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The Effects of Computer and AI Engines on Competitive Chess

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ABSTRACT

With more unique games than the number of atoms in the universe, chess has always been a mark of human intelligence. However, in the historic moment where world renown, grandmaster Kasparov was defeated by Deep Blue, chess engines have shown their power over human intelligence. This paper examines the impact of computer engines like Deep Blue, StockFish, and AlphaZero on competitive chess, considering their merits and drawbacks in shaping the game's landscape. The analysis reveals that while engines have significantly strengthened chess play, they have also posed challenges to human creativity and strategic thinking. By relying on engine-generated moves, players risk losing their individuality and turning chess into a memorization exercise. However, it is argued that a strategic collaboration between human intellect and computational power can yield optimal results in a technologically advanced chess era. The findings highlight the importance of integrating engine assistance with human cognition, emphasizing the need for players to harness engines as tools rather than substitutes for critical thinking. By utilizing engines for analysis, preparation, and validation of ideas, players can enhance their understanding of the game and explore new possibilities. Moreover, engines have played a crucial role in attracting a wider audience to competitive chess, leading to a rise in participation and an overall elevation in the level of play. Ultimately, the paper asserts that the combination of human intelligence and engine capabilities offers the most promising path for the future of competitive chess.

Introduction

Since the mid-1800s chess has always been a flex of intellectual prowess and human creativity. Chess has been played by some of the smartest humans, such as Einstein and Benjamin Franklin. It was always a court game played by the most intellectual as a battle of calculation and human ingenuity. However, since the introduction of chess engines, chess but more specifically competitive chess has never been the same. A chess engine is a computer program created to “solve” chess. A chess engine is able to see multiple moves in the future and evaluate the given position. The problem with chess engines was how to make them see far in advance, and how to make it play strong moves. In the late 20th century, it was the goal of computer scientists to figure out how to create the perfect engine to defeat the top humans in chess. Eventually, due to creative computer algorithms and strong hardware computer scientists achieved their goal because the top chess players, and even World Champions fell victim to the strength of engines. Ever since the creation of Deep Blue, the first engine capable of beating a World Champion in a match, the competitive chess world changed forever. However, DeepBlue was just the beginning of engines in competitive chess. The strongest emerging engines today such as Stockfish and LelaZero, are light-years stronger than DeepBlue. Both these engines are considerably stronger than the best humans, and it is not even close. These engines are built with even stronger custom chess heuristics, stronger processing power, and self-learning neural networks. The engines today are only getting significantly better, leaving even the top humans in the dust. However, humans have continued to play chess at the highest level. In fact, humans at the top level have gotten better and this can largely be credited to the emergence of these strong chess computers. Novice players and Grandmasters are able to have any potential question they may have answered almost instantaneously. This paper will discuss the relevance of chess engines, old and new, to competitive chess, and how the evolution of these engines affects competitive chess in the present.

Overview of Notable Chess Engines

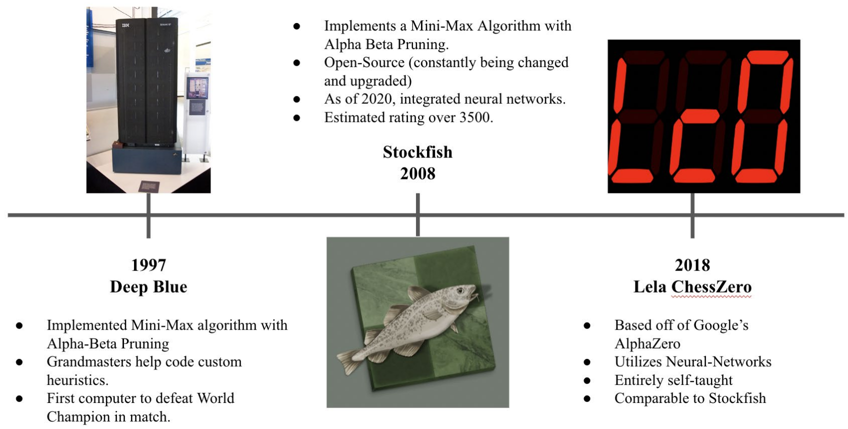

Figure 1. Timeline of Chess Engine Releases

Deep Blue

Deep Blue was first developed by graduate students at Carnegie Mellon University in the 1980s. It was a significant leap in computer science, as it was the first engine capable of beating a World Champion. Deep Blue's algorithm was groundbreaking at the time, as it used a mini-max algorithm with alpha-beta pruning. A minimax algorithm constructs a tree of all possible moves, and considers all of them. Deep Blue utilized a parallel system, which is a multithread system that used multiple processes to check iterations of a given game. Deep Blue was able to check 500,000 positions in one second, and had processing speed of 700,000 positions per second. Deep Blue's novel technology allowed it to be a very strong engine given the time period.

