed for the assessment. An informational analysis indicates that Go game have been searching not only for a harmonic balance between deterministic and stochastic aspects found in the similar board games (Chess and Mahjong) but also the expected fairness when playing Go. Three aspects of the game have been analyzed: the perspective of game designer (using the GR measure), the perspective of Go evolution relative to Chess and Mahjong evolutionary histories, and other perspectives that closely related to the cultural and strategic development of Go game. Based on such aspects, the impact of komi values and the reasons for 19×19 board size to the contemporary Go popularity had been identified.**

***Index Terms*—Boardgame, game refinement theory, evolutionary history, Go, komi**

I. Introduction

Game is a form of entertainment and excitement that people pursuit since the dawn of a human civilization [1]. Understanding the evolution of games may lead to the understanding of human pursuit in games; thus, understanding the human pursuit in life. One of the oldest games in the world is Go, which potentially originated from China some three to four millennia ago[1]. Investigating the evolutionary history of Go, the evolution of rules of the Go game may also be potentially discovered. One of the crucial questions of the modern board game of Go, also corresponds to the research question of this study, is how the game comes to 19×19 board size? Interestingly, the first introduction of the Go game by the Chinese Emperor Yao is a Go game with a board size of 9×9. Also, it is interesting to explore the differences in the evolutionary history of the Go game compared to other similar board games.

The objective of this paper involves exploring the evolutionary history of the Go game. The main focus of this paper is the evolutionary changes of the board size impacted the play experience of the board game as well as the entertainment expected from the players. The game refinement (GR) theory was adopted to quantify such aspects where data collected from the Go game were analyzed to provide the insights necessary for understanding the implications of the modern version of the Go game. Note that this study is the continuation of the work previously conducted on Chess and Mahjong [2], which differed from this study based on three aspects. Firstly, this study focuses on the evolutionary history of the Go game. Secondly, this study specifically focuses on the development and impacts of physical changes in the Go board sizes. Finally, this study also considers the impact of komi values towards the expected sophistication of the Go game, especially the contemporary Go board size (19×19) through the application of the game refinement (GR) theory.

The structure of the paper is given as follows. Section II presents a brief history and origin of the Go game. The methodology and application of the game refinement theory to analyze the Go evolutionary history are given in Section III. Then, Section IV presented the results obtained from the methodology conducted, and further discussion on the result analysis is presented. Finally, Section V concludes the paper.

II. History of Go

A board game is a tabletop game that involves counters or pieces moved or placed on a pre-marked surface or "board", according to a set of rules. Some board games are based on pure strategy, but many contain an element of chance, and some even purely chance-based, with no element of skill. Go game is one of such tabletop games and typically known as two-players abstract strategy board game [3] where the goal is to surround more territory than the opponent. A survey in 2016 conducted by the International Go Federation, there are over 46 million people worldwide, know about playing the Go game, and over 20 million people who live in East Asia are the current players of Go[2].

The playing pieces are called "stones". One player uses the *white* stones and the other, *black*. The players take turns placing the stones on the vacant intersections ("points") of a board. Once placed on the board, stones may not be moved, but stones are removed from the board if "captured". Capture happens when a stone or group of stones is surrounded by

[1]https://www.britgo.org/intro/history

[2]https://www.intergofed.org/

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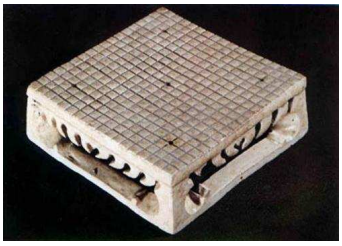
opposing stones on all orthogonally-adjacent points. The game proceeds until neither player wishes to make another move. When a game concludes, the winner is determined by counting each player's surrounded territory along with captured stones and *komi* (points added to the score of the player with the white stones as compensation for playing second). Games may also be terminated by resignation.

The Go game is believed to be the oldest board game continuously played to the present day and was conceived in China more than 2,500 years ago [4]. The historical annals Zuo Zhuan (4^{th} century B.C.) that refers to a historical event of 548 B.C., is the earliest written reference to the Go game [5]. The Go game is referred to as $y\grave{i}$. Today, in China, it is known as $we\acute{i}q\acute{i}$, that literally means the "encirclement board game".

