THE ROLE OF connectivity IN CHESS

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Introduction

Primary improvements in the performance of computer chess programs during the past 14 years have been attributed to more efficient brute force tree searching using the alpha-beta algorithm (Thompson, 1982; Hsu, 1987, Rivest, 1988). It is true, as per the arguments of Donskoy and Schaeffer (1989, presented here), that research in computer chess needs to regain credibility within the artificial intelligence community by focusing on techniques, tools, algorithms and methods of representing chess knowledge. We believe that the ideas expressed in this paper are an example of research directed towards the above goals.

We attempt to define a measure of connectivity of forces or simply connectivity, and substantiate it as an important term which should be included in the evaluation function of every strong computer chess program.

It has been accepted since the work of Slater (1950) that there is a strong correlation between the general mobility of chess pieces and the outcome of chess games played at the master level and above. Consequently, mobility has always played an important role in the evaluation function of computer chess programs. This belief gained further substance from the analysis of mobility in 862 grandmaster games by Hartmann (1987a). Analysis of chess play at all levels has led the authors to the belief that success in strong (master and above) play is also directly correlated to having well protected forces. It has long been accepted that material is the single, overriding, most important factor in the evaluation function of strong computer chess programs (Botvinnik, 1969; Slate and Atkin, 1977). The research reported here describes efforts to quantify the measure of connectivity and its statistical significance as correlated to strong chess play as distinct from novice play both by humans and machines.

Well established notions of "positional play" in chess refer to an awareness of piece configurations (clusters) and how well the pieces in a given configuration can coordinate together. Such terms as "strategy" and "planning" in chess are usually associated with positional play. The quantification of good positional play has thus far proven a great stumbling block for computer chess programmers.

Notions of "tactical play" relate to the active deployment of forces, which can be derived to some degree from the measurement of mobility. For example, a "tactical combination" involves interaction between opposing forces involving the exploitation of either 1) one side's superior mobility or 2) the insufficient defense of the weaker side's King, pieces, or pawns and/or the vital squares affected by these forces. The result of a

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tactical combination is usually a clear gain of material, significant increase in mobility or a decisive attack on the opposing King. In short, all chess moves can, by some form of evaluation, be classified as either tactical or positional in nature.

Moreover, it has been argued quite convincingly by leading researchers in computer chess (Thompson, 1982) that if we could calculate far enough ahead, all chess play would ultimately be reduced to tactics. The design and approach of most computer chess programs in recent years, with few exceptions, gives credence to this supposition. At the other end of the pendulum lies the point of view of the authors, who, while recognizing the importance of the ability to calculate deeply and precisely, refuse to underrate the role of knowledge in chess programming (Berliner,1986; Kopec, Newborn, & Yu,1986; Schaeffer 1986). We argue that knowledge, when represented by rules, patterns and heuristics enables the quantification of chess moves. This can result in a tremendous reduction in the number of nodes requiring evaluation. Thus it could be said, "a little knowledge can go a long way."

Over 35 years of experience in chess programming has demonstrated that mobility is one such easily quantifiable concept which lends itself to speedy evaluation. Connectivity can also be defined in a way so as to facilitate rapid evaluation. Study of the relationship between connectivity and mobility suggests ways in which the two factors can be incorporated into a chess program's evaluation function in a meaningful way (Fouda,1987).

The Study Design

We have selected two hundred chess games in four categories whose distributions are as follows: Games 1-100 are computer vs. computer; Games 101-120 are computer vs. human; Games 121-145 are the games of the second Kasparov vs. Karpov World Championship Match in 1985; and Games 146-200 are human vs. human. Games (other than Kasparov vs. Karpov) are selected randomly according to their ability to meet specificatons (in terms of frequency) as a representative sample of chess games played within and between the following four rating categories:

Category	Name	Ratings
I	Novice	1000-1599
II	Intermediate	1600-1999
III	Strong	2000-2199
IV	Very Strong	>= 2200