However, Deep Blue's biggest challenge was Garry Kasparov, the World Champion. Deep Blue I, the first version of Deep Blue, used 216 chess chips with each individual chip searching 1.6-2 million chess positions per second. The overall speed of this chip was 50-100 million positions. However, even with all this technology it was not enough to beat Kasparov. In 1996, Deep Blue I, lost to Kasparov 4-2, scoring 1 win 3 losses, and 2 draws. The next version of Deep Blue, Deep Blue II, was able to defeat Kasparov 3.5-2.5. It was able to do this by improvement in technology and custom chess heuristics. On the technological side, Deep Blue II's technological improvements came in the use of its chip. It could now see more than the Deep Blue I. Also, grandmasters helped improve the heuristics, and openings. It was given a proper opening book, and more chess-specific programming was introduced. This made it play more human-like but the difference was that its calculating ability was significantly stronger than a human. The combination of improved technology and stronger chess backing propelled it to beat Kasparov. This was significant as it was the first engine to beat a World Champion in a match.

At the time people were worried if this was the end of chess. No man-made computer had been able to defeat a World Champion, yet Kasparov just lost. However, others were not worried. "The fact that Deep Blue can go through a series of electrical processes that we can interpret as 'beating the world champion' is no more significant for human chess playing than it would be significant for human football if we built a steel robot which could carry the ball in a way that made it impossible to be tackled by human beings." (Lipking, 2003). According to Lipking, Deep Blue was significantly stronger than Kasparov and Kasparov's loss to DeepBlue proved to be insignificant to the continuation of human chess.

Stockfish

Stockfish is the current strongest engine in computer chess. It was initially released in 2008, and the newest version Stockfish 15 was released in December 2022. The original version of Stockfish uses a minimax algorithm like Deep-Blue, which leads to immense calculating abilities. Stockfish can see up to **x** positions. In addition to its minimax, Stockfish uses intense pruning to reduce the number of positions that need to be checked. "The engine applies two main classes of heuristics to reduce the search space: forward pruning and reduction. Forward pruning techniques remove game tree subgraphs that are unlikely to be contained in the optimal play. For example, if the evaluation of a position is significantly worse than the value guaranteed by a player's best alternative, the position's children are pruned early. This is known as futility pruning." (Maharaj et al, 2022) The combination of these two pruning techniques allows Stockfish to significantly decrease the number of positions it needs to check, increasing speed and efficiency.

Stockfish's accolades include winning the Top Chess Engine Championship 8 times. This is very impressive, as Stockfish is the only engine to have multiple versions dominate top-level chess. The most recent versions of Stockfish have recently added Neural Networks, which is the newest craze in engine chess. Engines such as AlphaZero/Lc0 utilize Neural Networks. Neural Networks allow Stockfish to gain impressive positional advantages. This paired with its calculating abilities has given it an estimated elo of above 3500, much higher than any human.

Stockfish's heuristics are coded with input from Grandmasters and are exceptionally strong and are constantly refined. Stockfish's heuristics like many engines value concepts like piece activity, king safety, space, etc. These heuristics allow for better play and also more efficient runtime. "However, when a nominal search depth of D is reported by chess engines, it does not mean that the search has considered all possible variations of D moves. This is due to heuristics which cause the engine to search promising variations to a greater depth than nominal and less promising variations to a lesser depth than nominal." (Maharaj et al, 2022) With already some of the best heuristics in engine chess and constant improvements to software Stockfish is miles ahead of any other chess engine. With unlimited time, Stockfish is actually able to solve any problem available. "Given infinite time, the engine will converge to the optimal line of play. Depth caps prevent lines from being overlooked via pruning, and reductions become inconsequential at infinite depth." (Maharaj et al. (2022). All of this shows the true strength of Stockfish.

