What Computer Chess Still Has to Teach Us:

The Game That Will Not Go

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***Abstract* – Computer chess started as a promising domain of research in Artificial Intelligence (AI) more than five decades ago. The basic idea was that as a 'thinking sport' it would be a good challenge toward better understanding and potentially simulating (human) cognition in machines. Unfortunately, it was soon discovered that computers could be made to play chess (and certain other games like it) using computational methods quite different from how humans are thought to think. This spawned a competitive computer chess gaming industry and in 1997, the world chess champion was defeated by an IBM supercomputer. Since then, computer chess has seen further improvement with programs playing at the strong grandmaster level even on desktop machines. In the field of AI, attention has therefore shifted to even more-complex games like Go in the hope that computational approaches toward them will succeed where chess had apparently failed. In this paper I challenge that contention. I have reasons to believe that chess still has some things to teach us not only about computation and its limits but also about the human mind and how it probably works. As such, this is not a technical paper but rather one on 'computational philosophy'.**

Keywords – artificial intelligence; chess; go; games; machine consciousness; computational philosophy

I. INTRODUCTION

Computer chess[1] can often be traced to Claude Shannon's seminal paper on 'Programming a Computer for Playing Chess' [1]. In it, he describes precisely that but in what (by today's standard of computer chess) might be considered fundamental though somewhat rudimentary terms. Alan Turing is also sometimes credited in this regard given a paper of his in which he proposes a chess-playing program [2]. A notable difference between the two papers that might be of interest to chess players is the slightly different 'pawn unit' values attributed to the queen (♕), rook (♖), bishop (♗), knight (♘) and pawn (♙).[2] In Turing's case it was 10, 5, 3.5, 3 and 1 whereas Shannon had suggested 9, 5, 3, 3 and 1. The relative values of the pieces – even considering earlier endgame analysis [3] or in the light of scientific analysis over the years [4, 5] – have not varied from these by much. Generally, the values applied by Shannon are still the most widely used today. Early chess programs appeared soon after the work by Shannon and Turing (two people also famous for other things in engineering and computer science such as information theory and computability, respectively.) Initial success in computer chess was modest (e.g. the programs OSTRICH and CHESS 3.0 in the 1970s played at the 1400 Elo point level), but by the mid-1990s computers could play at the grandmaster or 2500+ point level. This was due not only to increased processing power but also improved computational approaches [6].

Getting a computer to play good chess is basically about having a good compromise between 'search' and 'knowledge.' The number of possible legal positions in chess is quite large; estimated to be around 10^{46} [7]. It is therefore impossible for contemporary computers to search and examine every position (or 'node') and 'solve' the game as in tic-tac-toe, and relatively recently – though in this case not by actually examining *every* position – checkers, which has about 5 x 10^{20} possible positions [8]. This means that a computer can only look so far ahead (i.e. the *depth* of the search) into the 'game tree' before having to decide which move to make. One method of doing this is using the traditional *minimax* algorithm.[3]

This is where 'knowledge' or game-playing heuristics come in. Game-playing heuristics can be described as formalizations of general 'good practices' of play such as, *'do not let your pieces be captured'* and *'control more space on the board.'* They can usually be represented in the form of evaluation functions that, for example, in a given position, calculate the amount of material (such as piece value) on the board, or the mobility of the pieces (such as the number of squares they control.) In reality, heuristics today are far more sophisticated than these. An example of an evaluation function to calculate how spread out or sparse *(S)* the pieces in a position are is shown in equation 1; $s(p_n)$ = the number of pieces on the squares immediately around a particular piece [9].

$$S = \left[\left(n^{-1} . \sum_{1}^{n} s\left(p_n \right) \right) + 1 \right]^{-1} \qquad (1)$$

[1] Chess, for the rest of this article, relates primarily to the Western (or 'International') version of the game.

[2] The king is seen as being of infinite value since losing it means losing the game. For programming purposes it can be attributed a relatively high number e.g. 200 (much more than all the other pieces combined).

