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Charles Babbage and the Computer

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Some years ago, in response to an altogether unusual number of reader requests, I wrote a column on the work of a woman usually called Ada Lovelace. (See *Function,* Volume 24, Part 5; October 2000.) Ada was the only legitimate daughter of the poet Byron, and she has acquired a considerable reputation as a mathematician – a reputation which I argued she does not deserve. She was certainly greatly *interested* in Mathematics and studied it under three excellent mathematicians of the time: Mary Somerville, Augustus De Morgan and Charles Babbage. Here I want to tell a related story, although this will involve my repeating, to some extent, the earlier one. Her connection with Babbage is what brings us to the primary concern here.

Charles Babbage (1791–1871) was a well-recognized mathematician, a fellow of the Royal Society of London and a Professor of Mathematics at Cambridge (occupying the Lucasian chair once held by Newton). Today he is best remembered for his interest in mechanical computation, and he is often seen as a pioneer of automatic computing. He envisaged first a machine that he called the *Difference Engine*, and later a much more ambitious one, the *Analytical Engine*. He worked on the Difference Engine for about ten years in the 1820s, and made some progress towards its actual construction, although he never completed this project. However, in 1833, he abandoned it in favor of a new idea: the Analytical Engine, which he saw as much more versatile. It is this latter machine that incorporated many of the concepts that later came to be seen as important in computer design.

The Difference Engine was designed to produce mathematical tables, such as those used to list the values of logarithms and trigonometric functions. (Such tables were much employed until quite recently and, although software packages have largely replaced them, they are still not entirely without their uses.) In essence, the Difference Engine was an ambitious calculating device. It was somewhat like the machines already in some use even back then (although not widely employed) for computational purposes, but much more ambitious. As recently as my own student days and indeed for some considerable time thereafter, desktop calculating machines were much in use, and there were even electrically-driven versions that were much larger and faster. All these were mechanical in operation, and essentially relied on precisely machined gear-wheels in order to function. (Electronics, of course, lay well in the future when Babbage lived, and so he envisaged the use of trains of gear-wheels as the underlying principle of his two engines.)

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The work on the Difference Engine had been in large measure supported by the British Government, and indeed by 1833, they had invested the considerable sum of £17,470 towards its construction. In his 1834 request for further funds, Babbage hinted that he had a better idea (the Analytical Engine) in mind. The Duke of Wellington, assessing his submission, read between the lines, and foresaw that the Difference Engine was to be abandoned in favor of this new project. The usefulness of the Analytical Engine was not apparent to him, nor to anyone else other than Babbage and a few of his followers, so the duke hesitated to throw more money into a project that so far had yielded almost no result. Babbage received no further funding.

Without such funding, he could not even contemplate the actual construction of his new machine, but this did not prevent his working tirelessly on the underlying theory. What distinguished the Analytical Engine from the Difference Engine was the feature that the result of one calculation could be put to automatic use in a subsequent one. In exploring how this might be done, Babbage prefigured many of the concepts of modern computer programming. On the hardware side, too, he envisaged the use of punched cards, such as were indeed used in computers until quite recent times.

This work occupied him from 1834 till 1846, and it was all entirely theoretical; indeed it was also almost entirely unpublished, existing mainly in the thousand or so handwritten pages he generated. However, it was during this period, in 1840, that Babbage was invited to Turin to deliver a seminar on his ideas to the Italian Scientific Academy. In the course of this visit, he met a young engineer, Luigi Menebrea[2], and discussed his ideas with him. It was Menebrea who, with Babbage's encouragement, published an account of the Analytical Engine and its underlying principles. This account was written in French and saw print in 1842.