Legends traced the origin of the game to the mythical Chinese Emperor Yao (2337 - 2258 B.C.), who was said to have had his counselor Shun design the Go game for his unruly son, Danzhu, to gain favorable influence over him [6]. Other sources pointed-out the Go game from the pottery pots unearthed at the end of primitive society in Yuanyangchi, Shuichang County, Gansu Province (Figure 1(a)). The shape is very similar to the current Go board, but the vertical and horizontal lines are only 11 to 13, rather than 19×19. A model of the Go board was excavated in 1959 from the tomb of Zhang Sheng at Anyang, Henan Province, with 19×19 lines that formed 361 crossing points, which can be dated from 595 A.D. (Figure 1(b)).

(a) Unearthed pottery pots with shapes similar to Go board



(b) A 19×19 Go board model from a Sui dynasty (581–618 C.E.) tomb

Fig. 1. Origin traces of the Go board

Four-persons Go, also known as "four-country Go," is a variant of Go game that was played by four peoples together. The rules of the game are roughly the same as those of two-persons Go. Black and white stone pieces can be used as well as adding other colors, which resulting in four-colored pieces to play the game. Two people play in a team or four people play independently [7] [8] [9] [10] [11].

A. Ancient Go rules

There are several ancient Go rules adopted along with the incremental changes of the Go board game. Several variants are available depending on the country. Today only Tibetan' Go still uses 17×17 board, with slightly different rules of play from go elsewhere [12] [13] [14]. The major differences in the rules between Chinese, Japanese, and Korean version of Go are the initial set-up, handicaps, and the method of counting up a finished game.

In Chunqiu times (770 BC - 453 BC), the two eye rules were born. If both sides do not have qi (liberty), every stone remaining on the board must have at least one open "point" directly orthogonally adjacent, or must be part of a connected group that has at least one such open point ("liberty") next to it. Stones or groups of stones which lose their last liberty are removed from the board.), both side keeps the pieces of the previous player's turn. The production of two eyes live rule, dramatically enriches the changes of Go, and makes it a game with self-improvement of logic [15]. Then, came the birth of the K.O. rule.

Another ancient Go game rule is Zouzi, which means pedestal or in the context of Go game, initial positions. The rule is one of the earliest rules adopted in the Go game during the ancient Chinese period, which differed from the modern Go rules. It involves putting four stones at the stars, which are on the corner, two blacks and two whites in a staggered arrangement. For example, when play go with no komi and no zuozi, the black can put the first step in the middle, then imitate the white to win the game. Zuozi can effectively avoid imitating chess [15].

Another related ancient Go game rule is the Huanqitou [15] [16]. Every time one player separates stone pieces of another player, the opponent will give a point to that player when the game finally calculates the victory or defeat. For example, when a game is over, if black had three pieces and white had only one piece, then the black should give two points back to the white. Table I and Table IV summarizes the historical overview of the development of the Go game and the rule changes of Go game based on location and time.

III. Assessment Methodology

In this study, the method of assessing the evolutionary history of the Go game is conducted primarily through the adoption of an open-source game-playing algorithm, known as the Leela Zero, to play the Go game for data collection. Also, the application of the game refinement (GR) theory to the collected data is conducted to quantify the evolutionary trends of the Go game. The assessment method is framed within the aspects of the evolutionary change of the Go board game, in particular, the physical board sizes. A similar measure of GR is conducted on Chess and Mahjong, which is used as the benchmark game for comparative purposes [2].

A. Game refinement theory

The game refinement (GR) theory is a logistical model of game progression, interpreted from the perspective of the game designer [23] [24], first formally proposed by [25]. The information on the game result is an increasing function of time (the number of moves in board games) t. Here, the information on the game result is defined as the amount of solved uncertainty (or information obtained) $x(t)$, as given by (1). The parameter n (where $1 \leq n \in N$) is the number of possible options and $x(0) = 0$ and $x(T) = 1$.