[3] An explanation of this algorithm and related enhancements (e.g. alpha-beta pruning) can be found in many introductory AI or game programming books and courses. It is a deceptively simple algorithm (usually fewer than 10 lines of code) but through recursion permits searching through millions, even billions, of positions.

Sparser positions are usually easier for computers to evaluate so this function could act as a precursor to other evaluation functions in order to determine how far the program should look ahead given the available computational resources and time allocated. This particular function returns a value between 0 (less sparse) and 1 (more sparse.) It is also not limited to chess. In principle, a good combination of heuristics, coupled with effective searching (that includes clever techniques for skipping 'unlikely' moves and 'pruning' the game tree) – along with some well-developed opening theory[4] – gives computers the remarkable ability to play the game very well. So well that in 1997, the then world chess champion, Garry Kasparov, was defeated by IBM's supercomputer 'Deep Blue' in their 6-game match by a score of 2.5-3.5.

(This was actually a rematch since in the previous year Kasparov had defeated it 4-2, even though the computer won the first game, making it the first computer to beat a reigning world chess champion even then.) Deep Blue was able to evaluate around 200 million positions per second; many orders of magnitude more than any human is conscious of evaluating. During game 2 of the 1997 match, Kasparov was amazed but troubled at how human-like some of the computer's moves were. Interestingly, Kasparov himself attributed his defeat in the match not to Deep Blue's *calculating* ability, but its ability to *evaluate* positions [10]. The Deep Blue team agreed but Kasparov still had some difficulties accepting this. *"If that is the case,"* he said, *"then they have to explain it to the rest of the world. Tell us how you accomplished it, because it's far beyond anyone's understanding. I met something I couldn't explain. People turn to religion to explain things like that. I have to imagine human interference, or I want to see an explanation."* (ibid.)

Since then, there have been other chess programs to have also made curious moves. 'Junior,' for example (currently in its 10th edition), significantly factors in positional evaluation. One of the best examples of this was the bishop sacrifice by (at the time) Junior 9 on the *h2* square in move 10 of game 5 of the Kasparov-Deep[5] Junior match in 2003. The game (and the match) ended in a draw; see Fig. 1.

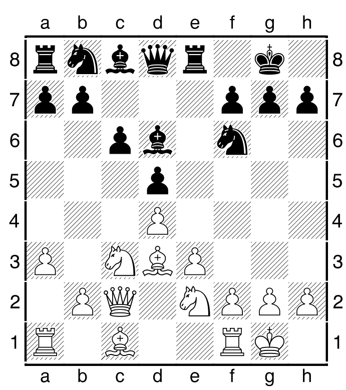

Figure 1. Deep Junior now plays the unexpected 10. … ♗xh2+

[4] The 'opening' in chess refers to the first 8-12 moves or so. One can always opt to play a move that is 'out of book.'

[5] 'Deep' implies the use of multiple processors.

In 2006, the then world chess champion Vladimir Kramnik lost 2-4 against the computer program 'Deep Fritz.' This program ran on a computer containing two Intel Core 2 Duo CPUs, allowing it to calculate around 8 million positions per second [11]. Modern chess programs are therefore arguably becoming more efficient and effective [12]. 'Intelligent,' if you will. Monty Newborn, professor of computer science at McGill University in Montreal, said of future man-machine matches that "*the science is done,"* and while acknowledging that the development of chess computers had been useful, suggested poker and Go[6] as future research directions [13]. This is where I would partially disagree.

II. GAME 'INTELLIGENCE'

Other computationally challenging games such as Go (in terms of its complexity e.g. the number of possible positions) and poker (in terms of its 'imperfect information,' i.e. there is concealed information, unlike in chess) are often seen as the logical 'next step' after chess. However, is this really the main direction in which we, in AI, should now be heading with regard to games like these? The general direction of research in a field cannot be ignored because it influences what is considered 'important' work. If we have learned anything from chess, checkers and the like, is that being able to program a computer to play complex games is apparently not going to contribute the kind of knowledge and understanding about the human thinking process that we hope to attain.[7] Even less so any more insight into the nature of human consciousness.

