Smalltalk Opportunities at Tektronix

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Introduction

Smalltalk is a programming language designed to support interactive applications on personal computers. In this document we present background information related to Smalltalk, describe its history at Tektronix, discuss the market for Smalltalk-related products, and describe possible opportunities for Tektronix.

What is Smalltalk?

The Smalltalk programming language was developed over the last ten years at the Xerox Palo Alto Research Center. The inventors of the language had anticipated the development of the high performance personal computer and they envisioned Smalltalk as the central software component of such systems. The result of their work is a language which is unsurpassed for the development of complex, highly interactive computer applications.

Smalltalk-80 is the latest version of Smalltalk. It consists of a programming language and a set of programs (called the "virtual image") written in the language. The language is intended to support easy manipulation of symbolic information; it is based on the concept of objects which communicate by sending and receiving messages. Objects are members of classes which define sets of known messages. Classes are organized hierarchically and provide a uniform framework for designing Smalltalk programs.

The Smalltalk-80 virtual image is a large, but logical and well-structured, set of programs. These programs provide a sophisticated display-oriented software development environment; the Xerox Star and Apple Lisa user interfaces are both modelled on Smalltalk's. The virtual image contains integrated text and graphics editors, program development tools including a compiler and symbolic debugger, and an extensive set of facilities for constructing interactive applications. It has over sixty different classes including text and graphics representations, numeric and collection classes for basic data types, process and synchronization classes for multitasking, and data stream classes for file systems and networking.

At Xerox, Smalltalk was developed using several internally designed computers: the Alto, Dorado, and Dolphin. These machines share architectural features which distingish them from conventional

computers and which enhance their ability to execute languages similar to Smalltalk. The Dolphin and Dorado are the only commercially available Smalltalk computers and are priced at $45,000 and $189,000 respectively. Xerox has announced that it will implement Smalltalk on a new computer called the Dandelion which will sell for around $30,000. We are also aware of development at Xerox of Smalltalk for the MC68000 processor on the Sun Terminal (apparently under contract for Fairchild).

Performance figures for Smalltalk systems are usually estimated by running benchmark programs supplied in the virtual image and scaling performance relative to a Xerox Dolphin. For example, Dorado performance is 9.1, meaning that a Dorado is about nine times faster than a Dolphin. The Smalltalk implementation is not yet complete for the Dandelion but it is expected that its performance will be comparable to the Dolphin's. The Dolphin's level of performance is generally considered the minimum acceptable for execution of Smalltalk.

Smalltalk Outside Xerox

Until recently, Smalltalk was available only within Xerox. In July 1980, Xerox decided to publicize Smalltalk and, ultimately, to distribute it to outside groups. The first step taken by Xerox was to approach a small group of companies and ask them to review the design and documentation for Smalltalk in preparation for the publication in book form of a complete description of the language and virtual image. The companies were DEC, Hewlett-Packard, Tektronix, and Apple (Intel was also approached but declined to participate). In return for assisting in the review, the companies received licenses to market Smalltalk-based products without royalties to Xerox.

As part of the review process, the companies implemented Smalltalk on conventional processors. At DEC, Smalltalk interpreters were developed for both a VAX 11/780 and a VAX 11/730. The VAX 11/730 implementation was written in the Bliss language for VMS and was intolerably slow (0.08 of a Dolphin). The VAX 11/780 implementation was written in assembly language for VMS but was still disappointingly slow (0.44 of a Dolphin). The primary Smalltalk implementor at DEC has left for a position at Three Rivers, the makers of the PERQ workstation. We do not know of any new Smalltalk development being done at DEC.

At Hewlett-Packard, a VAX 11/780 was also used with development in the C language for the Unix operating system, but the performance achieved was significantly less than at DEC (only 0.17 of a Dolphin). This work was done at H-P Labs; the group which did the work has been redirected. Hewlett-Packard apparently considered developing a Smalltalk product in Corvallis, but current indications are that they did not follow through with it.

At Apple, a Smalltalk interpreter for the MC68000 processor was developed. Apple had a particularly strong interest in Smalltalk because many of the engineers working on the Lisa workstation had come from Xerox PARC. The MC68000 interpreter was written in assembly language but performance was hindered by the hardware limitations of the Lisa (e.g., 5 MHz processor) and reached 0.47 of a Dolphin. Apple has announced its intention to distribute Smalltalk for Lisa despite the low performance.