A program in Pascal was written to accept any legal chess game in algebraic notation as input. This program employs a pointer-based representation to maintain lists of squares attacked and defended by each side's pieces during the course of a chess game. Connectivity was measured for each side's forces as an inverse relation based on the product of the sum of the number of defenders of each piece in a position. After a number of iterations and refinements, the function used on our data sample is:

$$\text{connectivity}= [V * (0.5)^N] * [P_1/50 +0.8)(P_2/50 +0.8)...(P_N/50+ 0.8)]$$

Where P_i is the i'th protector of a piece, for i=1..n and protector values are: pawn = 1, knight = 3, bishop = 4, rook = 5, king = 6, and queen = 9; V is the value of a protected piece with pawn = 10, knight = 30, bishop = 35, rook = 50; n is the number of unpinned protectors (queen & king excluded).

This computation takes into account the value of forces credited as defenders and leads to smaller connectivity values as the number of defenders of a piece increases. Originally we had coined this computation as entropy, a term taken from physics, which measures the tendency of matter to increase in its level of disorder. A low entropy score is therefore indicative of a high degree of protection and order amongst a side's forces. However, we are dealing in the realm of computer chess, where most evaluation functions tend to accrue positive scores as a measure of the strength of their current material or positional situation.

Hence it was decided that the entire computation should be revised in order to provide a more accurate representation of the important features in a chess position and to facilitate their evaluation. Since table lookup is much faster than the computation of each combination of protectors, it was decided that each unique combination of protectors should have a predefined value (see Table 1). It was further decided that the term connectivity better describes the relationship between one side's pieces which is being measured on the chessboard.

The values of protected pieces which might be involved in a connectivity computation, were assigned as follows: P = 50, N = 35, B = 30, R = 10, Q = 4. This is precisely in the inverse order of the accepted material values of these pieces, with some scaling. This stems from the idea that the less mobile a piece is, the more protection it needs. That is, the weaker a piece is, the more subject to attack it is and the less useful it is as an attacking force. On the other hand, stronger pieces are more prone to attack from all other weaker pieces. Combinations of protectors involving a single piece can never outweigh the contribution of two protectors. The same is true when two protectors are evaluated as compared with three. Pieces operating in the same line of defense (e.g. a bishop behind and on the diagonal of a pawn which is guarding another pawn), represented in "( )" are less efficient as defenders than pieces operating from separate directions. Finally, ordering effects for defenders inline always give preference to having the highest valued piece (in real chess terms) ordered last.

Table 1: Combinations of Protectors

Symbols: P= pawn; B=bishop; R=rook; Q=queen; K=king

Singletons

P= 8.00	B = 4.50	N = 4.00	R= 3.00	K= 2.50	Q= 2.0

Two Protectors

PP= 15.00	PN= 11.0	PB= 11.5	(PB)= 10.0	PR= 10.00	PQ= 9.00	(PQ)= 8.00
PK= 10.00	NN= 7.00	NB= 7.50	NR= 6.00	BR= 6.50	RR= 5.00	(RR)= 4.50
NQ= 5.00	BQ= 5.50	(BQ)= 5.00	(QB)= 4.50	RQ= 4.00	(RQ)= 3.50	(QR)= 3.25
NK= 5.50	BK= 6.00	RK= 4.50	QK= 4.00	(KQ)=3.50	(KR)= 4.00	(KB)= 5.00

