History of the Computer and the Jacquard Loom

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Jacquard’s Loom & The Modern Day Computer

HIST 3900

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Table of Contents
The Story Of Silk ................................................................................................................................. 2
The Silk Industry In France .................................................................................................................. 4
The Drawloom .................................................................................................................................. 4
Jacquard and His Loom ...................................................................................................................... 8
Charles Babbage ...............................................................................................................................11
Ada Lovelace .....................................................................................................................................16
Herman Hollerith ...............................................................................................................................18
The Birth of IBM ...............................................................................................................................21
Dawn of the Computer Age – Howard Aiken ....................................................................................23
The Evolution of Computing ...............................................................................................................26
Jacquard’s Legacy .............................................................................................................................27
The Story Of Silk

Our story begins in ancient China with the discovery of silk several millennia ago. According to folklore, Empress Si Ling-Chi discovered silk around 2700 BC. While variations of this tale exist, a common version is that a silkworm cocoon fell into a steaming teacup while the empress was enjoying afternoon tea in the Imperial Gardens. When she removed the cocoon, it began to unravel as a fine thread. As she pulled on the thread, she found that it could be unwound into long filaments that were very light, yet strong, which the Empress realized could be fashioned into yarn for weaving. It is said that Si Ling-Chi subsequently developed sericulture, the cultivation of silkworms, and invented the silk reel and silk loom. In Chinese mythology, Si Ling-Chi is regarded as the “Goddess of Silk”.

It is not known how much, if any, of this story is true, but it is certain that the oldest surviving archaeological evidence of sericulture and silk weaving were discovered in China. Some of this evidence suggests that the cultivation of silk, and its use as a fabric, predate this legend. The silkworm appeared as a decorative motif on sculptures and vessels from the Neolithic period dating back to 6000-7000 years ago. Parts of a primitive loom were found in Zhejiang province dating to about 4900 BC. In 1927, a domesticated silkworm cocoon, cut in half by a sharp knife, was found dating back to between 2600 and 2300 BC.

Prized for its texture and lustre, silk became a precious commodity in China, highly sought after as a luxury item. At first reserved only for royalty, the use of silk gradually spread to other classes and more general widespread use within China. From there it spread to other

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1 Government of Andhra Pradesh. Dept. Of Sericulture, History of Sericulture
2 Tsang G C. C., Textile Exhibition: Introduction
regions in, Asia leading to the development of the Silk Road, a network of trade routes that connected Asia with the Mediterranean as well as North Africa and Europe.

The Chinese jealously guarded their secret of silk production, and for nearly three millennia had a global monopoly on it. While the Chinese exported finished silk products such as yarn and fabric, it was a crime punishable by death to reveal the secrets of silk production or smuggle eggs, cocoons or silkworms out of the country. Despite these efforts to keep their knowledge of silk production under wraps, by 200 BC sericulture had spread to Korea via Chinese immigrants who settled there. By about 300 AD, silk making had also spread to India, Japan, and Persia.  

The secret of silk making reached Europe in about 550 AD via the Byzantine Empire. According to Procopius, two missionaries revealed to Byzantine Emperor Justinian I that they had learned the art of silk making while living in a region of Central Asia they called “Serinda”. At Justinian’s request, the missionaries returned to Serinda and succeeded in smuggling to Constantinople thousands of silkworm eggs in the hollows of their bamboo canes. With due care the eggs hatched, initiating silk production in the West.  

In the 7th century the Arabs conquered Persia and spread sericulture through Africa, Spain and Sicily as they expanded their empire. The Crusades also helped spread silk making in the West. By the 13th century, Italy was the silk capital of the Western World.

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3 Government of Andhra Pradesh. Dept. Of Sericulture, History of Sericulture
The Silk Industry In France

Prior to 1466, France was involved in the silk trade, but not yet its manufacture. Lyon France was the primary centre of this trade. Silk manufacturing was established in France between 1446 and 1540 through a series of royal initiatives that aimed to replace expensive silk imports with indigenous French silk. King Louis XI who ruled from 1461 to 1483 offered incentives to silk workers from Genoa, Florence and Venice to set up shop in Tours France, thereby establishing silk production there. It was Francois I, king from 1515 to 1547 who extended silk making to Lyon. In 1536 Francois I granted a letters-patent to two Italian merchants, Étienne Turquet and Barthélemy Naris, to develop a silk weaving industry at Lyon. In addition, Lyon was granted a monopoly on raw silk imports. Francois I also enacted a number of privileges for silk workers, such as tax exemptions, as a means of attracting craftsmen to the city. At first Lyon produced only plain and simple patterned silks, but their growing expertise, coupled with creativity and technical innovation, lead to increasingly elaborate designs and higher quality output. By the 1739 there were 8000 looms in Lyon and the city was the dress silk manufacturing capital of Europe.

