The Pioneers in Computer Science: Charles Babbage and Ada Lovelace

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Helsinki 15.03.2016
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1 Introduction

Charles Babbage and Ada Lovelace are some of the most well-known characters in the history of computer science. Babbage invented and designed some of the world's first computers but failed to build them. Lovelace on the other hand helped Babbage in designing his Analytical Engine and, unlike Babbage himself, saw that similar machines could have other applications besides mathematics, such as arts like music. Furthermore, Lovelace was one of the world's first computer programmers, and the first of them that was female, and has been thus considered an example that computer science is a field that is suitable for both men and women [Cha15]. This paper will first examine the life of Charles Babbage and his work with the first Difference Engine. After that it goes through the life of Ada Lovelace and her and Babbage's work on the Analytical Engine. Finally, the paper is concluded by a description of what Lovelace and Babbage did after their most notable project that was the Analytical Engine.

2 Charles Babbage

Charles Babbage was born in December of the year 1791 in Surrey, England, and was one of the four children of Benjamin Babbage and Elizabeth Teape [Com16]. Because his father was a banker or a merchant, as the trades were interchangeable at the time, Charles was brought up in a wealthy family [Hym82, p. 5 & 8-13]. In his childhood Babbage suffered from a couple of bouts of severe fever, and was thereby sent under the care of a clergyman, who was instructed to look after the boy's health [Bab11, p. 10-12]. The clergyman was also a teacher, but was told to “not press too much knowledge upon” Babbage, which Babbage recounts the clergyman accomplished successfully. Being a curious child Babbage was unable to stay idle however, and came up with different projects of his own. For instance, he collected ghost stories from the local boys and extracted a process from those on how to raise the devil. He even tried
summoning him, but was, needless to say, unsuccessful in his attempt.

Young Babbage was very interested in algebra [CBI15] and studied the subject enthusiastically on his own [Bab11 p. 23-27]. By the time he entered Trinity college in Cambridge, he was already much more advanced in the subject than his tutors [Lee96, p. 142], which lead him to be disappointed in the university's mathematical instruction [Bab11, p. 27-29], which was in a poor state at the time [Hym82, p. 22]. Instead he studied the works of famous mathematicians on his own and ended up founding, with a group of other mathematically inclined students, the Analytical Society for the cultivation of mathematics. Babbage wanted to bring the notation of Leibnitz into use at the university and overall promote the reforming of the Newtonian mathematics taught then at Cambridge [CBI15]. This was a bold move, as choosing and backing up a notation method other than the Newtonian one was also seen as a political move by many, and at the time British mathematicians tended to be loyal to the Newtonian way [Hym82, p. 23].

During his time at the university Babbage took part in several societies and clubs besides Analytical Society and was also an avid player of chess [Bab11, p. 34]. He graduated from Peterhouse, Cambridge, in 1814, and married Georgiana Whitmore in the same year [Com16]. The marriage was a happy one, but did not please Babbage's father, who thought his son should first earn a good living before settling down [Hym82, p. 31]. Babbage and Whitmore had eight children together, of whom only three reached adulthood [Com16].

2.1 Babbage's First Difference Engine

Babbage's interest in machinery began already in boyhood [Bab11, p. 17], but the first time he began to think about using machines for calculating arithmetical tables happened somewhere in 1812 or 1813 during his time at the Analytical Society [Bab11, p. 42]. Yet Babbage worked mainly as a mathematician in his
twenties, during the years 1815 to 1820, and wrote several significant papers during that time [Hym82, p. 36]. He also helped founding the Astronomical Society in 1820 [CBI15]. Thereby Babbage invented his first machine, the Difference Engine, only in 1821. The invention was not supported merely by Babbage's interest in machinery, however, but also the great effort needed in producing mathematical tables by hand, and his growing annoyance with the errors found in the manually computed tables [Com16]. Many trades, such as ship navigation, construction and finance, depended on these manual tables, so automating their computing would have greatly benefited the society of that time as well.

Babbage designed his first engine, Difference Engine no. 1, to automatically calculate polynomials, which are mathematical functions with various powerful applications [Com16]. The first engine design listed 25 000 parts for the machine and it was estimated to weigh four tons and be 2,4 meters tall when built. A skilled craftsman, Joseph Clement, was hired to make the parts and the British Government funded the project.

The engine was designed to use digits from 0 to 9 and accept only integers as valid numbers [Com16]. Babbage considered using other number systems as well, such as binary numbers, but decided decimal numbers would require the least amount of moving parts while being also easy to read and understand. To prevent miscalculations the engine would jam if it encountered a fractional number during calculation, and to prevent human errors, the machine would print the results of its calculations directly on paper. The difference engine was based on the idea that all tables could be calculated with with the mathematical method of differences [Bab11, p. 57-58]. The counting of these differences would just need to be converted into machine form.

