Once Upon a Pocket: Programmable Calculators from the Late 1970s and Early 1980s and the Social Networks Around Them

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Programmable pocket calculators of the mid-1970s opened up a new segment of the personal computing devices market. Calculator users established clubs, magazines, and conferences, and their interaction with manufacturers shaped the products' further development. This article explores one of the understudied roots of personal computing, through the evolution of the user communities formed around the TI-59 and HP-41C calculators.

The development of integrated circuits and the miniaturization of components in the early 1970s made it possible to construct small and affordable computers. The long road that led to personal computers commenced on several parallel tracks. Many attempts to record these events started with the Altair project in 1974, which Paul Ceruzzi called the *annus mirabilis* (wonderful year) of personal computing.[1] Specifically, Intel announced the 8080 microprocessor in the summer of 1974; in July *Radio-Electronics* described the Mark-8; and in late December, *Popular Electronics* subscribers received their January 1975 issue with an Altair prototype on the cover. Before all these events, in January 1974, Hewlett-Packard introduced the HP-65 programmable calculator, advertising it as a personal computer,[2] which according to Ceruzzi is possibly the first use of the term ''personal computer'' in print. This launched a series of events not commonly studied in the history of computing.

The evolution of programmable calculators is closely related to the development of dedicated software. Martin Campbell-Kelly claimed that the personal computer software industry had almost no connection with the preceding software industry, and therefore it established most of its development and marketing practices *de novo*.[3] With programmable pocket calculators, users were the predominant, driving force behind software production; they established clubs, communicated through magazines, and joined social networks that exceeded geographical limits. Manufacturers welcomed this grassroots movement that helped them enrich their software base and provide additional new user support. This article primarily focuses on the origins, practices, and accomplishments of those programmable calculator user communities.

The Beginning of Programmable Pocket Calculators

The first pocket calculators were not programmable,[4] but the Sharp EL-8 (introduced in 1970) and scientific calculators such as the HP-35 and the TI-2500 Datamath were useful enough to make the slide rule obsolete, thus replacing one of the main engineering tools at the time.[5] Recognizing this milestone, IEEE in 2009 awarded HP the prestigious IEEE Milestone in Electrical Engineering and Computing Award for its HP-35 scientific calculator.[6] Further advances in chip density and system software led to more powerful pocket calculators with memory registers, trigonometric, statistical, and/or business functions.

a b

Figure 1. The HP-41CV and TI-59 programmable calculators. Due to its alphanumeric capabilities, (a) the HP-41CV had fewer keys but more functions than (b) the TI-59. The TI-59's advantages included numerical precision and simpler access to synthetic functions.

Programming, the obvious next step, was a way to replace long, repeating sequences with the press of a key.

Programming was at first rudimentary because the sequence of keystrokes was stored in the calculator's memory. Even the term ''programming'' was frequently substituted with the term ''learning''—the calculator ''learned'' how to solve a problem by performing a series of program steps. The only instructions exclusively related to programming were LRN (start ''learning''), R/S (run/stop toggle), and RST (reset the program counter). Program editing was not particularly user friendly; the SST (single step) key was used to read the program step by step, and instructions were displayed as numeric codes.

From 1974 until 1979, HP and Texas Instruments by turns introduced programmable calculators, starting with the HP-65 and TI SR-52.[7] These models introduced flow control instructions, loops, and indirect addressing, and their program memory capacity was approximately 200 bytes. Both calculators had an integrated magnetic card reader so users did not have to enter the programs each time they turned on the calculator. An optional 20-column thermal printer was introduced for the SR-52.

The first programmable calculators induced new social networks of users. Mainframes were out of reach for average engineers, and even when students were allowed to access a university's mainframe, the use was restricted and there was no interactivity.[1] A programmable calculator was a truly personal device; users could carry it in their pockets and use it all day (and night). Personal computers, such as the Apple II, Commodore PET, and Tandy TRS-80 (all introduced in 1977), were also a possibility, but the first personal computers cost between US$600 and US$1,300. Introduced the same year, the TI-59 only cost US$300. The difference in price, portability, and numerical precision, together with the fact that personal computers had full-sized qwerty keyboards and high-resolution graphic modes suitable for gaming, meant the two types of machines attracted different categories of users. A new software industry emerged from the early personal computers,[3] with many companies selling system software, productivity applications, and games. Programmable calculators took a different path. According to one TI survey,[8] 27 percent of TI-59 users were engineers, 61 percent purchased their TI calculator for company or business use, and the rest bought it for personal and educational use.