TABLE I
HISTORICAL OVERVIEW OF GO RULES

Time period	Remarks	Size	Fairness Measure
2356 BC	Yao created Go game to teach his son Danzhu [4]	9×9	
2130 BC	Pottery jar with Go board pattern (11 to 13 lines above)		
770-476 BC	Two eyes rule was conceived [15]		
400 BC	The earliest ancient records of Go (Zuo Zhuan) [5]		
200 BC	A damaged pottery Go board unearthed from an archaeological excavation It is also likely to be a chessboard with 15 or even 17 lines During the period of Qin and Han Dynasty alternation, Go was introduced to Korea	13×13 15×15	Huanqitou,Zuozi?
25-220 AD	A stone Go board was discovered in tomb (Eastern Han Dynasty) Zuozi begin to prevail [11]	17×17	Huanqitou,Zuozi?
1st-4th AD	Go was introduced to Japan	17×17	
4th AD	Go was introduced to Tibet	19×19	
420-589 AD	Go rules are formalized [17] It is recorded that the Go board has changed to 19 channels Zuozi came to 4 from 5	19×19	Huanqitou,Zuozi
6th	A small White Porcelain Go Board with 19 lines	19×19	Huanqitou,Zuozi
13th-16th AD	Territory scoring into area scoring in China (Ming dynasty)	19×19 21×21?	Huanqitou,Zuozi
1253 AD	A small White Porcelain Go Board with 19 lines	19×19	Huanqitou,Zuozi
1939	Komi was invented in Japan	19×19	
1949	Modern Japan rules [18] Modern China rules (reference to the Japanese rules) Zuozi is canceled	19×19	Komi (4.5)
1964	Komi was changed to 5.5 [19]	19×19	Komi (5.5)
2000	Korea changes Komi to 6.5 [20]	19×19	Komi (6.5)
2001	China changes Komi to 7.5 [21]	19×19	Komi (7.5)
2002	Japan changes Komi back to 6.5 [22]	19×19	Komi (6.5)

TABLE II
RULES CHANGES BASED ON LOCATION AND TIME [18] [19] [20] [21] [22]

Location	Board size	Changes	Century*
China	9×9?	Play until no space available	2356 BC
China	13×13		200 BC
China	15×15		200 BC
China	17×17		1st - 2nd AD
China	19×19		4th - 6th AD
China	21×21		Unknown
China	19×19	Initial stone placement	6th - 20th AD
China	19×19	"Return chess head"	14th AD
Japan	19×19	Komi 4.5	1949
Japan	19×19	Komi 5.5	1964
Korea	19×19	Komi 6.5	2000
China	19×19	Komi 7.5	2001
Japan	19×19	Komi 6.5	2002

*estimated based on available records

$$x'(t) = \frac{n}{t}\ x(t) \tag{1}$$

$x(T)$ stands for the normalized amount of solved uncertainty. Note that $0 \leq t \leq T$, $0 \leq x(t) \leq 1$. The rate of increase in the solved information $x'(t)$ is proportional to $x(t)$ and inverse proportional to t, which is given as (1). Solving (1), (2) is obtained. It is assumed that the solved information $x(t)$ is twice derivable at $t \in [0, T]$. The accelerated velocity of the solved uncertainty along the game progress is given by the second derivative of (2), which is given by (3). The acceleration of velocity implies the difference of the rate of acquired information during game progress. Then, a measure of game refinement (GR) is obtained as the root square of the second derivative (Eq. 4).

$$x(t) = \left(\frac{t}{T}\right)^n \tag{2}$$

$$x''(t) = \frac{n\ (n-1)}{T^n}\ t^{n-2}\ |_{t=T}\ = \frac{n\ (n-1)}{T^2} \tag{3}$$

$$GR = \frac{\sqrt{n\ (n-1)}}{T} \tag{4}$$

A skillful player would consider a set of fewer plausible candidates (say b) among all possible moves (say B) to find a move to play. The core part of a stochastic game assumed that each among b candidates may be equally selected. Knowing that the parameter n in (4) stands for the number of plausible

moves b, $n \simeq \sqrt{B}$ is obtained. Thus, for a game with branching factor B and length D, the GR can be approximated as in (5). Similarly, the GR measure to analyze Chess and Mahjong is also conducted (see [2] for further details).

$$GR \approx \frac{\sqrt{B}}{D} \tag{5}$$

The sophistication of games was found to have almost the same degree of informational acceleration value, which is within $GR \in [0.07, 0.08]$ (Table III).