The Tektronix Smalltalk effort was targeted for the MC68000 processor also. Two different interpreters have been developed at Tek. The first was written in the Pascal language as a learning exercise. The performance was only 0.18 of a Dolphin but a variety of problems in the Xerox language specification were identified and several strategies were proposed for faster implementations. The second interpreter has been written primarily in assembly language and includes numerous design improvements over the approaches suggested by Xerox. Running on a 10 MHz processor, this interpreter achieves a performance of 1.53 of a Dolphin.

In addition to these four corporate efforts, a Smalltalk interpreter was developed at the University of California at Berkeley. The Berkeley group targeted their implementation to the VAX 11/780 and wrote in the C language for the Unix operating system. They spent considerable effort optimizing the interpreter and were able to achieve 0.60 of a Dolphin. This group is now trying to design a custom VLSI implementation of the Smalltalk interpreter.

The book describing Smalltalk-80 is scheduled for publication in April 1983. A second book detailing the experiences of the early implementors (including three articles written by Tektronix engineers) is projected for release in the third quarter of 1983. Articles describing Smalltalk in some detail have appeared in Byte magazine (August 1981) and Infoworld (January 1983). Several articles about the Smalltalk language, implementation and applications written in it have also appeared in the technical literature.

History of Smalltalk at Tektronix

Tektronix was approached along with the other companies in July 1980. The Graphics Computing Systems business unit in IDD was approached as a result of contacts with Jack Grimes. Tektronix agreed to review the Smalltalk specifications and implement an interpreter. In September 1980 a three person team from the Modular Computer Program managed by Dave Heinen was designated to lead this effort. The team included Paul McCullough, Allen Wirfs-Brock and Larry Katz. This team was transferred in January 1981 to a new DAD Systems Engineering group managed by George Rhine.

From October 1980 till May 1981, the team met regularly to discuss the Smalltalk specifications and prepare responses to be sent to Xerox. In addition to the above three people, the team included a person from Computer Research in Tek Labs (Rick Samco), and a person from Terminals and Displays (Bob Reed). During this period many presentations were made within Tektronix about Smalltalk and considerable interest was developed in both the language and graphical user interface. The review process was considered successful; Xerox acknowledged that Tektronix provided the best inputs of all the companies.

In April 1981, the first implementation of Smalltalk was started by the DAD Advanced Concepts group. This group took the conservative approach of implementing an interpreter in Pascal; the first interpreter was not expected to be usable but, rather, to provide the experience necessary to design a faster one. The MC68000 was chosen as a target because of the availability of hardware and development tools and because of an expectation that future Tektronix products would be based upon it. An additional software engineer was assigned to the project (Jason Penney). The first interpreter was finished in October 1981 and three papers were written by the team. In November 1981, Allen Wirfs-Brock left the group to continue work on Smalltalk within Computer Research. The DAD group continued development of their interpreter until March 1982.

The focus of work on Smalltalk within Tektronix moved with Allen Wirfs-Brock to Computer Research. Allen brought up the DAD interpreter on the Magnolia workstation by February 1982 and then started implementation on the second interpreter. The second interpreter was written in assembly language and employed new algorithms carefully-optimized for traditional processors such as the MC68000 (as compared to the custom processors used by Xerox). This interpreter was completed in January 1983. Continuing development of Smalltalk (and applications written in Smalltalk) is planned within Computer Research.

The Tektronix investment to date in Smalltalk is approximately $450,000 (assuming $50,000 per man-year). The review process involved five people for about six months. Approximately five man-years of effort have been dedicated to development of the interpreters (four in DAD and one in Computer Research). Computer time on the Wilsonville DEC-10 system for the first interpreter totalled around $40,000. Hardware resources dedicated to the development cost around $35,000.

Most of the people involved with Smalltalk at Tektronix have left the company. Of the people mentioned in this section, Jack Grimes, Dave Heinen, Paul McCullough, Larry Katz, Rick Samco, and Jason Penney have gone.

Smalltalk Implementation

The varying degrees of success in implementing Smalltalk interpreters at DEC, Hewlett-Packard, Tektronix, Apple and UC Berkeley are indicative of the difficulties involved. Performance of a Smalltalk implementation is dependent on both the power of the available hardware and the quality of the interpreter.