The Drawloom

Despite Lyon’s success and status in the silk making industry, the weaving technology available at the time was hindering output and growth. To understand why this was so, it is first necessary to describe the process of weaving, especially as it relates to the drawloom, the

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5 Franck R R., Silk, Mohair, Cashmere and Other Luxury Fibres, 6
6 Campbell G., The Grove Encyclopaedia of Decorative Arts: Labhardt to Zwischengoldglas, Volume 2, 66
primary silk weaving apparatus of the day. Weaving is the interlacing of two or more sets of fibres or threads, usually at right angles to each other, to form a useful material such as fabric or cloth. The threads that run lengthwise are known as the warp and the threads that run crosswise are called the weft, also known as filling. The manner in which the warp and weft threads interlace with each other is referred to as the weave.\(^7\)

Textiles are usually woven on a loom, a device that holds the warp threads in place under tension, to facilitate the interweaving of the weft threads. A simple loom is sufficient for plain and simply patterned fabrics, but for more complicated patterns and images, a loom is required that allows individual warp threads to be raised and lowered, such that different coloured weft threads can be inserted between the warp threads to produce the required design. Such a device is the drawloom, so named because it allowed the individual warp threads to be “drawn up” individually to create the design to be woven. The drawloom required two people to operate it, the weaver and a draw-boy. The draw-boy sat on top of the loom and raised and lowered individual warp threads according to instructions from the weaver.\(^8\)

Despite the ingenuity of the drawloom, in the 18\(^{th}\) century, weaving decorated silk fabrics was still a slow and laborious process. With more complicated designs, the arrangement of warp threads for each row of weaving was likely to be different from the last, and decisions about raising or lowering the warp threads had to be made on a row by row basis. That, coupled with the fact that silk fabric is very fine, meant that even the most experienced two man drawloom

\(^7\) Dooley, W.H., Textiles, 54-55
\(^8\) Broudy, E, The Book of Looms: a history of the handloom from ancient times to the present, 124
team could produce only two rows of woven silk per minute. At that rate, an inch of brocade, the most elaborate of the silk fabrics, took one full working day to complete.  

At the same time, there was a great demand for French silk. Silk had long been associated with prestige and luxury by European nobility. The mystery of its origins, its history as a prized trading item, the intricacies of its production and the high quality of French silk all contributed to its status as a highly sought after commodity.

Thus, there was great incentive to find a more efficient way to produce decorated silk fabric. During the 18th century there were a number of attempts to automate the silk weaving process. In 1725, Basile Bouchon, a textile worker from Lyon designed a method of controlling a loom with perforated paper tape. The son of an organ maker, Bouchon was familiar with the rotating pegged cylinders used in automated organs, such as the barrel organ. These cylinders, similar to music box cylinders, controlled the sequence of notes played by the organ. Bouchon also knew that the instructions for programming the musical notes were first laid out on paper, prior to being applied to the cylinders. In essence, holes were punched in paper to create a template which was wrapped around the cylinder. The holes indicated to craftsmen where to drill holes in the cylinder for the pegs. Bouchon’s insight was that the information content of the cylinders was already contained in the paper template, and hence perforated paper could be used for directly relaying instructions to a loom.

Bouchon’s loom used a system of hooks and needles to lift the appropriate warp threads. The punched paper was wrapped around a perforated cylinder. When the cylinder was pushed forward against the hooks, if the hook encounter solid paper it would be pushed forward and the

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9 Essinger J., Jacquard’s Web, 17
10 Stobbs, Gregory A., Software Patents, 32
corresponding warp thread attached to it would be raised. If there was a hole in the paper, this would allow the hook to slip inside the cylinder and the corresponding warp thread would not be raised.11 As revolutionary as Bouchon’s ideas were, his invention was not popular because the paper tape was prone to tearing and the number of hooks and needles were not sufficient for complex designs. In 1728, Jean Falcon, a co-worker of Bouchon’s, improved upon Bouchon’s loom, increasing the number of hooks and needles by arranging the holes in multiple rows, instead of the single row used by Bouchon. This was enabled by using a four sided “square” cylinder with flat surfaces, rather than a round cylinder. He also replaced the paper tape with rectangular cards chained together. The paper cards were more durable and a single card could be easily replaced if worn or damaged. The Bouchard-Falcon loom was moderately successful: about 40 of these looms were sold by 1762.12

Bouchon’s and Falcon’s inventions served to partially automate the draw-boy’s task, but still required an extra person, in addition to the weaver, to operate the loom. The first attempt to fully automate the draw-boy’s function was by Jacques Vaucanson in 1745. Vaucanson did away with the chained cards and instead used a perforated paper roll which was wrapped around a large perforated cylinder. A ratchet mechanism was used to automatically advance the punched paper each time the cylinder was pushed against the row of hooks. While Vaucanson’s loom was a step forward in some respects, in other ways it was a step backwards. Clearly the automatic advancement of the perforated paper roll was an improvement and enabled the elimination of the draw-boy. The adoption of round cylinder instead of a flat surface, however, caused this design

11 Bell, T. F. Jacquard Weaving and Designing, 18-20.
12 Usher, A.P. A History of Mechanical Invention, 290.
to revert to a single row of hooks used by Bouchon, with its consequent reduction in ability to weave complex designs. Vaucanson’s loom was not commercially successful.\textsuperscript{13}

\section*{Jacquard and His Loom}

Joseph-Marie Jacquard was born on July 7, 1752 in Lyon France. His father Jean-Charles was a master weaver. Like many children of his time, Joseph did not attend school, as his father needed him to perform odd jobs at his workshop, where Joseph grew up surrounded by the craft of silk weaving. In 1765 Joseph’s sister Clémence married Jean-Marie Barret. Barret, a bookseller and printer, took an interest in Joseph’s education and taught him how to read and introduced him to a world beyond the silk weaving shop. In 1772 Jean-Charles died and Joseph inherited his father’s house, his workshop and looms, a vineyard and quarry. Over the next several years Joseph dabbled in a number of occupations including his father’s trade, but in large part supported himself with his dwindling capital. Jacquard fell into debt and was forced to sell his remaining inheritance and some of his wife’s jewellery to avoid bankruptcy.\textsuperscript{14}