Researchers in many disciplines discovered programmable calculators were valuable, yet relatively inexpensive tools for scientific calculations. Results were reported in major scientific journals, in papers often containing program code for the TI-59 or HP-41C. The research areas ranged from aerospace[9] and electronic systems[10] to antennas and propagation.[11] Even medical research utilized these programmable calculators; in one example, bacteria identification was performed with a calculator instead of the code book.[12]

Main Competitors

Because of their relatively long time on the market and enthusiastic user communities, yet not to ignore our personal microhistory, this article is mostly devoted to two competing calculators that dominated the market in the late 1970s and the early 1980s: the TI-59 and the HP-41C (see Figure 1). The TI-59 was introduced on 24 May 1977 as the successor to the SR-52, which had a strong user base and even a dedicated monthly magazine, *52 Notes*, published by Richard Vanderburgh. The HP-41C was introduced on 16 July 1979[13] as a successor to the HP-65/67, which also had a strong user base and a dedicated magazine, *65 NOTES*, published by Richard Nelson.

Table 1. Comparative characteristics of the TI-59 and HP-41C.

Characteristic	Texas Instruments TI-59 (1977–1983)	Hewlett-Packard HP-41C (1979–1985) and HP-41CV (1980–1990)
Initial price	US$300	US$295/325
Dimensions	16.3 × 7.3 × 3.6 cm	14.27 × 7.86 × 3.33 cm
Weight	240 grams	205 grams
Display type	LED	LCD
Numeric precision	13 digits	10 digits
ROM	6 Kbytes, 13-bit words	12 Kbytes/15 Kbytes, 10-bit words
Memory registers	120	64/320
User memory	960 bytes	560/2,352 bytes
Continuous memory	No	Yes
Alphanumeric	No	Yes
Sound	No	Beeper
Magnetic card capacity	2 × 30 registers	2 × 16 registers

Although these calculators were similar in many ways (see Table 1), their programming differed. TI used an algebraic operating system (AOS), where the arithmetic expressions were entered the way they are written on the paper—for example, "1 + 2 × (3 + 4) =". HP used reverse Polish notation (RPN) based on a four-register stack—for example, "1 Enter 2 Enter 3 Enter 4 + x +", or more efficiently, "3 Enter 4 + 2 x 1 +". RPN gave HP calculators a dose of exclusivity because amateurs couldn't calculate even the simple expressions ("Where is the = key?"), whereas the gurus could perform complex math with a minimal number of keystrokes.

Texas Instruments TI-59

The TI-59's original price was US$300, which according to the US inflation calculator, is equivalent to US$1,080 today. According to the TI-59 patent,[14] the most important innovation was its solid-state software module slot. Modules addressed the common weakness of early programmable calculators—the limited amount of RAM, which was insufficient for storing multiple programs. Those programs could have been stored in ROM memory, but that would have made the calculator specialized for a specific type of professional. Mathematicians, civil engineers, and electrical engineers, to name just a few examples, require different programs for their everyday work. Loading programs from magnetic cards prior to use was slow and inconvenient, so the TI-59 introduced a replaceable 5-Kbyte ROM module.

With each TI-59, the user received a master library module, and other modules were available for purchase. The master library contained 25 programs, with something for everybody.[15] Engineers got matrix operations, mathematicians got numeric integration, business people got annuities calculations, and home users got unit conversions, calendar functions, and a simple game, Hi-Lo. Other modules included Math/Utilities, Applied Statistics, Real Estate, Aviation, Marine Navigation, Surveying, and Leisure Library. The most talked about was the Olympic module, which helped verify the results at the 1980 Winter Olympics in Lake Placid.[16] The programs in library modules were written in the same language as user programs stored in TI-59's RAM. The user could download any program from the module into the RAM memory. Because the programs were written by excellent TI-59 programmers, there was always something to learn from them.

The TI-59 instruction set was limited to 100 instructions, which was enough for complex commands such as statistical functions, branching, calling subroutines, and indirectly addressing memory registers. To allow for (directly) addressing up to 100 memory registers, some instructions were designed to occupy two or even three program steps. For example, to store a number in memory register 25, the instruction STO 25 was used and coded as 42 25. One prefix, 69, was entitled OP and used for some rarely used operations, so it was possible to introduce another 100 instructions; only 40 of them were actually used.

TI-59 Programs and Community

TI's software strategy relied on library modules targeting groups of professionals, but even more specialized programs were necessary. Therefore, TI established a Software Exchange Library. The library's initial content consisted of approximately 200 programs written by TI's programmers.[17] With an annual US$15 membership, subscribers received three programs of their choice. Each additional program cost US$3. These amounts covered the nominal costs of copying the documentation and the listings and mailing all that to the purchaser.

