“Chess is beautiful enough to waste your life for,” the oft-quoted aphorism of Dutch Grandmaster Hans Rees, most succinctly describes the human obsession with the ancient game of kings. For centuries, the act of playing chess has been upheld as the very paragon of intellectual activity. Voltaire said, “Chess is the game which reflects most honor on human wit,” and Goethe called chess “The touchstone of intellect” (Spaans). The first internationally recognized World Champion of the game, Paul Morphy, echoes these sentiments, “Chess is eminently and emphatically the philosopher's game.” (ChessVille) The deep strategic nuances of the game has kept players enamored with the game for centuries and more books have been written about chess than all other games combined. It is the game’s reputation as both a strategically deep system and as a thinking man’s activity that originally made the idea of a mechanized chess player an intriguing notion. There is a romantic appeal to building machines to do battle with the mind of man that has propelled computer chess from humble beginnings to the 1997 defeat of world champion Garry Kasparov to IBM’s Deep Blue.

The seminal paper in the field of computer chess was written by Claude Shannon in 1949 and since then generations of chess programmers have looked to it for inspiration (Atkinson 39). It was about this time in the United States that the nascent field of artificial intelligence looked ready to burst forth with revolutionary thinking machines. Such was the enthusiasm of the time that Herbert Simon (an AI researcher and Carnegie Mellon and a Nobel laureate in Economics) and Allen Newell suggested in 1958 that,
“Within ten years a digital computer will be the world’s chess champion, unless the rules bar it from competition” (7). In this great era of exploration, researchers were looking for model problems to develop new AI techniques with that, they hoped, would eventually lead to a mathematical model of conscious decision making – the true artificial intelligence that the world has yet to witness. In 1950, an abbreviated version of Claude Shannon’s paper was printed in Scientific American, making the case for the use of chess as a model system to be used for this purpose. “The investigation of a chess-playing program is intended to develop techniques that can be used for more practical applications,” he wrote. “The chess machine is an ideal one to start with for several reasons. The problem is sharply defined, both in the allowed operation and the ultimate goal. It is neither so simple as to be trivial or too difficult for satisfactory solution. And such a machine could be pitted against a human opponent, giving a clear measure of the machine’s ability in this kind of reasoning.” (48) For these reasons, the idea of building a machine that could play chess better than any man became one of the holy grails in the field of artificial intelligence (Bynum, 215).

Surprisingly, the romance of chess-playing machines begins centuries before Claude Shannon or even before the computer. At first, computer chess was the realm of dreamers. In 1770, Baron Wolfgang von Kempelen constructed an automaton composed of a manikin sitting cross-legged on a four by two by three foot wooden cabinet, sporting a handsome turban. The automaton was capable of playing chess. Though Kempelen never gave his creation a name, it was known throughout Europe as “The Turk” (Standage, 23). The Turk had an illustrious and prolific playing career. When first built it was displayed at the court Austrian Empress Marie Theresa in Vienna to the empress’s delight. In 1783,
after a tour through Russia, the Turk was again exhibited in Vienna for Emperor Joseph II. The same year the machination beat Benjamin Franklin in a game played in Paris. Two years later, while the Turk was touring Prussia, Fredrick the Great played it a game and lost. Perhaps the most famous game the Turk ever played was against Napoleon Bonaparte at Schonburnn during the Wagram campaign in 1809, checkmating the emperor in 24 moves. In 1820, the Turk sailed west to America where it visited New York, Boston and Philadelphia. In Philadelphia, the excitement caused by the Turk resulted in the formation of the first American chess club there. Charles Carroll, one of the original signers of the Declaration of Independence, played the Turk in 1827 (Wall). Edgar Allen Poe wrote about the Turk on two separate occasions, once in 1836 in an analytical essay describing how the machine worked, and again in 1850, when the machine was featured in a short story called Von Kempelen and His Discovery (Standage, 211). The Turk’s celebrated 85 year career came to an end in 1854 when it was destroyed in a great fire that devastated Philadelphia. The Turk, of course, was merely a brilliant illusion, not a brilliant chess-playing machine. Though the doors of its cabinet could be opened to demonstrate that there was only machinery inside, a small chess master could be squeezed into a secret compartment and control the automaton’s moves. Over the course of its long history, the Turk was occupied by no fewer than 15 masters of the game (Wall). Von Kempelen very pointedly never claimed that the Turk was actually playing chess for itself (Standage). Considering the power of some of Turk’s more historical opponents, this was no doubt a wise decision. As the Industrial Revolution trundled on and people became more familiar with what a machine could and could not be expected to do, that the Turk was an elaborate hoax became the prevailing
opinion. But this did not dispel the Turk’s mystique. The very idea that a machine could be constructed that would play chess was the most compelling aspect of the Turk’s novelty – it set the imagination on fire. At the time of the Turk’s demise, ideas regarding the creation of honest chess automata had already been engendered.