In the late 1790s, after fighting in the French Revolution, Jacquard turned his attention to improving the loom. Jacquard took out a patent on his first loom on 23 December 1800. Through the use of foot treadles, this loom could weave simple decorated patterns in silk fabric without the help of a draw-boy. Jacquard entered this loom in an exhibition of French industry in Paris France in 1801. He was awarded a bronze medal for the loom by the French government. In

\textsuperscript{13} Bell, T. F. Jacquard Weaving and Designing, 18-20.
\textsuperscript{14} Essinger, J Jacquard’s Web, 22-24
1802 Jacquard entered a contest for the creation of a loom to weave fishing nets. This loom was successful and Jacquard was awarded 1000 francs.\textsuperscript{15}

In 1804 Jacquard travelled to Paris where he studied the Vaucanson’s loom, which was stored at the Conservatoire des Arts et Métiers there. Incorporating his own ideas with those of Vaucanson, Bouchon and Falcon, Jacquard gradually perfected his loom. Jacquard eliminated the perforated paper roll from Vaucanson's loom and returned to using Falcon's chain of punched cards. This enabled the set of instructions to be as long as the weaver desired. He also replaced the expensive metal cylinder of Vaucanson’s loom with a perforated square cylinder.\textsuperscript{16}

Jacquard’s genius lay not in originating the revolutionary ideas behind his machine, but in building upon the work of previous innovators, bringing their ideas together, adding his own insights, and solving a variety of practical engineering problems, to create an automatic loom that was fast, reliable and most importantly commercially viable. In April 1805, Napoleon visited Lyon and viewed Jacquard's new loom. Three days later he granted the patent for Jacquard's loom to the city of Lyon. In return, Jacquard was compensated with a lifetime pension of 3000 francs per year, as well as a royalty of 50 francs for each loom sold for a period of six years.

Jacquard’s loom revolutionized the speed at which decorated silk fabrics could be woven. Using the Jacquard loom, a skilled weaver could produce two feet of decorated silk fabric per day, compared with one inch per day that could be produced by a skilled two man drawloom team. From a commercial perspective, Jacquard’s loom was a success. According to Essinger, by 1812 an estimated 11,000 Jacquard looms were in operation in France.\textsuperscript{17} This claim however has

\textsuperscript{15} Huchard, J, Between Legend and Reality: Twelve Years in the Life of an Artist-Mechanic Following a Late Calling
\textsuperscript{16} Bell, T. F, Jacquard Weaving and Designing, 23
\textsuperscript{17} Essinger, J, Jacquard’s Web, 42
been disputed by Jean Huchard. Citing archival records from the Lyon Chamber of Commerce, Huchard claims that only 41 Jacquard machines were sold in 1806 and 16 in 1811. Huchard further contends that the slow adoption of the Jacquard loom was due to problems with the punch card mechanism, and that it was only after Jean Antoine Breton perfected this mechanism in 1815 that the Jacquard loom took hold. In any case, it is generally agreed that by the 1820, the Jacquard loom was in widespread use in France.

The reception of the Jacquard loom by silk workers was less than enthusiastic. Drawboys and silk weavers fearing that their livelihoods were threatened, destroyed many Jacquard looms and threatened Jacquard’s life. Eventually this resistance faded and the Jacquard loom became widely accepted.

It may be tempting to categorize the Jacquard loom as part of the Industrial Revolution that took place in the 19th century. There are, however, significant differences between the Jacquard loom and the machines used in the textile mills that characterized the Industrial Revolution. The Jacquard loom was hand-operated by individual weavers. As such, the structure of the weaving industry in Lyon was that of small workshops operated by weavers and their assistants under a guild system. In contrast to this, the textile mills of the Industrial Revolution were mechanized and used steam or water power.

Eventually, the manual loom gave way to factories, and small weaving shops gradually disappeared. The forces behind this are likely the reason that Samuel Lowry of Warsaw, Ontario abandoned his loom in 1909. This is the loom that now resides at Lang Pioneer Village. Lowry used his loom for weaving carpets, flannel and horse blankets. By the turn of the 20th century

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18 Huchard J., Between Legend and Reality: The True Inventor of the So-called Jacquard Mechanism
19 Sheridan, G.J., Craft Technique, Association and Guild History: The Silk Weavers of Nineteenth-Century Lyon
20 Lang Pioneer Village, Weaver’s Shop/Jacquard Loom Project
there were several carpet factories in the Peterborough area. The mass production methods used by these factories made it increasingly difficult for small operators such as Lowry to compete.

Charles Babbage

The Jacquard loom is remembered not only for its impact on the textile industry, but also for its impact on computing and information systems. Jacquard's loom strongly influenced Charles Babbage, who is considered a pioneer of the modern computer. Charles Babbage was born on December 26, 1791 in London, England, son of Benjamin Babbage, a banker and merchant. From an early age Charles displayed a fascination with engineering and mechanics, and as a boy would often take things apart to see how they worked.21 Unlike Jacquard, Babbage had the advantage of a wealthy father that wished to further his education. He received much of his early education from private tutors and in 1810 entered Cambridge University where his primary interest was mathematics.