TI encouraged users to submit their own programs, so the growth of the library depended on user input. These programs were evaluated by TI's staff and accepted to the library only if they were deemed to be functional and useful. The authors were not paid for accepted programs, but they were awarded two other programs from the library. This was somewhat similar to open source software,[18] which came later, with one significant difference: users wrote (free) programs in order to receive other (free) programs. Over the years, the library grew to 3,000 programs covering different areas—mostly engineering, math, and utility.[19] From January 1977 to December 1982, TI published a bimonthly newsletter, *Professional Program Exchange* (*PPX*).

The most important TI-59 related publication was *TI PPC Notes*.[20] This newsletter, together with the TI Programmable Calculator Club, was founded in January 1980 by Maurice E.T. Swinnen. Although Swinnen was a TI Professional Productivity Program seminar teacher,[21] the club was independent from TI. Beginning in April 1981, a big LRN logo was printed on the cover, so many subscribers called the newsletter Learn.

The club's purpose, as stated by the founder, was ''to disseminate member-generated software, programming aids and tricks, to report on hardware modifications, new hardware, to tell about books, programs and other material related to programmable calculators that has been published, and to report on news about our beloved machines.''[22] The club was loosely organized and activities centered around the newsletter, which was about 16 pages per issue and published 10 times a year. The annual subscription rate was US$20.

TI PPC Notes became the focal point for other TI-59 related clubs and publications from all over the world. Being a polyglot (fluent in seven languages), Swinnen was able to translate results from other countries and publish them in the *Notes*.[23] By the end of 1982, *PPC Notes* had a circulation of approximately 4,000.

Some of the important TI-59 related publications include the following:

- *TI Software Exchange*, a Belgian software library, was an important channel for the international distribution of TI-59 programs, because *PPX* didn't accept subscribers from outside the US, Canada, and Mexico. TI SOFT also published a quarterly newsletter edited by Thomas Coppens.
- *Programbiten* was a Swedish quarterly magazine founded in 1980 and edited by Lars Hedlund and Bo Nordlin. The publication had a carefully designed layout and looked like a magazine, rather than a club newsletter.
- *L'Ordinateur de Poche*, a neatly printed French magazine, covered the TI-59, HP-41C, and Japanese pocket computers.
- *Galaksija*, a Serbian popular science magazine, established a programmer's club and a library with more than 500 programs, mostly for the TI-59 and HP-41C calculators. The first computer magazine in the former Yugoslavia, *Računari* (The Computers), grew out of that club.[24]

TI-59 Secrets

In addition to writing math and engineering programs, club members mostly talked about secret commands that enabled their machines to do something the manufacturer hadn't foreseen. Although the TI-59 was programmed in a relatively low-level script, no interface to the machine language programming was provided, so users had to rely on operating system bugs to access hidden features.

HIR Registers. The first trick came from analyzing the instruction set. Some instructions consisted of two program steps—the first was the instruction code, and the second was the address part. For example, the program RCL 82 x^2 brought the content of data register 82 and calculated its square. The program was coded as 43 82 33, where 43 was the code for RCL instruction and 82 was the address. If the user deleted the first code, 43, 82 became the instruction code, taking 33 as its address. According to the owner's manual, 82 is not a valid code, but when the program was listed on a PC 100C printer, HIR 33 was printed, HIR being the new, secret instruction.

In addition to 100 data registers, the TI-59 had eight internal registers used for advanced arithmetic calculations, statistic functions, and printing. Using a hierarchical internal register (HIR) instruction, it was possible to access internal registers and use them as additional storage space. Discovered by Heinrich Schnepf in September 1977,[25] HIR registers became well-known and were routinely used to free conventional registers for data storage.

Fast Mode. The TI-59's fast mode was the most controversial discovery, letting users run programs at double speed. Soon after the TI-59 became available, users realized that the code executed from a library module ran significantly faster than the same code when downloaded into the user memory.[26] It turned out that internal arithmetic operations were executed with numbers in exponential format. To format the trace on the printer, programs running in the main memory converted the virtual display to standard floating-point format and back again between two instructions. Because the module programs were not traceable, this conversion was unnecessary, letting module programs execute faster.

In early 1980, Martin Neef discovered the sequence of instructions that could trick the calculator into running the user program as if it is stored in the ROM.[27] Fast Mode's limitations were severe, but because the TI-59 was not a particularly fast computing device, doubling its speed was considered important.

Keyboard Branching. The TI-59 was not designed for arcade games because the running program could not acquire any information from the keyboard, and the only active key, R/S, suspended program execution. Martin Neef found a way to use R/S not to halt the running program, but to start a ROM program instead.[28] Dejan Ristanović found a way to use this feature to control program execution[29] and wrote the 5/10 Start and TI-59 Super Test programs using this feature.