Charles Babbage, a man born before his time, was consumed for much of his life by a powerful vision of programmable computing machines. Today he is recognized as one of the grandfathers of the Digital Age. Limited by technology in Victorian England, his greatest invention, the Difference Engine, an enormous mechanical calculator, was not actually constructed until 1996 (Swade). On March 6, 1819 Babbage saw the Turk play in the Spring Gardens on one of its tours to London (Standage, 140). A year later, he actually sparred with the device, losing to it in about an hour. Babbage began to consider whether it was possible to create a machine capable of playing games of skill, specifically chess (among others), and even considered constructing several to fund the construction of the Difference Engine. Though he wrote about game playing algorithms, he never attempted to construct an automaton. In his memoirs, Babbage relates how he causally polled people about whether or not they thought machines could ever exist that could play games of skill. They answered, unequivocally, no. Never.

The technology required to build true chess playing machines did not yet exist, but during and after the Turk’s reign, many chess automatons were built. The romance of the idea that a machine could hold its own in a province previously exclusive occupied by man almost had a life of its own. Plans and designs and algorithms for chess-playing automata were made, but never built. There are a few notable exceptions. Around 1890, Spanish inventor Leonardo Torres y Quevedo built a series of mechanisms that could
autonomously play a subgame of chess against a human opponent. When completed the
automaton could play a technically perfect king and rook versus king endgame (the
simplest chess endgame). The device was very fancy and involved an electromagnet that
would move pieces across the board, lights that would go off if an illegal move was
entered, and a phonograph that would yell “Checkmate!” in Spanish when the machine
won. The device remains in perfect working order and is on display at the Polytechnique
University in Madrid (Atkinson, 22). Another notable advance in mechanized chess was
Alan Turing’s “Paper Machine” that he experimented with in the late 1939s. Not having
access to an actual computer, Turing wrote down simple search and move evaluation
moves onto a couple dozen pieces of paper and would painstakingly play games against
fellow academics by executing all of the instructions by hand. Turing’s chess program
performed dismally against opponents, but it was the first time that all of the algorithms
related to chess programming were put together in one place and used to play a game
(Newborn, 28, 1996). The foundation for computer chess was being laid.

In terms of Game Theory, the chess is a game of perfect information. Everything
about the state of the board is known by both players of the game at all times. If one
player makes a brilliant move, it is because his opponent didn’t see it coming in time to
counter it. From any position in the game, there are a finite number of moves that any
player can make, and a finite number of moves his opponent may make in return. Thus,
from the starting position there is a widely branching game tree that represents all
possible moves and counter-moves that can be played. The approach that nearly all chess
programs take to finding the move to make in any particular position is to search this tree
of moves and counter-moves, applying various heuristics that good players use to evaluate
each position (axiomatic rules of thumb like having knights in the center is good or an uncastled king is bad) and choosing the first in a sequence of moves that result in the best position for the program if it is assumed that both sides play perfectly (according to these heuristics). This is the basic idea behind the MiniMax search algorithm developed by Von Neumann and Morganstern in 1944. Any chess program, at its heart, is a search engine.