After graduation Babbage devoted himself to a number of endeavours as a mathematician, inventor, scientist and political economist. From 1828 to 1839 Babbage was Lucasian professor of mathematics at Cambridge. He wrote a number of academic papers, several full length books, was a member of the Royal Society and helped found the Astronomical Society and the Statistical Society. As an inventor, Babbage pioneered light house signalling, proposed ‘blackbox’ recorders for railways, designed a cow-catcher for the front end of locomotives, failsafe quick release couplings for rail cars, multi-colored theatre lighting, an altimeter, a seismic detector, a hydrofoil and an arcade game.

21 Babbage C, Passages From the Life of a Philosopher, 8
But what Babbage is most known for is his work on the Difference Engine, an automatic calculator, and the Analytical Engine, an even more ambitious general purpose computing machine. Babbage’s interest in calculating machines stemmed from his frustration with the inaccuracies contained in the logarithmic tables of the day. Babbage himself published a more accurate version of these tables calculated manually, but he longed for a machine that would take the tedium out of mathematical calculation and eliminate the errors that manual calculations were prone to.

Prior to Babbage, there were a number of attempts to produce a calculating machine and Babbage was aware of these, having studied them at Cambridge. Among these were Blaise Pascal’s Pascaline and Leibniz’s Stepped Reckoner. Pascal is credited with creating the first mechanical calculator in 1642. Pascal reportedly developed this machine to help with his father’s work as a tax collector. The Pascaline could add and subtract directly and through repetition multiply and divide. The Pascaline was not commercially successful because it was expensive, unreliable and resented by workers, such as accounting clerks, who feared the invention would replace them.22

The Stepped Reckoner was invented by Gottfried Leibniz in the 1670’s. On the subject of calculation Leibniz once remarked: "It is unworthy of excellent men to lose hours like slaves in the labor of calculation, which could be safely relegated to anyone else if machines were used."23 Leibniz’s Stepped Reckoner was capable of adding, subtracting, multiplying, dividing, and calculating square roots. The device employed a component designed by Leibniz known as a Leibniz Wheel or stepped drum, which was a cylinder with nine bar-shaped teeth of different

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22 Chase, G.C., History of Mechanical Computing Machinery
lengths, which increased in equal steps around the drum. Only two prototypes of the Stepped Reckoner are known to have been built. The machine was unreliable due to mechanical problems and the limited fabrication technology of the time, a problem that had also plagued development of the Pascaline. The stepped cylinder mechanism was subsequently used by others in commercially successful mechanical calculators for more than 200 years.\(^\text{24}\)

Getting back to Charles Babbage, in Passages from the Life of a Philosopher, he recounted the genesis of his idea for the Difference Engine: I was sitting in the rooms of the Analytical Society, at Cambridge, my head leaning forward on the table in a kind of dreamy mood, with a table of logarithms lying open before me. Another member, coming into the room, and seeing me half asleep, called out, "Well, Babbage, what are you dreaming about?" to which I replied "I am thinking that all these tables" (pointing to the logarithms) "might be calculated by machinery". \(^\text{25}\) As this idea took root in Babbage’s mind, he conceived of a machine with capabilities far beyond what had been attempted by Pascal and Leibniz. While the Pascaline and Stepped Reckoner were designed to perform basic arithmetic functions, the purpose of the Difference Engine was to calculate polynomials, for example the expression \(x^6 + 4x^3 + 3x^2 - 7\). Polynomials are commonly used in engineering, astronomy, construction, finance, banking, insurance and navigation. The Difference Engine was also designed to be automatic, unlike its predecessors which required human intervention for processes that produced intermediate results.\(^\text{26}\)

Babbage began work on his calculating machine at some point during 1820 or 1821. On June 14, 1822 he presented to the Royal Astronomical Society a small working prototype of the

\(^{24}\) Dyson, G., Darwin Among the Machines: the Evolution of Global Intelligence, 36-37.
\(^{25}\) Babbage C, Passages From the Life of a Philosopher, 42
\(^{26}\) Hyman A., Charles Babbage: Pioneer of the Computer, 51-52
Difference Engine, as well as a paper entitled “A note respecting the application of machinery to
the calculation of astronomical tables.”\(^{27}\) The proposed design featured cogwheels and other
mechanical parts and was to be operated using a hand crank. Input was to be accomplished via
dials, and a printing device would output the results.\(^{28}\) Babbage sought government funding for
the development of a full scale Difference Engine, and in 1823 met with the Chancellor of the
Exchequer who granted him £1,500 towards its development. It was expected that the project
would take 3 years, but delays and cost overruns plagued the project. By 1834 over £17,000 in
government money had been spent on the Difference Engine, yet it was still incomplete.
Construction of the engine was halted in 1833 following a dispute with the engineer, Joseph
Clement. The government ceased funding the project in 1834 and formally abandoned it in
1842.\(^{29}\) A number of reasons have been put forth to explain the project’s failure including
Babbage’s allegedly difficult personality, his penchant towards perfectionism, lack of concrete
progress, disputes with his engineer, political instability, funding difficulties and the limitations
of Victorian machine tool technology.