A Smalltalk implementation requires considerable hardware resources, including around a million bytes of memory to hold the programs and virtual image, a high resolution bit-mapped display, a pointing device such as a mouse or graphics tablet, a mass storage device such as a floppy or Winchester disk, and a powerful 16- or 32-bit processor. Current systems on the market with these resources include the Apollo Domain, Three Rivers PERQ, Hewlett-Packard 9000 and the Sun Terminal.

The Smalltalk interpreter includes three key elements: instruction execution, storage management and primitive subroutines. Instruction execution involves performing the elementary operations which make up a Smalltalk program, such as moving objects and sending messages. Storage management involves allocating new objects and reclaiming the memory used by old objects (called "garbage collection"). Primitive subroutines provide basic capabilities such as arithmetic operations, input/output and screen graphics. Interpreters vary between 10,000 bytes (in microcode on a Dolphin) and 40,000 bytes (assembly language for a MC68000). The performance of the interpreter depends heavily on the speed of storage management.

The Tektronix implementation clearly demonstrates that acceptable performance for Smalltalk is possible on a conventional processor. The disappointing performance achieved by the implementors at DEC, Hewlett-Packard and Apple can be attributed to their following the interpreter design as specified by Xerox. This design appears to be unsatisfactory for non-microcoded processors. The success of the second Tektronix interpreter is the result of incorporating new and innovative techniques which depart radically from the original design. In particular, the performance was gained through the use of fast garbage collection algorithms, efficient data representations, and special tables for quick access to commonly-used objects and messages. These innovations were only possible because of the experience gained during the development of the first interpreter. (The Xerox MC68000 Smalltalk interpreter is said to have achieved comparable performance to the Tektronix implementation through the use of similar innovations.)

The MC68000 appears to be the best commercially available microprocessor for Smalltalk because of its architecture (primarily the number of registers and uniform address space) and because it is available in high-speed versions. The number of registers is significant in the processor because they can be used to hold

addresses which are used often by the interpreter, thereby speeding up execution. The National 16032 offers fewer registers than the MC68000 but does offer good support for virtual memory; however, Smalltalk interpreters do not yet require virtual memory and, because it is new, the 16032 is not yet available in high-speed versions. The Intel 286 has excellent speed but will be more difficult to develop an interpreter for because of its segmented address space and its very limited number of registers.

The development of a Smalltalk interpreter for a new processor requires considerable design effort because it is necessary to write most of an interpreter in assembly language to obtain adequate performance. Also, bringing up an interpreter is complicated by close interaction between the interpreter and system-dependent features such as the display and pointing device.

Smalltalk Licenses

A license is necessary for the use of Smalltalk outside of Xerox. Licenses are commonly used to restrict the use of software products. For example, the Unix operating system is licensed by Western Electric for use on a variety of computers and workstations, and Unix license fees vary from $125 for a single-user workstation to $10,000 for a multi-user computer with complete operating system sources.

The four companies which participated in the review of Smalltalk with Xerox are currently the only holders of Smalltalk licenses. The license agreements were made very favorable to the companies in order to induce them to participate. The agreements grant "a world-wide, irrevocable, nonexclusive, royalty-free right and license together with the right to sublicense others to use, copy, reproduce, modify and distribute" Smalltalk products. The only restriction in the license is that it forbids the companies from distributing the Smalltalk virtual image as a stand alone item without permission of Xerox.

The current situation for other companies is simple: licenses are not available from Xerox. However, the effort that Xerox has put into the review and the preparations for the publication of books on Smalltalk indicate an interest at Xerox in making it generally available. It is highly probable that Xerox will announce a license policy in the near future.

An Opportunity for Tektronix

Tektronix has a unique opportunity to take advantage of any market which develops for Smalltalk products.

The four companies involved in the review process each have a license to offer Smalltalk without paying royalties to Xerox. Of these companies, only Tektronix and Apple are still developing Smalltalk.

DEC and Hewlett-Packard both lost interest when their VAX interpreters turned out to be too slow. Apple intends to distribute Smalltalk for the Lisa workstation, but their interpreter is only half the speed of the Xerox Dolphin and will be too slow for most applications. Tektronix has an excellent Smalltalk implementation and is developing considerable in-house expertise with it.

