A METRIC FOR ENTERTAINMENT OF BOARDGAMES: ITS IMPLICATION FOR EVOLUTION OF CHESS VARIANTS

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Abstract In this paper we investigate the evolutionary changes of chess variants. For this purpose we propose a measure of the game's entertaining impact. The measure is derived from grandmaster games and is applicable to chess variants independent of the game under consideration. For the case where no grandmaster games are available we perform computer self-play experiments to estimate the measure. For several old chess variants the measure as well as other measures, such as the search-space complexity and draw rate, are calculated. Some relationships between the measures investigated are found. Based on these relationships the evolutionary changes of chess variants are discussed.

Keywords: entertainment measure, evolution of chess variants

1. Introduction

In computer-games related studies the complexity of the game is an important issue. We can distinguish at least two types of complexity: search-space complexity and decision complexity. The decision complexity depends on the intricacies of a given game, such as the rules, the possible strategies and the depth of search. The measure of decision complexity is highly subjective and differs from game to game, even if they use the same class within chess variants. For an adequate comparison of the measures of complexity of several chess variants, we restrict ourselves to a measure of the search-space complexity[1]. In a first approximation this complexity can be measured as the size of a minimax search tree necessary for solving the game. The complexity measure is then given by the value B^D in which B is the average number of possible moves and D is the average game length.

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However, this measure indicates only the potential range of the full search tree. In the actual playing, the real search space of a player is much smaller than this potential search tree. In this article we would like to relate the search space, i.e., the search tree without its duplication to an entertainment feature. In itself the search space does not provide any clue with respect to the entertainment in game playing. Therefore, we propose a game strategic-complexity measure which may reflect some aspects of entertainment. The impact of and a measure of entertainment for a class of boardgames is then investigated.

We should notice that the complexity of a game should have changed over the long history of chess-like boardgames. Maybe there is even some form of optimization of entertainment factors, because a game variant that disappeared/extincted and is replaced by a new more attractive game might be not so entertaining. In this sense the history of games is somehow related to or can be considered as representing the evolutionary changes in entertainment factors. Consequently the history of games can be viewed as an evolutionary optimization of game entertainment factors.

In a first historical reconstruction of board games in terms of such factors, Iida *et al.* [3] studied the old and current shogi (Japanese chess) variants by means of evaluating the draw rate and other statistics of endgames. Their approach seemed to be rather powerful but rather limited too, because the analyses are only valid in the endgames and do not cover the entire games. Therefore, the historical reconstruction of games can be better viewed in term of the evolutionary optimization of some game measures, such as the entertainment measure and/or the complexity measures.

In this paper we evaluate the entertainment measure and other complexity measures based on the statistics of many grandmaster games. Unfortunately, such statistics are only available for a few present-day game variants. For the games where no grandmaster game scores are available (e.g., ancient chess variants), we carried out computer self-play experiments with material evaluation only [4]. From these experiments, the statistics of specific features were obtained, such as the average number of possible moves and the average game length.

Several chess variants are compared by means of the entertainment measure and other measures using the statistics obtained from grandmaster games and the self-play computer simulations. Then we discuss the insight into the evolutionary changes of chess variants. Finally, we briefly discuss the chance and necessity in the evolutionary history of chess variants.

2. An Estimate for Entertainment of Boardgames

When a player of some skill must choose a move in a position of a game, a set of plausible moves is first distinguished and then a move to play is determined. In this paper the term 'a set of plausible moves' means that this set contains the optimal move(s). Hence we may assume that the average number of plausible moves is greater than the number counted in the usual sense.

For a given game G, let b be the average number of plausible moves for a player. We propose the following estimate of the measure of entertainment in playing games, denoted as $E(G)$.

$$E(G) = \frac{D}{b} \tag{1}$$

where D stands the length of the game. The estimate assumes that a player would make his/her decision with probability $\frac{1}{b}$ at each position. In some sense this reflects the entertainment factor in playing games. During a game both players have a total of D opportunities for doing so. Therefore, if this estimate is low, the entertainment of a game is high (D is relatively small, and b large). In contrast, if it is high, the entertainment impact is low for each decision because we have so many choices to make (D is large) among not so many options (b is relatively small).

Moreover, we assume that there is a direct relation between the number of plausible moves and the player's strength[4]. A player with perfect knowledge (i.e., an omniscient player) would select the optimal move(s) at any position. A novice usually is unable to distinguish between good and bad moves at all, i.e., all possible moves are plausible moves.

Let s be a real-valued variable indicating the player's strength, and let B be the average number of possible moves. We then expect a relationship between the player's strength and the number of plausible moves, such that

$$b = B^{\frac{1}{s}}. \tag{2}$$

In Table 1 we show our calculations of the number of plausible moves for three possible values of the player's strength ($s = 1, 2, 3$) for chess.