Hex Codes. TI-59 data and program storage were interchangeable. The user could turn program steps into data registers or vice versa, eight program steps per register. However, the eight program steps took two bits less than the data register, so it was possible to insert "undefined" instruction codes at each step with a position that was divisible by eight. By varying extra bits, programmers could execute some internal instructions. Hex codes were discovered by Patrick Acosta[30] and researched by Robert A.H. Prins. Ristanović decoded some of the new instructions.[31]

Graphics Mode. The PC100C printer was a character-oriented device, so it was not possible to plot high-resolution graphics. However, Michael Sperber and his colleagues discovered that the h25 (h stands for hex) code halted the printing operation so only the top three pixels of the characters printed.[32] By carefully choosing characters, programmers were able to design fascinating output (for that time, anyway).

Hewlett-Packard HP-41C

To compete with the popularity and sales of the TI-59, Hewlett-Packard needed to offer a significant improvement over its top model HP-67 to stay competitive. HP's answer was the HP-41C alphanumeric calculator with continuous memory,[33] the contents of which were retained even when the calculator was turned off.[34] The initial review published in the *BYTE* magazine claimed that "The HP-41C has an array of features that blurs the distinction between calculators and personal computers."[35] HP claimed that the HP-41C was designed to be not just a calculator, but a "mini personal information center, or simply said, computing system."[36] The initial price was US$295, which is equivalent to US$900 today.

This system's key elements were four expansion ports in the display end of the calculator. This idea took the concept of TI-59's library ROMs a few steps further because users could insert ROMs with programs into these ports as well as RAM modules, a card reader, a printer, a bar-code reader, and other peripherals. In later years, HP introduced the HP-IL (interface loop),[37] a short-range interconnection bus and predecessor to the Universal Serial Bus (USB). HP-IL allowed devices such as printers, tape readers, RS-232 controllers, and floppy disk drives to be connected to a programmable calculator or a desktop, ISA-bus-based PC.

HP also introduced new concepts on the calculator itself. Early observers were astonished by the fact that the HP-41C keyboard was far less cluttered than the HP-67.[33] There was only one shift key, whereas previous models had two or three. Where did all the functions go? Actually, the HP-41C's alphanumeric capabilities permitted function names to be keyed in and shown in the display. The alpha key toggled the keyboard between alphanumeric and classic calculator modes, and the letters were printed on the slanted faces of the keys. Because frequently typing function names was tedious, it was possible to assign any function to any key, so users could redesign the keyboard to suit their personal needs. HP introduced the concept of overlays, thin plastic matrices the user could place on the keyboard and glue preprinted labels on, making it easier to remember which function was assigned to which key.

The HP-41C used a custom CMOS/SOS processor called Nut.[38] The case also contained five RAM chips, each with 16 7-byte registers and three 40-Kbit ROMs (later models used one 120-Kbit ROM), so the total ROM capacity was approximately 12,000 10-bit words.[34] Four size *N* alkaline batteries powered the device, which differed from previous models that used rechargeable NiCad cells. With this change, HP made the device lighter, and a rechargeable battery pack was offered later as an option.

HP-41C's programming language was similar to the dialect used on previous HP's calculators and, for that matter, similar to the TI-59's programming language (they even shared a lot of mnemonics), but alphanumeric capabilities brought a new level of user friendliness. Programs had descriptive names, could prompt the user for input, and could label program output.

The HP-41C brought memory management to the programmable calculators market. Unlike earlier models, each instruction could consist of many bytes, up to 16 in rare cases. Instead of the number of instructions, the program length was measured in bytes. It was possible to have many independent programs stored in the user memory, and each program could have the same local labels, use the same registers, and so forth. When a program was deleted from the memory, the HP-41C could do defragmentation called packing. User key assignments were also stored in the main memory, requiring more advanced packing algorithms.

With all these possibilities, HP-41C's initial memory of 63 registers (about 440 bytes) quickly became insufficient, so the user had to purchase memory modules, increasing the memory up to 320 registers (about 2 Kbytes). To keep the expansion ports free for other peripherals, HP introduced the HP-41CV (V is the Roman numeral symbolizing five times more memory) on 15 December 1980. An even more powerful version, the HP-41CX, was introduced in November 1983.

HP-41C Programs and Community

The official source of the HP-41C programs was the User Program Library (UPL) founded in Corvallis, Oregon, by HP. UPL formed a software catalog that eventually collected approximately 2,800 titles for the HP-67 and (mostly) HP-41C.[39] The annual library subscription was US$20,[40] and the programs cost US$6 each, which included documentation, listing, and recorded magnetic card(s). Recognizing Europe as an important market, HP also founded the User Program Library Europe (UPLE) in Geneva, Switzerland.

