“I commenced an examination of a game called 'tit-tat-to'”: Charles Babbage and the “First” Computer Game

Devin Monnens
3300 University Blvd
Winter Park, FL 32792
303-506-5602
dmonnens@gmail.com

ABSTRACT
This paper examines Charles Babbage's tic-tac-toe automaton using original notes and sketches taken from Babbage's notebooks. While Babbage's work with games and computers has been mentioned previously by other authors, this is the first attempt to study that work in detail. The paper explains the origins of the automaton, imagines how it would have operated had it been built, describes how it might have functioned, and Babbage's inspirations for building it. The paper concludes with an analysis of Babbage's place in the history of videogames.

Keywords
Ada Lovelace, Alan Turing, Automata, Bagatelle, Chess, Charles Babbage, Claude Shannon, Computer Chess, *El Ajedrecista*, John Joseph Merlin, Nim, Nimatron, Ralph Baer, The Turk, Tic-Tac-Toe, Torres y Quevedo, Wolfgang von Kempelen

INTRODUCTION
The origins of the computer game can be difficult to trace. Before early games such as *Pong* (1972), *Spacewar!* (1962), and *Tennis for Two* (1958), the history of games on computers becomes deeply entangled with experiments in computer chess, Goldsmith and Mann's 1947 patent for a “cathode ray tube amusement device”, and the Nim-playing computer by Westinghouse in 1939. Montfort (2005, p. 76) defines the first computer game as Leonardo Torres y Quevedo's chess-playing automaton (1914). While many of these inventions were not directly tied to the later development of the videogame industry, they stand out as anomalies in mankind's relationship with games and computers. One such anomaly was an invention of Charles Babbage, designer of the world's first computer. That invention was an automaton capable of playing tic-tac-toe.

Babbage documented the tic-tac-toe automaton in his 1864 autobiography, *Passages from the Life of a Philosopher*, describing the genesis of the idea, the automaton itself, and how it would work. Babbage originally pursued the problem from a philosophical perspective, asking whether he could build a machine capable of playing chess, checkers, or tic-tac-toe. After concluding that it was possible for an automaton to play any game of skill, he devised an algorithm by which it could win by analyzing every possible move for a guaranteed win condition. Furthermore, he considered the Analytical Engine

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perfectly capable of achieving this:

> [T]he whole question of making an automaton play any game depended upon the possibility of the machine being able to represent all the myriads of combinations relating to it. Allowing one hundred moves on each side for the longest game at chess, I found that the combinations involved in the Analytical Engine enormously surpassed any required... (p. 467)[1]

Babbage then proceeded to focus his efforts on tic-tac-toe, the simplest game available to him, calculating the number of moves and considering how an automaton might play it. After concluding the feasibility of building such a machine, Babbage realized it might be used to fund his more serious project, the Analytical Engine (p. 468). However, after some investigation, Babbage concluded projected profits would be far too low to offset the time and money involved with designing and manufacturing the automaton, even if it were financially successful. The project was ultimately shelved, and it would more than half a century before the first computer game was realized.

Since the 1950s, the tic-tac-toe automaton has come up again and again in books referencing Babbage. However, most of these mention the automaton only in passing, outlining its use as a money-making venture with little attention made to its actual workings (Bates, et. al 1953; Spencer 1968). The automaton is still referenced by media scholars such as Bruce Sterling (2010), and the rise of the steampunk genre of science fiction has also renewed interest in Babbage's work.

However, one element of the tic-tac-toe automaton that has been overlooked is Babbage's specific mention of diagrams illustrating how the machine would work:

> I then proceeded to sketch various mechanical means by which every action could be produced. These, when compared with those I had employed for the Analytical Engine, were remarkably simple. (p. 468-9)

These sketches were distributed across a series of Babbage's journals, called the Scribbling Books, provide fascinating insight into the workings of the automaton and its feasibility. This paper is the first attempt to study it in detail.[2]

Babbage's notes on the tic-tac-toe automata date from September 25, 1844 to October 24, 1868, with the majority of the work on the system's mechanisms and decision-making algorithms completed by late 1848. The algorithms for determining winning moves were fully calculated by October 1860.