This is what appears to be the real question, if not for AI researchers then philosophers or neuroscientists. If a machine can 'think' (as in playing chess, Go or poker), is it 'conscious' of doing so? Few people will concede that a machine that can do these things – even if better than the best human players – is actually 'conscious.' So why are many in AI actively pursuing more-complex games? This is because – aside from the challenge and thrill of developing a computer program that is more 'intelligent' than you are in some respect – doing so often leads to the development of technologies than can also be of use in other areas within and outside of AI. For example, investigations into chess (e.g. the use of iteratively-deepening depth-first search) have made contributions to automated theorem proving (i.e. using a computer program to prove mathematical theorems) and also in solving state-space search problems [14].

Research into chess has also had an influence on molecular computing [15, 16], computer music composition [17], machine reading [18], cognitive development [19] and the treatment of psychiatric illness [20]. Research into other

[6] In scientific literature, there is some common agreement that the game be referred to using a capital letter to differentiate it from the English verb.

[7] An elementary demonstration could be the development of a new 'highly complex' game around rules and strategies that are amenable to computation. (This can be interpreted as looking at the problem from the 'opposite' direction.) The idea of 'greater complexity' in a game leading to improved AI – where chess had supposedly failed – would then be exposed as little more than the desire for a 'new challenge' (if not misguided optimism.) In short, it is not a question of complexity.

games like Go and poker could therefore likely make similar contributions. It is interesting, for example, how Monte Carlo simulations used there have had promising results. The basic idea is about quickly playing through and examining the outcome of randomly-generated games from a particular point, and selecting the move or action that most often resulted favourably [21]. A statistical 'sampling' approach. Once again, not very 'intelligent,' but it works.

Returning to the question of the science (of chess) being done, it would appear that a similar level of achievement in more-complex games would likely result in the same thing. 'Brute force' methods will probably also be among the most effective there [22]. This is the first reason why I would say that if games are to provide the kind of revolutionary insight into (human) intelligence that we are hoping to find, we should be able to find it in chess where there is already a strong body of literature (technical or otherwise) without expending more effort into 'conquering' more-complex games using the same or analogous techniques. However, I would not go so far as to say that the 'key(s) to intelligence' should also be found in say, checkers and tic-tac-toe. The game of chess, while in some ways similar to them is also in significant ways different. For example, there are more pieces and piece types which provide greater opportunity for *creativity* in play; 'greater' to an extent that matters, of course. Go, for example, has only one piece type but an estimated 10^{170} possible legal positions [23]. This makes it far more 'complex' than chess, but its (strategic) complexity does not necessarily imply higher levels of creativity.[8]

Take, for example, the following chess ending composition; see Fig. 2 [24].

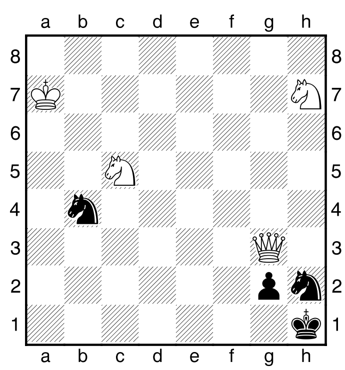

Figure 2. A. S. Gurvich, Bakinski Rabochi, 1927,
White to play and win

In those days, i.e. 1927, it would have been quite a feat of imagination to see the following: **1. ♘e4!** (1… g1♕+? 2. ♘f2+ ♕xf2 and White wins), **1. … ♘d3!** (2. ♕xd3 g1♕+ and White has insufficient material advantage to win) , **2. ♕f2!! ♘xf2** (2. … ♘f1 3. ♕h4+ wins, 2. … g1♕ 3. ♘g3+ and White wins), **3. ♘g3+!! ♔g1 4. ♘g5** and Black is put in a zugzwang[9] with checkmate to follow. Chess computer programs today would be able to 'see' the solution from the position in Fig. 2 within a matter of seconds by analyzing millions of positions in the resulting game tree very quickly. Subsequently, players today would benefit and quickly learn to recognize the pattern in their games. Therefore, a 'true' test of intelligence for a computer would be the ability to arrive at the solution – as (perhaps only a handful of) human players could at first glance – by 'looking' at only a few positions (e.g. 20 or 30) and creatively 'imagining' the possibilities. Imagine the potential in combining *this kind* of 'computer creativity' with the vast computational power at our disposal even today.[10]