According to De Groot's observation[2], expert players like top grandmasters only consider a few plausible moves. Lately this was supported by the experience of many game experts and researchers. From these facts, we estimate that on average the playing strength of grandmasters is represented by $s = 2$ (in Table 1), i.e., that the number of plausible moves roughly corresponds to the square root of the average number of possible moves. When we suppose $s = 2$, we obtain Equation (3) from Equation (1) and (2).

$$E(G) = \frac{D}{\sqrt{B}} \tag{3}$$

Table 1. The number of plausible moves.

	$s=1$	$s=2$	$s=3$		
CHESS	35	5.9	3.3	$\cdots$	$35^{\frac{1}{s}}$

3. A Hypothesis on Game Characteristics

Table 2 shows some statistical measures together with our calculations for some derived quantities. B denotes the average number of possible moves and D the average game length. B^D is a measure for the search-space complexity. Moreover, Table 2 shows that the values of $E(G)$ for three major chess-like games are in the range of [12.86 – 15.41]. This observation forms the basis of our hypothesis formulated below.

Hypothesis 1 *The value of $E(G)$ for chess-like games converges to a value within a fixed interval which is independent of (the precise variant of) the game. As the value of $E(G)$ decreases (not beyond the above fixed interval), the entertaining impact increases. Moreover, the value of $E(G)$ basically decreases in the process of the evolutionary sophistication of games.*

Table 2. Some characteristics for chess.

	B	D	$E(G)$	B^D
CHESS	35	80	13.52	$35^{80} \approx O(123)$
XIANGQI	38	95	15.41	$38^{95} \approx O(149)$
SHOGI	80	115	12.86	$80^{115} \approx O(218)$

4. Self-Play Experiments

Below we examine the value of $E(G)$ for ancient chess variants to test our hypotheses. Since most ancient variants are currently obsolete, there are no expert players for these variants at present. Furthermore, there are hardly any game scores left. Therefore, we introduce a method of computer self-play[4]. Using this method we have performed some experiments and gathered data on the average number of possible moves and the average game length.

4.1. Experimental design

The experiments have been performed according to the following setup. (1) A game is played between two identical copies of a computer program. (2) A computer program has an evaluation function which simply concerns the material balance. For this task we obtain the piece values for each chess variant through many self-play games. (3) A computer program is able to look ahead by 3 to 5 ply using a quiescence search for captures and promotions only. (4) For each experiment 1000 or 2000 games are played to gather data on the average number of possible moves, the average game length and the draw ratio.

4.2. Chess variants

For the experiments we collected several important chess variants. Table 3 shows these variants with key differences. In Table 3 P, N, B, R, Q, K, H and M denote Pawn, Knight, Bishop, Rook, Queen, King, Hasty and Mantri respectively. The column of 'P2M' denotes the Pawn's two-move option. The column of 'En' means En passant. 'K-knight' means that King additionally has the right to make one Knight-move during the game, provided that he has not been checked before he makes his Knight-move. 'K(Q) leap' means that on the first move Queen or King may leap over one square, on the rank, file, or diagonal.

We provide some insight into each variant, which is taken from [5][6]. Each chess variant described in Table 3 is played on 8x8 square board by two players. In each variant one player has a piece called King. The goal is to checkmate, stalemate or isolate (leave it alone) the opponent King. Chaturanga is believed to be the precursor of modern chess. It was born in the 4th century. There are two well-known variants: Four-handed Chaturanga and Two-handed Chaturanga. We here evaluate the Two-handed Chaturanga only because the current chess is basically two handed. Shatranj is an old Arabic chess variant, and is a little different from Chaturanga. It was first spread in Europe, and later replaced by the medieval games. There were many medieval variants of chess. A record of the 13th century includes the rules of 44 variants. We selected 3 major variants (denoted as I, II and III) for the self-play experiments performed in this study. New chess is a successor to Medieval chess originated/born around the 16 century. It had been played until the establishment of the modern rules. New chess is characterized by the increased powers of Queen and Bishop.

Table 3. Comparisons of chess variants.

	Pieces	Promotion	P2M	En	Castling
Chaturanga	P, N, H, R, M, K	piece in file	no	no	K-knight
Shatranj	P, N, H, R, M, K	Mantri	no	no	no
Medieval I	P, N, H, R, M, K	Mantri	ok	no	Q leap
Medieval II	P, N, *B*, R, M, K	Mantri	no	no	no
Medieval III	P, N, H, R, M, K	Mantri	ok	ok	K, Q leap
New chess	P, N, *B*, R, *Q*, K	Queen	ok	ok	castling
Chess	P, N, B, R, Q, K	N, B, R or Q	ok	ok	castling

4.3. Experimental results

Table 4 shows the results of the self-play experiments performed with the chess variants concerned. Next to the results for D, B, $E(G)$ and B^D, it includes the percentage of drawn games and the century in which the game was born[5][6]. A game is counted as a draw only when the game length exceeds 1000 plies. Stalemate is counted as a win. The average values for B and D and the derived quantities $E(G)$ and B^D are calculated for the experiments.