Although Babbage had detailed plans for building the engine, the project was never finished [Com16]. In 1827 Babbage's father, wife and two sons died. The
deaths of so many family members weighed heavily on the man and he left for Europe to recuperate. The craftsman and tool artisan Clement abandoned the project in 1832 because of unreconcilable differences with Babbage over his compensation, as the British government had ceased its funding in the same year [CBI15]. During his stay in Europe Babbage lost one more child, as his teenage daughter died in 1834 [Com16]. Some years later the government stopped its funding for the project conclusively, and Babbage was forced to bury it. He had ended up spending 17 500 £ of the government's money, which could have bought, at the time, approximately 22 brand new steam locomotives.

The twenty-year project had only managed to produce one seventh of the planned machine after 9 years of production in 1832 [Com16]. That part consisted of three columns, each containing six cages with one-figure wheel in each cage [Bab11, p. 63-65]. Each wheel had the numbers from 0 to 9. The columns were used as the input for the machine and its operator could enter any number from 0 to 99999 on each of the three columns using their six wheels. The rightmost of the columns was called the table column, while the middle column was the 1\textsuperscript{st} difference column and the leftmost the 2\textsuperscript{nd} difference column. After receiving the desired numbers the machine would add the number from the 1\textsuperscript{st} difference column to the number on the table column. The number on the 2\textsuperscript{nd} difference column would then be added to the number on the 1\textsuperscript{st} difference column. Thereby the machine could be used to compute any table if the table itself and its 1\textsuperscript{st} and 2\textsuperscript{nd} differences each contained less than six figures. The finished machine would have had more difference columns as well as more room for bigger numbers. Nevertheless, the seventh of the original machine was the world's first successful automated calculator [Com16].

3 Ada Lovelace

Augusta Ada Byron, better known as Ada Lovelace, was born in 1815 to Anna Isabella “Annabella” Milbanke, 11th Baroness Wentworth, and the poet George
Gordon Byron, 6th Baron Byron [Cha15]. The marriage between Ada's parents was not a happy one and only a month after giving birth to her daughter Annabella moved away from her husband together with her infant child. Ada never saw her father after that, as he died when she was 8 years old.

Ada's mother was well-educated and wanted her daughter to have a good education as well [Cha15]. Annabella was also worried that her daughter might have inherited her father's madness, and hoped studying science would prevent her from succumbing to it. The girl was thus educated at home by the best tutors available and developed an interest for machinery in her pre-teens. She studied inventions and periodicals and came up with a design for a steam-powered flying machine at the age of 12.

Ada was a sickly child, however, and some believed this sickliness was caused by too much studying, although she was clearly gifted with mathematics [Cha15]. Still, women were not encouraged to take part in science at that time, and it was even suggested that a woman's body would be incapable of physically handling the great mental effort needed to successfully study mathematics. Lovelace recovered from her illnesses, continued studying mathematics and proved this accusation wrong.

Ada was an intelligent and independent woman, who made friends easily [Cha15]. Thus it is not all that surprising, especially with her interest in mathematics, that she quickly became friends with Charles Babbage in 1833, after one of her tutors had introduced the two. Ada was just 17 years old and Babbage 42, but as Ada was fascinated with Babbage's machine designs and he took an interest in her sharp analytical mind and skills in mathematics, their friendship had a rather logical foundation. Only two years later, at the age of 19, Ada married William King, the 8th Baron King, who was made 1st Earl of Lovelace in 1838, thereby giving Ada the name by which she is known today. The marriage was a happy one. Lovelace's husband supported her in her
scientific pursuits, and they had three children together. After the birth of her third child Lovelace fell ill once more, however, but recovered after several months.

4 Babbage, Lovelace and the Analytical Engine

A few weeks after the party where Lovelace and Babbage met in 1833, Babbage invited Lovelace to see his unfinished Difference Engine [Kim99]. She was mesmerized by the machine and followed its development intently over the next years. The Difference Engine was limited, however, in that it could only add and subtract and solve polynomial equations. Even during the development of the Difference Engine, Babbage had begun to plan something better. He shared his ideas about a new machine, the Analytical Engine, with Lovelace, and the two started making more elaborate plans for it.

The new Analytical Engine would not have the limitations of the old Difference Engine, and would be able to solve general computational problems [Kim99]. Its design was very similar to today's computers, having a store, mill and a punch-card reader that resembled the memory, CPU and input device or modern computers. The punch card reader especially was a highly creative and a novel idea, being borrowed from the Jacquard loom that was used for weaving textiles with complex patterns [Com16]. With this new kind of architecture, the machine would be able to do addition, subtraction, multiplication and division, and it could utilize conditionals resembling modern if clauses in deciding whether to perform and action or not [Kim99].

