Looking Back

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Abstract: In this chapter, I am reminiscing on some of my experiences from my 53 years of living with computers. I am currently a professor and chair in the department of Information and Computer Sciences at the University of Hawaii. Over the years, I have only experienced computing environments in three locations (Colorado, Washington, D.C. and Hawaii) but they have all been memorable. The computers that I describe are a part of computing history but are rarely documented.

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I was not aware of computing before I went to college. I majored in mathematics and I had a professor who believed that computers would be the wave of the future so he gave some short courses on machine language and numerical analysis techniques. Little did I realize that this would make me a qualified applicant for a computing career. I graduated with a Bachelor of Science degree from Colorado State University (CSU) in 1959. At that time, calculators were mechanical and very large and heavy and no one would consider owning one. Also, very few commercial digital computers could be found in the United States and the ones that existed usually occupied a room and were primarily for calculations. I planned to teach mathematics in high school after graduation from CSU. However, I finished my classes a quarter early so teaching positions would be at least a half year away. I was offered positions at Martin Marietta in Denver, Colorado and the National Bureau of Standards (NBS) Central Radio Propagation Laboratories (CRPL) in Boulder, Colorado. Since my job at Martin Marietta would have primarily been data entry and CRPL had a variety of interesting projects that seemed to require some mathematics, I accepted what I thought would be a temporary position in a government research laboratory.

CRPL was responsible for producing monthly maps that represented characteristics of the ionosphere that might cause problems in radio communication. Methods developed for creating these maps by hand or with calculators were tedious and frequently required keeping track of extensive tables. In addition, creation of the maps was time consuming and could take as much as six months to complete. The need for the use of computers to produce world-wide mapping methods had been felt for many years. Roger M. Gallet, a CRPL physicist had obtained a grant for that purpose and had been working with William B. Jones, a CRPL mathematician, to develop numerical methods that would represent the world wide complex variations of ionospheric characteristics as a function of latitude, longitude and time over a 24 hour period. Development of this method was influenced by: statistics and information theory; functional approximation and orthogonal series for representation of the real physical variations; inclusion of the empirical knowledge accumulated from

ionospheric research; and the necessity that the method could be adapted to the available digital computers. The method developed was general enough that it could apply to any world-wide geophysical parameters that vary continuously with time. After a few months, I postponed my plans to teach mathematics because I was offered an opportunity to continue the work of Anne Hessing, a CRPL mathematician-programmer, who was moving to California. Anne had begun programming the 'mapping problem' methods on the IBM 650, a decimal computer leased by CRPL. Other features of the IBM 650 included an extra address in the instruction that specified the location of the next instruction. This meant that it could take the entire rotational speed longer for the instructions to be programmed sequentially than if they were optimized to correspond to the rotational speed (approximately 6 milliseconds per revolution) of the drum. The amount of storage in the CRPL IBM 650 consisted of 2,000 10bit (+sign) words. It also had floating point capability; this meant it had a mantissa of base 10 and the exponent was of a different base. The number representation and the vast range in the magnitude of the geophysical data required at least some knowledge of numerical analysis. The IBM 650 had vacuum tube technology that is not known for its reliability and, as a result, the computer could only be counted on to run reliably for approximately two hours at a time. Thus, it was essential to formulate a plan for storing intermediate results. Punched cards were the only medium of input and output. CRPL did not have printer but it had a plotter. The punched card intermediate results had to be organized and read back in to the computer. If the computer happened to fail during this process, the most information that would be lost was the last two hours of intermediate results. Once the coefficients for each map were completed, the contour maps could be drawn on the plotter. The size of the code for the mapping program, with its many subroutines, far exceeded the capacity of the IBM 650. It was only by using this scheme of partitioning that it was possible to produce the results. The process took approximately a week to make a map. The good news was that the map from the numerical methods represented the ionosphere almost as well as the corresponding map made by manual methods. The numerical methods developed by William B. Jones to represent the ionosphere may have been the first computer-based use of numerical mapping. This was a major breakthrough because it meant that computers could be used to map almost any geophysical parameters that varied continuously with time.

The time required to produce a map was reduced from months to hours, however, it became obvious that a larger computer would be needed to fulfil CRPL's requirement to produce monthly maps. The IBM704 was the largest commercial computer available at that time and there were approximately 50 of them in the United States (Bell and Newell, 1971). However, even using the one leased by Martin Marietta in Denver (which was only 19 miles from CRPL) was impractical either because of the cost or availability. Fortunately, CRPL was a laboratory of the National Bureau of Standards (NBS) in Washington, D.C. and NBS not only had an IBM704 but it had been developing computers since May 1950, when a group of employees from NBS built the 'Standards Eastern Automatic Computer' (SEAC). Also, NBS Mathematicians had written a general purpose program for statistical and numerical analysis and had devised many algorithms that were published in journals and NBS technical reports. Although the IBM 704 still used vacuum tubes, it had 32,768 (32K) 36-bit words and other advantages such as core storage and a 2 microsecond cycle