Taken as a whole, the journals do not provide a complete outline for building the automaton. However, by comparing them with Babbage's blueprints and notes on his Difference Engine and Analytical Engine, a more complete picture of the automaton can be inferred. By tracing Babbage's connections with early computer chess programs, it is hoped we may gain a greater understanding of the automaton's importance and its place in relation to the history of videogames.

IMAGINING THE AUTMOTON AT WORK

In *Passages*, Babbage envisioned an automaton with a game board and two mechanical children, as well as a lamb and rooster. When the game was finished, the child who won would clap while the rooster crowed, then the child who lost would cry and wring his hands while the lamb bleat (p. 468).

We can imagine what that experience might have been like in 1850s London. From a crowd of gawking onlookers, a young boy steps forward, paying a small fee to challenge the automaton. Spurred by the crowd, the boy places an X token on the board. Perhaps the rooster crows, acknowledging the move; undoubtedly a heckler criticizes his opening. Then there is the sound of mechanical clicking, and soon one of the dolls lifts its arm to place an O, to the astonishment of the player and onlookers. Is this magic or farce, or is the machine really thinking like a human being? Play continues until the game is completed, upon which the player, victorious, is rewarded with an animated display. The audience applauds the cleverness of the device and the player's victory performance. Or perhaps instead we hear the roar of laughter and lighthearted jeers – he has lost a simple game of tic-tac-toe to a machine!

Babbage predicted the challenge and spectacle of a mechanical game would draw sizable crowds. An automaton capable of beating a child would attract the child's mother and father, while parents who saw the device would return with children in tow. Homo ludens has a certain attraction to challenge, particularly the conflict of man and machine that would later be capitalized by bagatelle and pinball. To best oneself against a machine not only proves the prowess of the individual, but also reaffirms the superiority of man over his creations. To meet this demand, Babbage proposed building six automata, placing two at three separate locations. The second construct would be used to replace the first in case it were damaged, a rather expensive solution to the problem of on-site maintenance.

Underneath all this display and flashy showmanship, however, is a black box by which the real magic occurs. When the player places a token on the board, the piece would activate a series of weights and gears recording the current state of the game. The automaton would then evaluate the move to determine the best move.

How Babbage envisioned this might work is something of a mystery if we rely solely on his account in *Passages*, but thankfully, sketches of his ideas exist in his notebooks. However, these sketches are not a detailed set of blueprints from which a working automaton can be created, and are often crude in nature (or “remarkably simple”, as Babbage described them). Certain components of the mechanism are also missing entirely. Still, by comparing these sketches and notes with more detailed drawings, an image of what Babbage envisioned begins to emerge.

RECONSTRUCTING THE BLACK BOX

The workings of the tic-tac-toe automaton may be divided into two parts: “software” and “hardware”, although these are obvious analogies. The software portion consisted of the game-playing algorithms. The hardware portion consisted of the mechanisms by which those algorithms were realized: axes for determining the state of the board, a system of weights for activating each axis, and a barrel for recording a library of moves. As described in *Passages*, the automaton also required hardware for the dolls that composed its pagentry.

Software

The software portion of the automaton is the portion that is best understood, primarily because Babbage documented it clearly in *Passages* (p. 466-467). The algorithm consists of seven basic steps and could be applied to any turn-based game:

1. Is the state of the board legal?
2. If so, has the automaton lost the game?
3. If not, has the automaton won?
4. If not, can the automaton win in the next move? If so, make that move.
5. If not, could its opponent, on his or her next move, win the game? If possible, the automaton must prevent that move.
6. If neither the automaton nor the opponent could win the game in the next move, the automaton must check two moves ahead to see if after two successive moves, there are two different ways of winning.
7. That failing, the automaton must look ahead three or more successive moves until such a state is identified.

