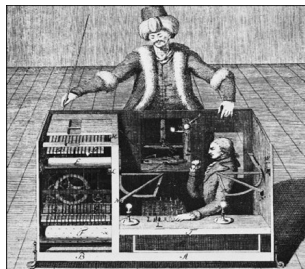


Chess Playing Machine

Programming a Computer for Playing Chess

- Chess is believed to have originated in India, some time before the 7th century.
- Chess is a two-player strategy board game played on a chessboard with 64 squares arranged in an eight-by-eight grid.
- One of Shannon famous hobbies as well as cycling and juggling.
- First machine built in 1769.
Constructed by the Hungarian engineer von Kempelen for queen Maria Theresia.
- Mechanical device supplied by a human chess master hidden inside. It was a *FAKE*.



Playing a Rook-King Endgame

- An honest attempt to design a chess-playing machine was made in 1914 by a Spanish inventor named L. Torres y Quevedo.
- The device played an end game of king and rook against king.
- The machine, playing the side with king and rook, would force checkmate in a few moves however its human opponent played.
- IBM Deep Blue – first machine to overcome a reigning World Chess Champion, Garry Kasparov in 1997.

Why Chess?

- Sharply defined both in allowed operations (the moves) and in the ultimate goal (checkmate).
- Neither trivial nor too difficult for satisfactory solution.
- Its discrete structure fits modern computers very well.
- No element of chance as each opponent has perfect information at each move.
- In a given position, all possible moves can be considered, then all moves for the opponent, to the end of the game (in each variation).

Definition of a Chess Position

- A statement of the positions of all pieces on the board.
- A statement of which side, White or Black, has the move.
- A statement as to whether the king and rooks have moved.
- A statement of, say, the last move. This will determine whether a possible en passant capture is legal.
- A statement of the number of moves made since the last pawn move or capture.

- In typical chess position there are 30 – 40 legal moves.
- One move for white, and one for black yields 10^3 possibilities.
- Typical game lasts ~ 40 moves to resignation of one party.
- Need to check 10^{120} variations to be calculated from the initial position.
- A machine operating- at the rate of one variation per μs would require over 10^{90} years to calculate its first move.
- Another (equally impractical) method is to have a "dictionary" of all possible positions of the chess pieces.

Evaluation function - $f(P)$

- Sometimes a simple evaluation function can be applied to any position P to determine whether it is a won/lost/drawn position.
- Although in chess there is no known simple and exact evaluating function $f(P)$.
- It is still possible to perform an approximate evaluation of a position.
- The relative values of queen, rook, bishop, knight and pawn are about 9, 5, 3, 3, 1 respectively.
- If we add the numbers of pieces for the two sides with these coefficients, the 'side with the largest total has the better position.
- Mobility - Rooks should be placed on open files.
- Backward, isolated and doubled pawns are weak.
- An exposed king is a weakness (until the end game).

Approximate Evaluation function - $f(P)$

- $f(P) = 200(K - K') + 9(Q - Q') + 5(R - R') + 3(B - B' + N - N') + (P - P') - 0.5(D - D' + S - S' + I - I') + 0.1(M - M') + \dots$
- K, Q, R, B, N, P are the number of White kings, queens, rooks, bishops, knights and pawns on the board.
- D, S, I are doubled, backward and isolated White pawns.
- M = White mobility (measured, say, as the number of legal moves available to White).
- Primed letters are the similar quantities for Black.
- The player chooses the variation leading to the highest evaluation for him when the opponent is assumed to be playing to reduce this evaluation.

