Women in Computing History

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Invited Papers

Introduction

Exciting inventions, innovative technology, human interaction, and intriguing politics fill computing history. However, the recorded history is mainly composed of male achievements and involvements, even though women have played substantial roles. This situation is not unusual. Most science fields are notorious for excluding, undervaluing, or overlooking the accomplishments of their female scientists [1, 16, 17, 22]. As J.A.N. Lee points out, it is up to the historians and others to remedy this imbalance (see this issue [14]). Some steps have been taken towards this goal through publishing biographies on women in technology [2, 5, 6, 8, 10, 12, 13, 18, 20, 21, 23, 24], also see this issue [7], and through honoring the pioneers with various awards such as the GHC'97 Pioneering Awards(2) (Figure 1), the WITI Hall of Fame(3), and the AWC Lovelace Award(4). A few online sites contain biographies of women in technology, shown in Table 1 below. However, even with these resources, many women who have contributed significantly to computer science are still to be discovered.

Figure 1: Computer Science Pioneer Celebration, at the Grace Hopper Celebration of Women in Computing '97. Left to right: (Fran Allen, Ruzena Bajcsy, Adele Mildred Koss, Denise Gürer, Anita Borg, Jean Jennings Bartik, Judy Levenson Clapp, Thelma Estrin, Joyce Currie Little (Courtesy Institute for Women in Technology, Palo Alto, California)

Table 1: Online sites containing biographies of women in technology[5]

Website	URL
United Kingdom Ambassador Site (ACM-W site)	http://www-theory.dcs.st-and.ac.uk/~tom/women/
Pioneers Honored at GHC'97 (ACM-W Site)	http://www.acm.org/women/speech.html
Old TAP site (ACM-W site)[6]	http://www.cs.yale.edu/homes/tap/past-women-cs.html
WITI Museum	http://www.witi.com/center/witimuseum/
AWC Lovelace Awards	http://www.awc-hq.org/lovelace/index.html
SDSC[7] Women in Science	http://www.sdsc.edu/ScienceWomen/
Biographies of Women in Mathematics at Agnes Scott College	http://www.agnesscott.edu/lriddle/women/
Men and Women Computing Pioneers[8]	http://ei.cs.vt.edu/~history/people.html

Inventing Programming

Software is an essential part of every business, research, and home and its use takes on many shapes and forms from creating new software, creating and using websites, or using preprogrammed software for needed tasks (in particular word processing, email, and database access). Software will only become more important to our society as it becomes ubiquitous and computer scientists continually develop new and exciting computer applications. While forging ahead, we should also remember where this all started. Women were the key pioneers in the origins of software, which starts with inventing programming. This paper discusses just a few of the women pioneers and their impressive contributions to programming and software development.

The First Programming Constructs

From the very birth of computing machines, women have made substantial contributions. Augusta Ada Byron Lovelace is credited with inventing the first programming constructs, albeit at a conceptual level. She achieved this distinction through her translation from French to English of a lecture Babbage gave on his design of the Analytical Engine in Turin, Italy, 1842.[9] The original report was written by L. F. Menabrea, a military engineer at the time, later to become Prime Minister of Italy. Lovelace added a series of Notes (A-G), appended at the end, which was three times the length of the original article. In the Notes, using Bernoulli numbers as an example, Lovelace develops concepts and structures that resemble today's programming constructs. You can find Menabrea's report with Lovelace's Notes in whole at <http://www.fourmilab.ch/babbage/ sketch.html>.

Lovelace (Figure 2) was able to see past the mechanical gears of the Analytical Engine and visualized how to program it to perform many tasks from calculations to producing music. She developed a method of storing sequences of operations or instructions as well as informational values,

Figure 2: Augusta Ada Byron Lovelace, inventor of programming structures and concepts. (Courtesy Charles Babbage Institute, University of Minnesota)

similar to today's concepts of subroutines and a stored program. In order to manipulate numbers, she first made a distinction between numbers and the operations performed on those numbers, known to today's programmers as types and operators. Lovelace then described upper indices in her table for the Bernoulli numbers, in order to trace the current operation, resembling what we recognize today as arrays. She also dubbed the term "cycle" which was a "recurring group", similar to today's loops. In this manner, she was the first to envision and understand the potential for a computing machine. Further discussion of Lovelace, her life, and her contributions to computing appear in [23, 24] and also at <http://www.well.com/user/adatoole>.