The second reason is the well-establish aesthetic aspect of chess (as a game) that is developed significantly beyond other zero-sum perfect information games [25]. People appreciate beauty in chess to a level and extent that is arguably equivalent to other art forms [26-31]. Aesthetic 'recognition' by a computer may not quite equal aesthetic 'appreciation' but it breaks new ground (AI-wise) that other games are not yet ready for. Other art forms (e.g. music and art), on the other hand, do not possess the computational amenability that chess does. The reason I say (even passable) aesthetic 'recognition' is more advanced than *playing* ability is because it takes us from mere 'raw intelligence' and encroaches into the arena of human 'feelings.' Our ability to recognize or identify beauty is, in itself, often seen as a 'mysterious' quality of conscious beings [32]; something that separates us from animals and especially 'lifeless' machines.

There is a particular kind of romanticism to chess (not to be confused with the brash *style* of play in the 19th century) that we do not typically attribute to other games. This is evident both in history and in pop culture [33, 34]; something that sets it apart from games like backgammon, checkers, poker and Go. I am not, ironically, alluding to something mysterious here but am trying to make the point that chess has evolved in a way that makes it the de facto 'intelligent board game.' It was played mainly by aristocracy even until around the 19th century. The painting, *The Chess Game* by Francesco Beda (c. 1880) presents a fitting artistic depiction.

There are likely more books written on chess than books on all other games – board or otherwise – combined [35, 36]. More than this, chess, unlike other games like it, has also been elevated on many occasions in literature and art; even worthy of the attention of among the highest supernatural powers. Friedrich Moritz August Retzsch's *Die Schachspieler* (1831) is a well-known painting on this theme. Whether man is playing for his soul against Satan, or for temporary reprieve against Death [37], chess seems – at least in the minds of the artistic – to offer the most worthy and fair challenge. It is no wonder, then, that Garry Kasparov himself reportedly described Deep Blue as *"playing like a God"* (sic)

[8] Admittedly, creativity is a difficult thing to measure even though we tend to know it when we see it. Perhaps one indicator of 'distinct' creativity is when the experts *and* even those with comparatively little knowledge of the domain, are able to see and appreciate it with minimal effort.

[9] This term refers to positions where any move puts the player whose turn it is at a greater disadvantage (e.g. checkmate, loss of material) than if the turn could simply be skipped (which in chess, it cannot).

[10] I am hard-pressed to think of a more mature (i.e. developed) and computationally-amenable domain than the game of chess, where this level of 'glaring' creativity can be more effectively analyzed and tested.

in some situations [38]. Such an idea possibly stems from the apparent fact that even an all-knowing god would, at best, be only able to match a computer that could play the game perfectly.

Chess is also known for its many (relatively unexplored) variants. By some estimates, there are more than a thousand [39] spanning from the game's obscure origins thousands of years ago [40] to 'modern' variants. A good example of the latter is *Tri-D* chess which has been featured prominently in the Star Trek[11] television series since the 1960s. All of this 'fiction,' as it were, nonetheless has an influence on those who would judge machines and their 'intelligence.' More effective, I think, than a computer that is one day able to play Go on the level of (or better than) the best human players using sophisticated computational techniques and serious computing power, would be a computer that could play strong chess in a way that simply did not require much computing power and also did not *appear* computational (or appeared *less* computational), even upon close inspection. An example of a technique that does not *appear* very computational is the artificial neural network or ANN, for short. [12] Unfortunately, these have not been the most successful in chess.[13]

If the technique is 'fuzzy' enough[14] humans will likely be more willing to accept it as genuine (given our own approaches to such games) than a clear and precise computational technique. I am not suggesting that we opt for the more 'mysterious' approach even if we had two equally effective ones to choose from; rather that the real challenge lies in convincing humans, and not in finding the most challenging game. Our brains did not evolve to play chess or games like it – but we can learn to do so, however difficult it is or poor at it we turn out to be – whereas computers are usually programmed to do specific things and to do them as effectively and efficiently as possible.

