Calculating by Steam

Book Review

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ANTHONY HYMAN (1982). *Charles Babbage - Pioneer of the Computer,* Oxford, University Press.
ANDREW HODGES (1983). *Alan Turing - The Enigma,* Burnett Books.

Those who would like to see the world's oldest computer, should go to London. In the Science Museum, between a 250 million times enlarged model of the DNA molecule and a collection of antique navigation instruments, there is a construction that reminds one of some old-fashioned gas-meters. It is the Difference Engine built by Babbage in 1832 and still in perfect working order. Of course, it is not the oldest calculating aid. The abacus has been in use for thousands of years and the first multiplicator, the slide rule, was invented in the seventeenth century. Also from those days are the first calculators that deserve the name of machine. The ingenious clockworks of Pascal and Leibniz could add or even multiply numbers, but they were not automatic machines. When a calculation involved more than one step, the result had to be read each time and the apparatus readjusted. The difference engine, however, only needs a few starting instructions and then goes through the whole cycle without any additional assistance. It is as automatic as a modern washing-machine.

The England of 160 years ago, in which this engine originated, was a quiet little world in which production was still largely manual. Electricity was known, of course, as a natural phenomenon, but industrial applications were not yet thought of. Even the use of steam was still in its infancy. Darwin and Marx had not yet disturbed mankind. There was no place in London that was more than a quarter of an hour's walk from the edge of town. Few realized that the Industrial Revolution had already begun.

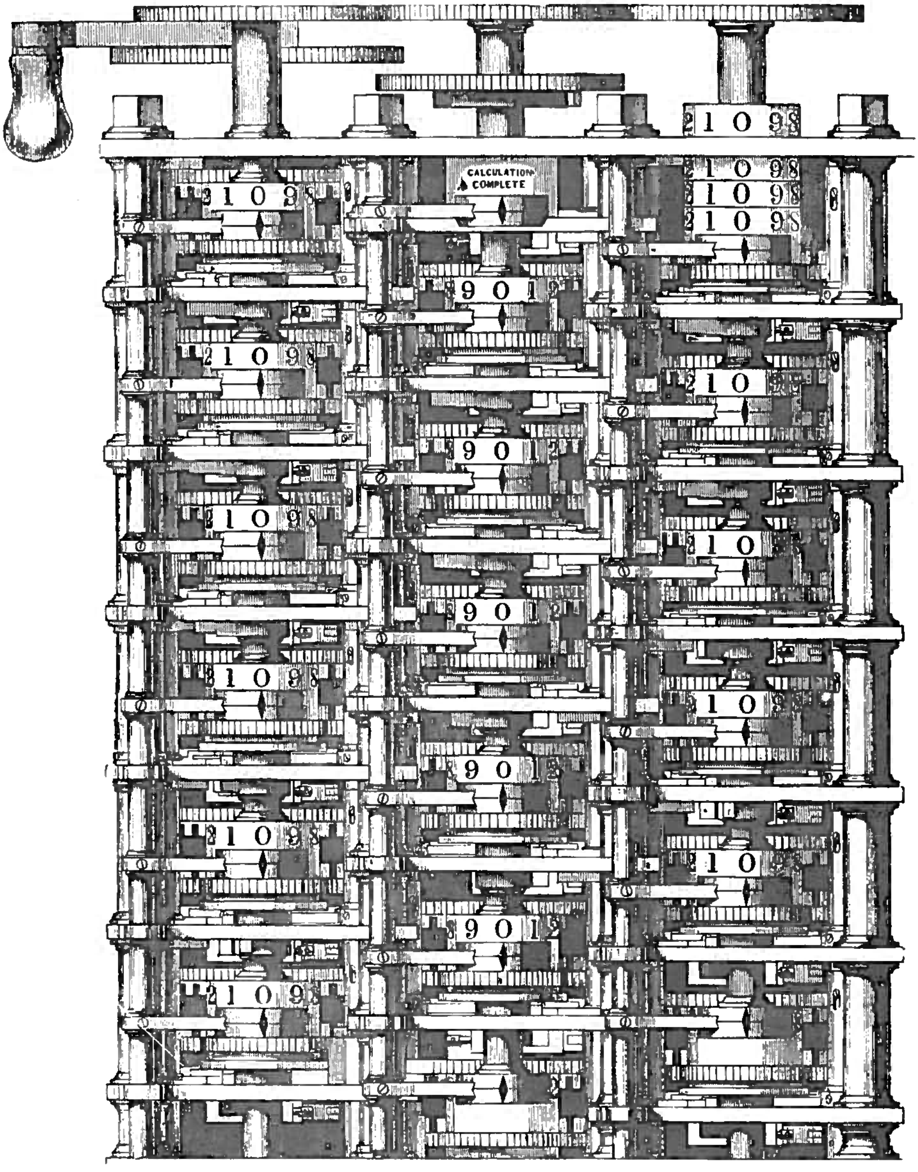
Charles Babbage (1791-1871), however, had seen it all coming. He belonged to the London upper middle class and had sufficient means to occupy himself all his life with unpaid scientific research. Hyman's biography gives a good description of this social background. Babbage's family life, his travels, his circle of friends: all is vividly portrayed. The discussion of Babbage's books gives us an idea of how universal the work of one man could still be in those days. In a theological treatise, for example, he tried to show that the plan of creation corresponds to the pattern of a quartic equation. But first and foremost he was interested in mathematics and physics, engine-building, and economics, three branches of science that were closely connected in his world-picture. Unlike the classical economists Adam Smith and Ricardo, he did not consider agriculture but industry as the pivot of the economic system. And the progress of industry depended on science and technology. This point of view was behind his decision on how to spend his life.