TABLE III
MEASURES OF GAME REFINEMENT FOR BOARD GAMES USING HUMAN DATA [25] [24]

	B	D	GR
Chess	35	80	0.074
Shogi	80	115	0.078
Go	250	208	0.076

Let t be the length of a given game, then solved uncertainty $y(t)$ is given by (6). A sophisticated game postulates an appropriate game length to solve uncertainty while gaining the necessary information to identify the winner. If the game length or the total score is too long (or too short), the game would be boring (or unfair).

$$y(t) = mt \tag{6}$$

The GR measures correspond to the sense of informational acceleration encoded and transported in our brain, which likely to obey the forces and laws of physics. Applying (4) and (6), the cross point (say t_0) between $y(t) = mt$ and $y(t) = \frac{1}{2}GR^2t^2$ is found at $t_0 = \frac{2m}{GR^2}$. The cross point t_0 indicates the right balance between skill and chance given by the informational acceleration in the game under consideration. Thus, (7) can be deduced for m, which corresponds to the levels of sophistication that meets fairness, gamified experience, and the sense of comfortable thrill.

$$m = \frac{1}{2}\frac{B}{D} \tag{7}$$

B. Leela Zero algorithm for Go

In order to understand the rules of Go at different times (see Table IV), Leela Zero algorithm is adopted to self-play against itself to get data. Leela Zero's algorithm is based on DeepMind's 2017 paper about AlphaGo Zero [26]. Unlike its predecessor, the original Leela, which has a lot of human knowledge and heuristics programmed into it, the Leela Zero algorithm is a "tabula rasa" algorithm where it only knows the basic rules to play the game. The knowledge that makes the Leela Zero algorithm becomes a strong player is contained in its neural network architectures. Such architecture is trained based on the results of previous games that the program played [27].

The Leela Zero algorithm utilizes the Monte-Carlo tree search (MCTS) technique (exclusion of the MCTS playout stage) and a deep residual convolutional neural network stacks. The MCTS originated in statistical physics, which used to obtain approximations to intractable integrals, and has since been adopted in a wide array of domains, including games research [28]. In Leela Zero, the MCTS is a reasonably faithful re-implementation of the algorithm described in AlphaZero paper [26]. Nevertheless, the playing strength of the Leela Zero lies in the self-training phase of the algorithm which contained in its network weight values. By adopting the Elo rating system [29], which often used to rate player's strength[3], the playing strength of Leela Zero utilized for this study is rated to be better than the grandmaster player performance which is 3726 Elo rating (3600 Elo rating is similar to AlphaGo that beat Lee Sedol [26]).

In order to adapt Leela Zero algorithm with respect to the interests of this work, some modifications is conducted. Firstly, the board size is resized based on the evidence of the evolutionary history of the Go board sizes. As such, six board size variants are considered: 9×9, 13×13, 15×15, 17×17, 19×19 (contemporary version), and 21×21. Secondly, the changes of the komi values is adopted based on the most recent changes of the komi values.

C. Experiment Setup

The experiment is conducted in two stages: the training phase and the testing phase. The training phase is initiated by training the Leela Zero algorithm (denoted as the AI player hereof) to play against itself in the game of Go, where the starting Elo rating of the AI player is about 3726 from the start[4]. The training is conducted for 1000 games on each board size considered for this study, which is six in total (9×9, 13×13, 15×15, 17×17, 19×19, and 21×21). The training time for each game for 9×9, 13×13, 15×15, 17×17, 19×19, and 21×21 board sizes were about 5 minutes, 7 minutes, 15 minutes, 18 minutes, 20 minutes, and 25 minutes, respectively.