The third reason why I think we need not look any further than chess is therefore the disillusionment of 'intelligence.' Questions about 'intelligence' today have slowly but surely become conflated with questions about 'consciousness' [43]. A machine that is able to accomplish *any* task ordinarily requiring human-level intelligence today is seen as nothing spectacular (as it may have been 50 years ago) unless it can also be demonstrated that the machine 'knows' it is doing so or is aware of itself, as we self-evidently are. A kind of *'we will know it when we see it'* criterion. I would not dismiss this out of hand even though it tends to fall short of the scientific standard. (Who is to say that an objective criterion here is impossible?)

The problem is that such a criterion is tricky. The fact that we do not yet know exactly what makes *us* tick (i.e. awareness, free will etc.) qualifies as an excuse for humans, does not mean it also qualifies for machines. Of course, we cannot have a machine that does something intelligent without anyone being able to explain how it works![15] So, computers have lost this challenge before it even begins. No computer poker or computer Go champion is likely to change this. Humans should therefore abstain from benchmarking machines against themselves because it is simply holding machines back.

One of the most valuable lessons that computer chess has already taught us is that there can be an alternative and possibly even more effective way (than humans know) of performing a task that requires reasoning and intelligence. We have already won this 'battle' in AI. All that remains is to demonstrate how a computer can simulate consciousness as well; and where better than in the zero-sum perfect-information game of chess where it has already mastered 'intelligence?' This is why a viable option – as opposed to 'starting over' with other games, if it was thought that it would help in this regard – is pursuing other facets of chess (e.g. creativity, aesthetics) and looking for alternative computational techniques for it that work just as well yet benefit from a kind of machine 'self-reflection;' a 'will' to do something, if you will. It is difficult to argue why simulated consciousness or any other kind of revolutionary AI should work in a game like Go or poker but not in chess.

III. LEARNING FROM CHESS

Chess was once used as a tool for military strategy. The national defence arena today has changed somewhat [44] but there are still significant things we can learn from this game. Here, I will not focus on the benefits we have already obtained from computer chess (see section II) but elaborate on what it still has to teach us. As mentioned in the previous section, there are reasons why exploring chess further, rather than other similar games, is still a viable option today. However, what have we overlooked with regard to chess in the quest to beat the world champion, now that we have succeeded? One thing is simply the ability to formulate a plan in the game – even a creative one – like a human usually does and preferably *in the way* that a human is thought to do. The uncanny ability to see beyond a certain depth or a series of forced exchanges into what *might* or is *likely* to occur at a (much) later stage.

[11] Star Trek, apparently, not only inspires common fans but also researchers and entrepreneurs. Half of all entrepreneurs in the space flight industry, for example [41].

[12] ANNs can have 'hidden' layers that make their derived weights (for certain features in a domain, for example) difficult to trace, unlike with a direct mathematical formula.

[13] ANNs, however, have been quite successful in backgammon [42]. It is important not to forget that AI research into games should be *less* about using existing techniques to play them, and *more* about discovering new techniques that not only play them but do other useful things as well.

[14] There is no particular reference to *fuzzy logic* here.

[15] The popular 2007 *Transformers* film (which tells of a race of alien robots), for example, cleverly addresses the problem of machine consciousness by alluding to the mysterious powers of the 'All Spark' (an artefact in itself) which can give independent life to mechanical objects. Things like this are not always the last resort for intelligent robots in science fiction but it occurs often enough to suggest that it is not machines per se that are necessarily the problem for humans when it comes to 'true' AI, but the fact that we tend to know precisely how they work. In fairness, I think that a well-defined machine that behaved *convincingly* like a human in all respects would nonetheless qualify and quite possibly teach us more about ourselves. This is something AI has yet to achieve. Then again, is that what we really want to invest in? Why not just settle for a human? Could we, for instance, bring ourselves to put such a 'machine' in harm's way when it is, for all practical purposes, indistinguishable from one of us?