He first had an inspiration when round about 1820 he met a French engineer who applied the principle of the division of labour, as described by Adam Smith, to the making of logarithmic tables. The success was amazing. The whole job, that would otherwise have taken a lifetime, was now done in a few years (division of labour: 6 scientists, 8 trained assistants, and ca. 60 executors who could only do additions and subtractions). Babbage's ideas went much farther. An operation that consists of the continuous repetition of a simple action, such as addition, could in principle be mechanized. That means better quality (in this case fewer mistakes), faster results, and cheaper production. Driven by steam it might become even faster and cheaper. Babbage began to dream of logarithmic tables 'as cheap as potatoes'.

Shortly after he began to design a machine that would make mathematical tables. The working of such a machine is not really difficult to understand. Suppose we want to have a table of the squares of all the numbers from 1 to 1000, i.e., 1, 4, 9, 16, 25, etc. If we subtract from each square the preceding square, we find the so-called difference series: 3, 5, 7, 9, etc. These numbers can also be found in another way, viz., by starting with 3 and then adding 2 each time. Having found the difference series in this way, the computation of the squares in only a simple trick:

$$\begin{aligned} 1+3&=4\\ 4+5&=9\\ 9+7&=16\\ 16+9&=25 \end{aligned}$$

This table then can be obtained by means of addition. For a great many other mathematical tables there are similar tricks for computing each term by two or more additions of preceding terms. They are always based on a difference series, hence the name Difference Engine. In this way there is no need for multiplication. This is a great advantage, for addition is easier for a machine (just as it is for a human being) than multiplication. So Babbage could keep this part of his machine quite simple. The rest of the mechanism, however, occasioned so much brain-racking that its design and construction took over ten years. The outcome was the Difference Engine which, after the necessary



B. H. Babbage, del.

Impression from a woodcut of a small portion of Mr. Babbage's Difference Engine No. 1, the property of Government, at present deposited in the Museum at South Kensington. (Facsimile of frontispiece from 'Passages from the Life of a Philosopher' published in 1864.)

adjustments, could work quite independently. The results were even recorded in matrices of printing type, so that both reading and printing errors were avoided. The whole contraption, however, had to be kept in motion by turning a handle without interruption; the dream of calculating by steam was never realized.

Babbage still had all sorts of improvements in mind, but for financial reasons he had to leave it at this first model. Originally, the project was subsidized by the government, but this was stopped by the politicians' short-sightedness. They did not even want to take over the machine. Eventually, it was put in Babbage's drawing-room, and moved to a museum later on.

Babbage realized that he would never be able to build another complete machine, but he had sufficient means at least to continue to design and experiment. His new plans concerned a far more sophisticated calculating engine, the Analytical Engine, which could also solve mathematical equations. With each improvement the design began to resemble a modern computer more and more closely. For example, there was a clear division between the memory and the processing unit (Babbage called it 'store' and 'mill', according to the layout of cotton mills in those days). Both parts were run by a 'control'. To this end the control was given the necessary commands on punched cards made of tin in which the program was recorded. For the output of the results Babbage had first thought of the matrix press of the Difference Engine or of a line printer. Later it proved to be simpler to have the results recorded by the machine on punched cards that could then serve as a program for an automatic printing press. In this way, moreover, human errors were avoided completely.