The ENIAC Pioneers

The world's first electronic computing machine was called the ENIAC and this intimidating and impressive machine was first programmed by six women: Kathleen (Kay) McNulty Mauchly Antonelli, Jean Jennings Bartik, Frances Synder Holberton, Marlyn Wescoff Melzer, Frances Bilas Spence, and Ruth Lichterman Teitelbaum. These remarkable women were hired by the Army during World War II (1945) to run ballistic calculations on the ENIAC at the University of Pennsylvania, which could perform much faster than the traditional "human computers" [5].

At that time, no one had ever programmed a computer before, so there was nothing and no one to learn from. The only tool available was the logic block diagrams of the ENIAC [12]. To matters even more difficult, they did not even have access to the machine itself until they got their security clearances, yet they still had to write programs. This was no small feat since they had to develop a method to physically route the data and program pulses through the machine by manipulating approximately 3000 switches and dozens of cables and digit trays. To add to that, the ENIAC was a parallel machine with digit trays carrying the numbers, program trays carrying the program signals, and components that were doing the calculations. Not only was programming the ENIAC an intellectually difficult problem, it required physical strength and stamina.

Increasing Accessibility to Computers

Women's contributions to computing continued in the following years. One area where women have made fundamental impact is in the ease of use of computers. In the 1950s-1960s, people assumed that computing machines were in the purview of mathematicians and scientists for performing complex calculations. Women played a large role in making computers more accessible to society as a whole. This in turn made computers more powerful since they were applicable in a wider variety of applications in business and industry.

Practical Applications

Getting the computer to perform practical tasks, such as payrolls and inventory, was a goal of the Eckert-Mauchly Computer Corporation[10] with their UNIVAC computer. The corporation meant to sell the UNIVAC commercially so getting it to perform business tasks was essential. Betty Holberton (one of the ENIAC pioneers) was responsible for the bulk of the software delivered to the U.S. Census Bureau for the UNIVAC. This software was one of the first practical applications of a computer and revolutionized the way the world perceived and used computers. Holberton also wrote the C-10 instruction code for UNIVAC I which made it easier and faster to program (rather than using only 1's and 0's).

A key practical problem that made computers much more useful was the task of sorting. Thus, much of the early days at Eckert-Mauchly was spent on developing programming strategies for sorting. In 1952, Holberton developed the Sort-Merge Generator" for the UNIVAC I which produced a program to sort and merge files. This was the first step toward actually using a computer to write programs (i.e., a precursor to the concept of a compiler) and was called "the first major 'software' routine ever developed for automatic programming" [4].

Betty Holberton's colleagues very much noticed her exceptional work. In some of her talks and interviews, Grace Hopper(11) described Betty Holberton as the best computer programmer she knew [5]. As Jean Bartik (one of the ENIAC pioneers) said:

> "Actually, Betty could do more logical reasoning while she was asleep than most people can do awake." [5]

Another pioneer that developed the early sorting algorithms was Adele Mildred (Millie) Koss. She developed the Editing Generator for the UNIVAC I that read specifications describing the input file, records, the desired output format, and then produced a program to transform one format to the other. As Koss put it:

> We had to teach the computer how to sort and I realized for a long time that sorting was the quintessential program for machines. [9]

Invited Papers

The First Compilers

Grace Murray Hopper (Figure 3) had a vision of easing the burden of writing machine code and making programming more efficient [10]. Inspired by Holberton's Sort-Merge Generator(12), Hopper conceived the idea of writing a program to create a program, or in modern day terms, building a compiler. The idea was to get commonly used subroutines automatically inserted into another program based on calculated offsets. Most people at that time assumed this was impossible. As Hopper recalled:

> The Establishment promptly told us, at least they told me, quite frequently that a computer could not write a program; it was totally impossible; that all that computers could do was arithmetic, and that it couldn't write programs." [11]