What prevents Xerox from dominating any potential market for Smalltalk? Xerox has announced an expensive product line starting at around $28,000 and going up to close to $200,000. These prices are too high to attract a large number of customers. Also, Xerox has not been successful in interfacing the Smalltalk products to other computers, severely limiting their use in highly-automated offices and laboratories. Xerox is by far the most experienced company with Smalltalk but without reasonably-priced products which fit in the customer's environment they will not be able to create a Smalltalk market.

The Market for Smalltalk

Smalltalk has only recently become available outside of Xerox (and the four companies which participated in the review), and only for a cost of over $50,000. Market estimates, therefore, are difficult to make. We know that there is significant interest in Smalltalk. The articles in Byte magazine and Infoworld about Smalltalk and its use as the model for the much-praised user interfaces on the Xerox Star and the Apple Lisa has been responsible for much of the interest. Also, we know that Xerox has received a large number of letters requesting Smalltalk licenses and information.

What does Smalltalk offer to justify this interest? First, many people share a desire to explore the new concepts in the Smalltalk language and user environment; it is this type of use which led to design of the Star and Lisa user interfaces and which could result in sales of Smalltalk systems to other system developers. Second, Smalltalk is an excellent language for developing complex, highly interactive applications; a market could develop for Smalltalk systems which include such applications. Third, the virtual image provides a highly-integrated, powerful program development environment for the Smalltalk language; Smalltalk systems could be sold for software design. Fourth, Smalltalk is readily adapted to uses such as pre- and post-processing of data, graphical presentation of data, and monitoring of concurrent operations; a market could develop for Smalltalk systems which function as very intelligent terminals when used in conjunction with large time-sharing computers.

A Smalltalk market would include a variety of system and application products. Software products could be developed to add Smalltalk to existing computers which have the resources to support it, such as the Apollo Domain. Various hardware subsystems could be sold to expand other computers to where they could support Smalltalk (e.g.,

a 68000-based card for the IBM PC). Systems could be marketed which specifically support Smalltalk, such as the Xerox Dolphin. Systems could be developed which support Smalltalk in addition to other software products, for example, Smalltalk could run as a user interface to a closely-coupled Unix subsystem. Once Smalltalk systems are widely available, a market for applications written in Smalltalk will develop.

The obvious risk involved in developing Tektronix Smalltalk products is the possiblity that a market for such products will fail to develop. This type of risk is always present with products which incorporate new concepts or technologies. However, there is a good probability that a significant market will develop for Smalltalk products and Tektronix, through early entry, could potentally be a major force in it.

What Should Tektronix Do?

We believe that Tektronix must move agressively to take advantage of the unique opportunity it has with Smalltalk. The publication this year of the Smalltalk books with descriptions of the language, virtual image and implementation experiences will allow others to begin developing interpreters. Within eighteen months, Smalltalk packages will probably be available with comparable performance to the current Tekronix interpreter.

What can Tektronix do quickly with Smalltalk? With its license, Tektronix is allowed to market any type of Smalltalk product except the virtual image as a stand alone item. Probably the quickest way to get to market would be with a software-only product based on the MC68000 interpreter and the virtual image which would run on workstations with sufficient hardware resources. Such a product would require some customization for each workstation. It could be sold either on an OEM basis to workstation vendors or directly to current users of workstaions.

Alternatively, Tektronix could acquire workstations from outside and resell them with Smalltalk. This would potentially allow Tektronix to get to market quickly. However, previous evaluations of workstations with the required capabilities indicate that they would be too expensive for this purpose.

Tektronix can simply wait and offer Smalltalk as an option on the workstations under development in the Engineering Computing Systems business unit. It is probably desirable to offer it in any case - such workstations would be competitive in performance and cost with the Xerox Smalltalk systems. However, this approach by itself will be too late to establish Tektronix as a leader in the Smalltalk market.

What would be the ideal product for Tektronix to produce? A Smalltalk system for less than $10,000, with good performance and which fits well into existing computing environments would establish Tektronix as a leader in the market, if it was available within a year. Can Tektronix do this? Possibly, but only if major portions of the design were shared with other products and minimum new development had to be done. For example, it appears to be possible to build a Smalltalk system with components under development for the Unicorn product line. With this option, Tektronix has an opportunity to do something which will help create a market for Smalltalk products.