Quite a modern feature were the special commands to react to interim results. In the design of the Analytical Engine punched cards were connected in such a way as to form a chain. Normally, they would pass the 'control' in fixed order. After one of the special commands, however, the mechanism would depart from this pattern whenever an interim result satisfied certain conditions. The whole chain would then move a few places, for example. In other words: an automatic modification of the program. This approaches what is nowadays called conditional branching. (Without this facility our computers would not be so uncannily clever; Hodges calls it the mechanization of the word IF.) This is as far as the resemblance to a modern computer goes. In Babbage's machine the binary system was (deliberately) not used and the program could not be stored in the memory. Of course, the Analytical Engine was not electronic, nor even electrical. This made the parts so large and their movements so slow that the working of the machine, if it would ever have been built, could have been followed with the naked eye. The 4.50 meter high colossus would have needed a few seconds for an addition and a few minutes for a multiplication. The whole machine has been described by Ada, Countess of Lovelace, a daughter of Byron. According to her, its features were so universal that in principle it could compose music. She also wrote some programs for the engine.

The question has been raised whether at this stage Babbage's plans were still realistic. Hyman is inclined to think that, with sufficient funding, construction would have been technically feasible. But Babbage was far ahead of his time. After 1840 the gap between pure science and the art of engineering grew wider and wider, and the Engine 'fell through this gap into a century's oblivion.'

Indeed, for the next hundred years little was heard about calculating engines. Babbage's brain-children were sleeping in the Science Museum. The mathematics student Turing, who had been in Cambridge since 1931, was not aware of their existence. He, too, had invented a calculating machine, but one that will never be on view in a museum. Of the design only one part is known, viz., a tape that is divided into little squares. It can move one square at a time, either forwards or backwards. Then there is a simple operation: if the new square is empty, it may be marked with a cross; if it already contains a cross, it may be erased. Then there is another cycle. Turing has shown that such a tape-machine, if supplied with the necessary clockwork, can do additions. After some changes in the mechanism it can also do multiplications or other arithmetical operations. He even described a universal machine that could do 'anything'. We shall never know, however, how it was supposed to function, as Turing never worked out the technical aspects of his ideas. There are no models or blueprints. Indeed, it never was his intention to construct anything.

The so-called Turing machines were no more than abstract constructs intended to give a precise meaning to the notion of 'effective procedure', which needed clarification in the context of mathematical logic at that time.

Alan Turing (1912-1954) was regarded as an eccentric in Cambridge, and also in later years he always remained the incredibly intelligent outsider in whatever circles he moved. In his biography, Hodges has treated this aspect at great length. Alan's parents, who lived in India, sent him to England when he was two years old, to be brought up by strangers. He became a withdrawn little boy, but won all the prizes at school. Later he applied himself to such an individual sport as long-distance running, and as an adult he asked his mother a teddybear for Christmas. His fellow students were shocked by the frankness with which he admitted his homosexual inclinations. As a topic for conversation it was not taboo in Cambridge, but in those days the actual practice of it was limited to certain exclusive circles (hence, 'higher sodomy') to which Turing was not admitted. After all, this was the time in which King George V is supposed to have said: 'I thought men like that shot themselves.'

For his intellectual achievements, however, and this is Cambridge, too, he was openly honoured and rewarded. Yet, he left for America in 1936 to graduate. While there, he built an apparatus in his spare time derived from the Turing machines, with which text could be encoded. In the mean time, Europe was heading for war. Information was as important as guns were, and it was necessary to intercept as much as possible of the wireless communications between the enemy forces. But naturally the Germans sent their messages in code, so that each message had to be deciphered. To that end Churchill created a new service, the famous Bletchley Park. A puzzle club of well-meaning amateurs rapidly developed into a tight organization of 10,000 people (mostly women, by the way). Turing, who was back in England by now, was put in control of a department that was concerned with the movements of the enemy submarine fleet. German submarines were particularly active in the Atlantic. The outcome of the war depended on American material (and later on American men), and supplies were almost exclusively by sea. There was no lack of messages, but decoding often took so long that in the mean time the information had become useless. That was why Turing concentrated all his efforts on cracking the code itself. The code was defined by the wiring of the Enigma, the electro-mechanical coding and decoding machine, which belonged to the equipment of every German unit.