The testing phase of the experiment was conducted in twofold. Firstly, a supposedly superhuman-level performance of the AI player is adopted to self-play against itself for 1000 times for each board size (six board sizes) on a 7.5 komi value. Secondly, a similar experiment setting with the same AI player is also conducted for each board size but with different komi values (5.5, 6.5, 7.5, 8.5, and 9.7). The results interpretation is also conducted through the GR theory concerning the evolutionary history of Go and other relevant factors that lead to the contemporary version of the Go board (19×19 board size).

IV. EXPERIMENTAL RESULTS AND DISCUSSION

A. Interpretation from the game refinement perspective

In order to study the influence of board size changes based on the evolutionary history of Go, utilizing the modern rules of Go, data collection was conducted with respect to the

[3]The basis of the Elo rating system involves assigning each player a rating where this rating is updated after each match.

[4]The LeelaZero is equipped with the network weights of about 3726 Elo rating downloaded from http://zero.sjeng.org/

different board sizes (Table IV). The komi value is fixed to 7.5, following the most recent change of komi value in professional Go competition in Japan [18].

Observing the pattern of the data with the increase in the board size, the length of the optional branches and games in each sizes increases significantly. Furthermore, the GR value of the game is relatively reduced, and finally, 17×17 and 19×19 fall within the GR "zone" values ($GR \in [0.07, 0.08]$). This trend can be better observed in Figure 2, where changes of the board size showed convergence of its GR values towards the "zone."

The results in Table IV is aligned with the Go board of 19×19 size obtained from human data (grandmaster player) where the $GR = 0.076$ (see Table III). For the Go board of 19×19 sizes in this study has obtained $GR = 0.0758$, which have slightly higher branching factor and game length. This case is due to several factors. Compared to the case of the Go game that uses human data, the AI player was able to solve more information and played longer games. Thus, it can be conjectured that m also relates to the strength of the player, where high player strength approaches $m = 1$, and vice versa. However, such conjecture may require further evidence from future studies.

The convergence of the Go evolution may imply that the 19×19 board is the best direction possible for the Go game. Compared to the 21×21 board, the 19×19 board situated within the GR zone, which means that it has enough sophistication as a board game that harmonically balances the aspects of skill and chance within the game. Also, the 21×21 board seems to have higher game length, which translates to more conservative gameplay and even considered it less exciting or boring.

From another perspective, the parameter $m = \frac{1}{2}$ (see Eq. 7) lies in what perceived to be a *strongly fair* game. This situation corresponds to $B \simeq D$, which is typically portrayed by the evolution of the Go game. However, while Go board of 9×9, 13×13, 15×15, 17×17, and 21×21 were more inclined towards the $m = \frac{1}{2}$ line, it does not applies for the 19×19 case. Several factors may cause these situations. First, 19×19 Go board retains some other aspects that make the game more thrilling, thus justified it positioned in the GR "zone" (see Section IV-D for some examples). Second, 19×19 Go board provides the most appropriate sophistication compared to other board sizes (either outside the sophistication zone or close to the $m = \frac{1}{2}$ line). Third, the adopted komi value may influence the gameplay of Go dependent on the size of the board.

B. Interpretation relatives to other board games

Figure 2 also shows the historical evolution of the Go board in comparison to Mahjong and Chess. It can be observed that the evolutionary direction of these three kinds of games is very different.

The evolution of Chess follows the trend that game complexity increases first and then decreases, while the GR value decreases first and then increases. It is worth noting that the game length increases slightly which then decreases drastically, while slowly increasing its branching factors. Such situation implies that Chess is directed towards development of skill-based playing, where manipulation of the available in-game information is vitals.

In contrast, the complexity of Mahjong first decreases and then increases, while its GR value first increases and then decreases. The evolution of Mahjong showed that their game length decreases drastically, which then increases again, while the opposite was true for its branching factors. Such trends showed the evolution of Mahjong is directed towards increasing reliance on chance-based playing, where major part of its game play is heavily dependent on player's intuition and experience.

Eventually, both converge towards approximately similar "zone" region known as the "noble uncertainty" ($GR \in [0.07, 0.08]$). Such a zone is uniquely related to the sophistication of the classic board game, where the appropriate uncertainty solved within the appropriate amount of time makes the game felt exciting, attractive, and thrilling to play.