AlphaZero/Lela Chess Zero (Lc0)

AlphaZero/Lela Chess Zero (Lc0) is a relatively new chess software. AlphaZero is a product of Google's DeepMind and is not currently available to the public, yet has taken the chess world by storm. Completely different from Stockfish, AlphaZero does not use a min-max algorithm but instead uses solely Neural Networks. AlphaZero learned chess empirically through self-play and was eventually able to grow to a very strong level comparable to Stockfish. "Once enough self-played games have been generated, the states of these games (i.e. the triple of current position, vector of move probabilities as well as the result) are sent back to the central server. This training data is then used to train the current network and improve its weights." (Klein, 2022) AlphaZero was given 9 hours to learn chess, and after 4 it was able to surpass Stockfish8. AlphaZero's playing strength was improved by constant revision from these training games until it got to a level comparable to top engines. In 2017, AlphaZero was able to beat Stockfish8, the current version at the time, with a score of 155 wins 6 draws, and 839 draws.

AlphaZero's algorithm is completely unique yet bears a resemblance to the way humans learn chess. Firstly, AlphaZero learns empirically through trial and error. Next, it learns the value of pieces, for example, the Queen is worth around 9 points, while a rook is worth 5. After the initial hump, it begins to learn opening theory, utilizing good/common openings and discarding "bad" openings. This serves like an opening book in a traditional engine. Finally, it is able to learn abstract concepts like king safety, space, and piece mobility. After many games, "The theme of king safety in tactical positions resurfaces in the comparisons between 64k and 128k, where it seems that 128k has a much deeper understanding of which attacks will succeed and which would fail, allowing it to sometimes accept material sacrifices made by 64k for purposes of attack yet then, proceed to defend well, keep the material advantage, and ultimately convert to a win. There seems to be less of a difference in terms of positional and endgame play." (McGrath, T et al, 2022) Unlike other engines with custom heuristics AlphaZero was able to learn chess and its intricacies at a high level, and it has been able to beat top engines in matches.

Unfortunately, AlphaZero is not open to the public, however, LelaZero (Lc0), an engine open to the public, is. LelaZero is very similar to AlphaZero and has the exact same learning methodology. This paper will discuss both AlphaZero and LelaZero but for practical purposes, they can be classified under one group of engines.

Comparisons among Engines

The two major engines in computer chess today are Stockfish and LelaZero. Yet due to their completely different methodologies towards chess, their results towards problems, both practical and artificial are different. One comparison between these two engines was done with Plaskett's Puzzle, an incredibly difficult endgame study even for top grandmasters. When both Stockfish and Lc0 were pitted against each other, Stockfish came out on top. This is due to the fundamental difference between Stockfish and Lc0.

After many studies, experts have come to the conclusion that Stockfish, and minimax algorithms, are much better with brute calculation, while Lc0, is much more human-like playing intuitive moves. "When tasked with solving Plaskett's Puzzle, Stockfish's approach proved superior. The engine searched through nearly 1.9 billion different positions to identify the minimax solution. The algorithm's sheer efficiency—due in part to domain-specific search optimizations—enabled it to find the surprising, unlikely solution." Plaskett's Puzzle is immensely difficult and due to Stockfish's algorithm of checking billions of positions it was eventually able to come up with the solution while LelaZero missed it. LelaZero's algorithm isn't as intensive and therefore is not as good with brute calculation. According to one expert, "After annotating 40 games between Stockfish and LCZero, FIDE Master Bill Jordan concluded that "Stockfish represents calculation" and "Leela represents intuition". (Maharaj, et al (2022) Plaskett's puzzle is one example of this notion, that Stockfish represents brute force, while LelaZero represents more human-like chess

Both engines have their merits, but due to their completely different natures they excel in different areas. For one, AlphaZero has been praised by top players and commentators as being different then conventional engines and therefore more useful to human chess. According to Kasparov, a former World Champion,"The conventional wisdom was that machines would approach perfection with endless dry maneuvering, usually leading to drawn games. But in my observation, AlphaZero prioritizes piece activity over material, preferring positions that to my eye looked risky and aggressive. " (Kasparov) Kasparov having played a match against one of the first strong engines, truly understands the methodology and strengths of traditional engines, has suggested and continues to suggest that AlphaZero and neural network chess is on the rise, especially for human use.

