THE DEVELOPMENT OF THE JACQUARD LOOM: EARLY HISTORY OF COMPUTER DATA STORAGE

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Please do not fold, spindle, or mutilate.

– modern admonition

A necessary byproduct of human existence is information. Every possible facet of our lives produces data, and sometimes we wish to store this data for future use. The earliest form of storage was the invention of writing, which in this case may be broadly defined as all manual forms of storing information that may be visually recognized by humans, from cuneiform to ancient English tallies to the Inca *quipu* to accounting ledgers.

The storage of information for use by computers presents an entirely different problem. Computers generate, store, and process enormous amounts of data at incredible speeds – that is their *raison d'être*. However, all computers must have data presented to them according to strictly defined rules. The data also must be quickly accessible in order for the computer's speed to be at all meaningful. These two rules disallow the human techniques of information storage, requiring instead mechanical devices controlled by the computer. The concepts behind the development of these hard disks, floppy drives, and RAM, as commonly happens with great inventions, came about as a result of converging technologies and the need to make an operation faster, cheaper, and less prone to human error.

Machines

Europe in the 12th and 13th century was a bustling economic and industrial center, recovering after the Black Death wiped out half the population during the period from 1347-1351.[1] Those who died left their money to those who lived, however, and so in the late 14th century much capital was available to start businesses, promote inventions, and spend frivolously. When the printing press was invented in the 15th century, the accumulated knowledge of Greek and Roman science became widely available to the public (with the help of Aldus Manutius, who was one of the first to publish "pocket editions" of classic literature).[2] As people read works such as those of Hero of

[1] Burke.
[2] *Ibid*.

Alexandria, who detailed many kinds of pneumatic and hydraulic automata (including the ancestor of the famous drinking bird)[3], they became fascinated with complex mechanical toys, especially the aristocrats who could afford them.[4] Much money was spent on mechanical singing birds, wind-up tortoises that crawled a dining table delivering toothpicks, and elaborate constructions to amuse (or to play pranks on) guests.[5] The best surviving examples of the latter are the automatic water gardens at the Castle Hellbrunn, in Salzburg, built in 1615. They consist of a multitude of hydraulically-powered tableaux, fountains, and mechanisms to squirt water upon unsuspecting visitors. It also features a mechanical organ to drown out the noise of the hydraulic machinery.[6]

Silk

One has only to examine a map to understand the enormous economic growth in ancient times of Lyon, in the Rhone Valley of France. It lies at the junction of the Saone and Rhone Rivers; the latter is navigable from the Mediterranean to Lyon, and routes to Switzerland, Germany, and Paris existed during the time of the Roman Empire.[7] It was here that Henry IV and Francois I encouraged silk production in the 16th century, to break the Genovese monopoly.[8] These efforts succeeded, and Lyon became a center of silk weaving and design. Silk was in high demand by the aristocrats at this time, printed *a la lyonnaise*, embroidered, and especially brocaded.[9]

Early Lyonnaise weavers used a simple draw loom for weaving complicated designs.[10] The threads of the warp (the longitudinal threads) each ran through a ring and each ring had a cord tied to it. These cords ran out the top of the machine, and were pulled by an assistant to raise certain threads so that the thread of the weft (the lateral thread) could be run beneath them. Repeating this process with different threads raised produced a woven design.[11]

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[3] Woodcroft.
[4] Burke.
[5] *Ibid*.
[6] Burke and Woods.
[7] Baird.
[8] Lyon.
[9] Burke.
[10] Demoule
[11] Demoule and Burke.

Attempts were made to speed the process by tying the cords (called *briddles*)[12] in bundles , with one bundle for each set of threads in the warp that had to be raised for a particular line in the design. Assistants pulled a bundle upwards to raise threads for the shuttle to be run underneath. Variations on this theme included attaching the bundles to wooden levers to be pressed by the weaver or his assistant, *a la* carillon keyboards. As can be imagined, this was an incredibly slow and error-prone process, especially since the assistants were usually children, who became tired and inattentive and made costly mistakes.[13]

Machines Plus Silk

This was the state of affairs in 1725, when a Lyonnaise weaver named Basile Bouchon, in the classic mode of invention, combined ideas gleaned from mechanical automata and weaving technology. Bouchon was the son of a maker of automatic organs, the same type as used at the Castle Hellbrunn, and with the same basic design as the music boxes and automatic carillons also enormously popular at the time.[14] The typical way of "programming" an automatic organ or music box was with cams mounted on a revolving cylinder, which opened air valves as they passed. The concept of the cam had been around for centuries, used mainly in water-powered mills, where the rotary motion of the water wheel had to be transferred to trip hammers and the like.[15]

The usual way of making a cylinder for an organ was to wrap a piece of paper around it and mark off the locations of the pegs for the carpenter, who then carved out the pegs. Bouchon realized that the marked paper was a way of storing information, just as the cams on the cylinder stored information.[16] By tying each bundle of briddles to a steel pin, and arranging the pins in a row, a pin setting for a particular thread in the weft could be recorded by a line of punched holes in a piece of paper. If the thread of the warp was to be below the thread of the weft, there was no hole in the paper, which pushed the steel pin down. If the warp was above the thread of the weft, there was a hole,

