Ada Byron and her contributions to early computer science

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Abstract: This paper focuses on the life and work of Augusta Ada Byron, usually referred to as the first computer programmer. Her life and education in the early 19th century are discussed. An overview of Charles Babbage's work on mechanical computers is given and how it relates to modern electronic computers. Ada's contributions in early computer science are presented explaining how Ada helped Babbage to create explanations of his unbuilt inventions and saw its potentials far beyond the mechanization of mathematical calculations, similar to the way computers are used nowadays.

Keywords: Augusta Ada Byron (Lady Lovelace); Charles Babbage; difference engine; analytical engine; computer history.

I. Introduction

In recent years there is a growing interest in the history of scientific contributions of women. As part of this discussion people often refer to Ada Byron and her role in early computer science linked to the Analytical Engine, a proposed mechanical computer designed by Charles Babbage.

After her death she was largely forgotten, until in the 1950s her contributions were rediscovered by B.V. Bowden who republished her paper about Analytical Engine [1]. Since then she has been honored in several ways: the U.S. Department of Defense named the "Ada" programming language [2] after her, and in 2009 the international Ada Lovelace day was founded [3], which is celebrated each second Tuesday of October and celebrates achievements of women in science, technology, engineering and mathematics.

Although she is often referred to as the first computer programmer, not many people know who she was exactly or what her contributions entailed. This paper will look at Ada's life, the education of women and the opportunities they had in the field of science in the early 19th century, and in particular what Ada's relationship was with the work of Charles Babbage and why is she referred to as the first computer programmer.

II. Early life and education

Augusta Ada Byron (later Countess of Lovelace) was born into high class British society on the 10th of December 1815. Her father was Lord Byron, a famous poet and leading figure in the Romantic movement. Her mother was Anne Isabella (Annabella) Milbanke, an educated, religious woman, that came from a wealthy family. She had a strong interest in mathematics, leading her husband to give her the nickname „Princess of Parallelograms". Lord Byron was well known not only for his poetry, but also for his involvement in many scandals, money debts and tumultuous love life. One of his lovers described him in the famous phrase „mad, bad, and dangerous to know". Ada was his only legitimate child. Due to a lot of scandals Annabella left her husband when Ada was only one month old. Ada never saw her father again and her mother had a much larger influence on her future life.

Figure 1: Ada Byron. By Unknown - Scanned from The Calculating Passion of Ada Byron by Joan Baum. Originally from the Lovelace-Byron Collection., Public Domain, https://commons.wikimedia.org/w/index.php?curid=19076813.

At the time children were seen as incomplete adults that needed to be cultivated. Ada was spending time only with children that were approved by her mother causing her to have a lonely childhood spent mostly in the company of adults. Annabella invested a great deal in Ada's education, she received lessons in a variety of subjects: history, chemistry, poetry, French, Italian, Latin, Greek, drawing, music, dancing and especially in mathematics. Through mathematics her mother hoped to develop her daughter's rational thinking and suppress anything that had imagination and playfulness. She was afraid that her imagination would produce suffering to her and the people around her as it did for Lord Byron.

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However Ada showed an independence of thinking and had ideas and projects that were not well received by her mother, for example she was interested in flying and tried to explore different ways of making wings [4].

In the early 19th century females were considered to be intellectually inferior to males due to their biologically smaller brains and were educated only to be able to run the household. Bedford College was the first higher education college opened for women in the United Kingdom in 1849, three years before Ada's death. In Ada's childhood young girls from wealthy families would get education by high level private tutors.

Before her marriage Ada was taught mathematics by a series of tutors, one of which was a friend of her mother called Mary Somerville. She was a well-known self-educated polymath famous for translating Laplace's work and the first female member of the Royal Astronomical Society. Through her Ada met Charles Babbage at a high society event in London in 1833. Babbage invited her together with her mother to see part of the Difference Engine he built which ultimately lead to their collaboration during which they were visiting each other and exchanged numerous letters. Between June 1835 and August 1852. Ada wrote 85 letters to Babbage and he wrote 32 letters to her [5].