However, different from Mahjong and Chess, the Go game took the "middle-ground" trend between them. Based on the results in this study, with an increase in the board sizes, the complexity and the GR value gradually increases and decreases, respectively. Such a situation showed that the Go game had been carefully designed to balance the game, not only on the skill and chance but also on the perceived "fairness."

As provided in Table IV, the wining rate gradually increases towards ≈50% for the board size of 17×17, 19×19, and 21×21, which also implied that the game is relatively fair. In another perspective, the evolutionary trend of the Go game tends to follow the line of $m = \frac{1}{2}$; thus, translate to the $B \simeq D$ that corresponds to the game being *strongly fair* in term of its in-game progression, compared to the *weakly fair* portrayed based only on the winning rate (game outcome).

C. Interpretation based on different komi values

According to the results obtained from the previous experiments based on the 7.5 komi value, another experiment was carried out based on the neighboring komi values for each board size. Then, the appropriate komi for different board sizes can be roughly estimated through the experimental results (Table V). The standard komi value is set at 7.5, where only komi value less than the standard is tested for smaller board size (9×9 and 13×13), higher and lower komi value is tested for larger board size (15×15, 17×17, and 19×19), and finally larger komi value is tested for the largest board size (21×21). The rationale here lies in determining the effect of the komi have on the winning rate, which is roughly relevant to the specific board sizes.

Observing Table V, the winning rate based on the komi values estimated from each board size is relatively inconsistent and maintaining a $\approx 50\%$ winning rate is tricky. An exception case is the 19×19 board, where the game outcome is relatively fair with 7.5 komi value. This situation implies that the perceived fairness of the game outcome is not reflected by the

TABLE IV
RESULTS OF SELF-PLAY EXPERIMENTS WITH CHANGES OF BOARD SIZE (FIXED KOMI OF 7.5)

Board size	B	D	Win rate*		GR	Data sample
			Average	Std. Dev.		
9×9	52.1	62.06	0.423	0.4940	0.1163	400
13×13	107.4	105.73	0.461	0.4985	0.0980	400
15×15	152.3	145.31	0.470	0.4991	0.0849	400
17×17	203.4	175.51	0.489	0.4998	0.0813	400
19×19	255.5	210.90	0.503	0.4999	0.0758	400
21×21	310.1	290.15	0.526	0.4993	0.0607	400