Babbage presented his plans to a group of scientist in 1840 [Kim99]. During this presentation a man called Menabrea took notes on Babbage's lecture and later wrote a paper on the engine, stating the engine would be able to solve any algebraic formula it receives via punched cards. Lovelace read Menabrea's paper, written in French, and started translating it into English [Cha15]. As her
knowledge of Babbage's engine was deeper than Menabrea's she corrected any errors the original author had made. When Lovelace was finished with her translation she showed it to Babbage, who asked her to add her own comments to the paper as she was so knowledgeable about the subject. She did as Babbage asked and ended up tripling the paper's length with her footnotes, which basically included early computer programs. Although Babbage had sketched his own programs earlier, Lovelace's notes were more elaborate and, unlike Babbage, she published her translation along with her notes, making the world regard her as the first computer programmer. Although with the intense collaboration with Babbage some have expressed their doubts over the extent of Lovelace's own contribution, accusing Lovelace of not having enough mathematical skill to be able to write so advanced programs [Cha15, Com16].

In her notes Lovelace emphasized that when using punch cards as the input method the engine could basically be used for calculating any kinds of equations [Kim99]. She also focused on explaining the significance of the machine's ability to branch to different instructions as assigned by specific if-conditions. Furthermore, she deduced that because the machine could be used to operate on numbers it could be used with other symbol sets as well, making it possible to utilize it for composing music, for example. Lovelace finally concluded her translations and notes in a program designed to count the Bernoulli numbers, which showed the machine's ability to do conditional branching. Her code even used looping structures, familiar in today's programs, and the machine was able to perform actions nowadays called microprogramming, parallel processing, iteration, latching, polling, and pulse-shaping, although these terms were not used in Babbage and Lovelace's time [Com16]. Lovelace's code was a great deal more advanced than anything Babbage had been planning for his engine [Kim99], and demonstrated the machine could be used to calculate something without it having been first worked out manually [Cha15]. Thus it would seem that Babbage was the mind behind planning the first computer machines, whereas Lovelace was the first to write detailed programs for the Analytical Engine and
understand its full potential not only as a machine that could be used to operate numbers, but that could have other, much more general applications as well [Cha15, Kim99].

5 Life after Designing the Analytical Engine

Although Babbage and Lovelace are famous figures in the history of computer science today, regarded even as pioneers in their field, neither Babbage's Difference Engine nor his and Lovelace's Analytical engine were ever built during their time [Com16]. The work of both pioneers seemed to be relatively obscure to the larger audiences until the 1950s, when Lovelace was mentioned as a “prophet” in Bowden's work on the history of computers [Kim99].

Babbage's original Difference Engine project was buried because of his disagreement with the main craftsman Clement, the several consecutive deaths in his family and the insufficient funding from the government [Com16]. The Analytical Engine, had it been built, would have been even larger than the enormous Difference Engine, and thus very likely even more expensive. Babbage was annoyed by the lack of funding for his new engine from the government [Kim99], and seemed to make no attempt to actually build it for many years [Bro98]. Instead he refined his design for both the Analytical Engine and the Difference Engine (no. 2) [Com16], until he stopped designing calculating engines altogether for a long time after 1849 [Bro98]. Only at the age of 64 did he continue developing the Analytical Engine. By the time he died in 1871 he had already begun the construction of a smaller model of the Analytical Engine. Babbage's son continued his father's work, but the engine was never completed and ran but few programs – with rather obvious errors [CBI15].

Lovelace's idea of a general computer that could be programmed to do almost anything was an extremely creative idea and a large theoretical leap at the time [Cha15]. She could be considered to have been a hundred years ahead of her time,
and even after her breakthrough about the general computer she continued her studies with private tutors. In 1852, just a few years after Babbage had started working on the Analytical engine once more, Lovelace fell ill. This time she did not recover, however, and died during the same year after several months of the illness. Like her father, the late Lord Byron, Lovelace was only 36 years old at the time of her death.

Babbage and Lovelace's work was extremely detailed, as proven by their publications and personal documents [e.g. Kim99 & CBI15]. So detailed in fact, that Babbage's revised notes on his Difference Engine no. 2 dated to years 1847-1849 [Com16], were used to build the machine [CBI15]. The project was initiated by the Science Museum in London in 1985 and the calculation part of the machine was finished by 1991. Its printer device was completed nine years later in 2000. Both devices have 4000 parts each and weigh over 5,5 tons altogether. The project proved that Babbage's design had, in fact, been entirely working despite of all the funding and manufacturing difficulties over 100 earlier.
6 Sources