On the 8th of July 1835 Ada married William King an English aristocrat with whom she had three children: Byron (born 12th of May 1836), Anne Isabella (born 22nd of September 1837) and Ralph Gordon (born 2nd of July 1839). During her marriage she received tutorship from mathematician and logician Augustus De Morgan, who was friends with George Bool the inventor of Boolean algebra. De Morgan wrote a letter to Lady Byron where he suggested that Ada's talent in mathematics could make her become "an original mathematical investigator, perhaps of first-rate eminence" [6].

III. Charles Babbage and the Difference Engine

Charles Babbage was born on the 26th of December, 1791, into a wealthy upper class family. He studied mathematics at Cambridge University and as a student was one of the founders of the Analytical Society that promoted reforms in mathematical notation for differentiation in calculus. He was a co-founder of the Astronomical Society whose aim it is to promote the sciences of astronomy and geophysics. In 1828 he became professor at Cambridge University. After his father's death Babbage inherited a fortune (£100K, or the equivalent of $14 million today), which allowed him to pursue his own scientific interests.

During a visit to France in 1819, Babbage learned about an ongoing government project to calculate logarithm and trigonometry tables. These mathematical tables were crucial in science, engineering and finance. The tables were calculated by hand and were prone to human errors which could have costly repercussions. After returning to England Babbage himself was involved in the creation of these types of tables and he realize the possibility to mechanize this process. His vision was to employ steam power to drive mechanical calculators that would be more reliable and faster than the manual process.

Babbage was not the first to see the possibilities of mechanized calculations. In 1642 Blaise Pascal invented a mechanical adding machine, but it was mechanically unreliable. A couple of decades later in 1673 Leibniz developed a more advanced machine that could add, subtract, multiply and divide. This machine also had reliability issues and both devices were driven manually by an operator [7].

In 1822 Babbage started working on his project called the Difference Engine, a device that would calculate the values of polynomial functions up to a certain degree of accuracy using the method of differences. In 1823 the British government agreed to provide funding for the construction of such an engine. By 1833 he constructed 1/7th of the machine that was originally planned. The constructed machine had the ability to operate on 6-digit decimal numbers and second-order differences. This constructed machine was the prototype that Ada and her mother saw.

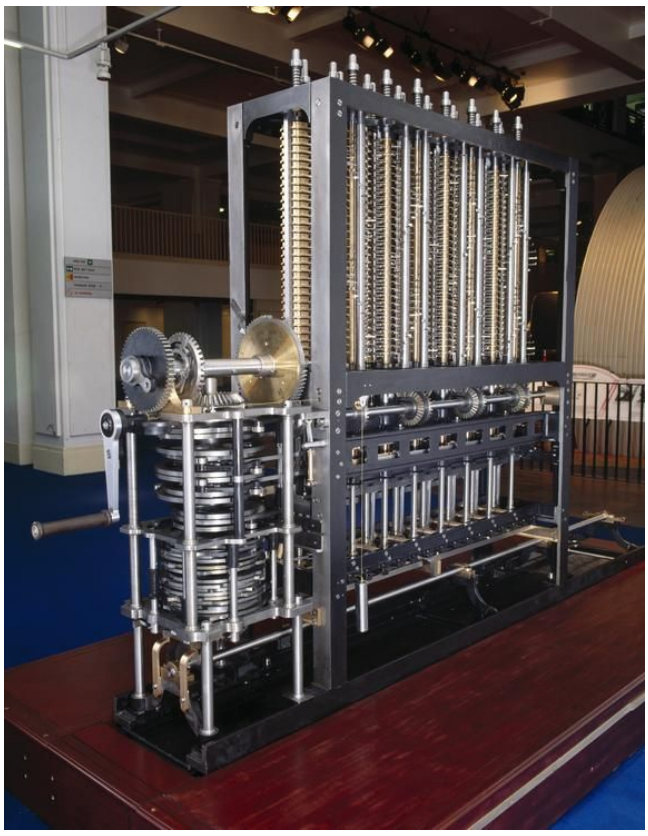

Figure 2: Science Museum Group. Difference Engine No.2, designed by Charles Babbage, built by Science Museum. 1992-556 Pt1. Science Museum Group Collection Online. Accessed September 12, 2018. https://collection.sciencemuseum.org.uk/objects/co526657.