time. From 1959 through 1962, I worked refining the algorithms of the mapping program by commuting from CRPL to NBS. I wrote the programs in assembly language first on the IBM 704 and IBM 709 then on the IBM 7094 (which had transistors instead of vacuum tubes). For a complete description of the program, logic, instructions for use and additional methods of mapping see Hinds and Jones (1963). The initial mapping program took the entire capacity of the IBM 704 so I had to reserve the computer for 2-3 hours, usually during the 12:00pm-6:00am shift. The output from the NBS computer was written onto 2,400 foot reels of magnetic tape. However, the data had to be converted to the punched card format that was needed for the plotter at CRPL in Boulder. This meant I had to physically take the tapes to another government agency across town, get the several thousand cards of coefficients that represented the ionosphere and mail them to CRPL. The mapping problem continued after I left CRPL. Figure 1 shows William B. Jones and me transferring the artifacts to Ronald P. Graham (center). Despite the implementation improvements on the increasingly powerful computers, these basic numerical methods developed over 50 years ago are still used to map several time-varying geophysical parameters.

Figure 1: October, 1962 Transfer of Mapping Program Artifacts

In 1962, I transferred to another government agency, The Harry Diamond Laboratories (HDL) from CRPL. HDL is an Army research facility that was closely affiliated with the NBS in Washington, DC. I was a hired as a research mathematician primarily to work on problems involving risk analysis and reliability. I also began taking graduate courses in statistics that were offered at HDL through the University of Maryland. I was also given the opportunity to attend national conferences such as the Spring and Fall Joint Computer Conference where I learned more about the

computer science discipline. Most programs were written by scientists who worked for large corporations or the federal government. Part of my duties included writing general-purpose mathematical computer programs and making them freely available. Algorithms and their implementations were not viewed as commodities so intellectual property rights hadn't been articulated for individuals or groups of individuals. Users of the IBM 701-704 series formed a group called SHARE that helped with the exchange of software. Many of these routines that in today's environment might be called 'open source' became part of a Scientific Subroutine Package that IBM provided for IBM's 360 System of computers. The emphasis of these basic computational functions was to provide many of the tools necessary to solve commonly encountered problems that required mathematical or statistical solutions. In 1966 IBM published a manual that included the code for single or double precision mathematical and statistical applications including matrix manipulations (IBM internal document H20-205-3). Today, many of these same functions are found in commercial packages such as SPSS and SAS.

In 1970, my husband accepted a two year assignment in Hawaii (43 years later we are still here). Once it was clear that our stay in Hawaii was no longer temporary, I began looking for employment opportunities. In 1971, I went to work part time as a scientific programmer for Kentron, a branch of LTV aerospace that provided support to the Kwajalein Missile Range. Kentron used a Control Data Corporation (CDC) computer that was located in the CDC building that was approximately 10 miles from Kentron. Since Kentron employees didn't have easy access to the CDC building, we had to rely on daily courier service as we debugged our programs. This meant that the test cases had to be carefully planned in order to get as much as possible out of each test otherwise you would be delayed another day. After Kentron, I began working in the department of Oceanography at the University of Hawaii (UH) where I continued mapping other geophysical parameters. Some of my Kentron colleagues had told me that the department of Information and Computer Sciences (ICS) at UH offered a Master of Science (M.S.) degree. Although I had worked with computers for 11 years, I thought this program would be an excellent opportunity to learn more theory and be involved in the emerging discipline of computer science so I enrolled in the ICS graduate program in 1973. The ICS graduate program was initiated in 1968 as a degree in Information Sciences but by 1970 it had become a M.S. in ICS. Courses were offered in the background areas of Information Processing Machines, Logical Analysis and Probabilistic Analysis. Working with Joe Ganino, another ICS graduate student, I volunteered to debug a partially implemented BASIC/Fortran compiler on an unusual computer system developed by the Berkeley Computer Corporation (BCC) in the late 1960s. In 1971, Professor Norman Abramson was funded by DARPA to link Hawaii to the ARPANET so he and Dr W.W. Lichtenberger brought this advanced time sharing computer to Hawaii. The computer was called the BCC-500 because it could accommodate approximately 500 simultaneous users and over 2,000 terminals. This system had significantly more capability than other commercial time sharing systems that could only support 32 interactive users at the same time. The BCC-500 permitted a large number of interactive users to compute without experiencing degraded service because of the following features: critical parts of the operating system were built into the hardware; memory swapping ran concurrently with operations in the two central processing units; the communication system was an

integral part of the system; high transfer rate drums provided fast swapping and access to files. The system had nanosecond capability; a speed that was accomplished by a combination of the 90bit fast memory, rotating drums and an array of one meter in diameter disks (BCC-500 System Manual, 1971). In addition to the higher level Systems Programming Language (SPL) for the BCC-500, the computer also incorporated a simulation of the SDS940. The SDS940 was originally designed as a time sharing computer for the Genie project at the University of California, Berkley. Running in the SDS940 mode, all of its software was available for further development and debugging of the BCC500 software. I had taken a short course on Multiplexed Information and Computing Service (Multics), a mainframe timesharing operating system developed at MIT in 1968 so I had some understanding of distributed computer systems.