The first working chess programs appeared in the late 1950s. From the beginning chess programming was a hobby that people worked on during their spare time. The very first of these was developed at the Los Alamos by some rather prominent scientists (including Paul Stein and Stanislaw Ulam) as a way to test the new mainframe that the lab had just received. It was a pared down version of the game, played on a 6x6 board, and ran on a Univac MANIAC I. The MANIAC I ran at 11,000 instructions a second, making it several million times slower than a typical desktop machine today. Its level of play was “less than impressive” (Newborn, 29, 1996). The first major advance in chess programming was the development and application of the alpha-beta search algorithm, which can be exponentially faster than MiniMax under some conditions. The complexity of a MiniMax search is $O(b^n)$, where $b$ is the average number of moves considered at each ply (in a typical game this runs around 36). Comparatively, in the best case, alpha-beta takes a twice the square root of the time it would take to do a MiniMax search. In practice, this allows chess programs to search several plies deeper into the game tree with no drawback (Laramee). Alpha-beta was first implemented in the Nss Chess program (Newborn, 29, 1996). The first computer program to compete against humans under tournament conditions was Richard Greenblatt’s MacHack (Atkinson, 53). Developed in
the 1960s, MacHack was the first computer program to implement a transposition table. Tranposition tables were a brilliant innovation that let the computer take advantage of the fact that roughly 25% of all move sequences transpose to the same end position (Shedletsky). According to Bob Hyatt, author of Clay Blitz, at higher depths, transposition tables can save around 70% of the computation (Newborn, 56, 1996). The basic idea is that when a board position is evaluated during a search, a 64-bit Zobrist key is generated from the board position and the board evaluation is hashed into a large table in memory using this key. In the future, whenever the search needs to evaluate a board position, it first checks to see if this work has already been done, and if it has, simply pulls the evaluation out of the hash table – doing much less work than actually evaluating the board position again (which, depending on how the chess program in implemented, can be a large overhead). There are also some optimizations that can be done with a hash table that improve move ordering for the alpha-beta search, which help it to run at close to best-case time. MacHack maintained an ELO ranking around 1400, a strong class D player. In 1974 the first computer chess world championship was held in Stockholm. The competition was won by the Soviet program KAISSA and marked the rising popularity of computer chess competitions (Newborn, 45, 1996).

<table>
<thead>
<tr>
<th>Ranking</th>
<th>ELO Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grandmaster</td>
<td>&gt; 2500</td>
</tr>
<tr>
<td>International Master</td>
<td>&gt; 2300</td>
</tr>
<tr>
<td>Expert</td>
<td>2000 – 2200</td>
</tr>
<tr>
<td>Class A</td>
<td>1800 – 1999</td>
</tr>
<tr>
<td>Class B</td>
<td>1600 – 1799</td>
</tr>
<tr>
<td>Class C</td>
<td>1400 – 1599</td>
</tr>
<tr>
<td>Class D</td>
<td>1200 - 1399</td>
</tr>
<tr>
<td>Class E</td>
<td>1000 - 1199</td>
</tr>
</tbody>
</table>

Ratings are normalized such that a player rated 100 points higher than his opponent has a 64% chance of winning. A player rated 200 points higher wins 72% of the time.
Up until 1977, computer chess programming had been the realm of the amateur with an interest in pushing hardware to its limit and a passion for developing chess programs. That chess software requires development in the truest sense of the word, over many iterations of debugging and heuristic tuning is the real thrill. Monty Newborn, the author of two books on Deep Blue and the author of Ostrich, a chess program that competed again KAISSA in 1974 for the title of world champion, explains that part of the joy of computer chess is that when you are developing a chess program, the programmer imparts something of his playing style into the machine. Its strengths and weaknesses echoes those of its creator. And a chess engine is never truly completed, there are always new things to teach it; new algorithms to add. Newborn explains that, “It is very much like having a child.” In 1977, through the rising popularity of computer chess tournaments, the problem of designing the next faster, smarter, better chess program became an increasingly popular research topic in corporations an in academia. The first professional entrant into the fray was UNIX originator Ken Thompson, of AT&T Bell Labs. Backed by corporate research and development funds, he created the first chess machine with custom-designed chess logic in hardware. This improvement speeded up search and move generation incredibly, netting his program Belle the computer chess world championship in 1978 (Newborn, 92, 1996). In 1983, Belle was the first chess program to reach the master level (Stork, 85).