In 1834, as work on the Difference Engine stalled, Babbage envisioned of an even more
ambitious machine, later dubbed the Analytical Engine. Unlike the Difference Engine, which
was a special purpose calculating machine designed for solving polynomial equations, the
Analytical Engine was conceived of as a general-purpose programmable computing machine.
Many of the Analytical Engine’s features are analogous to the functions of a modern day
computer. It was designed to contain a “store” (memory) where numbers and intermediate results
could be held and a “mill” (central processing unit) where arithmetic processing was to be

\(^{28}\) Babbage, B.H., Manual to Operate Difference Engine
\(^{29}\) Babbage C, Passages From the Life of a Philosopher, 80-96
performed. Data and instructions were to be input via punched cards. A variety of output mechanisms were planned, including paper printouts, punched cards, graph plotting and stereotypes, from which moulds could be made for printing plates. It was to be a steam-powered mechanical computer.  

Babbage kept extensive handwritten journals which have been preserved at the Science Museum in London. In an entry dated June 30, 1836 Babbage wrote: “Suggested Jacard’s (sic) loom as a substitute for the drums.” Prior to deciding on punch cards as a control mechanism for the Analytical Engine, Babbage had considered a revolving studded drum, similar to the control system used by Vaucanson’s loom. The decision to use punch cards was important not only because they were more convenient than the drums, but also because they enabled greater flexibility in program design, and allowed for storage and reuse of programs. Babbage envisioned 3 types of cards for use with his machine. The Operations Cards were to be used to control the actual operations of the machine. The Variable Cards would specify from where in the store the number to be operated on would be fetched, and finally the Number Cards would specify the actual numbers on which to operate.

Babbage was so enamoured with the Jacquard mechanism that he procured a portrait of Jacquard that was woven in silk. The portrait was deliberately designed to show off the Jacquard loom’s capabilities and was so complex it required 24,000 punched cards. Babbage would often

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30 Babbage C, Passages From the Life of a Philosopher, 116-118  
32 Babbage, C. On the Mathematical Powers of the Calculating Engine 12-15
show the portrait to his guests. The craftsmanship of the woven portrait was of such quality that many people mistook it for an engraving.\textsuperscript{33}

\textbf{Ada Lovelace}

Babbage was aided in his efforts to promote the Analytical Engine by Ada Lovelace. She was born Augusta Ada Bryon on December 10, 1815, daughter of famous British poet Lord Byron and Anne Isabella Milbanke, Lady Byron. The marriage did not last long due to a rumoured extramarital affair between Lord Byron and his own half-sister, as well as what Lady Byron described as frequent bouts of insanity. Ada’s mother left Lord Byron shortly after Ada was born. Afraid that Ada might end up being like her father, Lady Byron insisted that Ada be educated in mathematics and science, disciplines that she felt would counter the emotional tendencies that poetry inspired. Lady Byron herself was mathematically inclined and was dubbed “Princess of Parallelograms” by Lord Byron.

When Ada was 17, she met Charles Babbage and shortly thereafter visited his London studio where a working portion of his Difference Engine was on display. Babbage demonstrated the machine to her, with which she was fascinated. Thus began a friendship that was to last the rest of Ada’s life. Ada and her mother often visited Babbage when they were in London and Ada frequently corresponded with Babbage on a number of topics including math and logic. Babbage was impressed by Ada’s intellect and referred to her as “The Enchantress of Numbers”.

\textsuperscript{33} Essinger, James, Jacquard’s Web, 3-5
Ada married William King in 1835 at the age of 19. Ada’s husband received a title in 1838 after which she was known as Ada, Countess of Lovelace. Despite marriage and motherhood, Ada attempted to continue her intellectual pursuits, no small ambition in an era that did not encourage women to aspire to any achievement beyond marriage and family.

In 1840 Babbage was invited to attend a conference of Italian scientists in Turin. As a result of that meeting, Luigi Federico Menabrea, an Italian mathematician, wrote a paper on the Analytical Engine in French, which was published in the Swiss publication *Bibliothèque Universelle de Genève*, in October, 1842. This paper was translated into English by Ada Lovelace, who was uniquely suited to the task. As the daughter of a mathematical mother and a poetic father, Ada was gifted with the ability to comprehend scientific and mathematic material, and write about it in a captivating manner. In writing about the use of punched cards in the Analytical Engines control system, Ada eloquently states: “the Analytical Engine weaves algebraical patterns just as the Jacquard-loom weaves flowers and leaves”\(^{34}\). This turn of phrase serves not only to demonstrate Ada’s ability to use metaphor to reach her audience, but also to underscore the connection between the Jacquard loom and the computer.

Ada appended a set of notes to the translation, whose length was more than double the original article. Among these notes are step by step instructions for solving various mathematical problems including a method for calculating a sequence of Bernoulli numbers with the Engine. As a result, Ada Lovelace has been widely credited as the first computer programmer. This claim is controversial for two reasons. First, it is more accurate to say that Ada designed the first computer algorithm, rather than what we think of today as a computer program. Secondly, Ada collaborated very closely with Babbage on the paper and there is some debate over the extent and

\(^{34}\) Menabrea, Luigi Federico. Sketch of the Analytical Engine Invented by Charles Babbage.
originality of Ada’s contributions. The programming language, Ada developed for the department of defense was named in Ada Lovelace’s honour.\textsuperscript{35}

Despite Ada Lovelace’s efforts to promote the Analytical Engine, it was never built. It was, however, designed in great detail on paper including extensive drawings, plans, specifications and notes relating to its design. By the time Babbage conceived of the Analytical Engine, his relationship with the British government had soured. Though Babbage was brilliant, he lacked diplomacy and was not skilled at promoting his endeavours. He also made the fatal mistake of telling the British government in 1834 that he had stopped working on the Difference Engine because he invented a machine that superseded it. While it is easy to understand Babbage’s enthusiasm for his new creation, it is difficult to fault the British government for thinking that the money they spent developing the Difference Engine had been wasted.