*winning rate of the first player (black player); Std. dev.: standard deviation

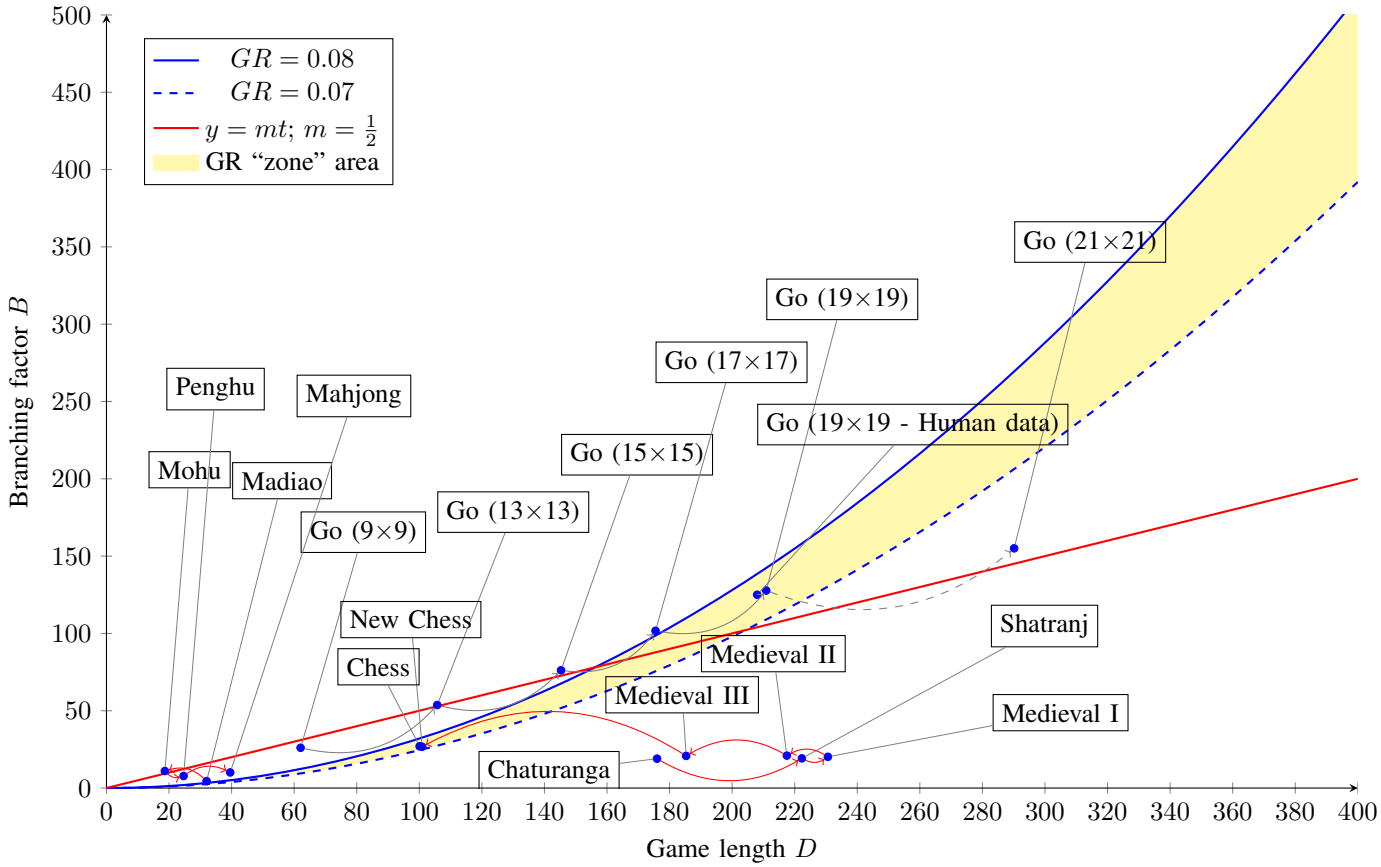


Fig. 2. Evolution of games: Chess, Mahjong and Go (7.5 komi) compared

contemporary komi value (7.5) and perceived to be uniquely tied to the 19×19 board. As such, it can conclude that the 7.5 komi value is not suitable for all board sizes. To ensure the perceived fairness of the game can be maintained across different board sizes, different komi values are needed.

D. Interpretation from other factors

After thousands of years of evolution, the Go game has finally retained the contemporary board size, which is the 19×19. By looking from the perspectives of cultural and strategic point-of-view, the reason for such a Go board size can be further strengthened.

From the cultural perspective, the Go board size of 19×19 corresponds to the initial astrological connotations (19×19 = 361, which is approximately the number of days in a year) [19]. The color of the stone pieces (black and white) symbolizes the sun and moon, Yin and Yang, as well as day and night. In another view, the round stone pieces symbolize the sky, and the board itself symbolizes the universe, while the four corners of the board symbolize the four cardinal directions (north, south, west, and east). Such a view implies the Go game to be aligned with the legend of the round sky and square earth[5] and have primarily influenced the ancient

[5]https://en.wikipedia.org/wiki/Flat_Earth

TABLE V
EXPERIMENTAL RESULTS WITH CHANGES OF KOMI VALUE BASED ON DIFFERENT GO BOARD SIZES

Board size	Komi value	Win rate*		Sample
		Average	Std. Dev.	
9×9	5.5	0.67	0.4702	100
9×9	6.5	0.51	0.4999	100
9×9	7.5	0.42	0.4936	100
13×13	5.5	0.54	0.4984	100
13×13	6.5	0.48	0.4996	100
13×13	7.5	0.46	0.4984	100
15×15	6.5	0.53	0.4991	100
15×15	7.5	0.47	0.4991	100
15×15	8.5	0.44	0.4964	100
17×17	6.5	0.54	0.4984	100
17×17	7.5	0.49	0.4999	100
17×17	8.5	0.46	0.4984	100
19×19	6.5	0.52	0.4996	100
19×19	7.5	0.50	0.5000	100
19×19	8.5	0.48	0.4996	100
21×21	7.5	0.53	0.4991	100
21×21	8.5	0.48	0.4996	100
21×21	9.5	0.38	0.4854	100

*winning rate of the first player (black player);
Std. dev.: standard deviation;

Chinese culture in the perception of geography, architecture and coin design[6].