Babbage revised this algorithm several times over the course of the automaton's development. The earliest notes date from September 25, 1844,[3] where Babbage outlined a mathematical formula and flowsheet by which the automaton would make its decisions. The formula he created was $M_n = W_n + L_n + I_n$, where M is the number of moves remaining, W and L are the number of ways in which the game may be won or lost on the next move, and I represents the number of moves in which neither player will win. Babbage developed this further on September 27, introducing a "look-ahead" function where he subdivided I_n into moves two or more ahead. The goal was to identify those moves by which the automaton would have two or more ways of winning if it had two successive moves. This formula was refined on August 16, 1848 to include nearly the same seven steps as in *Passages,* and finalized on October 5, 1860 in a two-page flowsheet.

In addition, Babbage provided a solution for determining the automaton's next move when presented with two or more equally good moves. It would do this by tracking the number of games it had won (Babbage 1864, p. 469). If presented with two equally good moves, *A* and *B,* the automaton would pick *A* if the number of wins was even, and *B* if the number of moves was odd. When presented with three moves, it would divide the number of wins by three and choose between *A*, *B,* and *C* based on whether the remainder was 0, 1, or 2.

Babbage's journals also identify this need for choosing between two equally good moves (Babbage, n.d.). However, this solution is not the one mentioned in *Passages,* but rather uses a barrel (described below) for consulting which move to make. In these same pages, Babbage also identifies a means of forcing a move by placing two pieces in the same line, causing the opponent to fill the empty spot. He also included a set of notes from September 15 and 16, 1860 describing various tic-tac-toe board positions that lead to forced moves and win states, with the purpose of determining "the conditions that render it possible for place [sic] a man so that there may be two modes of winning at the next move."

Another problem was determining which player had the move. On November 23, 1844, Babbage decided to count the number of turns: player 1's moves (X) would occur every odd number of steps, while player 2's (O), would occur in every even step. However, by October 1860, this method had changed. Now the automaton counts the number of pieces on the board: if black has one more piece than red, then it is red's turn, and vice versa. (Babbage assigned the automaton red and the player black.) Note this algorithm also allows the automaton to determine whether there is an illegal position, based on the difference in the number of pieces on the board, and allows the player to determine who will go first.

Babbage also wrote an entry dated July 27, 1845, which presents an interesting mathematical formula for calculating the chances of winning a prize. While the context of this entry is unclear, Collier (1990) considered it a part of the notes for the automaton. Perhaps it indicates Babbage was considering allowing players to occasionally win when it would have been easy to allow the machine to play without making any mistakes.[4]

Hardware

The mechanical component of the tic-tac-toe automaton is more difficult to ascertain, since Babbage never described it in *Passages*. In addition, his sketches of the mechanism lack detailed notes, so their purpose must be deduced based on knowledge of Babbage's Engines.

One of the most important components to the automaton was the mechanism of axes and weights used for determining the state of the playing field. An axis is a rod containing any number of gears, metal arms, or studs. When turned, these would either display a number on a gear or interact with another portion of the mechanism. Babbage's earliest sketches date to October 3 and November 23, 1844. These illustrate a row of three axes, one for each position on a single line of the tic-tac-toe board and labeled *A*, *B*, and *C*. When a piece was placed on the board, a weight would press down, lowering the corresponding axis. An axis would be lowered one level for an odd-numbered move (an *X*) or two levels for an even-numbered move (*O*). The highest position of the axis would indicate an empty space. This system is described in the November 23, 1844 entry:

> Let the placing of men upon any space press down an axis which is balanced or let it put an obstacle in the way so that the regular course of the machine shall lower the axis. Let the axis be lowered one step when an even move is made but two steps when an odd one is made.

The November entry also contains tables listing all 27 possible positions of the axes *A*, *B*, and *C*. The first table describes where a piece has been placed in relation to one of the three "feelers" (referred to as levers by Bromley (1982, p. 205-206) – essentially sensor bars that activate other parts of the mechanism when struck by gears or levers on the axis). The second table illustrates the position of the cogs in each axis. Once an axis was lowered into position, it would interact with a lifter or feeler.