Babbage claimed that the original funding was insufficient and that he was required to spend a significant sum of his own money. The main problem was that metalworking techniques of the era were unable to economically produce the numerous parts of the engine (including the 25000 cogwheels) with the precision and

quantity required. Shortly afterwards the work on a larger engine was canceled.

After this setback Babbage started working on the much more ambitious project of designing the Analytical Engine, a machine that was capable of more general operations. During his work on the Analytical Engine he realized he could greatly improve the design of the original Difference Engine using only 8000 cogwheels rather than 25000. The machine was called Difference Engine No.2 and was designed to evaluate polynomials up to the order of 7 (31-digit numbers and seventh-order differences). Babbage also designed a printer which had the ability to directly output results to paper as well as create molds that could be used in the creation of printing plates allowing for mass production of the results.

Although Babbage never managed to build the machine, a working Difference Engine No.2 was constructed and placed in the London Science Museum in 1991. In 2002 a printer was added after the original design of Babbage. The construction of the engine and printer used tolerances that could be achieved with 19th century technology, proving that Babbage's design was feasible [8]. Currently there is an ongoing project called Plan 28 that is attempting to build the Analytical Engine [9].

IV. The Analytical Engine and Ada's contribution

By 1838 Babbage had finalized plans for the Analytical Engine, the first general-purpose programmable computing engine that had many of the essential features that can be found in modern digital computers. The machine was designed in-line with technology available at the time, and would have been driven by steam power.

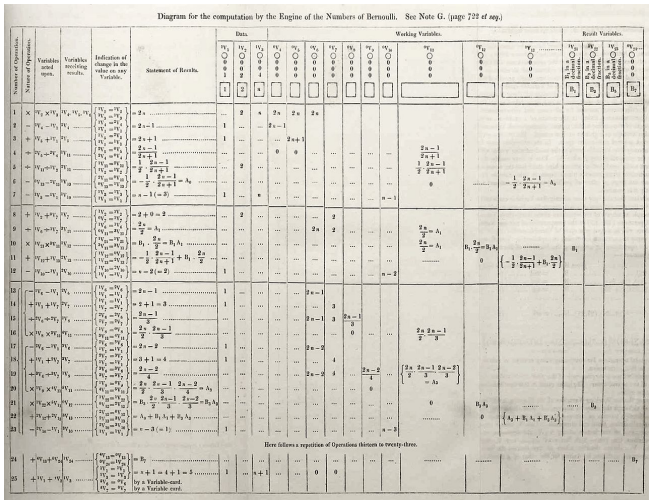
Diagram for the computation by the Engine of the Numbers of Bernoulli. See Note G. (page 722 et seq.)

Figure 3: Diagram of an algorithm for the Analytical Engine for the computation of Bernoulli numbers. By Ada Lovelace - http://www.sophiararebooks.com/pictures/3544a.jpg, Public Domain, https://commons.wikimedia.org/w/index.php?curid=37285970.

Babbage's machine closely resembled the structure and design of modern electronic computers and would have been Turing complete. The "Store" component functioned as the machine's memory and could contain 50 digit decimal numbers. It would have been 7 m long and 3 m high. The "Mill" was the component where the arithmetic operations would be performed, equivalent to a CPU. The program was stored on punched cards called "Operation Cards" and the instructions were similar to assembly language and included conditional branch statements, jumps and loops. Data could be read from "Number Cards" directly into the "Mill" or from the "Mill" could be transferred to the "Store" on locations specified by "Variable Cards". This setup is very similar to the concept of a data-bus and addressing system. More complicated instructions were implemented using so-called "Barrel Controllers" which correspond closely to modern microprograms.

In 1840 Babbage was invited to give a lecture on the Analytical Engine in Turin and to receive honors handed to him by the Italian government. During the lecture a 30 year old army Engineer called Luigi Menabrea was taking notes. In October 1842, Menabrea published a paper in French based on his notes. When Ada read the paper she decided to translate it into English and submit it to a British publication.