**Herman Hollerith**

As the 19\textsuperscript{th} century drew to a close, the US census department had a looming crisis on their hands. According to the US constitution, a census must take place every 10 years to ensure accurate representation in the House of Representatives, whose apportionment is based on population. As the US population grew it was becoming increasingly difficult to collect and tabulate census data in a timely manner using traditional manual methods. The first US census conducted in 1790 enumerated 3.8 million people and took 9 months to complete. By 1860, the US population had increased tenfold to 31.8 million. The 1880 census took more than 7 years to complete and it was predicted that the results of the pending 1890 census would not be complete

\textsuperscript{35} Ada FAQ: comp.lang.ada
before the next census was to begin in 1900.\footnote{Shurkin, J. Engines of the Mind, 48-49} Clearly there was a need for a faster, more efficient way of collecting and processing census data.

This is where Herman Hollerith and the Jacquard loom come in. Herman Hollerith was born on February 29, 1860 in Buffalo, NY. His parents were German immigrants, who came to the United States in 1848 to find a better life. When Herman was 9 his father was killed in an accident, leaving his mother to raise Herman and his brother alone. He attended City College of New York after which he entered the Columbia School of Mines, where he received a degree in engineering in 1879. Shortly after graduation Hollerith joined the US Census Bureau as a statistician.\footnote{US Census Bureau, History: Herman Hollerith}

It was Dr. John Shaw Billings, Director of Vital Statistics for the Bureau who provided the inspiration for Herman Hollerith's tabulating system. There is some controversy over the exact details surrounding this. According to Hollerith, over dinner one evening Dr. Billings remarked: “There ought to be a machine for doing the purely mechanical work of tabulating population and similar statistics…his idea was something like a type distributing machine. He thought of using cards with the description of the individual shown by notches punched in the edge.”\footnote{Austrian, G.D., Herman Hollerith, Forgotten Giant of Information Processing, 6} Another account, however, indicates that Billings specifically suggested a system based on the Jacquard loom. In this version Dr. Walter .F. Wilcox, who worked with both Billings and Hollerith at the Census Office, recalled that Billings made the following comment to Hollerith one day as they observed rows of clerks laboriously transferring data from schedules to record

\footnote{36 Shurkin, J. Engines of the Mind, 48-49\n37 US Census Bureau, History: Herman Hollerith\n38 Austrian, G.D., Herman Hollerith, Forgotten Giant of Information Processing, 6}
sheets by hand: “There ought to be some mechanical way of doing this job, something on the principal of the Jacquard loom whereby holes in a card regulate the patterns to be woven” 39

It was about a year later that Hollerith observed a train conductor punching holes in a ticket to record passengers’ physical characteristics such as gender, hair colour, and ethnicity. This was to verify that the passenger occupying the seat was in fact the same one who had originally presented the ticket. Hollerith referred to this as a “punch photograph”.40 Applying this concept to census data, Hollerith conceived of a system using cards with standardized holes to represent various traits such as gender, ethnicity, occupation etc. By 1884, Hollerith had designed a prototype and filed his first patent for a census tabulator.41 A production machine followed soon after. Hollerith’s system was first used by the City of Baltimore in 1886 to process mortality statistics.42

Hollerith’s design handily won a contest by the US Census Bureau seeking the best automated counting device for the 1890 census. Hollerith's system was successful and the 1890 census was completed in much less time than the previous census, at a savings of $5 million. In addition, Hollerith’s system allowed census takers to profile the population with far greater detail and greater accuracy than ever before.43

Hollerith’s system was not a single device, but rather a set of machines that worked together as an integrated system to automate census tabulating and processing. This set of machines consisted of punch cards to record data on, a pantograph for punching the cards, a

40 Shurkin, J. *Engines of the Mind*, 73
42 Cortada J.W., *Before the Computer: IBM, NCR, Burroughs, and Remington Rand*, 49
43 IBM Archives –Herman Hollerith
tabulator for analyzing the results and a sorter. Hollerith’s system did more than just tabulate results. It could record, process, store, retrieve and analyze data.

The operating principle behind Hollerith’s system can be described as follows: The tabulator contained a press with pins protruding down from the top half and cups of mercury in the bottom half. Where the pins encountered a hole, the pin went through the card and dipped into the mercury, thus completing the circuit, which then signaled the counter to increment.44

In principle, the punched cards used by Hollerith were identical to those used by Babbage and Jacquard. In each case, the cards consisted of cardboard rectangles with rows and columns of spaces which could be punched out or left solid, conveying information through some kind of sensing mechanism to the machine which they were to control. Hollerith never acknowledged the influence of either Jacquard or Babbage on his work. While it is reasonable to conclude that Hollerith may not have been aware of Babbage’s work, the same cannot be said about Jacquard. Hollerith’s brother-in-law was reputed to be in the silk-weaving business and they were known to have had conversations about the silk-weaving technology.45 In addition, although Hollerith’s initial experiments involved punched paper tape, used in the telegraph industry, rather than punch cards, punched paper tape itself was a descendent of punch cards used in the weaving industry.46 Though inconclusive, the weight of the evidence suggests that Hollerith did not “reinvent” punch cards independently, as some people claim.