Based on the sketches alone, it is unclear how many axes would be incorporated in the automaton or if they would be arranged linearly as with the Difference Engine. Sketches on the October and November 1844 entries suggest they may have been arranged in three rows of three axes. However, a later, more detailed sketch from August 16, 1848 illustrates a row of seven pairs of axes, designated *a* and *p* for automaton and player. These are also divided into three levels, *A*, *B*, and *C*, each attached to a pair of levers. Unfortunately, the meaning of these sketches is unclear, as they are not accompanied by any detailed notes.

Likewise, the system of weights used for indicating game moves is not well-documented. The first set of weights date from September 1844 and show various crude sketches of balances regulated by tubes filled with fluid or springs. A later diagram from November 1844 shows a weight and balance system, which is probably what Babbage envisioned. A further set of sketches from August 16, 1848 show a system of lines connecting each position on the board, although their purpose is unclear. Unfortunately, without further context, greater understanding of these sketches is difficult, at best.

Babbage also mentions a third component to the automaton, a barrel for recording board positions (Babbage n.d.). Barrels are cylinders embedded with a series of studs, similar to a music box.[5] The barrel, which may be aligned vertically or horizontally, is rotated at the start of each cycle so the desired column of studs is placed into position. However, unlike a music box where the studs strike a series of levers as the barrel is rotated, with Babbage's Analytical Engines, the barrel is rotated into position, then moved sideways so the tips of the studs punch the levers outward. The levers in turn raise or lower sets of gears, which execute the rest of the computer's program. The barrels serve as the computer's "microprogram store", the studs acting as a type of storage for micro instructions.[6] Babbage would have likely put important board positions onto the barrel for reference.

Undefined Components

Many mysteries remain regarding how the components of the automaton would be assembled to create a fully working machine. Unfortunately, there is no overall diagram of the automaton and how its systems would interconnect. Some components, such as the automaton's power system, were simply never defined. The Difference Engine was driven by a hand crank, although Babbage made provisions for using steam power. If the automaton were small (Babbage never specified scale), it could have also been wound with a key and powered by a system of weights, similar to a grandfather clock - a falling weight was used in Babbage's 1822 trial model of the Difference Engine.

In addition, while Babbage describes in detail the algorithms by which his automaton will make its decisions, he never defines the mechanism for evaluating board positions. One clue comes from the magic square diagram dated August 16, 1848. In the magic square, all horizontal, vertical, and diagonal rows add up to 15. After adding up each of the eight possible lines, their relative values could be checked. Rows missing only one number would therefore be more valuable than rows missing two or three.[7]

The other major component not mentioned anywhere in the Scribbling Books is the mechanical children, lamb, and rooster. Babbage's description from *Passages* suggests they would make noises, such as the bleating of the lamb and the crowing of the rooster, but overall, the animations seem very basic compared with contemporary examples. Masterpieces of automata, such as The Writer by Henri Maillardet (1805); The Writer, Draughtsman, and The Musician by Pierre Jaquet-Droz (1768-1774); and the Digesting Duck by Jacques Vaucason (1739), demonstrate the wide range of motion and sound production possible with automata. The duck in particular could sit, stand, splash in the water, quack, and simulate eating. However, the more sophisticated the animations, the higher the development cost: hand clapping requires fewer gears and levers than writing, although more points of articulation can increase the lifelike qualities of the automaton.

One final element that will remain a mystery is how the pieces would move. We can imagine one of the child's hands manipulating the pieces, but Babbage never defined whether the automaton would move the pieces by itself, but if so, this arm would have likely been the most sophisticated component of the dolls.