This is where Ada enters the story. But first let us clear up the question of her name. She was born Ada Augusta Byron, and retained this name until she married one William King, whose surname she took, thus becoming Ada Augusta King. So she remained from 1835 till 1838, when her husband was elevated to the peerage as the Earl of Lovelace. Ada thus became Ada Augusta [King], Countess of Lovelace, but it seems that she adopted *Lovelace* as her surname. The paper I am about to describe was published over the name Ada Augusta, Countess of Lovelace, and the appended notes were signed A. A. L. So she has now become known as Ada Augusta Lovelace.[3]

Ada, as a pupil and friend of Babbage's had visited his home and there seen a small model of the Difference Engine. This had aroused her interest in the possibility of machine computation. In pursuance of this interest she translated Menebrea's memoir into English, and at Babbage's urging, added to her translation some extensive notes (seven in all) amounting in fact to some 75% of the total length of the final product. That final product was titled "Sketch of the Analytical Engine", or to give it its full title "Sketch of the Analytical Engine invented by Charles Babbage Esq. By L. F. Menebrea, of Turin, officer of the Military Engineers, with notes on the memoir by the translator".

[2]Subsequently Prime Minister of Italy (1867-1869).

[3]A strange anomaly however occurs in Campbell-Kelly and Aspray's book (detailed later). She is referred to in the text and the reference list as Ada Lovelace, but this name is missing from the index. There she is called Ada Byron!

It appeared in 1843. Quite how much of it is actually hers has become a matter of some dispute. There is quite a lot of good evidence that her unaided mathematical abilities were inadequate to the task.

That is what I looked into in my earlier article. Here I am concerned with a similar and related question: to what extent has Babbage's work influenced the development of the computer as we know it today? Some popular opinion makes Babbage the hero of the story, the man who started the whole business going. Thus another computer pioneer, the New Zealander L. J. Comrie, wrote:

> The black mark earned by the [British] government of the day more than a hundred years ago for its failure to see Charles Babbage's difference engine brought to a successful conclusion has still to be wiped out. It is not too much to say that it cost Britain the leading place in the art of mechanical computing.

In contrast, I had long entertained the thought that the answer to my question was: "Not at all!", although I had never looked into this matter in any depth. However, this is actually not quite the correct answer, although it very nearly is. I found a most revealing discussion in Martin Campbell-Kelly and William Aspray's *Computer: A History of the Information Machine* (2nd Ed, Boulder CO: Westview, 2004), a book on which much of this article is based. In particular, their Chapter 3, "Babbage's Dream comes True" addresses the point directly.[4]

Following his return from Italy, Babbage once more sought funds from the British Government which had changed complexion in the interim. The new Prime Minister, Robert Peel, however also turned him down. The year was now 1846, and Babbage was in no position to make any further advance with his Analytical Engine. Instead he returned to the Difference Engine and completed plans for an upgraded model that he called Difference Engine Number 2. But when this also attracted no government sponsorship, he finally gave up.

Here the matter rested, and the whole episode would indeed have died but for the intervention of a later mathematician, Howard Aiken (1900-1973). In 1936, Aiken, then a graduate student in the Physics department at Harvard University, was trying to solve complicated problems that needed advanced computing techniques. He approached several companies that produced computing machinery, urging them to develop more versatile machines, but without luck until he found a sympathetic ear at IBM.

[4]These authors also look into the matter of Ada's contribution. They conclude:

> Lovelace's intellectual contribution to the *Sketch* has been much exaggerated. She has been pronounced the world's first programmer and has even had a programming language (Ada) named in her honor. Recent scholarship has shown that most of the technical content and all of the programs in the *Sketch* were Babbage's work. But even if the *Sketch* were based almost entirely on Babbage's ideas, there is no question that Lovelace provided its voice. Her role as the prime expositor of the Analytical Engine was of enormous importance to Babbage ... .

Meanwhile, however, a technician at Harvard got in touch with him and told him that the department already had a machine of the type he was seeking but "nobody ever used it". True enough, up in an attic, was a part of a Babbage Difference Engine (donated to Harvard by one of Babbage's sons). The reason that "nobody ever used it" was immediately obvious: it was a mere fragment, and of no practical use whatsoever. However, Aiken's interest was aroused, and he began to look into Babbage's ideas. He soon warmed to, as he saw things, a kindred soul.

Babbage had written:

> If, unwarned by my example, any man shall undertake and shall succeed in constructing an engine embodying in itself the whole of the executive department of mathematical analysis upon different principles or by simpler mechanical means, I have no fear of leaving my reputation in his charge, for he alone will be fully able to appreciate the nature of my efforts and the value of their results.