Most of the programs were written by HP-41C users all over the world. The review process was strict—only high-quality programs with extensive documentation were accepted. Authors of each accepted program received a point certificate, which they could exchange for four programs of their choice from the library catalog. Library points could also be collected and exchanged for hardware—three points for an HP-41C module, seven points for a bar code reader, 18 points for a printer, and so on.[41] For 100 points, a user could claim the HP-85 home computer, a US$3,250 value at that time. Furthermore, as recognition of ace programmers, a bronze, silver, and gold overlay was issued to every person who had one, five, and 10 programs, respectively, accepted to the library (see Figure 2).

The UPL and UPLE shared a newsletter called *HP Key Notes* (*HP-65 Key Notes* until 1976). *HP Key Notes* was distributed all over the world for free. Published four times per year, each issue had about 20 pages and was mostly dedicated to using the HP-41C, hints, and tricks. The newsletter reached the height of its popularity in March 1982 when it published exclusive footage from a NASA space shuttle mission. (Columbia's astronauts routinely used HP-41C calculators for various flight-related, radio contact, and backup operations.[42])

When Henry Horn (1928–2007), the longtime editor of the *HP Key Notes*, retired in August 1983, HP discontinued the newsletter and the UPLE.[43] The Corvallis library continued operation up to 1988, but without a newsletter and with somehow lower ambitions. The user community was redirected to independent organizations, especially the PPC.

The PPC grew around its publication, which in various periods was called *65 NOTES*, *PPC Journal*, and *PPC Calculator Journal*. The club's founder Richard Nelson explained that PPC didn't stand for anything special, but it could mean Personal Programmer Club.[44] The *PPC Journal* was published irregularly, usually eight to 10 times per year. The standard issue had 32 pages of condensed, printed text and listings. Articles and programs were written by the club's members and usually left unedited. Articles were reproduced from the submitted printout, so the issues consisted of many different fonts and layouts, especially after dot-matrix printers became affordable.

PPC was a global organization with members in more than 30 countries. The club encouraged members to form local chapters and pursue local activities, especially regular meetings. Chapters received organizational help from PPC but operated autonomously. In 1982, PPC had 43 chapters, 29 in the US and 14 in nine other countries: Australia, Canada, Denmark, France, Spain, Sweden, South Africa, Norway, and the United Kingdom.[45] Some of the chapters published HP-41C related newsletters. The most active chapters were in Australia, which published *Technical Notes* (later *HPHH Melbourne*) from 1979 to 1993, and the PPC-UK, which began publishing *Datafile* in 1982. (At the time of this writing, the current issue of *Datafile* is vol. 30, no. 2, April 2011).

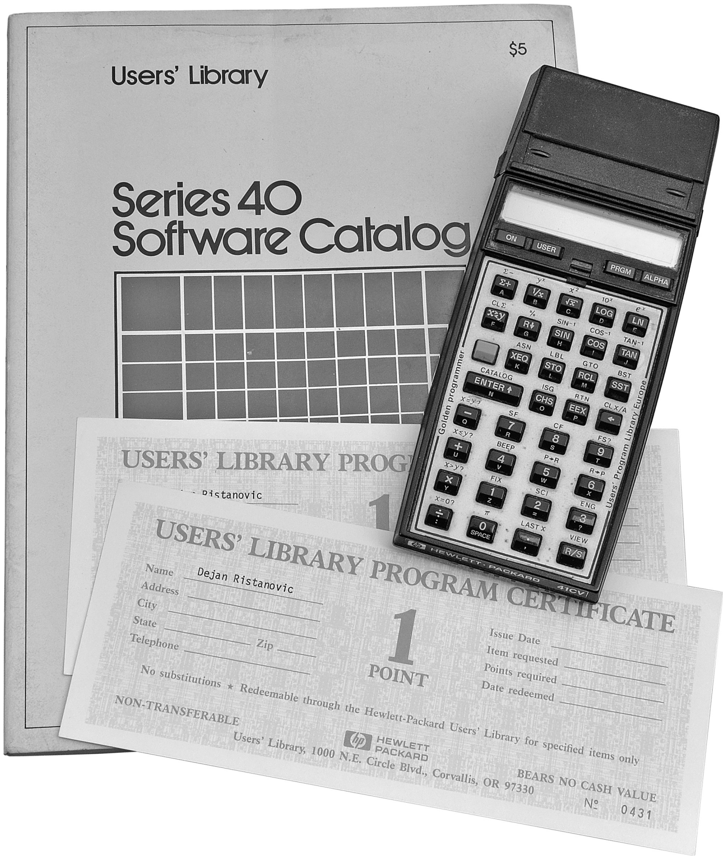

Figure 2. Hewlett-Packard's official Users' Program Library (UPL) published a catalog with more than 2,800 top-quality HP-41C programs. Programs were mostly written by users. The author of an accepted program received a point certificate that could be exchanged for other programs or hardware.