INFLUENCES

Based on the overall lack of detail in the Scribbling Books, Babbage apparently only recorded pressing issues, developing ideas, or large sets of information that could not be easily memorized, such as tables. If Babbage had a more concrete idea of the structure of the automaton, he kept it in his head; if documented, the records appear to have been lost. This is surprising, considering how sporadically he worked on the device. Over a period of 24 years, Babbage returned to the problem at least five times:

> 1844 – September, October, November
>
> 1845 – July
>
> 1848 – August
>
> 1860 – September, October
>
> 1868 – October

In addition to these journal entries, Babbage mentioned the automaton in a letter to Lord Rosse on July 22, 1852, stating, “I am obliged for a time to vary my occupation, and am now busied with the Automaton player at Tit-Tat-To” (Collier 1990, ch. 4).[8] Indeed, Babbage seems to have enjoyed discussing the automaton with others, even if he never followed through with the project. During a visit with Ada Lovelace in the autumn of 1848, he revealed his ideas for the game to her. In a letter to Babbage dated September 30, Lovelace affirms her excitement over Babbage's interest in games and a desire to support him with any ideas she might come up with. However, by this time, Babbage seems to have once again lost interest, as a letter dated October 18 suggests:

> You say nothing of Tic-tac-toe – in yr [sic] last. I am alarmed lest it should never be <u>accomplished</u>. I want you to <u>complete</u> something; especially if the something is likely to produce <u>*silver & golden*</u> somethings... (Toole 1992, p. 340; emphasis in original text)[9]

It seems surprising Babbage worked on the automaton so frequently, yet recorded so little. Indeed, Collier (1990) concludes Babbage considered the automaton “more as an amusing diversion than as a serious subject”, although the range of time on which he worked on it suggests a particular fascination. Whether the tic-tac-toe automaton was a simple diversion or serious pursuit, Babbage retained his interest in programming his Engines to play games nearly until the end of his life. In his last entry on the subject, dated October 24, 1868, Babbage reaffirms the Analytical Engine was capable of playing chess – although he stopped estimating the number of possible moves after turn two.

One of the reasons for this longstanding interest comes from Babbage's background at Trinity College, where during his attendance from 1810-1812 he became a chess enthusiast. Babbage played chess frequently and became quite skilled, able to readily recreate and explain board positions after a game had been completed (Babbage 1864, 35-

36). He also explained mathematician Leonhard Euler's method for solving the knight's tour in 1817.[10] One of Babbage's strongest opponents was an enthusiast named Brande, who devoted dozens of hours each week to studying the game, familiarizing himself with nearly every treatise on the subject. Brande eventually toured Europe to take lessons from famous chess instructors and play European masters. Babbage eventually discovered the only way he could defeat Brande, who had memorized all of the traditional openings and understood the strategies for beating them, was to make “early in the game a move so bad that it had not been mentioned in any treatise” (36). Like Claude Shannon, father of computer chess, Babbage's understanding of chess can likely explain his desire to program a computer to play it.[11]

It is important to note Babbage's sketches are predated by another famous automaton, the chess-playing Turk. Built in 1770 by the prolific Austrian inventor Wolfgang von Kempelen, this elaborate automaton consisted of a large cabinet with a chess board and a mannequin in Turkish garb. Inside the cabinet was a series of drawers that revealed an intricate clockwork mechanism. As expounded by its inventor, this complex machinery was what allowed the Turk to play chess. The automaton, which was able to quickly defeat its opponents through no readily apparent means of trickery, soon became famous, and von Kempelen toured it throughout the courts of Europe, where its players included Benjamin Franklin. In reality, a master chessplayer was concealed within the cabinet by means of a false drawer that presented the illusion the interior space was completely filled with machinery.

After von Kempelen's death in 1804, the Automaton was acquired by Leonard Maelzel of Regensburg, who eventually took it on another tour of Europe. The Turk found its way to England where Babbage saw it on March 16, 1819 (Standage 2002, p. 140). Impressed with the automaton's chess-playing abilities moreso than by the movements of the chess player (which he found wanting), Babbage purchased a French edition of Carl Gottlieb von Windisch's *Letters on Kempelen's Chess Player*, the first book on the Turk (p. 61). After studying its design, Babbage challenged the Turk on February 12, 1820. Babbage lost the game (which lasted about an hour), and came away convinced the Turk was controlled by a human, although he was unable to figure out how it worked.[12]

Babbage acquired an interest in automata at an early age when he visited the Mechanical Museum of John Joseph Merlin, a prolific Austrian inventor credited with the inline skate. When Babbage was about nine or ten, his mother took him to the Museum, where he became enamoured with Merlin's automata, which included an elegant dancing lady made of silver. Babbage purchased the Silver Lady in 1834, restored it, and displayed it alongside his prototype of the Difference Engine. This comparison illustrated how the Difference Engine was more than a mere automaton, since it could be programmed to change its actions based on logical rules (Standage 2002, p. 145).