However, many experts suggest that Alpha-Beta engines (like Stockfish) are the best engines and will only continue to get better. "But if I want to make one prediction, it's that alpha-beta searchers will prevail for chess. Moreover, if neural network circuitry and accelerators will become more common on desktop and mobile computers, it is likely that other, more powerful ways of combining alpha-beta search with fast neural network based position evaluation will start to appear." (Klein, 2022) Klein suggests that the combination of brute force with neural networks will yield the best results but for now, Stockfish is the better engine then Lc0. Keeping this in mind, it is now possible to understand how humans can utilize engines to further understand their understanding of chess, and apply it to competitive chess.

Effects on Competitive Chess

The introduction of engines to chess took the competitive chess community by storm. Since engines are so much stronger and efficient then humans, top players began integrating it in their preparation. Due to the accessibility of engines, anyone was able to check anything at will and surprise their opponents. For example, engines allow people to test new opening ideas and prepare novelties. It also helps people study difficult yet objective portions of the game, such as the endgame. Also considering the easy access to a strong opponent at any given moment, computers have helped humans practice very specific portions of the game. Overall, engines have helped the opening, ending, and overall play.

Opening Theory

The Opening phase, being the most amenable to preparation, plays a pivotal role in chess games. The advent of computer engines has brought about a substantial transformation in this aspect of the game. According to Acher and Esnault (2016), popular first moves like d4, e4, Nf3, and c4 have remained consistent over time, as evidenced by existing databases and current practices from 1960 to 2015. These were the preferred openings employed by top players even before the introduction of computer engines, and interestingly, they have continued to dominate after the advent of these advanced tools. This reaffirmation of traditional beliefs by computers confirms the soundness of certain openings that have withstood the test of time for centuries. Furthermore, neural-network engines have demonstrated the ability to introduce fresh ideas within tried-and-tested opening lines. Caruana, the former World #2, acknowledges the significance and creative potential of AlphaZero, a neural-network engine, and its impact on the world's top grandmasters (Caruana).

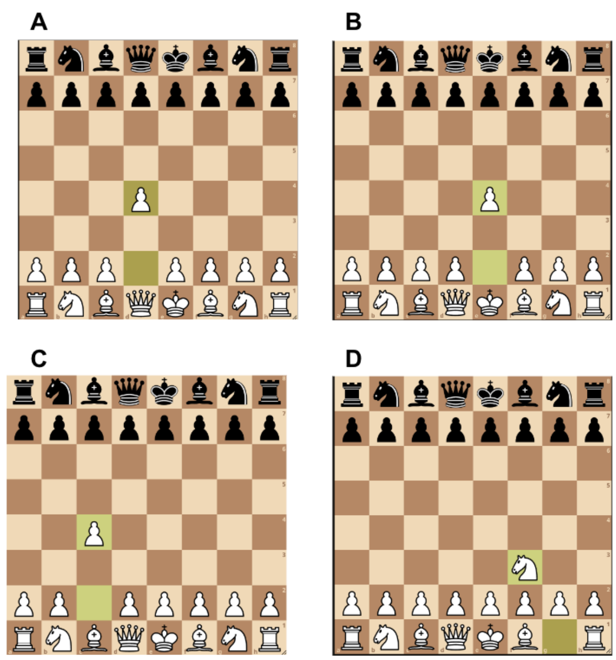

Figure 2. Common and Optimal Chess Openings A. D4 opening B. E4 opening C. C4 opening D. NF3 opening

However, computers have also challenged and refuted some openings from the past. Munshi (2014) notes that out of the ten opening innovations tested, five were found to weaken rather than strengthen the innovator's position. Notably, popular gambit lines such as the King's Gambit and the Evan's Gambit, once favored by past World Champions, are now rarely employed at the highest level due to the computer engines' ability to expose their inherent weaknesses.