This passage had a profound effect on Aiken, who, as he said, "felt that Babbage was addressing him personally from the past". So Babbage did have a direct influence on Aiken, who indeed went on to produce, in conjunction with IBM, a machine (the IBM Automatic Sequence Controlled Calculator, later to be renamed and better known as Harvard Mark I) that met his expectations.

It is however a matter of debate how much technical detail Aiken got from Babbage. The eminent historian of Mathematics I. Bernard Cohen thinks that the answer to *this* question is "almost none". He writes:

> Yet, despite Aiken's public reiteration of the kinship of his Mark I and Babbage's machines, a close examination of the architecture of Mark I does not show a marked similarity with Babbage's designs for either a Difference or an Analytical Engine. In fact, the Mark I didn't even emulate their operation. It seems clear that Aiken never even fully knew the features of Babbage's machines.

This would be compatible with the suggestion that Aiken did not in fact know of the work of Menebrea or of Lovelace. The passage from Babbage's writing that he was fond of quoting (and which I have reproduced above) comes from another source, Babbage's autobiography. Back in the 1930s, the more technical articles, although extant in the published literature, would not have been so easy for him to come by.

There is, moreover, an irony in this. The problems that drove Aiken to seek advanced computing machinery involved the design of vacuum tubes, and it was vacuum tubes that provided the basis of the first electronic computers. However, Harvard Mark I was not electronic, so, in that sense, it too was a dead end. It weighed 5 tons, took up all of a very large room and needed a 5-horsepower motor to drive it. It had 765,000 parts and some five hundred miles (800 km) of wiring. In other words, it was cumbersome! However, it *was* the first fully automatic computer to be completed and apparently also was very reliable, much more so than early electronic computers. Campbell-Kelly and Aspray however describe it as "profoundly slow" and a "technological dead end". They also downplay the significance of the actual results it produced, but see it as "a fertile training ground for early computer pioneers ... [and a] great influence on the design of early computing machines in Europe".

The later chapters in this story are rather sad. Aiken publicly claimed all the credit for himself and downplayed the role of the IBM engineers with whom he had worked (for seven years). The result was a rift that never mended, which has continued to tarnish Aiken's reputation, and which led to a public rebuke by Comrie, who was in a good position to know not only the influence that Babbage had exerted on him but also the important part played by the IBM engineers. Aiken did go on to develop further computers, including at least one fully electronic one. However, other strands of the story came to achieve more success and Aiken's part has come to be seen as much less important.

Thus Babbage's ideas had some influence on Aiken, who in turn influenced other "computer pioneers", but the modern computer was predominantly the product of other people's invention.

References

The full history of the computer is a very long story; whole books and many technical papers have been devoted to it. To add to the confusion, much of the work involved was carried out during World War II under the conditions of the utmost secrecy. No single person can claim the invention as their own; many people contributed. However, if we *were* to single out one name, it would probably be that of John von Neumann. He is the subject of a separate book by one of the authors of the one discussed here, William Aspray: *John von Neumann and the Origin of Modern Computing* (Cambridge, Mass: MIT Press, 1990).

The other author completed the task of collecting and publishing the whole of Babbage's writing. It runs to 11 volumes (Martin Campbell-Kelly: *The Works of Charles Babbage*, London: Pickering, 1989), of which Volume **3** concerns the Analytical Engine, and Volume **2** the Difference Engines. Volume **3** reprints Menebrea's original memoir (pp. 352-376) and also Ada's translation and notes (pp. 89-170). Ada's paper is also to be found in *Charles Babbage and his Calculating Engines* by P. and E. Morrison (New York: Dover, 1961). The remarks by I. Bernard Cohen come from the General Introduction in Volume **1** (see p. 12) and the passage of Babbage's writing that so moved Aiken is taken from Babbage's Autobiography, *Passages in the Life of a Philosopher*, which is reprinted as Volume **11**.

Menebrea's article was originally published in the journal *Bibliothèque universelle de Genève*, Volume **41** (No. 82), pp. 352-376. It was titled "Notions sur la machine analytique de M. Charles Babbage". Ada's first article appeared in *Scientific Memoirs*, Volume **3**, pp. 666-731.