Synthetic Programming

Like the TI-59, the HP-41C was a "closed" system that could only be programmed in user code, without access to the machine language and internal data structures. Additional access to internal structures was required to fully utilize the calculator's alphanumeric capabilities. Alpha string editing was virtually nonexistent in the main instruction sets, and when observing results from some of the calculator's irregular states, it was obvious that the character set contained ligatures that were impossible to type regularly.

In August 1979, John Kennedy and Richard Nelson published the first version of the HP-41C combined hex table,[46] demonstrating the use of a complete character set and "unprintable" ligatures. The same issue of the *PPC Journal* reported a useful bug: indirectly addressing nonexisting registers 704 through 999 would read/write program code interpreted as data.[47] The bug let users enter "nonexisting" instruction codes in the program memory and study their behavior. In the next issue, HP recognized users' interests by revealing some internal structures of the HP-41C,[48] so the quest started.

Quite a few articles were published based on trial-and-error research. Pieces started to fall into place in an article by W.C. Wickes entitled "Through the HP-41C with Gun and Camera."[49] His Black Box program let users access the HP-41C's internal structures. The next year Wickes introduced the concept of byte jumping as a "poor man's black box"[50]—that is, using a synthetic key assignment to enter synthetic functions without having any special program. It took almost two years to discover the ultimate synthetic programming tool, the Byte Grabber,[51,52] a synthetic key assignment that stuck the first byte of a regular instruction into a dummy text line, making the second byte of the instruction the first byte of a new instruction, just like the technique of entering "illegal" instruction codes on the TI-59.

Wickes wrote *Synthetic Programming on the HP-41C*, which soon became the "bible" for HP-41C's power users.[53] Shortly after publishing that book, Wickes (at that time an assistant professor of physics at the University of Maryland) was recruited by HP and became R&D director, responsible for developing advanced scientific calculators and (later) portable computers. Wickes held that position until he retired in November 2010.

PPC ROM Project

In August 1979, Nelson proposed that PPC members build an 8-Kbyte custom ROM for the HP-41C, containing utility and other programs.[54] The idea was "to provide a data handling structure that may be utilized as subroutine calls to reduce complex and long programs to a few steps, taking the opportunity for a new level in PPC software achievement and application." The *PPC ROM Manual* states that "the PPC ROM project represents one of those rare occasions where a group of people join together to accomplish a work for the primary reason that it's a good idea."[55]

The PPC ROM development was documented in the ROM Progress column of the *PPC Journal* from August 1979 to July 1981. Month after month, PPC members discussed, proposed, optimized, and corrected programs, trying to squeeze as many as possible into 8 Kbytes of code. Saving space was the imperative, so the alphanumeric prompting was kept to a minimum. Therefore, an important part of the project was the high-quality user manual, which became a 500-page book printed in a small font.

The ROM project disrupted normal operations of the PPC, but when the final product arrived in late 1981, it had something to show for its work. The tiny ROM module contained 122 state-of-the art programs[56] and became a necessity for any HP-41C power user. It prompted HP to introduce its own Extended Functions/Memory Module that provided machine-code instructions for string manipulation, thus reducing the need for synthetic programming.[57] The PPC ROM found new use as a tool for directly accessing newly introduced extended memory, designed as additional data storage. With some clever manipulation, the extended memory could be used as program memory.[58]

Because HP required the purchase of at least 5,000 units in order to produce the modules, PPC allowed each member to purchase two PPC ROM modules for US$95.[59] The idea was to let members keep one module and sell or give away the other, thus making the club more popular. After the initial purchase, the ROM was sold to new members for US$95 each.

The successful completion of this project naturally made the members ask for more. Why not produce a PPC ROM II, with machine-language programs that would make the HP-41C perform even better? The initial ideas were published in the *PPC Journal*[60] and the work started, but the PPC ROM II was never published.

Decline and Fall of the PPC Empire

In 1982 Sharp introduced the PC 1500 (and later the PC 1500A), a 19.5 × 8.6 × 2.55 cm pocket computer weighing 375 grams, with a 65-key qwerty keyboard, a 26-characters LCD display, 16 Kbytes of ROM, and 8 Kbytes of RAM. The use of the Basic programming language made the computer attractive to a broad audience.[61] However, its horizontal design and awkward way of storing multiple programs in memory didn't make the first pocket computers attractive to engineers and students, so PPC might have lasted for years, had it not fallen apart from the inside.