Type A strategy

- Let, $M_1, M_2, \dots$ be the moves that can be made in position P for player A.
- Let, $M_1P, M_2P, \dots$ denote symbolically the resulting positions when move M_i is applied to P .
- Then A chooses the M_m which maximizes $f(M_mP)$.
- While the opponent B chooses move M_{mn} out of all possible moves (after M_m move played by A) such that

$$\min_{M_{mn}} f(M_{mn}M_mP) \quad (1)$$

- Similarly, for a 2-move strategy we have

$$\max_{M_m} \min_{M_{mn}} \max_{M_{mno}} \min_{M_{mnop}} f(M_{mnop}M_{mno}M_{mn}M_mP) \quad (2)$$

Programming type A strategy for computer

- A game of chess can be divided into three phases, the opening, the middle and the end game.
- In the opening, which generally lasts for about ten moves, development of the pieces to good positions is the main objective.
- During the middle game tactics and combinations are predominant.
- The end game is mainly concerned with pawn promotion.
- A square on a chessboard can be occupied in 13 different ways : either it is empty (0) or occupied by one of the six possible kinds of White pieces ($P = 1, N = 2, B = 3, R = 4, Q = 5, K = 6$) or one of the six possible Black pieces ($P = -1, N = -2, \dots K = -6$).

Programming type A strategy for computer

- The state of a square is specified by giving an integer from -6 to +6.
- The 64 squares of the chessboard can be numbered according to a co-ordinate system.
- The position of all pieces is then given by a sequence of 64 numbers each lying between -6 and +6.
- One further number $\lambda = +1$ or -1 is used according as it is White's or Black's move.

4, 2, 3, 5, 6, 3, 2, 4; 1, 1, 1, 1, 1, 1, 1, 1;
0, 0, 0, 0, 0, 0, 0, 0; 0, 0, 0, 0, 0, 0, 0, 0;
0, 0, 0, 0, 0, 0, 0, 0; 0, 0, 0, 0, 0, 0, 0, 0;
-1, -1, -1, -1, -1, -1, -1, -1; -4, -2, -3, -5, -6, -3, -2, -4;
+1 ($=\lambda$).

Figure 1: Starting chess position

Programming type A strategy for computer

- A move is specified by giving the original and final squares occupied by the moved piece.
- Each of these squares is a choice from 64, thus 6 binary digits each is sufficient, a total of 12 for the move.
- To represent pawn promotion a set of three binary digits is added specifying the piece that the pawn becomes.

BLACK							
70	71	72	73	74	75	76	77
60	61	62	63	64	65	66	67
50	51	52	53	54	55	56	57
40	41	42	43	44	45	46	47
30	31	32	33	34	35	36	37
20	21	22	23	24	25	26	27
10	11	12	13	14	15	16	17
00	01	02	03	04	05	06	07
WHITE							

Programming type A strategy for computer

- Thus, a move is represented by (a, b, c) where a and b are squares and c specifies a piece in case of promotion.
- The complete program for a type A strategy consists of nine subprograms and a master program.
 - T_0 – Makes move (a, b, c) in position P to obtain the resulting position.
 - T_1 – Makes a list of the possible moves of a pawn at square (x, y) in position P .
 - $T_2, \dots, T_6$ – Similarly for other types of pieces: knight, bishop, rook, queen and king.
 - T_7 – Makes list of all possible moves in a given position.
 - T_8 – Calculates the evaluating function $f(P)$ for a given position P .
 - T_9 – Master program; performs maximizing and minimizing calculation to determine proper move.

Drawbacks of type A strategy

- These programs are highly iterative.
- The internal memory for positions and-temporary results of calculations when playing three moves deep can be estimated.
- The type A strategy is both slow and a weak player.
- A world champion can construct (at best) combinations say, 15 or 20 moves deep.

References

- Claude E. Shannon , Programming a Computer Playing Chess, Philosophical Magazine, Ser. 7, Vol 41, No. 312 March 1950
- The F.I.D.E. Laws of Chess,
<http://www.chessvariants.com/fidelaws.html>
- S. Russel, P. Norvig, Artificial Intelligence A Modern Approach, Prentice Hall, 1995.
- Lecture notes of Workshop in Reinforcement Learning 2003/4 by Prof. Yishay Mansour, TAU
- ChessBase, A short history of computer chess,
<http://www.chessbase.com/columns/column.asp?pid=102>