The move to specialized hardware paved the way for one more major improvement in computer chess algorithms: parallel evaluation and parallel search. Monty Newborn’s Ostrich, running on a five-processor Data General system, and Robert Hyatt’s CRAY BLITZ, running on a four-processor Cray-XMP were the first programs
to take advantage of multiple processors (Newborn, 140, 1996). Running on supercomputers, these programs would parse out positions to different processors for search and evaluation, collect them all back in one place, and then choose the best result. Parallel programming is one of the most complicated programming tasks when designing any system and chess programming in general is highly recursive and far from simple. Designing efficient algorithms for separating problems into smaller subproblems that can be solved in parallel remains a topic of serious research in computer science. Insofar as AI research is concerned, the development of parallel processing techniques may be computer chess’s greatest return contribution to the field.

“It appears to have imagination, because it can look ahead and see moves that nobody would have thought of,” pondered Murray Campbell (Newborn, 15, 2003). The subject of Campbell’s rumination was Deep Thought. Deep Thought, in 1989, was a part of a solution to what IBM research and development likes to call a “Grand challenge problem”. The “grand challenge” was to create a computer that could beat the reigning world champion, Garry Kasparov, widely regarded as the best chess-player to ever live, under tournament conditions. To spearhead this initiative, IBM hired Feng-hsiung Hsu, Murray Campbell, and Thomas Anantharaman, Carnegie Mellon graduate students with Ph. D. experience in developing parallel computer chess programs. Deep Thought used 6 of Hsu’s custom-designed VLSI (Very Large Scale Integration) chess accelerator chips to tear through chess positions at a hitherto unattainable speed (two million positions a second). After several disappointing performances, Deep Though made computer chess history in December of 1989, beating grandmaster David Levy in a six game match,
being the first computer to ever beat a grandmaster (Newborn, 32, 2003). When matched against Kasparov, however, the champion disabused the computer – beating it soundly.

Several years later Deep Thought’s descendant, Deep Blue again challenged Kasparov for the title of world champion. Running on a 32-processor IBM RS/6000 SP with 6 VSLI chess chips per CPU and capable of searching one hundred million positions a second, Deep Blue was capable of playing grandmaster-class chess. Its approximate strength was judged by Kasparov to range between 2200 and 3000 ELO points. Kasparov himself is rated at a record high of 2812 ELO, and most grandmasters sit between 2500 and 2600. The match was held in Philadelphia and in the first game, Deep Blue made history by becoming the first computer to ever beat the world champion in a tournament game. Kasparov, gathering his energy, however, was able to come from behind and win the match 4 – 2, collecting the $400,000 prize purse and “defending humanity’s pride”. The audience gave him a standing ovation (Newborn, 277, 1996). IBM, despite being the subject of playful banter in the media, was content with having generated tremendous publicity for their supercomputers. Plus, there would be a rematch next year.

The 1997 rematch in New York against Deep Blue and Garry Kasparov would be momentous; the stage for an epic battle was set. IBM researchers had estimated that Deep Blue needed to improve by about 100 ELO points to be a match for Garry Kasparov. Since Philadelphia, chess masters had been brought into IBM to help tune Deep Blue’s search heuristics and analyze its play. Mistakes in the opening book that caused it to lose several games in Philadelphia were correctly. Hardware improvements dictated by Moore’s Law doubled Deep Blue’s search speed. It was now capable of searching through two hundred million moves a second, and 100 billion moves in three minutes, the
average turn length in a tournament game. This machine was a far cry from the Los Alamos Univac crawling through positions at less than 200 nodes per second. The terms of the rematch were the same as in Philadelphia. There were to be six games, the winner takes $700,000 in prize money. In the beginning, it looked a lot like the Philadelphia matches, when Kasparov won the first game of the match. But that is the last time the world champion would ever beat Deep Blue. This contest, IBM CEO Lou Gerstner told the Deep Blue team, is “A chess match between the world’s greatest chess player and Garry Kasparov.” (Newborn, 175, 2003) And it was true.

