

Digital Computers applied to Games.

When one is asked 'Could one make a machine to play chess?', there are several possible meanings which might be given to the words. Here are a few:-

- i) Could one make a machine which would obey the rules of chess, i.e. one which would play random legal moves, or which could tell one whether a given move is a legal one ?
- ii) Could one make a machine which would solve chess problems, e.g. tell one whether, in a given position, white has a forced mate in three ?
- iii) Could one make a machine which would play a reasonably good game of chess, i.e. which, confronted with an ordinary (that is, not particularly unusual) chess position, would after two or three minutes of calculation, indicate a passably good legal move?
- iv) Could one make a machine to play chess, and to improve its play, game by game, profiting from its experience ?

To these we may add two further questions, unconnected with chess, which are ^{likely} ~~likley~~ to be on the tip of the reader's tongue.

- v) Could one make a machine which would answer questions put to it, in such a way that it would not be possible to distinguish its answers from those of a man ?
- vi) Could one make a machine which would have feelings ^{as} ~~like~~ you and I do ?

The problem to be considered here is iii), but to put this problem into perspective with the others I shall give the very briefest of answers to each of them.

To i) and ii) I should say "This certainly can be done. If it has not been done already it is merely because there is something better to do".

Question iii) we are to consider in greater detail, but the short answer is "Yes, but the better the standard of play required, the more complex will the machine be, and the more ingenious perhaps the designer".

To iv) and v) I should answer "I believe so. I know of no really convincing argument to support this belief and certainly of none to disprove it".

To vi) I should say "I shall never know, any more than I shall ever be quite certain that you feel as I do".

In each of these problems except possibly the last, the phrase 'Could one make a machine to....' might equally well be replaced by 'Could one programme an electronic computer to....'. Clearly the electronic computer so programmed would itself constitute a machine. And on the other hand if some other machine had been constructed to do the job we could use an electronic computer (of sufficient storage capacity), suitably programmed, to calculate what this machine would do, and in particular what answer it would give.

After these preliminaries let us give our minds to the problem of making a machine, or of programming a computer, to play a tolerable game of chess. In this short discussion it is of course out of the question to provide actual programmes, but this does not really matter on account of the following principles:-

If one can explain quite unambiguously in English, with the aid of mathematical symbols if required, how a calculation is to be done, then it is always possible to programme any digital computer to do that calculation, provided the storage capacity is adequate.

This is not the sort of thing that admits of clear

cut proof, but amongst workers in the field it is regarded as being clear as day. Accepting this principle, our problem is reduced to explaining 'unambiguously in English' the rules by which the machine is to choose its move in each position. For definiteness we will suppose the machine is playing white.

If the machine could calculate at an infinite speed, and also had unlimited storage capacity, a comparatively simple rule would suffice, and would give a result that in a sense could not be improved on. This rule could be stated:-

Consider every possible continuation of the game from the given position. There is only a finite number of them (at any rate if the fifty-move rule makes a draw obligatory, not merely permissive). Work back from the end of these continuations, marking a position with white to play as 'win' if there is a move which turns it into a position previously marked as 'win'. If this does not occur, but there is a move which leads to a position marked 'draw', then mark the position 'draw'. Failing this, mark it 'lose'. Mark a position with black to play by a similar rule with 'win' and 'lose' interchanged. If after this process has been completed it is found that there are moves which lead to a position marked 'win', one of these should be chosen. If there is none marked 'win' choose one marked 'draw' if such exists. If all moves lead to a position marked 'lose', any move may be chosen.

Such a rule is practically applicable in the game of noughts and crosses, but in chess is of merely academic interest.

Even when the rule can be applied to it is not very appropriate for use against a weak opponent, who may make mistakes which ought to be exploited.

In spite of the impracticability of this rule it bears some resemblance to what one really does when playing chess. One does not follow all the continuations of play, but one follows some of them. One does not follow them until the end of the game, but one follows them a move or two, perhaps more. Eventually a position seems, rightly or wrongly, too bad to ^{be} worth further consideration, or (less frequently) too good to hesitate longer over. The further a position is from the one on the board the less likely is it to occur, and therefore the shorter is the time which can be assigned for its consideration. Following this idea we might have a rule something like this:-

Consider all continuations of the game consisting of a move by white, a reply by black, and another move and reply. The value of the position at the end of each of these sequences of moves is estimated according to some suitable rule. The values at earlier positions are then calculated by working backwards move by move as in the theoretical rule given ^{before.} below. The move to be chosen is that which leads to the position with the greatest value.