Not only is this a challenge for computers [45] – many of which have apparently failed using this approach [46] – but also for humans. It takes a long time (if ever) for an amateur player to hone this all-important skill. As the saying in chess goes, *'it is better to have a bad plan than no plan at all.'* Learning, per se, does not appear to be the primary issue. There are many machine learning approaches. The real question, apparently, is the ability to imagine or dream, if you will, of what *might be*. This is also what separates humans from most animals.

Machines, similar to animals in this respect, lack the ability to recall specific past events (episodic memory) or to plan for the future [47]. Perhaps more precisely, they lack being self-evidently conscious (as we are) of doing so. This is why the kind of conscious and (deep) planning that is typically required by humans in chess is a good test for a 'lifelike' machine; but could a machine 'plan' without, on any visible level, being 'programmed' (even using genetic programming techniques) [16] to do so? This is the real challenge in AI today and chess is as good a domain for this as any. I do believe that whatever it is that humans are doing in their heads when they play the game can be replicated in a machine. Currently, we have settled for a satisfactory alternative approach (i.e. search and knowledge) but it is not quite the one we were looking for. We need to look deeper, not elsewhere.

As mentioned in the previous section, chess is also appreciated aesthetically. Chess compositions, for example, have been described as its 'poetry.' How is it that, a fundamentally mathematical game (not quite like say, visual art or literature), can have an equivalent aesthetic effect on humans? However we look at it, certain instances of the game are intricately connected with our aesthetic experience (we do not quite feel that way when looking at regular amateur games, for example). This is something worth exploring further given the unique amenability to computation that chess possesses. At what point and under what conditions, for example, do mere moves (that win, especially) become more than the sum of their parts and strike us as 'brilliant' or 'fascinating?' A few attempts at computer chess composition have been made in the past but they tend to suffer from the same 'mechanistic disease' of computational approaches and leave much of the creative aspect to humans [48-52].

Some composers and players are quick to point out that they do not, for example, look at the number of squares, legal moves, piece values or perform 'calculations' of any kind, and that there is 'something else' about the composition or move combination that they cannot describe and cannot, in any case they say, be sufficiently described. In short, it is a combination of factors vast and diverse. This may be true but it could also be that we are simply not aware of how our brains process the aesthetic response to particular stimuli. We are, in fact, not aware or conscious of many things about ourselves that our brains or brainstems 'mechanically' control and the precise methods and actions employed in doing so. For example, the medulla oblongata controls breathing, heart rate and blood pressure without conscious intervention from us. If described in precise detail to us, should we then claim that this is not what we 'really' do when we breathe? Do all those little actions that, on their own, appear so unlike breathing per se, *not* amount to *actually* breathing?

Could the same approach that gives computers the ability to 'dream up a plan' in the game also give them the ability to compose beautiful chess compositions or 'take a risk' with a highly irregular move in a real game that results in what we call a 'brilliancy?' Of course, it would only be fair that all of this come at the price of the computer *sometimes* completely messing up (as we do), but it would be a small price to pay given the kind of plasticity achieved; a plasticity in reasoning and thought that could be just as applicable in *other* domains. I do not believe we can have it both ways (i.e. computers reasoning as we do yet being perfectly reliable) but will not rule it out. After all, humans are, in principle, capable of being rational for the most part except for emotional considerations that need not necessarily be a side-effect to 'genuine' machine intelligence. Put simply, machines need not suffer from *our* evolutionary baggage [53].