On May 11th, 1997, a scant one hundred and fifty years since the Turk set foot in New York City, the game of chess no longer belonged to man. It was a great day for computer science, and a milestone event in the history of artificial intelligence. A question that psychologists, philosophers, and critics will question the nature of this romance of the regicide – what exactly have computers proved by beating the world champion? Humans built the beast and humans programmed it, adjusted it heuristics, and told it what to think. Is this an example of machine intelligence, mimicry, or fraud?

DeGroot, who did seminal research in the 1960’s on the thought processes involved in chess would argue that Deep Blue does not think at all, that it carries out predefined instructions, and nothing more profound. This is a point of view unlikely to be discredited in the near future. But some would disagree. “Something truly unbelievable happened, and it showed a sign of intelligence,” recounts Kasparov after the rematch (Bynum, 215). Deep Blue’s play was so human-like that during the rematch, Kasparov hinted that the Deep Blue team must be sneaking the computer moves to make. But what was really happening is what is known in the field of AI as emergence - in any
sufficiently complex rules-based system, complex behavior results. Mathematicians have been struggling with this phenomenon since Russell uncovered the set paradoxes in the 1930s, and it is well recognized in cellular automata and also studied in morphogenesis in biology. Kasparov notes that in Deep Blue, “Quantity had become quality” (Stork, 86). Deep Blue searches through billions of positions, finds the brilliant combination, and plays. If one saw Deep Blue play without knowing it was a computer, the instant conclusion would be that it was, in fact, a chess genius. Does knowing how it works not make it so? The Turk was widely appreciated even after general public opinion was that it concealed a man. And now the man has been taken out of the cabinet.

**EPILOGUE**

Baron Tassilo Heydebrand und der Lasa’s observation that, “Chess is in its essence a game, in its form an art, and in its execution a science,” fits, quite aptly, the description of the development of computer chess. The humble beginnings of chess-playing manikins and Turing’s paper chess automaton, was nowhere in evidence in the Deep Blue juggernaut that stole Kasparov’s title as the best chess-player on the face of the earth. Monty Newborn makes the conservative estimate that the New York rematch was worth three billion dollars to IBM in terms of the percentage the company’s stock rose during that week, adjusted by how much of that increase was judged attributable to the publicity generated by the rematch (237, 2002). Members of the Deep Blue publicity team won awards for the best public relations campaign of the year – making an incredible three billion impressions all over the world (216, 2002). Seeing as the Deep Blue project cost only twenty million dollars total over the course of its life, the return on
this investment was incredible. And yet, for all the money and publicity, IBM declined a second rematch with Garry Kasparov.

Computer chess in our time is a refined science. If it is a science with humble beginnings, it is now we who are humbled. The most cited reason internally at IBM for declining another rematch is that a publicity backlash was feared if the next incarnation of Deep Blue were to brutally crush and humiliate its human opponent. Moore’s Law, improvements in parallel processing, three-dimensional microchips, denser, lower latency memory, and advances in computer chess programming are all conspiring to bring a day when humanity can no longer compete with machines the ancient game of kings. In 1997, Kasparov was disappointed that he lost the match. Going up against a machine that can see twenty moves ahead in some positions and blaze through fifty billion positions in three minutes, it’s incredible that he won even once.

By 2005, IBM’s new high-profile supercomputer, BlueGene/L, is expected to be running at 200 TeraFLOPS. More powerful than the next 100 fastest machines on the planet combined, it will be used to simulate protein folding in close to real-time. BlueGene/L will be 4000 times faster than the RS 6000/SP used to beat Garry Kasparov in 1997. As a general rule of thumb in chess programming, to search an extra ply in the game tree takes six times more processing power than all the previous searches did. Another is that every ply searched adds approximately 200 points to the program’s rating. Even accounting for overhead in the parallel search (it is considerable), the DeepBlue software running on BlueGene/L would have a rating of 3500 ELO. The machine might as well be omniscient for all the chance a man would have against it. Bear witness as Charles Babbage’s Digital Age trundles on…
Bibliography


Trends in computers and supercomputers

SuperComputers:
Earth Simulator, 40 TeraFLOPS
http://www.es.jamstec.go.jp/esc/eng/outline/outline01.html