Turing replaced primitive techniques of trial and error by refined statistical analyses and introduced punched cards. During 1941 they succeeded in reducing losses of ships by 50%. This success did not last long, for the Germans regularly changed the Enigma key setting. On the other hand, they were so careless as to transmit their weatherforecasts, the contents of which were easily guessed, in the same code. Hodges thinks that they never realized that their code was being tracked all the time. Failure of a submarine mission was invariably attributed to espionage or treason, never to the silent crew of Bletchley Park, 'the geese who laid the golden eggs and never cackled,' as they were called by Churchill.

In 1942 Turing was sent to the United States to learn about the use of electronics in data handling. The subject was in the air, mathematicians and physicists all over the country were doing research, but all threads came together at one man, Professor Von Neumann of Princeton University. Turing had met him several times. Although scientifically they were on the same track, their approach was as different as can be. While the lonely hobbyist Turing soldered his own models, Von Neumann had organized his project as a large-scale enterprise. He visited universities, was on all committees, had his own professional journal, and made an immortal name for himself in the history of computer science.

Having returned to England in 1943, Turing changed his course on the basis of the newly acquired knowledge. Bletchley Park could now do without him, and he applied himself to the construction of a machine for speech-encipherment that would secure military telephone-traffic across the ocean. But his imagination was already much farther ahead. With the use of electronics the Turing machine, that was originally meant for thought experiments only, could now actually be built. It would even be possible to imitate the human brain by electronic means (in those days radio valves!). Of course this imitation was not in a physiological or psychological sense, but as a logical system. As soon as the war was over, Turing took up a post in a government laboratory to realize this vision. The design of the ACE (Automatic Computing Engine; the use of the word 'engine' is in honour of Babbage) was largely due to him. It promised to be a very fast computing machine with an enormous memory, but for the rest the hardware was a reflection of his modest lifestyle: a minimal machine, no built-in gadgets, the type of installation that is appreciated by very clever programmers only. It could have become the first real computer, but Turing had little or no consideration for 'user-friendliness'. Because of his inflexible behaviour, construction was out of the question for the time being. After all kinds of difficulties he left the laboratory.

After this incident, his fame declined. In 1948 he eventually accepted an appointment at Manchester University. There they had just finished building a computer, so that there was little original work left for him to do. It did not seem to bother him; his attention was now directed rather towards such questions as are frequently heard again these days: can a computer think? Well, said Turing, let's first see if a computer can do arithmetic. Each calculating machine is designed in such a way that if the input is 47+21, the output is 68. In Babbage's engine one could actually see the three numbers (the positions of the gear-wheels). In an electronic machine, however, they are not really present; those investigating the inside will only find some pulses darting to and fro. A computer does not do arithmetic in the way a human being does. It does come up with the desired result, but it is found in a completely different way. If you insist on still calling this 'doing arithmetic', was Turing's conclusion, then with as good reason I can state that in principle a computer can think. The same goes for playing chess, learning, making decisions, etc. He expected, by the way, that by the end of this century the definitions of all of these words would have been sufficiently expanded to make such discussions superfluous. (Compare the word 'computer' that 15 years earlier had been used for human calculators only.)

In Manchester, too, he was the eccentric genius again. People laughed about that lanky person who put an old tie round his waist to keep his trousers up, who changed his bicycle with his own hands into a moped, and in spring wore a gasmask for hayfever. Shrink-proof clothing he washed himself, the rest went to his mother.

His mastery as a programmer was openly acknowledged. He could make a computer do conditional branching, even if this was not provided for in the hardware. Primitive peripherals were forced to question and answer techniques in a way that is very much like a modern teenager playing games with his personal computer nowadays. Only once was he outrivalled by a colleague who wrote a program that made the computer (then still provided with a hooter) play the national anthem when it had performed its task.

In the mean time the engineers around him were a step ahead again; they were experimenting with transistors. Alan Turing was not involved. As Hodges points out, he had become the Trotski of the computer revolution.

In 1952 he was arrested for homosexuality. He was placed on probation for one year, with the condition that he submitted to a hormone treatment that rendered him temporarily impotent. A year after the end of the probation term, a few days before his forty-second birthday, he killed himself.

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