Researchers with access to Advanced Research Projects Agency Network (ARPANET) used a process called Request for Comments to develop telecommunication network protocols. This was similar to the open standards that applied to computer software. This collaborative process of the 1960s along with research projects such as the one that follows contributed to the birth of the Internet in 1969. Dr. Norman Abramson, a UH Electrical Engineering (EE) professor led the 'Additive Links On-line Hawaii Area' (ALOHA) network project. It was a new form of communications architecture that provided transmitters with multiple accesses on the same digital channel. Researchers from the departments of EE and ICS had designed an experimental UHF radio, packet switched computer network. Those packets, transmitted in June, 1971, on the UH campus, between terminals in the EE building and an IBM 360/65 in the ICS building marked the first use of what is now known as an ALOHA channel (Kamins and Potter, 1998). The ALOHA system used many of the design concepts of the ARPANET but it differed from it and other networks of the time because it used a burst random access method and multiplexing between the transmitting antenna at each user station and the receiving antenna at the central station. The ALOHA system used two channels for all remote units, one for data into a central machine and the other for data out of the central machine. Data packets from all remote users access the same 24K bits/sec. radio channel in 30ms bursts; each user multiplexes their data onto that channel when it transmits the packet (Abramson, 1973). Because of the ALOHA network and the BCC-500 computer, distance education has existed at UH for over 40 years. In 1971, because of the cost, there was a moratorium on leasing computers until an implementation plan could be completed. This meant that computers were not available to Hawaii public schools. Yet, high school students from the Hawaiian neighbour islands and other areas of Oahu used distance education to learn programming because access to the BCC-500 computer was available, free, and only required leasing a teletype machine. I worked with some high school mathematics teachers who wanted to teach programming concepts to their students. The teachers were able to convince their principals to rent the inexpensive teletypes and they were able to connect to UH remotely and their students became the primary users of this 'on-line' system by using the simulation of the Basic compiler on the BCC-500.

After earning an MS. Degree from UH in 1975, I began a non-tenure track position teaching computer sciences courses for the EE and ICS departments. At this time, it was possible to buy components such as an Intel 8080 and, with some hardware

experience, put together a computer. In order to teach a class of 40 how to program microcomputers, we wrote an emulator for the 8080 on the BCC-500 that the students used it to write their programs. They had all of the debugging capabilities and speed of the time-sharing computer and the experience of writing 8080 assembly language. The slowest part of the process was transferring the paper tape output from the BCC-500 to the Intel 8080. The students really enjoyed the experience of working on a 'personal computer' but they were happy to use the emulator.

In 1979, I enrolled in the Ph.D. program in the department of Educational Psychology at UH. The goal was to gain an understanding of the difficulties many students have in understanding algorithms so my dissertation research was on program comprehension. I compared how humans process both natural and computer languages. I originally expected the process to be like reading but it turned out to be more similar to problem solving. In 1984, my advisor, Dr. Peter Dunn-Rankin received a grant from the Air Force Research Laboratories to purchase an eye-movement monitor. It took the engineering expertise of the ICS chair, Dr. W.W. Peterson to make it really work. Once I was certain that we had accurate fixation algorithms I conducted research in the areas of the human use of computing systems, individual differences of users, cognitive styles and evaluation of innovative educational environments. After completing my doctorate, I joined the Information and Computer Science department as a tenure-track professor in 1986. With backgrounds in computer science and educational psychology, I gravitated to the emerging field of Human-Computer Interaction, one of the fastest growing sub-fields within computer science at the time. I was one of the first researchers to use eye movements to investigate program comprehension, a methodology that has now become highly influential, with the greater availability of eye-tracking technology. Dr. Jan Stelovsky and I developed one of the first open-source analysis tools to visualize data collected from eye-movement monitors using the algorithms of Dr. W. Wesley Peterson (Stelovsky and Crosby, 1997). This software gave observers the ability to see the coordinates of the eye fixations super-imposed over the viewed scene, in real time. This environment facilitated more naturalistic evaluations. We have performed several cognitive psychological experiments including how people read algorithms, how they search lists, how they search large database systems, and how they view data models. Most recently, Dr. Curtis Ikehara and I have extended this work to the use of other physiological measures such as heart rate, electrodermal activity, temperature and the pressure applied to a computer mouse. It was our objective to move toward a set of passive physiological sensors that provide real-time cognitive state measures independent of task performance measures and without requiring extensive sensor calibration. These sensor systems could be used to augment or replace task performance measures in cases where task performance measures are not available. We received a patent on an 'input devise to continuously detect biometrics' where physiological data is examined at four critical points of a task: pre-task physiological resting state, the initial physiological response upon starting the task, the physiological response to increasing task difficulty and the physiological response at task completion. We have used these measures to determine several potential indicators of cognitive load and found them more sensitive to interaction effects with task difficulty than some task performance measures.

Most of these examples of computing environments that I have described took place as the computer field was rapidly expanding and it still is. The implementations are always changing but the theory remains steady. Instead of working with ever bigger machines, my recent work involves smaller and embedded. Whatever the size, my experience with computers has been an amazing adventure.

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