Fortunately for the computing community, Hopper ignored the Establishment's "wisdom" and forged ahead with her ideas. While at Eckert-Mauchly, Hopper helped to transfer the concept of a compiler from Aiken's laboratory at Harvard to the commercial world through the UNIVAC A-0, A-1, and A-2 compilers (where "A" stood for "algebraic") [4]. In 1952, Hopper developed the first of the series, A-0. However, the most sophisticated of the three was the A-2, which was a front-end translator to the A-0 compiler. A-2 used a three-address machine code (e.g., to add X to Y to give Z, you would use [ADD 00X 00Y 00Z]). The A-2 compiler was the first compiler to achieve extensive use.

Figure 3: Admiral Grace Murray Hopper, a pioneer in compiler design and programming languages. (Courtesy United States Navy)

The First High-Level Programming Languages

The development of the A-series compilers made way for the development of higher level programming languages. Hopper had the vision of not only making programming easier for programmers, but also for all members of society. This was her motivation in creating a programming language that was in essence short hand English. Thus, FLOW-MATIC was born and became the first working and widely used business programming language at the time. As such, it had a profound influence on the well-known and widely used COBOL business language. As Jean Sammet, a co-developer of COBOL, said:

> "Without that existing practical use of FLOW-MATIC I doubt that we would have had the courage to develop a language such as COBOL." [19]

Inspired by FLOW-MATIC and encouraged by Hopper, the United States Department of Defense decided to develop a business language. Hopper was part of the CODASYL Executive Committee that overlooked the development of a common business language. This included a Long-Range, Intermediate-Range, and Short Range Committee. The Short-Range Committee actually developed COBOL (Common Business Oriented Language). Three of its nine members were women: Betty Holberton, Jean Sammet, and Mary Hawes.

Two scientific programming languages developed in parallel were MIT's algebraic translator, developed by J.H. Laning and N. Zierler for the Whirlwind computer, and IBM's FORTRAN (Formula Translation), developed by John Backus for the IBM 704. Betty Holberton played a key role in the standardization of FORTRAN. The standardization was essential so people could use FORTRAN on different machines, which would make the language more widespread.

A little later Hopper helped to develop the A-3 and AT-3 languages for the UNIVAC. These had a mathematical flavor and the company marketed them as ARITH-MATIC and MATH-MATIC, respectively. A-3 extended A-2 into a mathematical language. AT-3 was very similar to FORTRAN but with the additional capability to use exponents. Hopper's work helped to alleviate the tedious demands of machine coding and allowed programmers to create programs that are more powerful much faster. This in turn opened programming up to business and industry in addition to scientists and technicians.

Human Machine Interaction

Following Hopper's legacy of making programs more efficient, not for the machine, but for people, computer scientists thought long and hard about other ways to interact with a computer. Betty Holberton was often concerned with making computers more accessible to people. She designed the control console for the UNIVAC I and its computer keyboards and numeric keypad. Holberton's instruction code C-10 allowed for control of the UNIVAC by keyed commands, rather than switches and dials.

Judy Levenson Clapp worked on one of the world's first real time computers, the Whirlwind, at MIT. She helped to develop a prototype of one of the first nonnumerical applications of computers: an air defense systems that received input from radar, tracked flying aircraft, and directed the courses of other aircraft. This application required a display so people could see the aircraft tracks as they were being calculated by the computer (similar to what air traffic controllers use today). In addition, a person had to be able to interact with the computer in real time (i.e., while the program was running), which had not been accomplished before. To achieve this, a light gun was created that could be aimed at the display to produce information about the airline it was currently pointed at. Clapp and her colleagues also used this light gun to debug the software, a unique real-time software-development capability at that time.