Standage (2002) asserts this early encounter with Merlin's graceful and intricate automata sparked an interest in the capacity for machines to replicate human thought that would eventually lead to the creation of the Difference Engine.[13] Likewise, the Turk proved a catalyst that lead to Babbage's design of the first Difference Engine, starting in 1821, only a year after his encounter.[14]

The fact that von Kempelen and Babbage both invented game-playing automata is also not coincidental – von Kempelen's other ingenious inventions inspired many others to imitate and build off his successes, and the Turk in particular inspired discussion on the capabilities of machines to replicate human intelligence. However, unlike Kempelen's invention, Babbage's tic-tac-toe automaton would have been perfectly capable of playing – and winning – a game without human interference. Ultimately, it was Babbage's combination of mathematical skill, knowledge of machinery, interest in automata, and acumen at chess that combined to create his calculating engines and the first foray into computer games.

LEGACY

Today Charles Babbage is widely celebrated as the inventor of the first computer. Although he never completed a fully-working Engine, his sketches were detailed enough that in 1991, the calculating section of Difference Engine No. 2 was constructed by the Science Museum in London, with the output apparatus completed in 2002. However, the influence of Babbage's Engines was limited. Aside from early computing pioneers such as Percy Ludgate, Leonardo Torres y Quevedo, and Louis Couffignal (Randell 1973), Babbage's work did not lead directly to the modern computer. The inventors of the Mark I and ENIAC, while almost surely aware of Babbage, were unaware of the detailed design or logic of the Analytical Engine, and it was only in the early 1950s that Babbage's work was truly appreciated. Babbage's tic-tac-toe automaton tells a similar story. He never attempted to build one, and his sketches are far too incomplete to recreate one today. Furthermore, his work seems to have had little impact on early chess programmers.

To begin, most scholarly work on Babbage and his connections with chess, tic-tac-toe, and computers solely references *Passages* – it wasn't until Collier's thesis in 1970 that discussion expanded to include Babbage's notebooks and related letters. Of the early studies, none mention the algorithm for playing tic-tac-toe. Bates, et al (1953) and Spencer (1968) mention Babbage's tic-tac-toe automaton in passing, and both dismiss the work as a failed money-making venture. The earliest detailed analysis of Babbage's algorithm seems to be from Alex G. Bell (1978). Bell, an early chess programmer, examined Babbage's seven-step algorithm, but was unimpressed with the model, which he deemed “not very rigorous” (p. 13).[15]

Despite this, it would be reasonable to expect the earliest chess programmers might have used Babbage's algorithm as a starting point. However, there is no documentation that clearly establishes a connection. Alan Turing was clearly aware of Babbage's work on the tic-tac-toe automaton and chess, but his first mention is 1953, after his major work had been completed (Bates, et. al. 1953, 286). If Turing studied Babbage's algorithm, there is no record of it. Further, Claude Shannon's groundbreaking 1948 essay on computer chess, which outlines the type-A (brute-force) and type-B (selective search) strategies, does not mention Babbage at all, despite referencing von Kempelen's and Quevedo's automatons, along with the Nimatron, a special-purpose computer capable of playing nim (Shannon 1950).

The Nimatron was developed by Edward U. Condon of Westinghouse and displayed at the New York World's Fair in 1939 (Weiner 1968). While the Nimatron could play the game perfectly, it could not always win, since it allowed its human opponent to make the first move. Here also there are no connections with Babbage, as nim had been solved in 1901, and its solution was readily available in Hardy and Wright's *The Theory of Numbers* (1938). Also, no mention was made in the computer's patent (Condon, et. al. 1940).[16]

The strongest connection with Babbage's automaton comes from the chess player of

Leonardo Torres y Quevedo. The machine, named *El Ajedrecista* (The Chess Player) and constructed around 1914, was capable of playing a perfect endgame of king rook king. It had a mechanical arm to move its pieces and would also detect whether an illegal move had been made, ending the game after three such moves. Quevedo and his son Gonzalo continued to improve the device, eventually replacing its mechanical arm with magnets to slide pieces across the board.