Producing 5,000 PPC ROMs made it difficult for the club to operate informally, so on 18 January 1982 PPC filed incorporation papers with the state of California as a nonprofit corporation, run by a board of directors. Nelson became president of the corporation. However, a publication supporting the devices produced by a single manufacturer (in this case, HP) could not obtain tax-exempt status. Thus, beginning in May 1982, the *PPC Journal* also published TI-59 related material, mostly reprinted (with permission) from *TI PPC Notes*.[62] This decision was not received well by the membership because there were not many "bilinguals" familiar both with TI-59 and HP-41C programming. The social networks that emerged around these calculators therefore remained only loosely connected.

More serious problems came from within the board of directors. Running the corporation, managing employees, starting another magazine (the *PPC Computer Journal*), and handling financing increased the tension within the board, so on 11 April 1984 Nelson resigned as president and the journal's editor. This was probably just a tactical move, but the board quickly elected Emmett Ingram the new PPC president and David White the new journal editor. During the next few months, PPC was in the state of turmoil. As stated in a seven-page letter to members in August 1984,[63] the board had to hire a security guard to keep Nelson out of the clubhouse during regular Friday night meetings.

Nelson eventually started a new publication, the *CHHU Chronicle*, which (pronounced "chew") stands for the Club of Hewlett-Packard Handheld Users. The

Chronicle was an amateur publication but could not reach a critical number of members to support a full-time editor. Only 11 issues were published, and it folded in early 1986. The *PPC Journal* lasted a year longer but was struggling for content; it finally folded in May 1987. HP pocket calculator users lost a valuable source of information as the need for information increased after HP revamped the scientific RPN calculators by introducing the HP-28S in 1987 and the HP-48S in 1990. At that point, information exchange occurred at regular conferences, through books, and (later) over the Internet.

The TI-59 went down much less spectacularly, mainly because TI didn't follow it with a successful model. The successor, TI-88, was an alphanumeric calculator with an LCD, faster processor, up to 3-Kbyte memory, and better instruction set.[64] It could easily compete with the HP-41C, but not with the next generation of HP's graphic calculators equipped to solve symbolic equations, starting with the HP-28S. After a substantial R&D expenditure, TI cancelled the project and shifted its priorities to a family of handheld computers (such as the CC-40) and its desktop Basic computer, the TI-99/4A.[65]

Without a star calculator, user clubs stagnated. In January 1983, TI discontinued *PPX* and that same year terminated the production of the TI-59. *PPC Notes* continued to publish under a new editor, Palmer O. Hanson, and lasted for 14 years, until November 1991. European clubs mostly stopped publishing in 1984.

The Role of Users

As Campbell-Kelly and William Aspray claimed, "with the arrival of consumer-oriented machines in 1977 the market for applications software took off—applications software enabled a computer to perform useful tasks without the owner having to program the machine directly."[66] This claim applies to the Apple II, Commodore PET, and Tandy TRS-80. Although the HP-65, TI-59, HP-41C, and other programmable calculators could be categorized among the first consumer-oriented personal computers, their software development took a different path. Because no companies sold software for these calculators, the payment-by-royalties model was not implemented and few programs were actually sold for profit. The software was mostly written by users and distributed to users for free, similarly to the concept originated at the Massachusetts Institute of Technology (MIT) in the 1950s and 1960s[67] and followed in 1975 by the Homebrew Computer Club in the Silicon Valley.[1]

To understand the difference between the evolution of the software industries for early home computers and programmable calculators, we should consider Sherry Turkle's claim that when the early owners of home computers bought their machines, their software and hardware were in a state of disequilibrium.[68] Although the new Apple II, PET, or TRS-80 could do virtually nothing useful without application software, programmable pocket calculators could be used for its main purpose, numerical computation, and their manufacturers provided necessary programs in the form of application modules. Even when programming was a necessity, it did not require learning a language—elementary programs were simply a series of keystrokes. When users required more, they sought it from one another.

Ceruzzi claimed that HP and TI were unprepared for the mass sales of their calculators.[1] They sold the machines as commodities and could ill-afford a sales force that could walk a customer through the complex learning process needed to get the most out of one. Instead, the manufacturers helped shape user communities. TI initiated Professional Productivity Program seminars, in which engineers and technicians were trained to use the TI-59 (the price of the user course was US$1,200, three times the calculator's initial price).[21] HP's developers and other experts were regular keynote speakers at the annual user conferences hosted by the PPC (later HHC, http://hhuc.us), from Santa Clara, California, in 1979, to Fort Collins, Colorado, in 2010. More importantly, by establishing user libraries, both HP and TI shaped user communities that could provide advanced software and support for newcomers.

Because the calculators were sold in many countries, newsletters and magazines were the most effective form of communication between users. The groundwork was again laid by the manufacturers, but their editions, the *TI PPX Exchange* and the *HP Key Notes*, were insufficient. Users formed clubs and published their own newsletters. Between 1977 and 1984, the two most important magazines, *TI PPC Notes* and *PPC Journal*, published about 30,000 pages. Most of the articles were accompanied by programs ready to be keyed into the reader's calculator to solve math and engineering problems. Game programs were occasionally published, but the games did not shape the pocket calculator market as they did with home computers[3] because the TI-59 and HP-41C displays were unsuitable for gaming.