[12] Demoule.
[13] Burke.
[14] Burke, Demoule, and Posselt, page 8.
[15] Burke.
[16] *Ibid.*

which the needle passed through and remained unmoved. Then the paper was advanced to the next row of holes and the process repeated.[17]

Bouchon's concept was revolutionary - that the absence of a thing was equally as informative as its presence. This is of course also known as binary-encoded data storage. Bouchon's loom was never popular, though, because its single row of pins was not enough to make complex designs, and the paper tape was prone to tearing (a problem which would return more than two hundred years later on the World War II Colossus cryptographic computer).[18]

In 1728, Bouchon's assistant Jean-Baptise Falcon improved upon Bouchon's loom somewhat by increasing the number of pins, arranging them in the form of a rectangle.[19] Then, instead of using the paper tape, punched cards the size of the rectangle of pins were used. The operator took a card and pressed it upon the rectangle of pins, and those pins without corresponding holes were moved as before. Much more complex designs were now possible with the increased number of pins, and the cards were much sturdier than the paper tape. The loom was still manually operated, however, since the operator had to take each card and press it on the pins, run the shuttle, and then repeat the process.[20]

Jacques de Vaucanson, who bore a well-earned reputation as a designer of surpassingly clever automata,[21] was appointed the official inspector of the French silk industry in 1741.[22] In 1744, he redesigned Falcon's loom to eliminate almost all manual control by the operator. The new loom did away with the cards, instead using a revolving cylinder much like the automatic organs, with an escapement mechanism that automatically advanced the cylinder to the next row of holes after the shuttle was run. In spite of the automatic nature of the loom, it was in other ways a step backwards, since it returned to the single row of pins used by Bouchon, with its consequent reduction in ability to weave complex designs.[23] It was also not well received by the silk workers, since it presented something of a threat to their livelihood. This problem would return

[17] Demoule, Burke, and Posselt, page 8.
[18] Burke.
[19] Burke, Posselt page 8.
[20] Burke.
[21] Swarthmore.
[22] LaGarrigue.
[23] Demoule, Burke, *Science Online*.

with a vengeance later. In the meantime, Vaucanson's loom was largely ignored, and at some point the *Conservatoire des arts et métiers* (Conservatorium of Arts and Trades) in Paris acquired a disassembled unit. There it lay forgotten until the arrival of Joseph-Marie Jacquard.[24]

Jacquard was born in 1752, the son of silk weavers. He was employed as a child in the silk factory where his parents worked – his job was pulling the bundled briddles, thus giving him first-hand experience with the difficulty of this method of weaving brocaded silk. He dabbled in several other trades (among them bookbinding and working in a type foundry), endured the Revolution and the death of his son, and then took a position at the Palace of Fine Arts in Lyon, teaching weaving techniques. While there, to win a reward offered by the London Society of Arts, he invented a machine to make fishing nets. He demonstrated this machine at the *Conservatoire des arts et métiers* in Paris in 1804, won the reward, and was offered a position at the *Conservatoire*.[25]

Here he found or was shown Vaucanson's disassembled loom, and set about the task of rebuilding it. Realizing its limitations, he improved it by incorporating elements of both Bouchon's and Falcon's looms – Bouchon's spool of paper and Falcon's punched cards. By lacing the cards together, the machine was able to use Vaucanson's escapement mechanism to advance them automatically through the machine, without tearing as Bouchon's paper roll was prone to do.[26] A repeating pattern could be quickly and easily woven by using a loop of cards, run through the loom repeatedly. Moreover, the same pattern could be made on any Jacquard loom (as it was now called) simply by loading the same cards. When he presented his machine in 1805, Jacquard did not know of the revolution in data processing that would occur nearly a hundred years later when Herman Hollerith used punched cards for the 1890 census. What became immediately and painfully evident was that his machine was universally hated by the silk workers, resulting in one of them being burned in a public square in Paris in 1806.[27] It was such

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[24] LaGarrigue.
[25] Posselt, page 8.
[26] Burke.
[27] Posselt, page 9.

an improvement over the old methods of weaving, and increased profits to such a degree, that by the time Jacquard died in 1832, over 30,000 of the looms were in use in Lyon.[28]

It is interesting to note that the basic design of Jacquard's loom, with the exception of one factor (the ability to write data to the cards) is similar to the concept of a Turing machine, proposed by Alan Turing nearly 150 years later. The punched card method of data storage spread widely in the 19th century, used in other machines such as Richard Robert's automatic riveting machine,[29] and Hollerith's tabulating machines.[30] It continued to be used at least until the mid-1980s, even after other methods of permanent data storage were introduced.[31] The invention of punched-card storage was a computing revolution because it provided a cheap and reliable method for computers to store and use the information they needed to perform their necessary functions.

[28] *Ibid*.
[29] Norton.
[30] Russo.
[31] Personal observation by the author.

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