The Birth of IBM

44 Stobbs G.A., Software Patents, 35-36
45 Pugh, E.W., Building IBM: shaping an industry and its technology, 11
46 Pugh, E.W., Building IBM: shaping an industry and its technology, 6
In 1896, Hollerith founded the Tabulating Machine Company. At first Hollerith focused on census tabulating equipment. The company’s primary sources of income were from equipment rentals and punch card sales. With ten years between national censuses, the company sought new customers abroad, but Hollerith did not enjoy travelling or negotiating contracts. In the meantime, markets were developing for business information processing systems, yet Hollerith was reluctant to enter this market. He tended to see his company in narrow terms as a maker of census tabulating systems, which hindered his ability to consider the wider applications of his technology. Faced with financial pressures and recognizing that his competitors were targeting the commercial market, the Tabulating Machine Company began to pursue business customers early in the 20th century. By 1911 Hollerith’s company had more than one hundred major customers and several hundred smaller ones. By then, however Hollerith’s health was not good. His doctor recommended that Hollerith play a less active role in the business. As a result, he sold the business to Charles R. Flint who merged it with three other companies to form the Computing Tabulating Recording Corporation (CTR) on June 15, 1911.\(^{47}\) In 1914 Thomas Watson Sr. was named general manager of CTR and in 1924 the company was renamed International Business Machines (IBM).

One of Watson’s first initiatives was revamp the company’s sales force. To this end, he instituted a number of motivation techniques, including generous sales incentives and the 100 Per Cent Club. In addition, he established a comprehensive system of sales territories, commissions and quotas. Salesmen were expected to be well groomed and wear dark formal suits. Watson focused the company’s sales strategy on providing large-scale, custom-built tabulating solutions. He also stressed the importance of customer service.

\(^{47}\) IBM Archives – Computing Tabulating Recording Company,
Watson played a central role in shaping IBM’s organizational culture. One of his favourite slogans was THINK, which became the company’s mantra. He strove to install pride, loyalty and community in every employee. There were company songs, picnics, rallies a company newspaper, banquets and the like. 48

Watson’s strategies proved successful. During Watson's first three years, sales doubled from $4.2 million to $8.3 million and company operations expanded to Europe, South America, Asia and Australia. By 1918 sales were $9 million, then $11 million in 1919 and in $14 million in 1920.49

Dawn of the Computer Age – Howard Aiken

Despite the advances made in the field of information processing, by 1930 Babbage’s dream of an automatic general purpose computing machine had still not been realized. By the mid to late 1930’s, however, several projects were underway in this regard, and it was only a matter of time before one of them succeeded. Howard Aiken was one of the people involved with this effort. Aiken was born on March 8, 1900 in Hoboken New Jersey and grew up near Indianapolis Indiana. His father deserted the family when Aiken was 12 after which Aiken worked to support his mother and maternal grandparents. Despite working full time, he continued his studies through correspondence. One of his former teachers found Aiken a job that enabled him to work nights so that he could attend school during the day. Upon finishing high school, Aiken studied at the University of Wisconsin, where he again worked nights and attended

48 Sobel, R. Thomas Watson, Sr: IBM and the Computer Rrevolution, 58-62
49 Maney Kevin The Maverick and His Machine: Thomas Watson, Sr. and the Making of IBM
school by day. Aiken graduated with a degree in electrical engineering in 1923. Aiken continued his studies at Harvard in 1933 and earned a PhD in physics in 1939.

It was while working on his doctoral thesis in 1936 that Aiken first conceived of the idea of building an automatic calculating machine. Aiken needed numbers for his theory of space-charge conduction in vacuum tubes, but the mathematical calculations involved were beyond the technology that was available at that time. He was forced to conclude that this area of electronics might never be properly explored because it would be too time consuming and laborious to undertake the numerous and lengthy calculations necessary for the proper exploration of the subject. He believed that some way needed to be found to mechanize and automate the calculation of complex equations.

When Aiken first approached the Physics Department with his idea for a computing machine, they did not see the need for it and were reluctant to give up space for it in their building. In addition, he was told by Physics Department chairman Frederick Saunders that a lab technician mentioned that they already had such a machine in the Science Centre attic that nobody used. Aiken tracked down the lab technician who led him up into “the attic” of the old Research Laboratory of Physics. The machine in question was a demonstration model of Babbage’s Difference Engine, sent to Harvard by Babbage’s son Henry Prevost Babbage. This was apparently the first time Aiken had heard of Babbage, which led him to look up Babbage at the library and discover his autobiography.\footnote{Cohen I. Bernard, 
Howard Aiken: Portrait of a Computer Pioneer, 66-67}

The Physics Department later acquiesced to Aiken’s request for space and he set about finding funding for the project as well as and someone to build it. Aiken first approached the
Monroe Calculating Machine Co., who turned him down, but suggested he contact IBM's president Thomas J. Watson.