Table 4. Some statistics for several chess variants.

	D	B	$E(G)$	B^D	Draw(%)	Birth
Chaturanga	175.982	19.386	39.969	$O(225)$	1.700	A.D.4
Shatranj	222.298	19.180	50.759	$O(284)$	2.100	A.D.6
Medieval I	230.593	20.195	51.312	$O(299)$	2.800	A.D.8
Medieval II	217.458	20.981	47.475	$O(287)$	2.100	A.D.12
Medieval III	185.263	20.790	40.631	$O(241)$	1.200	A.D.15
New chess	100.852	26.684	19.524	$O(143)$	0.100	A.D.16
Chess	100.060	26.981	19.263	$O(142)$	0.700	A.D.16

5. Discussion

Based on the experimental results, we may categorize seven chess variants into three groups: (1) Shatranj, Medieval I and Medieval II, (2) Chaturanga and Medieval III, and (3) New chess and modern chess.

The first group is characterized by the larger values of the game length and $E(G)$ as well as draw ratio and the search-space complexity. The third group is characterized by the smaller values of the game length and $E(G)$ as well as draw ratio and the search-space complexity. This is owing to the inclusions of the powerful Queen and the promotion rule. The Queen provides the game with an increase of potential attack/defense, and a higher possibility of the game ending in a mate. This implies that the game length of the third group will be smaller on average as well as the draw ratio. The second group stands in the middle between the above two groups.

$E(G)$ and search-space complexity are positively correlated each other. A game variant with a low $E(G)$ has a low B^D, whereas the one with a high $E(G)$ has a high B^D. This positive relationship roughly holds true for the E(G) and the drawn ratio. These positive relations indicate some constraints in the games' evolutionary changes.

So, the history of chess variants may be viewed as the evolutionary changes in the following two directions. One direction of the evolution of chess variants is the change of the rules by which the search-space complexity increased. Indeed, this happened from Chaturanga onwards to some chess variants, such as Shatranj, Medieval I, II and III. Another direction is the change of the rules by which the value of $E(G)$ decreases. Actually, this happened from Chaturanga onwards to other chess variants such as New chess and modern chess.

The first direction is viewed as the enlargement of the game size. More complex games are favored and the search-space complexity increases. This means that the entire size of search space of game increases. Thus the game becomes more calculation oriented, rather than insight-oriented (the strength of a human player). Many variations of game can be created in this process of enlargement. However, such diversification of game sizes and complexity increases the game length and draw rate considerably. Thus the entertainment impact will decrease. Players can be easily tired of the game, and most game variants can be easily abandoned.

The other direction can be viewed as the refinement/optimization of the game rules. Experienced players came to notice that large and complex games were no fun at all. The players with more insight and feeling for the game naturally hope to enjoy the game playing. Thus, games with more entertainment impact are desired. The win/lose outcome of games is highly dependent on the strength of the players. In this process, most variants were outsourced and only a few variants survived to the present. Furthermore, the surviving variants went through the sophistication/optimization of the game rules to maximize the entertainment impact such that the depth of lookahead (i.e., intelligent aspect of games) is more critical for win/lose of the game. The variants finally reached the present modern chess world, which probably has a well balanced search-space complexity and entertaining impact. Thus modern chess may be considered a highly matured and optimized chess-like game.

Similar arguments may hold for other chess-like games such as shogi and Chinese chess. These games seem to be sophisticated and stable too. The evolutionary constraints of such games may be equal, but the optimization (maximization) of game impact may be achieved in a different manner in a different locality. This scenario is derived from the analyses of typical chess variants based on the game-related measures including a new metric proposed in this paper.

6. Conclusion

To explore the evolutionary changes of chess variants, we proposed a measure of the game's entertaining impact. The measure is estimated based on the average number of possible moves and game length. Since no grandmaster games are available for most old chess variants, self-play experiments were introduced to obtain the game statistics such as the average number of possible moves and the average game length. The proposed measure and the search-space complexity were applied to chess variants under consideration. The result is promising since more insight into the evolutionary changes of chess variants is obtained. The observations indicated by the measures fit to our intuition (see Hypothesis 1).

An important conclusion is that there were at least two directions in the process of the evolutionary changes of chess variants. One is the change of the rules by which the search-space complexity increases, while another one is the change of the rules by which the entertaining impact increases. We thus believe that the modern chess is the result of natural selection while being well balanced in the sense of search-space complexity and entertainment impact.

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