At Apple a Cray keeps the doldrums away

Kent Koeninger, Apple Computer, Inc., Cupertino, California

During the past decade the design and engineering of personal computers has evolved from a garage-based, hand-tool enterprise to one that taps the computational might of supercomputers. This leap in design and engineering technology has occurred within one company, Apple Computer, Inc. In 1986 Apple purchased a CRAY X-MP/48 computer system for advanced design projects and to serve as a resource for all Apple engineers. Apple's "Cray Evangelist" Kent Koeninger here explains Apple's reasons — practical and philosophical — for purchasing a Cray supercomputer.

Our decision to acquire a Cray computer system at Apple grew out of a central driving force, which was the need to design new user interfaces. An efficient way to evaluate new designs was needed as an alternative to actually building and testing a repertoire of hardware prototypes. Modeling interfaces, however, requires a powerful computer system on which to run the models. Apple's advanced computer development group also wanted to run complete simulations of multiple-layer printed circuit (PC) boards and complex VLSI chips. Although minicomputers could have handled partial simulations, a major computing resource — a supercomputer — was needed for the exhaustive hardware simulations the group wanted to run.

The manager of advanced computer development at Apple, Sam Holland, had previously completed a survey of U.S. and Japanese supercomputers. With the results of his research in hand, management determined that a Cray system would best meet the company's needs.

The computing environment

Our use of the Cray system so far has been strictly interactive, making response time for jobs critical. Apple was the first site to run Cray Research's interactive operating system, UNICOS, on a CRAY X-MP system. Originally we had planned to run the Cray operating system COS, and switch to UNICOS at a later time. But a last-minute decision was made to install UNICOS from the outset. This decision turned out to be a good one. UNICOS has been very stable. Cray Research has done an excellent job maintaining the flavor of AT&T's popular UNIX operating system, on which UNICOS is based.

To further enhance the interactivity of our computing environment, we currently are involved in a cooperative effort with several universities to produce software for a workstation environment that runs on a standard Apple Macintosh personal computer and interacts with the UNIX operating system. The Macintosh workstation will provide distributed editing and network communications from itself to the Cray system using the AppleTalk, Ethernet, and HYPERchannel networks. The workstation will use the TCP/IP protocol.

Our experience with the Cray system during the past year convinces us that it will significantly shorten the design cycles of future products. Already it has made possible some very creative and technically demanding progress. Two examples follow.

Significant bits

The value of the Cray system's speed was demonstrated recently by the solution of a large numerical study. Steve Perlman of Apple's advanced development group needed to determine the minimum number of significant bits required to give a type of integrated circuit (IC) acceptable precision. Preliminary numerical analyses generated four answers to the problem. Consequently, the group members chose not to trust these results. The group could have turned the problem over to expert mathematicians and waited for an eventual answer, but instead they chose to compute all possible cases and found all of the problem's boundaries by sheer brute-force computing using the Cray system.

Using dedicated time on a VAX 11/780 computer, the program would have required two weeks to run to completion. But when other users of the VAX computer were unable to use the system, Perlman lowered his program's priority status. At the lower status the program would have required six months to run to completion, so Perlman moved the program to the Cray system.

The code conversion to the Cray system took only half an hour, requiring only minor changes. An interesting modification was the removal of a "printf" statement in an inner loop that was included to monitor the progress of the program. On the VAX computer it printed about once every minute. The loop was executed so quickly on the CRAY X-MP system that the printer was unable to keep up. The print statement in the inner loop and one in the next outer loop were removed, completing the conversion to the Cray system.

As a result of moving the problem to the supercomputer, the solution was obtained in two and one-half hours. That is, a problem that would have required six months to run on a loaded VAX computer became one afternoon's work on the Cray system, including code conversion time. The practical result of the conversion was that the problem was solved 1700 times faster on the Cray system than would

have been possible on the VAX computer (180 days at 24 hours per day divided by 2.5 hours = 1728).

When using only one of the Cray system's four CPUs, the program ran 25 times faster than on an unloaded VAX 11/780 computer. When the problem was divided into sections that ran simultaneously on the Cray system's four CPUs, the run required one 1/100th the time needed on the unloaded VAX computer. These results were obtained using the first release of the Cray C compiler, which does not optimize or vectorize. Vectorization, included in the latest version of the Cray C compiler (see this issue's Corporate Register), would have generated a significantly faster running time. Perlman now plans to execute several more similar runs as a result of his first experience with the Cray system.

Disk head

A recent study of disk head configurations also benefited from the capabilities of the Cray system. Jim White and Conrad Chen in Apple's peripheral development group have been able to evaluate head configurations that they could not have evaluated without the simulation capabilities provided by the supercomputer.

The disk-head model simulates a three-dimensional, compressible, viscous, rarefied, time-dependent air flow between a disk head and a flexible medium. It solves a system of partial differential equations that describes the physics of the elastic medium, fluid flow, and rigid body dynamics. The Cray Fortran compiler CFT compiled the program in 10 seconds on the CRAY X-MP/48 system. The same compile using the F77 UNIX Fortran compiler on a VAX 11/780 computer required 30 minutes. On the Cray system, an average run of the program takes 30 minutes, whereas on a VAX computer the same run would take about one day. This reduction in turnaround time enabled White to try 20 different configurations. The fast turnaround has allowed him to be creative and exhaustive in searching for superior disk heads. Results such as these are only preliminary indications of the effect we expect the Cray system to have on productivity and turnaround.