Aiken prepared a formal presentation for IBM entitled “Proposed Automatic Calculating Machine” In addition to the proposal itself, the document contained a brief retrospective of historic attempts to mechanize calculation, including the Pascaline, the Stepped Reckoner, Babbage’s engines, Hollerith’s tabulating machines and business machines, such as those manufactured by IBM. The historical material is important here not only because it establishes Aitken’s awareness of the computer’s prehistory, but also because it establishes clear links between the Jacquard loom and the birth of computing.\textsuperscript{51}

IBM agreed to fund the project and build the machine, which was dubbed the Automatic Sequence Controlled Calculator (ASCC) by IBM, but has become known at Harvard as the Mark I. Construction began in 1939. Because of disruptions during WWII, the Mark I was not completed until 1944. Its cost to IBM is estimated to have been around $200,000. The Mark I was 51 feet long and 8 feet high and weighed 5 tons. Its components were electro-mechanical, consisting of thousands of switches, relays, shafts, wheels and wires. Data was input via punch cards, paper tape or manually set switches. Output was printed by electric typewriters or punched into cards. Sequencing of operations was controlled through perforated paper tape.\textsuperscript{52}

When it was built, the Mark I was considered to be the world’s first general-purpose programmable computer. It was later established that Germany’s Zuse Z3, also a general-purpose programmable computer, was operational in May 1941, 3 years before the Mark I. This computer

\textsuperscript{51}Aiken, H. Proposed Automatic Calculating Machine 10-12
\textsuperscript{52}IBM Archives: IBM's ASCC (a.k.a. The Harvard Mark I)
was little known in America and was destroyed in an allied bombing of Berlin in 1943. As such, it had little influence on the subsequent development of computers in America.

In the press release issued by Harvard leading up to the Mark I’s dedication on August, 7 1944, little mention was made of IBM, either in terms of financial contribution or engineering expertise. Few IBM people where mentioned by name and Aiken was referred to as the machine’s inventor. Thomas Watson Sr. was furious at the slight. Aiken’s speech at the dedication ceremony added further fuel to the fire. Aiken waxed eloquently about the history of calculating machines and the sense of destiny he felt the Mark I was fulfilling, but he too neglected to give enough credit to IBM for their role in the project. The resulting rift ended IBMs relationship with Aiken.

**The Evolution of Computing**

Much has happened since the infancy of the computer industry in the 1930’s and 1940’s. The rapid pace of change quickly renders yesterday’s innovations obsolete. Early computers that were based on electro-mechanical technology such as the Harvard Mark I and the Zuse machines were destined for the scrap heap of technology almost as soon as they were launched. In practice, the use of relays that physically move, in response to an electric current, places a physical limit on the speed at which the machine can operate. In addition, mechanical parts such as relays are prone to jamming and overheating.

During the 1930’s and 1940’s the technology of vacuum tubes continued to improve. WWII proved to be a catalyst for experiments involving the use of vacuum tubes in computers. It was hoped that electronic computers, based on vacuum tube technology, would result in rapid

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decryption of enemy communications. The ENIAC was the world’s first general-purpose
electronic computer. Construction commenced in 1943 and the machine was completed by
February 1946. It was based on vacuum tube technology and boasted speeds one thousand times
faster than electro-mechanical computers.

By 1959, transistors were replacing vacuum tubes as the switching device in computers.
Transistors were a great leap forward over vacuum tubes. Transistors were smaller, faster, more
reliable, cheaper to build, consumed less power, and emitted less heat than vacuum tubes.
Transistor based computers could process up to 1000,000 instructions per second.

Today, computers are built with microchips also known as microprocessors, which
contain miniaturized assemblies of transistors with millions and even billions of transistors on a
single chip. These chips are too small to be built manually and are manufactured in a dust free
environment using powerful microscopes.

As processing components have changed, so to have input and output media. For many
years punch cards dominated in this arena. As processing speeds increased, it became
increasingly difficult for sorting mechanisms to keep up. In addition, new media appeared that
was more convenient and had greater storage capacity. In the late 1940’s magnetic tape
appeared. Floppy discs appeared in the 1970’s. By the 1980’s it appeared that punch cards were
becoming obsolete, after an incredibly long run as an input and output medium. Today
information flows to and from our computers through a variety of channels including CDs,
DVDs, memory sticks, keyboards, network connections including the Internet, speakers,
microphones, and webcams.

**Jacquard’s Legacy**
The legacy of the Jacquard loom continues today, through the ever present computing devices we use for work and play. Though the punch card itself is no longer in use, the principle behind it is. To this day computers are still based on the fundamental concept of the on/off state, which on a punch card was represented by the presence or absence of a hole. Today this on/off state is embedded within the circuitry of microchips and microprocessors. It is this on/off state, often represented as zeros and ones, that provides the fundamental building blocks of the computer.

With the punch card no longer in use, the visual connection that linked the modern day computer with the Jacquard loom has faded. For those of us who were alive during the punch card era, it is likely easier to grasp the significance of the Jacquard loom’s impact on modern information systems. After all, we can remember a time when computer punch cards were relevant. It is only a minor leap of imagination to see the similarities between the two systems, and relate what we know about computer punch cards to the Jacquard loom. For those who are not familiar with either system, the connection might not be as readily apparent. Whatever the case, it is hoped that the narrative woven in the preceding pages sheds light on the fascinating story of how the Jacquard loom helped give birth to the information age.
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