El Ajedrecista was built to demonstrate the decision-making qualities of automata, primarily the capacity of both humans and machines to observe situations in their environment and make decisions based on that feedback. Quevedo was very specific in defining whether *El Ajedrecista* could 'think'. Quevedo's claims echo Babbage's comparisons of the Difference Engine and Merlin's Silver Lady when he contrasted his work with classical automata, which could only mimic the movements of living things. Quevedo asserted his automaton was merely making decisions based on a given set of conditions according to a set of arbitrary rules defined in advance (Torres and his remarkable devices 1914).

Given Babbage's inspiration from von Kempelen's Turk, it is tempting to conclude Quevedo may have also considered building his automaton after reading *Passages.* Quevedo specifically discussed in detail Babbage's work in his 1914 essay on automation and even designed an analytical engine of his own (Randell 1973). However, even here there are problems in making a direct connection. *El Ajedrecista*'s algorithm does not involve a look-ahead feature, but instead reacts solely based on the position of the pieces (Torres and his remarkable devices 1914). Babbage's algorithm in *Passages* is general and does not mention any specific strategies the automaton should take. Finally, Babbage first pursued game playing with the Analytical Engine as a philosophical problem before considering the tic-tac-toe automaton as a profitable entertainment device; *El Ajedrecista* was created as a scientific demonstration, and Quevedo does not seem to have considered its possible applications for entertainment.[17] Ultimately, the evidence is not strong enough to confirm a connection between Babbage's automaton and Quevedo's.

CONCLUSION

If Babbage did not inspire early game programmers of the 20th century, the fact remains his automaton is the earliest example of a game played on a computer and used for entertainment. His sketches also firmly demonstrate a proof of concept by which the automaton might be created, and are therefore historically important.

Yet being “first” does not alone necessitate the importance of one's work. Ralph Baer, inventor of the Magnavox Odyssey, the first home videogame console, has argued the keys to “fathering” an invention go beyond the idea itself and include the “development of the idea, marketing of the idea, and follow through to see it into significant production” (Baer, n.d.). Under these criteria, Babbage clearly demonstrated development of the idea and recognized its commercial applications, but ultimately did not create a working model or translate it into a salable product. This was due at least in part to the high projected cost and the time involved in its creation – it was extremely difficult to manufacture large quantities of identical machined parts by hand. However, Babbage was also unable to envision a mass-market entertainment industry simply because no such model existed.

Indeed, Babbage's thinking was largely grounded in the exhibition of singular automata such as the Turk, John Clark's *Eureka*, and Joseph Faber's *Euphonia*.[18] The success of these automata resulted largely from showmanship, much like modern carnival games, and their inventors grew in fame or dwindled into obscurity based on the success of their creations. Automata could also be commissioned, but due to their complexity and the absence of large-scale manufacturing in the early 19th century, automata were generally one-of-a-kind, and their inventors made money from their exhibition rather than sale.

If there were any inklings of mass-market mechanical entertainment, they came from the emergence of a new form of game: bagatelle. An offshoot of pool, croquet, and bowling, bagatelle are sloped wooden tables embedded with a series of holes and pins. The object is to get the ball into one of the holes by shooting it up the board using either the hand or a miniature pool stick. The game would later evolve into pinball and pachinko.