Ada not only translated the original paper but also added her own notes and ideas expanding the paper to three times the size of the original. She worked tirelessly on the paper and during this time exchanged numerous letters with Babbage. Among Ada's contributions to the paper was an algorithm that calculated Bernoulli numbers using the Analytical Engine. This algorithm can be considered the first published computer program and is the reason why Ada Byron is often referred to as the first programmer. The paper showed all of the steps in the calculation of the Bernoulli numbers, including how data is moved between the "Store" and the "Mill", and how this relates to the instructions read from the punched cards. The information was presented in a table that showed an execution trace of the instructions alongside the state of the machine including the data, variables and intermediate results.

Furthermore Ada realized the potential of the machine reached far beyond the mechanization of mathematical calculations. For example she speculated that the Engine "might act upon other things besides number... the Engine might compose elaborate and scientific pieces of music of any degree of complexity or extent". Ada saw numbers not as quantities but as entities that can be used to represent concepts from the real world that can be manipulated in the machine and then be mapped back to the real world.

Ada suffered from health problems throughout her life, both in her childhood and in her adult years. As a nine year old girl she became sick with measles and most likely developed encephalitis as a complication. As a result she stayed bedridden for 3 years. Later on in life she would have several health problems but after finishing her work on the paper her health deteriorated dramatically, most likely she suffered from uterine cancer. She was in chronic pain for the rest of her life and was prescribed large quantities of opiates. During the last

months of her life her mother moved into her house, isolating her from other people. During this time Ada made an unknown confession to her husband William with whom she then broke contact. She died in 1852 at the age of 36, the same as her father. At her request she was buried next to her father Lord Byron at the St. Mary Magdalena church in Hucknall, Nottingham where her grave can still be visited [10].

V. Conclusion

A hundred years after Babbage invented the Analytical Engine the first general purpose electronic computers were developed. Those computers were made using a different technology, but the logical architecture and the manner in which they were programmed were very similar to the Analytical Engine.

Babbage's work on his engines represented a brilliant achievement that was ahead of its time, however he did not realize its full potential. It was Ada who foresaw possible usages that closely match how computers are perceived nowadays. Ada's mathematical training combined with a poetical disposition inherited from her father allowed her to interpret and communicate the work of Babbage in a way that he could not. She remains an intriguing pioneer of early computer science and an admirable role model.

Acknowledgements

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References

[1] Augusta Ada Lovelace, Notes by A. A. L., Taylor's Scientific Memoirs, London, vol. 3, pp. 666-731, 1843. [Online]. Available http://fourmilab.ch/babbage/sketch.html [Accessed in August, 2018]

[2] H. Ledgard, *ADA Programming Language*, Springer-Verlag Berlin, Heidelberg, 1983

[3] Celebrating women in STEM, Ada Lovelace Day. [Online]. Available https://findingada.com/ [Accessed in August, 2018]

[4] J. Essinger, *Ada's Algorithm: How Lord Byron's Daughter Ada Lovelace Launched the Digital Age*, Gibson Square, UK, 2017

[5] B. A. Toole, *Ada, the Enchantress of Numbers: A Selection from the Letters of Lord Byron's Daughter and Her Description of the First Computer,* Critical Connection, Mill Valley, CA, 1998

[6] S. Wolfram, *Untangling the Tale of Ada Lovelace*. [Online]. Available http://blog.stephenwolfram.com/2015/12/untangling-the-tale-of-ada-lovelace/ [Accessed in August, 2018]

[7] M. L. Jones, *Reckoning with Matter, Calculating Machines, Innovation, and Thinking about Thinking from Pascal to Babbage*, University of Chicago Press, Chicago, 2016

[8] Computer History Museum, The Babbage Engine. [Online]. Available http://www.computerhistory.org/babbage/ [Accessed in August, 2018]

[9] Plan 28, Building Charles Babbage's Analytical Engine. [Online]. Available http://plan28.org/ [Accessed in August, 2018]

[10] D. F. Brailsford, *Ada Lovelace Talk*, The University of Nottingham, UK. [Online]. Available http://www.eprg.org/computerphile/new-adatalk.pdf [Accessed in August, 2018]