Unlike the computer magazines, *TI PPC Notes* and *PPC Journal* didn't publish advertisements or color pictures; they consisted mostly of small-print text, written by users and often not even touched by the editor. Because neither the TI-59 nor HP-41C supported program compilation, the source was always open, so users were judged by the quality of their code, and programs were often further optimized by other users, following the early hacker culture and the resulting philosophy, formulated later by Steven Levy as the Hackers Ethic.[67] Ceruzzi called early programmable calculator users "the intellectual cousins of the students in the Tech Model Railroad Club."[1] The important difference is that PPC users were not confined to MIT buildings;[26] they spread the Hackers Ethic in many countries.

Both HP and TI recognized the impact of user communities on the market success of their calculators. With each HP-41C sold, HP delivered a card that directed the buyer to the PPC for additional support and software.[69] TI produced a separate brochure with a list of user clubs all over the world, sending it to each user who asked questions about the calculator's advanced features and programming. The users' needs, expressed in some of the articles published in newsletters, shaped the development of these small systems; applications packs, modules, and peripherals, produced by TI and HP, followed some of the club's projects.

As Christina Lindsay noticed,[70] a technology's disappearance from mainstream public view is not necessarily the end of its life. The users stay even after the product is discontinued. The user networks formed in the early 1980s still exist, and today the Internet is the main forum for information exchange. The HP-41C's network is stronger, in part because HP later produced successful programmable calculators from the HP-48/49 series. Most of the materials published in the earlier days—22,300 pages spanning from 1968 to 2010—are available on a PPC DVD produced by Jake Schwartz (see www.pahhc.org/ppccdrom.htm). The materials were scanned in at a moderate resolution but not with optical character recognition, so searching is not possible.

Programs and materials about the HP-41C are available at www.hp41.org, a website operated by Warren Furlow. This site is also the main source for HP-41C emulators written for different platforms, from Windows and Mac OS X to iOS and Android. The site's archive DVD includes scanned HP-41C documentation, numerous books, and programs. Usenet newsgroups also still host HP-41C-related discussions.

The major TI-59-related publications, *PPX*, *52 Notes*, and *TI PPC Notes*, are available online at www.ti59.com (which is operated by Ristanović) and www.rskey.org (which is operated by Viktor Toth). Various documentation is also available on www.datamath.org, operated by Joerg Woerner. A TI-59 emulator running under all versions of Windows was written by Miroslav Nemeček. Another version was written by Alan Zanchetta (www.zanchetta.net). An online emulator Vertigo (www.n3times.com/vertigo), a PocketPC version TI-59ce, and an Android version ti5x written by Lawrence D'Oliveiro are also available.

Conclusion

The TI-59 and HP-41C were powerful programmable calculators designed in the late 1970s, aimed primarily at scientists and engineers. Although different in many aspects, they shared two important concepts: programming was done by memorizing series of keystrokes, and libraries of programs were distributed as ROM modules. Attempts were made to port programs from one platform to another: TI produced an RPN Simulator ROM, enabling the transcoding of programs written for earlier HP calculators. Ristanović wrote a TI-59 to HP-41 compiler,[71] enabling compilation of TI-59 programs into HP-41C user code and into the HP-41C's memory. However, the compatibility and overall usefulness of these attempts is debatable.

Similar to early personal computers, the TI-59 and HP-41C's small RAM was a serious limitation for programmers. Every program step was precious, so it was common for a programmer to spend hours trying to save a few bytes. Developers often effectively increased data storage by packing several values into the same register. Given all these obstacles, fascinating programs were written for these small computers, including chess programs.[72,73]

As historians have recognized in the history of computer systems in general, the users "refined, reshaped or (re)programmed systems to meet various purposes, needs, and desires."[74] The concept of users libraries controlled by a computer manufacturer reemerged in 2008 with the App Store, a digital application distribution platform for iOS maintained by Apple. Other mobile device manufacturers have followed suit, establishing the Android Market (now Google Play), Windows Phone Marketplace, and so on. The principal difference is these platforms follow the payment-by-royalties model, whereas authors of TI-59 and HP-41C programs were not compensated when other users purchased their programs.

The need for quality programs and the development of synthetic programming techniques led to the formation of strong user communities, spread over many countries. The principal means of information exchange were newsletters and books in the pre-Internet early 1980s. Users wrote tens of thousands of pages and spent countless hours researching and writing programs without any monetary compensation. These networks still partially exist, and a large percentage of published material is available in electronic form.

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