Other developments in that period produced a device that allowed you to do text editing online: what we now call a keyboard. However, due to the stigma of being similar to a typewriter and thus considered secretarial work (i.e., woman's work), it was not readily adopted. As Judy Clapp recalls:

> "In order to use this gadget, you had to type, and the men said, 'We're not typists. We're not going to use this!' And here was this wonderful capability and one of the largest deterrents to it is the resistance to typing. I remember we finally convinced our Vice President of Information Systems to get a computer. He got his computer and called me to come up and see him using it. I walked in and he was leaning back on his desk with his secretary in front of the computer. He was dictating and she was typing! So you never realize how culture can stop things from moving on." [9]

Programming Pioneers' Place in Computing History

Up to now, most of the accolades for computer pioneers have focused on hardware: on designing and building the first machines, which mainly include men. Programming, which has always had a high percentage of women, has taken second seat. Thus, the accomplishments of the ENIAC women and others went largely unnoticed. As Kay McNulty Mauchly Antonelli put it:

> The whole machine – the ENIAC – was the most astounding machine in the whole world and everybody was amazed that it could ever have been built at all. You know, it had 18,000 electronic tubes and they were all able to work together so that you could get answers out, and I think that the engineering feat that was accomplished there was so overwhelming to everybody, that the fact that you could actually solve a problem on it was not of great importance at that time. [3]

In the early days of computing, people considered programming as something that was easy. Given today's hindsight we know that building the first programs was not quite so simple. In essence, the early programmers, who were mainly mathematicians, were putting together a framework for future software engineering. Programming the first machines required an intimate understanding of the basic hardware and schematics of the computer they were programming, as the programming was all in machine code. It is one thing to create a computing machine, but it is quite another to program it to actually do something useful. In order to accomplish this, the pioneers had to invent programming.

Exciting Times

Most of the early women programmers had an opportunity normally closed to women. Due to the majority of men being overseas in the war (WWII), women were turned to as a resource for programming the computing machines [6, 8, 15]. These women were bright creative people who were finally given a chance to flex their mathematical muscles. Once the door was opened, women stayed in computing and changed its face forever.

The pioneers of that era agree that they were in exciting times. They knew that they were making history and enjoyed their work immensely. As Adele (Millie) Koss, one of the first programmers of the UNIVAC put it:

> It [her computing job] was flexible, it was open, it was such a wonderful, exciting, creative, rewarding job. [9]

Even so, they did not see themselves as pioneers. Again, software and programming were devalued and building machines was seen as the "real pioneering work". As Kay McNulty Mauchly Antonelli stated:

> We just thought we were doing the job we had been hired to do [3].

A Software Legacy

Briefly discussed here, women have strived to make computers more accessible and easier to use, thus making computers more applicable and useful for solving scientific, business, and industry problems. Many have largely overlooked these accomplishments, since most of computing history focuses on the creation of the first machines. Many would agree that software is the key driving force for the computing industry and has surpassed computing machines in importance.

It is always wise to have a sound understanding of where we have been in order to understand where we are going. In computer science, this means understanding the history of software and women's significant contributions to it. Today's achievements in software are built on the shoulders of the first pioneering women programmers.

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Endnotes

(1) ACM-W is the Association for Computing Machinery's Committee on Women in Computing, see <http://www.acm.org/ women>
(2) GHC is the Grace Hopper Celebration on Women in Computing, see http://www.gracehopper.org/
(3) WITI is Women in Technology International, see http://www.witi.com
(4) AWC is the Association for Women in Computing, see http://www.awc-hq.org
(5) All websites mentioned in this paper were accessed March 9, 2002
(6) TAP is The Ada Project, the current site is found at http://tap.mills.edu/
(7) SDSC is the San Diego Supercomputer Center, see http://www.sdsc.edu
(8) This is a website maintained by J.A.N. Lee
(9) The Analytical Engine, invented by Charles Babbage, is recognized as the first computing machine that could be programmed by an external set of instructions, which unfortunately, was never constructed in Babbage's lifetime. However, in 1906 his son (Major Henry P. Babbage) constructed the mill (what we know as the arithmetic unit) of the Analytical Engine, which was used to calculate and print the first 25 multiples of ❒ to 29 decimal places [25]. It is now physically located in the Science Museum, London.
(10) Eckert-Mauchly Computer Corporation was later bought by Remington Rand and then later merged with Sperry Corporation to create Sperry Rand.
(11) Grace Murray Hopper is a well-known computer pioneer. Her work is discussed further in the next section.
(12) It was also Betty Holberton who Hopper recalls as teaching her how to write flowcharts for computer programs [2].