ASCI White, 12.3 TeraFLOPS

BlueGene/L, 200 TeraFLOPS – online by 2005

Chess is a storm against man. – Mikhail Tal
Widely acknowledged to be the most tactically brilliant player to ever live

“Chess is life” - Fischer
Appendix

Pictures of the Turk
Claude Shannon, Reluctant Father of the Digital Age

Alan Turing, British Mathematician
Ken Thompson, Creator of Belle

Belle
One of Feng-Hsuing Hsu’s VSLI Chess Accelerator Chips
Garry Kasparov and Feng-hsiung Hsu are all smiles as they shake hands before the beginning of the first game of the Rematch.
The audience in the commentary auditorium watching Kasparov as he waits for Deep Blue to play its 35th move.
(By permission of Bill DeOre.)

(By permission of Steve Breen and Copley News Service.)
(By permission of John Deering.)

(By special permission of Jim Borgman and King Features Syndicate.)
YOU COMPUTERS.

YOU'VE CONFOUNDED US HUMANS, YOU'VE MADE US FEEL STUPID.

YOU'VE SHOWN US UP, YOU'VE TAKEN OUR JOBS.

WELL, TODAY I HAVE JUST ONE THING TO SAY TO YOU.

IN YOUR FACE!

Cartoonist Mike Thompson, Daily Hampshire Gazette, February 24, 1996.
(By permission of Mike Thompson and Copley News Service.)
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(By permission of Brian Duffy.)
Deep Blue really is behaving more like a human...

Tell IBM that I want a multi-million dollar deal—or I'm playing for Apple... Hey, what do I look like—a toaster oven? Show me the megabytes!!

Cartoonist John Sherffius, Ventura County Star, May 9, 1997.
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Cartoonist Jeff Stahler, Cincinnati Post, May 7, 1997.
(stahler@United Feature Syndicate.)
(By permission of Richard Crowson.)

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Maelzel’s
EXHIBITION,
MASONIC HALL.

ON SATURDAY, MAY 17TH, 1834.
There will be two exhibitions, one commencing at 4 o’clock. (at the usual time.—Doors open half an hour previous to the performance.)
Doors open at half-past 7 o’clock. Performance to commence at 8 o’clock.

PART FIRST.
THE ORIGINAL AND CELEBRATED
AUTOMATON
CHESS PLAYER.
Invented by De Kempelin, Improved by J. Maelzel.

The Chess Player has withstood the first players of Europe and America, and excites universal admiration. He moves his head, eyes, lips, and hands, with the greatest facility, and distinctly pronounces the word "Rejes," (the French word signifying "Check") when necessary. If a mistake is made, he perceives and rectifies it.

THE
Automaton Trumpeter.
The Trumpeter is of a full size, and dressed in the uniform of the French Lancers. The scenes executed by this Automaton are performed with a distinctness and precision unattainable by the best living performers; the execution of time being, from the nature of the mechanism, absolutely perfect. In double-tonguing, his superiority is particularly manifested, not only in the cleverness of the turns, but also in the number of the notes which are sounded. All the sounds are actually produced in the Trumpet, there being no pipes whatever within the figure. The pieces he plays were written expressly for him by the first composers. He will perform on each evening, two favorite pieces. 1st, the French or Austrian Cavalry Manoeuvres. 2d, A March, with an accompaniment.

THE
MECHANICAL THEATRE,
Purposely introduced for the gratification of Juvenile Visitors.

It consists of the following scenes:
1. The Amazing Little Bass Fiddler
2. The French Oyster Woman—who bow to the Company, and performs the duties of her station, by opening and presenting her Oysters to the audience.
3. The Old French Gentleman, of the ancient Regime, who drinks the health of the Company with great glee.
4. The Chinese Drummer, accompanying the Scenes with his Tambourine.
5. The Little Troubadour, playing on several instruments.
6. Punchinello will go through his comical attitudes in imitation of the celebrated Mazarin.

Part of a handbill advertising Maelzel’s Exhibition at the
Masonic Hall in Philadelphia May 17, 1834.