Advanced development

General engineering needs serve as one justification for acquiring the Cray supercomputer. The primary motivation for looking into supercomputing, however, came from the needs of the advanced computer development project. This group was organized to model future Apple products in their entirety prior to building new hardware. The models will simulate all product features including IC functions, PC board layouts, the system-level architecture, heat flow, and the user interface including graphics. The models also will be used to perform "crashworthiness" studies of physical frames. As is clear from the sample of applications, our need was for a general-purpose computing system to handle design work, not hardware optimized for a particular application. If this methodology works as planned, we will know what future products look and feel like before any of their parts actually exist.

As it is for all Apple products, the user interface will be our primary concern and will act as a springboard for the products' other features. Our observation is that our competitors seem to think very little about the user interface, and add it on almost as an afterthought. We consider the user interface to be primary and we plan to design the new products around it.

Ideas for new product interfaces will be dry run by modeling a display screen in real time using the HSX channel on the Cray system. This is the fastest way we have to determine the optimal screen display for a user interface. Once that is done, the challenge for us will be to see if a machine capable of providing that interface can be built inexpensively enough to be marketable; that is, through simula-

The Mandelbrot set shown at left was computed in less than two minutes on Apple's CRAY X-MP computer system. By linking Ultra graphics terminals via Ultra Corporation's UltraBus to the Cray system through the HSX high-speed external channel, Apple engineers have achieved data display rates of more than 80 Mbytes/sec. This has allowed them to display dense color images (1280 x 1024 pixels x 24 bits of color per pixel) at a rate exceeding 16 screens per second. At right are Newt Perdue (center), vice president of Ultra Corporation, with Sam Holland (left) and Kent Koeninger (right) of Apple Computer.

The essence of speed

Apple's rapid acquisition of a supercomputer may seem miraculous to anyone familiar with the usually lengthy process. But our need for supercomputer capabilities was clear, and the lack of bureaucratic obstacles within the company hastened the process considerably. As a result, Apple boasts one of the fastest Cray system installations to date, having prepared its installation site in only six weeks.

For most of these six weeks, crews worked three shifts, 24 hours a day, seven days a week preparing a machine room for the system. The crews gutted the building, installed the cooling tower, the chilled water and high-pressure freon plumbing, the wiring, the air conditioning, the walls, and the false floor. Nothing could be tested, however, because the 480-volt transformer did not arrive until the Friday before the Cray system was shipped. Everything worked perfectly except the transformer, which had to be exchanged Friday night.

The Cray system was installed and ready to use two weeks after its arrival. The first thirty days of use constituted an acceptance period, during which the system had excellent uptime (98.6 percent). Since then, it has shown itself to be a reliable performer. The speed with which the Cray System was installed was a good omen, considering the use to which the system would be put: giving engineers and designers rapid turnaround.

tion we want to design the optimal user interface that we can sell to the public.

The emphasis in using the Cray system for advanced development is not on solving problems of physics, but rather it is on trying out many ideas to solve problems creatively. We do not want our creative people to feel compromised or inhibited by a lack of computer resources. They should be able to try something and get turnaround fast enough so that they are encouraged to try more ideas. This approach in essence redefines the whole design cycle. If 30 minutes is all the time needed to try out an idea, you don't have to think about it much — just try it. If it doesn't work, try something else.

As far as we have been able to determine, the Cray system will be adequate for simulating new products completely. If we are able to compute user interface graphic displays in real time, the HSX channel will enable us to display frames at 600 to 800 Mbits/sec. If slow time simulations are necessary, we plan to run the simulation and store the information on striped disks. In this case, the playback speed will be determined by the speed of the disk drive. Using more conventional techniques, a 5-Mbit interface for example, it would take an hour or so to produce a segment of tape a few minutes long. With the Cray system we will be able to play the tape back virtually in real time and get a real-time display of the graphics. Of course, this strategy is somewhat speculative; we really can't know for sure if it will work this way until we try it.

If all goes as currently envisioned, engineers throughout Apple will move their most demanding problems to the Cray system, motivated by faster turnaround and by the opportunity to tackle problems unsuitable for conventional mainframe computers. Also, thanks to the Cray system, members of the advanced project group will be able to use the new products they are designing before the products exist. These "products in software" should function as if they were physical objects, and any bugs in their design should be evident from diagnostic checks. To the extent that we can accurately model the products' components, we will be able to bypass hardware-prototype testing in favor of software-model testing for these products. Achieving this end will mark a milestone in the evolution of CAD applications and could set the standard for similar future design projects. □

About the author

Kent Koeninger received his B.S. degree in mathematics from California State University in 1977. Prior to joining Apple Computer in March 1986, he worked for ZeroOne Systems, Inc. as manager of the systems group at NASA Ames Research Center's Advanced Computational Facility. As "Cray Evangelist" at Apple, Koeninger is responsible for "making the Cray system the most effective tool possible for Apple." His activities include coordinating the computer network through which Apple personnel access the Cray system, assisting in converting electronic design packages, and teaching courses to Apple personnel on using the Cray system.