Does the current 'computational paradigm' play a role? The question here is whether or not AI is limited by say, the binary system or a general lack of support for parallelism in computer programs (i.e. large problems divided into smaller ones and solved concurrently.) I am not quite sure either way. It could be that there is a revolutionary computer or software architecture waiting to be discovered or introduced to us (presumably by other intelligent life in the universe), [17] but it is difficult to imagine anything 'computable' that could not also be achieved based on the existing paradigm. One argument in support of this is that programmers have become complacent given the exponential rise in computing power over the last few decades. Computer programs are not as 'clever' as they would be had computers not become so powerful so fast. [18] This increase in computational power is commonly known as Moore's law.

Computer programs can become 'cleverer' in at least two ways. First, algorithms can be improved (a fitting example being alpha-beta pruning over traditional *minimax*) and second, new avenues for creative programming (e.g. facial recognition, genetic algorithms) can be created given increased processing power. One of the main arguments *against* this is simply that we are, today, no longer wanting for computational resources, especially with respect to what

[16] It is curious how we are usually more willing to accept the 'intelligence' of a computer program when it is not *directly* programmed by a programmer but programmed to program itself. This is another example of how computational techniques can appear *less* computational.

[17] Recent advances and discoveries in astronomy tend to support the idea that we may not, in fact, be alone in the universe [54]. By some estimates, the ability to traverse the vast distances between galaxies is actually less likely than there being some kind of life (perhaps even intelligent life) other than ours in distant galaxies. Far less likely is the possibility of a race of chess-obsessed Martians, as in the 1955 classic science fiction novel, *Men, Martians and Machines* [55].

[18] This is analogous to the 'resource curse' paradox in which countries with an abundance of natural resources tend to be inferior in terms of economic growth and development than countries that do not.

humans can already do with comparatively less (e.g. in terms of the 'firing speed' of a neuron). In chess, we can take this negatively, i.e. seeing it as a classic failure that relied too much on computational power and less on 'intelligence,' or positively, i.e. as a well-explored domain for intelligence that has taken its computational resources to the limit and is now falling back on 'cleverer' programs that rely less on those resources. I, for one, prefer the latter; which is why I would say that the science in chess is not quite done.

IV. CONCLUSIONS

With the defeat of the world chess champion to a chess computer over a decade ago, and given the strength of desktop chess programs today, some feel that it is time to move on to other, more-complex games. It is often hoped that we will be brought closer to 'true' AI by exploring those games. Chess is seen as either a failure in this regard or as being too simple to begin with [56]. I have shown and have argued that chess is neither a failure (from a computer science and AI perspective) nor is it too simple as a game. On the contrary, chess has made its share of contributions to science and is still meaningfully complex and even beautiful to humans. The game is also still far from being 'solved' (if ever), unlike tic-tac-toe and checkers. Even if it were to be solved in the near future, there are creative and aesthetic aspects to it that are largely unexplored and not outside the purview of contemporary science [25, 46]. Note that this is aside from the various aesthetic *designs* of chess sets that the game has inspired for centuries [57].

The seductive 'greater complexity' of games like Go is arguably little more than a desire for a new challenge after having beaten the best humans have to offer at chess. There are likely to be technological contributions (e.g. new computational techniques) in this new pursuit but far less likely anything that resembles the kind AI we had initially hoped for when computational investigations into chess began around six decades ago. This kind of AI, if it exists, could just as well (and can still) be found in chess. If more-complex games are actually meant to serve as a motivation to complacent programmers and computer scientists to find the 'key(s) to intelligence,' then we are perhaps unconsciously conceding to the idea that computational power has been more of a curse than a blessing in AI.

Even so, the fact that chess programs today are playing significantly better than their predecessors on significantly less computing power suggests that we are already on the right track. My concern is that a similar thing will occur with more-complex games (i.e. finding a very 'computational' approach before making programs 'cleverer') if we start the process again instead of looking deeper into chess, where we already have the groundwork covered. Diverting the attention of (especially AI) researchers toward other games will also affect the competitive aspect that existed – and that drove them to 'succeed' – when the focus was primarily on chess. Perhaps, in order to be taken seriously in AI today, it is simply a question of moving from the *objective* of (a computer) being able to beat the world champion, to being able to learn, improve in and ultimately 'appreciate' the game. Chess, as a domain of research, suffices.

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