In addition to their impact on the selection of openings, computers serve as valuable resources for checking and reviewing chess-related problems. Top computers are equipped with opening books, acting as comprehensive dictionaries of openings, and combined with extensive game databases. This enables players to enhance their understanding of openings and memorize lines. Levy (Year) suggests that by extracting relevant data from a playing program's openings book and game database, annotation programs can offer fashion-related or historically significant comments while a game is still "in book." Furthermore, engines enable players to test new ideas and create novelties within the opening. As Prost (2012) highlights, since the early 2000s, computers have been utilized as sparring partners by chess experts, allowing them to test opening ideas and analyze their own games to identify tactical errors and missed defenses. Consequently, players, from experts to Grandmasters, can rectify inaccuracies in their opening strategies and replace them with more precise moves. Moreover, given that the opening phase is extensively prepared, players can devise at-home novelties to catch their opponents off-guard. In summary, computer engines significantly aid the opening phase, empowering players to refine their skills and strategies.

The introduction of computer engines has had a profound impact on chess openings. While affirming the effectiveness of long-standing openings, computers have also challenged traditional beliefs and prompted the emergence of new ideas. By refuting outdated lines and providing valuable resources for analysis and preparation, computers have reshaped the landscape of the Opening phase, fostering innovation and elevating the level of play in competitive chess.

Endgames

The endgame, widely regarded as the most intricate phase of a chess game, has benefited significantly from the assistance provided by computer engines. These engines are equipped with built-in "tablebases," which essentially serve as repositories of solved positions involving fewer than seven pieces. By utilizing tablebases, engines facilitate the acquisition of knowledge regarding the outcomes of common endgame scenarios. Peterson (2018) describes a test position that was used to verify the correct functioning of engines' access to the five-piece tablebases. The experiment revealed that when played according to the tablebase, the move Ke4 was the only viable option. Conversely, without the aid of tablebases, engines tend to select Ke5, a suboptimal move. Consequently, the immediate detection of such discrepancies allows for the identification of misconfigured engines.

The integration of tablebases with chess engines has proven instrumental in solving complex endgame positions. While engines may occasionally err in their decision-making during the later stages of a game without tablebases, the combined utilization of these tools has significantly enriched our understanding of the endgame.

Sparring Partner

Computers can now be used to solve any problem a player may have. A chess game has over 10^44 legal possibilities, and it is simply impossible for humans to check even a fraction of that many moves. In a given position, there can be over 15 variations and potential deviations from the best move, and it is extremely difficult to foresee all of that. This is why computers excel where humans falter.“For example, in chess, there’s the human way, which is very pattern recognition–based and intuition-based, and then there’s the machine way, which is very search intensive and looks through millions or billions of possibilities” (Greenmeier, 2017) However, if humans use computers at moments where it is just simply too hard for them, it can yield very positive results for humans. Computers due to their impressive scope may analyze positions humans may not even consider, because humans may consider it too risky. There is no concept of risk for computers because each move has its own concrete evaluation, while humans have to self-assess and therefore miss critical moves.

Also, computers can now be used as sparring partners at any moment of the day. In the past, it was harder to find someone to play against, and on top of that play, what you want to practice. Now it is possible, and chess players have become stronger because of it. According to many experts, "Overall chess players are tougher today, they have a more pragmatic approach and better defensive skills than before. This is largely due to the resilience of chess engines in difficult positions: computers have influenced the style of play of the new generations. " (Prost, 2012) This is due to the constant use and revision that engines provide. The chess players of this generation are far more prepared than those of the past. This can also be seen in the way they approach chess. "Computers have inspired "concrete chess," allowing players to desert "old Russian school principles," a discipline popular during Karpov's era. Chess then was a dogmatic game, where one expected to be punished for not following the principles." (Bushinsky, 2009) Now in chess, principals can practically be thrown out the window if an engine says it is positionally sound. This has distorted the old views of chess and have introduced a new generation of chess, and chess players. Bushinsky was a programmer on many engines that beat top grandmasters, and his input shows the distinction between chess then and chess now. Chess now is a game of engines, to become better one must obey the engine.

Rating Distribution

Although engines have had an impact on competitive chess at the top level, overall chess ratings have been declining. Compiling the data from online rating records, a general trend is that the number of people playing has increased yet the average rating has been on a consistent decrease. According to Table 1, from 2015 to 2021 the mean chess rating, Q1, and Q3 values has been consistently decreasing. This means that fewer people are winning chess games. While this seems contradictory it shows that engines have overall made people stronger at all levels of chess which leads to a lower win rate, which in turn leads to lower ratings.