Emerging from late 18th century France, bagatelle were first sold primarily to aristocrats, who had the wealth and leisure time to enjoy them, but they soon became available in pubs, clubs, and barracks. Owners could charge players a nominal fee for several balls or marbles and allow them to play for a limited play time (Bueschel, 1988 p. 50). Coin mechanisms were integrated in 1889 (p. 56). Bagatelle were made of wood and possessed few moving parts – the spring launcher was not introduced until 1871 – and thus were relatively cheap to produce and could be manufactured in large quantities. While there were several manufacturers of bagatelle in England, French tables were considered the highest quality until they were surpassed by American manufacturers in the 1880s when the bagatelle market exploded (ibid, p. 36, 46-47). Even had Babbage been as interested in bagatelle as he was in chess, the level of technology available to Babbage in the 1840s and Victorian ideas of entertainment simply made it impossible for even a man with his vision to consider the mass-production of game-playing automata.

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ENDNOTES

1 It is unclear how Babbage arrived at this conclusion. The Analytical Engine was capable of manipulating numbers up to 25 decimal places, or 10^{25}. The number of possible legal board positions in chess is estimated at upwards of 10^{40}, while the game tree complexity is estimated at 10^{123} possible moves.

2 The first complete survey of Babbage's notebooks was conducted in 1970 by Bruce Collier, who published his thesis in 1990.

3 Citations are listed by date in the references section and include catalog numbers from digital reproductions of the journals at the Science Museum, London.

4 The placement of this entry is odd, as it located between a supply and demand formula (perhaps for determining the profitability of the automaton) and a formula for calculating the distance between the Earth, Sun, and Moon.

5 Babbage received inspiration from music boxes and other automatons, which also made use of barrels (Bromley 1982, p. 197).

6 For a more detailed description of the mechanism behind Babbage's Engines, see Bromley (1982).

7 The author is indebted to Rafael Fajardo of the University of Denver for suggesting this solution.

8 Note Collier does not reference any journal entries from 1852, and his detailed survey of Babbage's papers suggests no further entries survive.

9 Babbage references this exchange with Ada Lovelace, although not her name, in *Passages* (p. 470).

10 In this chess puzzle, the knight must move to each of the 64 squares on the board without landing on the same space twice. Babbage provides eight solutions, and explains each. Although he does not present an algorithm for solving the game, this does represent a very early attempt to find logical and symbolic formalisms for games.

11 Babbage seems to have also possesed a general interest in games, becoming addicted to sixpenny whist while at Cambridge, often playing his classmates from evening until dawn (36-37).

12 Babbage also likely encountered a popular 1821 pamphlet published by Robert Willis, who explained how a human could be hidden inside the machine. However, Willis incorrectly surmised how the chessboard was viewed and the pieces moved (the operator viewed the board from underneath the table rather than from behind the Turk's clothing).

13 Another influence was Pierre Simon Laplace's method of breaking down complex mathematical problems into simple repetitive steps of addition and subtraction, which Babbage later deduced could be done through machinery.

14 Standage erroneously states Babbage attempted to build a chess-playing automaton.

15 I discussed this model with Jonathan Schaeffer, creator of *Chinook*, the program which solved checkers. Babbage's model uses a type-A method where all possible board positions are analyzed by the computer. Schaeffer concluded that while the algorithm would have worked, it would have been very difficult to execute using Babbage's technology. For a detailed analysis of tic-tac-toe, see S. Schaeffer (2002).

16 A second nim-playing computer was developed by Raymond Redheffer at MIT in 1941 (Redheffer 1948). Unlike the Nimatron, which weighed over 2500 pounds, Redheffer's was a small box weighing only five pounds, leading him to conclude an article on his device would “be of interest.”

17 This is not to say, however, that Quevedo's audiences were not entertained by The Chessplayer. While no records of audience reactions to Quevedo's exhibition at Paris University remain, the automaton seems to have left a strong impact on author of the 1914 *Scientific American* article that describes it.

18 These two automata were exhibited at the Egyptian Hall in London, which Babbage visited while estimating the profitability of his tic-tac-toe automaton. Although Babbage does not mention them by name in *Passages*, he describes them briefly. Both the *Eureka* and the *Euphonia* lie outside the scope of this paper, but are described in Blandford, D.W. “The 'Eureka',” in *Greece & Rome*, Second Series, vol.10, no.1 (March 1963), pp.71-78; and Lindsay, D. “Talking head,” in *Scientific American* vol.13, no.1 (1997).

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