It is possible to arrange that no two positions have the same value. The rule is then unambiguous. A very simple form of values, but one not having this property, is an 'evaluation of material', e.g. on the basis

$$P = 1$$

$$Kt = 3$$

$$B = 3\frac{1}{2}$$

$$R = 5$$

$$Q = 10$$

$$\text{Checkmate} \pm 1000$$

If B is black's total and W is white's, then W/B is quite a good measure of value. This is better than W-B as the latter does not encourage exchanges when one has

the advantage. Some small extra arbitrary function of position may be added to ensure definiteness in the result.

The weakness of this rule is that it follows all combinations equally far. It would be much better if the more profitable moves were considered in greater detail than the less. It would also be desirable to take into account more than mere 'value of material'.

After this introduction I shall describe a particular set of rules, which could without difficulty be made into a machine programme. It is understood that the machine is white and white is next to play. The current position is called the 'position of the board', and the positions arising from it by later moves 'positions in the analysis'. 'Considerable' moves i.e. Moves to be considered in the analysis by the machine.

Every possibility for white's next move and for black's reply is 'considerable'. If a capture is considerable then any recapture is considerable. The capture of an undefended piece or the capture of a piece of higher value by one of lower value is always considerable. A move giving checkmate is considerable.

Dead position.

A position in the analysis is dead if there are no considerable moves in that position i.e. if it is more than two moves ahead of the present position., and no capture or recapture or mate can be made in the next move.

Value of position

The value of a dead position is obtained by adding up the pieces values as above, and forming the ratio W/B of white's total to black's. In other positions with white to play the value is the greatest value of: A) the positions obtained by considerable moves, or B) the position itself

evaluated as if a dead position, the latter alternative to be omitted if all moves are considerable. The same process is to be undertaken for one of black's moves, but the machine will then choose the least value.

Position-play value

Each white piece has a certain position-play contribution and so has the black king. These must all be added up to give the position-play value.

For a Q., R., B. or Kt., count

i) the square root of the number of moves the piece can make from the position, counting a capture as two moves, and not forgetting that the king must not be left in check.

ii) (if not a Q) 1.0 if it is defended, and an additional 0.5 if twice defended.

For a K, count

iii) for moves other than castling as i) above.

iv) It is then necessary to make some allowance for the vulnerability of the K. This can be done by assuming it to be replaced by a friendly Q on the same square, estimating as in i), but subtracting instead of adding.

Count v) 1.0 for the possibility of castling later not being lost by moves of K or rooks, a further 1.0 if castling could take place on the next move, and yet another 1.0 for the actual performance of castling.

For a P, count

vi) 0.2 for each rank advanced

vii) 0.3 for being defended by at least one piece
(not P)

For the black K, count

viii) 1.0 for the threat of checkmate.

ix) 0.5 for check.

We can now state the rule for play as follows.

The move chosen must have the greatest possible value, and, consistent with this, the greatest possible position-play value. If this condition admits of several solutions a choice may be made at random, or according to an arbitrary additional condition.

Note that no 'analysis' is involved in position-play evaluation. This is in order to reduce the amount of work done on deciding the move.

The game below was played between this machine and a weak player who did not know the system. To simplify the calculations the square roots were rounded off to one decimal place, (i.e. the table below was used). No 'random choices' actually arose in this game. The increase of position-play value is given after white's move if revelant. An asterisk indicates that every other move had a lower position-play value.

Number 0 1 2 3 4 5 6 7 8 9 10 11 12 13

Square
Root. 0 ; 1 ; 1.4 ; 1.7 ; 2.0 ; 2.2 ; 2.4 ; 2.6 ; 2.8 ; 3.0 ; 3.2 ; 3.5 ; 3.6 .