Another hypothesis as the reason for the contemporary Go board size of 19×19 relates to the strategic perspective of the gameplay, which specifically relates to the idea of balance. On a 19×19 Go board, the 3rd line is the territory line, while the 4th line is the influence line. Fifty-six stones are required to obtain all the points on the 3rd line and below, which resulted in 136 points in total. If we want to get all the points in the center on the 4th line and above, a total of 48 stones is needed, which resulted in 121 points in total (see Figure 3).

Taking the average number of points per stone for those cases, where $136/56 = 2.4286$ (for the sides and corners) and $121/48 = 2.5208$ (for the center), the difference between the two values is 0.09 points, which is almost negligible. This situation means that the efficiency of the stones on the 3rd line and those on 4th line are almost similar [30]. If the size of a go board gets bigger or smaller, it will lead to an imbalance between territory and influence. The value of the center will be different from that of the sides and corners. As such, the strategic balance is preserved for the 19×19 board size of Go.

V. CONCLUSION

This study had found interesting evolutionary changes of the Go in the aspect of the physical board sizes. Regardless of the evolutionary direction of the compared games (Chess and Mahjong), Go game also eventually converged toward the sophistication "zone" of the game refinement measure ($GR \in [0.07, 0.08]$) while having another unique tendency

[6]http://chinesecoins.lyq.dk/

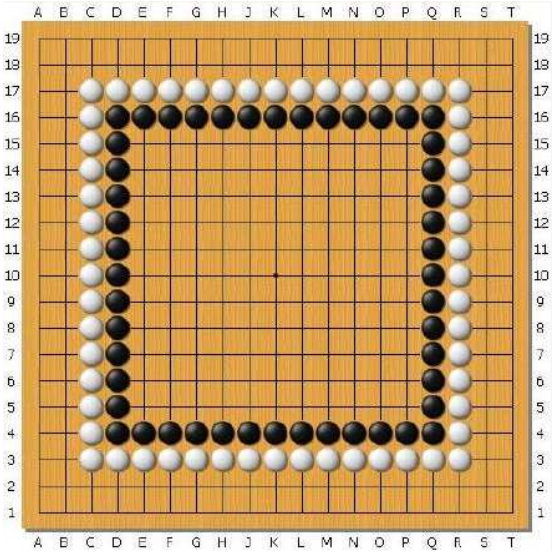


Fig. 3. Sample for divide

that focuses on the expected fairness in play. These lead to the understanding of the parameter $m = \frac{1}{2}$, which implies game that lies on such line perceived to have a *strongly fair* gameplay progression; thus, justifying their survival as a contemporary game.

Also, observing the effects of the modern Go game rules, *komi*, showed that the 19×19 board game provides the best-perceived fairness using the 7.5 komi value, compared to other board sizes. By observing from another perspective, such a situation is further justified by the harmonic balance between skill and chance required to experience an exciting and thrilling play portrayed by the levels of sophistication that considered to be part of "noble uncertainty" [2]. Also, 19×19 board game can be justified concerning the cultural drives, and strategic advantages of such a board possess. However, it was found that the standard komi value of 7.5 is not a universal solution in terms of ensuring the expected fairness in different Go board sizes. Future studies may expand on this issue, where identifying the appropriate komi value can be empirically identified for different board sizes. Also, the current study relies on the modern rule of ensuring fairness through the komi value. It is not yet known how ancient fairness measures such as Huanqitou and Zouzi would be useful in relation to the komi value in the context of the Go game, which an interesting prospect for future works.

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