Three Protectors

PPN= 18.00	PPB= 18.50	P(PB)= 17.00	PPR= 17.00	PPQ= 16.0
P(PQ)= 15.50	PPK= 16.50	PNN= 14.00	PNB= 14.50	(PB)N= 14.00
PNR= 13.00	PBR= 13.50	(PB)R= 13.00	PRR= 12.00	P(RR)= 11.00
PNQ= 12.00	(PQ)N= 11.00	PQB= 12.50	(PB)Q= 12.00	(PQ)B= 11.50
P(BQ)= 11.00	P(QB)= 10.50	(PQB)= 10.00	(PBQ)= 10.50	PRQ= 11.00
P(RQ)= 10.50	P(QR)= 10.25	(PQ)R= 10.00	PNK= 12.50	PBK= 13.00
(PB)K= 11.50	PRK= 11.50	PQK= 10.50	(PQ)K= 9.5	NNB= 10.50
NNR= 9.00	NBR= 10.50	NRR= 8.00	N(RR)= 7.00	BRR= 8.50
B(RR)= 8.00	NNQ= 8.00	NBQ= 10.00	N(BQ)= 9.50	N(QB)= 9.00
NRQ= 7.00	N(RQ)= 6.50	N(QR)= 6.00	BRQ= 7.50	B(RQ)= 7.00
B(QR)= 6.50	(BQ)R= 7.00	R(QB)= 6.50	RRQ= 6.00	(RR)Q= 5.50
R(RQ)= 5.50	R(QR)= 5.00	(RRQ)= 4.50	(RQR)= 4.00	(QRR)= 3.75
NNK= 8.50	NBK= 7.50	BRK= 6.00	RRK= 6.50	(RR)K= 6.00
NQK= 6.50	BQK= 7.00	(BQ)K= 6.50	(QB)K= 6.00	RQK= 5.5
(RQ)K= 5.00	(QR)K= 4.75			

Much of Opening play in chess is determined by a library of "book moves" and endgame play often has its own special characteristics. Therefore we have focused our data collection on "defined" middle games from our sample of games. A middlegame is said to begin when a side's rooks are connected or when a side has only one minor piece on the back row preventing this. The endgame for our purposes, has been defined as starting when less than 19 points of material, i.e. less than two rooks (or a queen) and three minor pieces, are present. Thus the two sides may be in different phases of a chess game, and the connectivity for each side may be evaluated starting (and ending) at different points (positions) in a game.

Results

The statistical analysis of our data with our original computational scheme (entropy) has revealed significant differences, both in connectivity and mobility when compared against the rating category of the winning side.

Using a simpler calculation to evaluate a set of nine carefully selected, high level (grandmaster) games (with material balance and decisive outcomes, Fouda (1987) obtained some remarkable results: for whichever side won the games at least one of the following was true throughout the course of the games:

1) the winner's mobility and connectivity were better (respectively higher and lower) than the loser's and/or

2) the winner's mobility was higher than the loser's and/or

3) the winner's connectivity was better (lower) than the loser's.

Fouda also found that in selecting random numbers of moves from this set of games (total 515 moves) the trends in terms of changes in connectivity and mobility (either or both going up or down from move to move) remained inexplicably consistent.

Future Study

The revised computation for connectivity is to be tested on a control group of 100 randomly selected games. Subsequent analyses will import large numbers of master games from a database of chess games for the evaluation of what role connectivity may have played and its possible correlation to outcome of these games. Further analysis of this kind and along the lines of Hartmann's (1987) studies, may help to unveil the secrets behind chess at the grandmaster level, especially with regard to positional play.

Credits and Acknowledgements

This research has been a continuing ongoing effort involving a number of students from the Department of Mathematical Sciences at San Diego State University (SDSU), in 1985 and 1986 and then at the University of Maine (UM), (1986-89). David Podber, was a graduate student at SDSU when he developed, as part of a special study course, the Pascal program which parses a chess game score and evaluates entropy (now connectivity). Yehya Fouda, as his master's thesis at SDSU, developed a program which tried to learn how to play the Opening in chess and in the course of his research did some separate studies of entropy. Professor Ed Northam of the UM Department of Computer Science, joined the project in 1988, and has made a number suggestions and contributions which have improved the method of evaluating connectivity.

Lee Deskus did much of the organizational and statistical work at UM. Other students who have contributed are Carol Roberts and Hayri Sever at UM; Angela Kofler and Richard Jorgensen at SDSU.

Dr. Danny Kopec, an International Chess Master, has served as the instigator of this research since 1985.

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