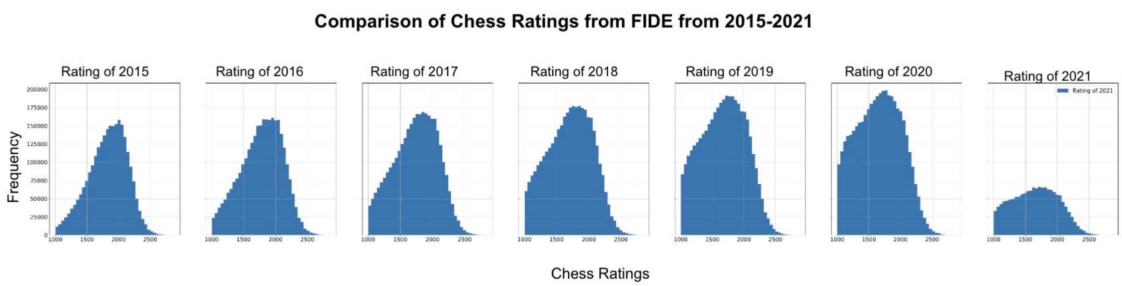

Figure 3. Chess Rating Distribution from FIDE from 2015-2021

Table 1. Summary Statistics of FIDE Chess Rating Data From 2015-2021

	Number	**Mean**	**Q1**	**Median**	**Q3**
2015	2680191	1828.015	1627	1856	2053
2016	3200346	1780.188	1557	1807	2024
2017	3721162	1740.233	1497	1764	1997
2018	4230762	1707.597	1448	1726	1972
2019	4741627	1679.410	1407	1692	1948
2020	5125950	1661.154	1382	1669	1931
2021	1728195	1658.456	1379	1665	1928

Conclusion

The advent of chess engines has undeniably revolutionized competitive chess, providing players with unprecedented access to powerful analysis and game preparation. However, this technological advancement has not come without its drawbacks. As engines surpass human capabilities, there is a risk of stifling creativity and reducing chess to a mere exercise in memorization. The mimicry of engine thought processes by humans, as pointed out by Wilkenfeld (2019), has led to a decline in holistic thinking and a blind reliance on predetermined moves. While this approach may work when opponents follow engine lines, it falls short when faced with deviations.

Furthermore, the increasing reliance on engines has diminished the human touch and originality in chess. As Bart (2016) argues, computers have surpassed humans in terms of creativity, raising concerns about the potential homogenization of chess strategies. This trend is expected to persist and intensify with the continued advancement of computer technology. Nevertheless, the defeat of humans by machines does not spell the end of chess as a pastime or the demise of interest in computer chess (Hsu et al., 1991). Competitive chess continues to hold value and appeal, albeit with a recalibrated understanding of the human-computer relationship.

The lessons learned from early encounters with engines, such as Deep Blue's victory over Kasparov, have shaped a more nuanced approach to competitive chess. Rather than surrendering to computer dominance, players have recognized the need to blend engine assistance with their own intellectual capabilities. This symbiotic relationship between humans and engines has yielded stronger play across all levels, from elite grandmasters to aspiring amateurs. The availability of cutting-edge engines like Stockfish and LelaZero enables players to explore and validate their ideas, empowering them with levels of analysis previously unimaginable. The integration of engines has also brought more enthusiasts into the competitive chess arena. Since Deep Blue's celebrated match in 1996, the number of people engaging in chess has witnessed a substantial rise as shown in Figure 3 and Table 1. Despite the vast discrepancy in strength between humans and engines, the joy and purpose of playing competitive chess endure.

In conclusion, the continuous improvement of chess engines will likely attract more individuals to competitive play while raising the overall standard of the game for future generations. The collaboration between human cognition and engines computing powers has opened up new horizons, allowing players to explore uncharted territories, uncover novelties, and bring fresh excitement to the chess landscape. While challenges remain in maintaining the balance between human creativity and reliance on engine analysis, the positive impact of engines on competitive chess cannot be denied.

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