<u>White (Machine)</u>		<u>Black.</u>
1. P-K4	4.2 ^x	P-K4
2. Kt-QB3	3.1 ^x	Kt-KB3
3. P-Q4	3.1 ^x	B-QKt5
4. Kt-KB3 ¹⁾	2.0	P-Q3
5. B-Q2	3.6 ^x	Kt-QB3
6. P-Q5	0.2	Kt-Q5
7. P-KR4 ²⁾	1.1 ^x	B-Kt5
8. P-QR4 ²⁾	1.0 ^x	Kt-Kt ch.
9. P x Kt		B-KR4
10. B-Kt5 ch	2.4 ^x	P-QB3
11. P x P		O - O
12. P x P		R-Kt ₁

W. Games

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White (Machine)

Black

13. B-R6 -1.5

Q-R4

14. Q-K2 0.6

Kt. - Q2

15. KR-Kt1³⁾ 1.2^x

Kt - B4⁴⁾

16. R-Kt5⁵⁾

B-Kt3

17. B-Kt5 0.4

Kt X KtP

18. O-O-O 3.0^x

Kt - B4

19. B-B6

KR - QB1

20. B-Q5

B x Kt.

21. P x B²⁾ -0.7.

Q x RP

22. B-K3⁶⁾

Q-R6ch.

23. K-Q2

Kt. - R5

24. B x RP⁷⁾

R - Kt7

25. P - B4

Q - B6ch. QXPch

26. K - B1

R - R7

27. B x BPch.

B x B

28. R x KtP ch⁵⁾

K x R

29. B - K3⁸⁾

(29) P - Kt3 (30) P x R

R - R8 mate

29 R - Kt1 ch

30 R x B ch

insert between
28 & 31

Notes: (O-O indicates castling)

- 1) If B-Q2 3.6^x then P xP is forseen.
- 2) Most inappropriate moves from a positional point of view.
- 3) If O-O then BxKt, BxB, QxP.
- 4) The fork is unforseen.
- 5) Heads in the sand!
- 6) Only this or B-K1 can prevent Q-R8 mate.
- 7) Fiddling while Rome burns.
- 8) Mate is forseen, but 'business as usual'.

Numerous criticisms of the machines play may be made, It is quite defenceless against 'forks', although it may be able to see certain other kinds of combination. It is of course not difficult to devise improvements of the programme^{so} that these simple forks are forseen. The reader

may be able to think of some such improvements for himself. Since no claim is made that the above rule is particularly good, I have been content to leave this flaw without remedy; clearly a line has to be drawn between the flaws which one will attempt to eliminate and those which must be accepted as a risk. Another criticism is that the scheme proposed, although reasonable in the middle game, is futile in the end game. The change-over from the middle game to the end-game is usually sufficiently clean cut for it to be possible to have an entirely different system for the end-game. This should of course include quite definite programmes for the standard situations, such as mate with rook and king, or king and pawn against king. There is no intention to discuss the end-game further here.

If I were to sum up the weakness of the above system in a few words I would describe it as a caricature of my own play. It was in fact based on an introspective analysis of my thought processes when playing, with considerable simplifications. It makes oversights which are very similar to those which I make myself, and which may in both cases be ascribed to the considerable moves being rather inappropriately chosen. This fact might be regarded as supporting the rather glib view which is often expressed, to the effect that 'one cannot programme a machine to play a better game than one plays oneself'. This statement should I think be compared with another of rather similar form. 'No animal can swallow an animal heavier than himself'. Both statements are, so far as I know, untrue. They are also both of a kind that one is rather easily bluffed into accepting, partly because one thinks that there ought to be some rather slick way of demonstrating

them, and one does not like to admit that one does not see what this argument is. They are also both supported by normal experience, and need rather exceptional cases to falsify them. The statement about chess programming may be falsified quite simply by the speed of the machine, which might make it feasible to carry the analysis a move farther than a man could do in the same time. This effect is rather less than might be supposed. Although electronic computers are very fast where conventional computing is concerned, their advantage is much reduced where enumeration of cases etc. is involved on a large scale. Take for instance the problem of counting the possible moves from a given position in chess. If the number is 30 a ^{man} ~~man~~ might do it in 45 seconds and the machine in 1 second. The machine has still an advantage, but it is much less overwhelming than it would be for instance where calculating cosines.

In connection with the question, numbered iv) above, as to the ability of a chess-machine to profit from experience, one can see that it would be quite possible to programme the machine to try out variations in its method of play (e.g. variations in piece value) and adopt the one giving the most satisfactory results. This could certainly be described as 'learning', though it is not quite representative of learning as we know it. It might also be possible to programme the machine to search for new types of combination in chess. If this product produced results* which were quite new, and also interesting to the programmer, who should have the credit? Compare this with the situation where the Defence Minister has given orders for research to be done to find a counter to the bow and arrow. Should the inventor of the shield have the credit, or should the Defence Minister ?