REAL-TIME LABORATORY FOR INTERDISCIPLINARY COMPUTER PROJECTS

by

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Computer science education has ceased to be the exclusive interest of the computer science department. Virtually all university science and engineering departments have computers. In the near future computing power will be routinely available in the humanities and creative arts as well. However, in spite of the proliferation of computers, it is still possible for a student to receive an advanced education which does not mention the computer. Such an omission would be understandable if it were a technical tool limited to specialized use. However, the computer is a culture defining instrument which will shortly permeate every aspect of American life. Given its encroaching significance, it is crucial that computer scientists consider the problem of reaching non-technical as well as technical students.

In addition, the traditional computer science course usually has all students spend a semester doing identical exercises, which are ultimately thrown away. This approach may have made sense when computers cost millions and students needed a standardized set of skills in order to get a job. However, at this point in time, with costs plummeting, it is reasonable to encourage students to assemble their own unique set of tools so that they can create as well as fill jobs. The new economics has also expanded the potential for new research and development. Government and industry funding cannot support the amount of work required to exploit all of the possibilities. To assure that this promise is fulfilled, individuals must be motivated to provide their own time and resources. Computer science education should create artists, inventors and entrepreneurs as well as specialized professionals.

This paper describes an approach to computer science education which has been successfully used at the University of Wisconsin to introduce groups of diverse students from the liberal arts, social sciences and technology to the computer. The first section discusses the conceptual basis for the course and the method of implementation which was used in the past. The second section considers the benefits of this type of course for students from each of several specific disciplines. The final section describes the type of facility necessary to implement the course.

The Course

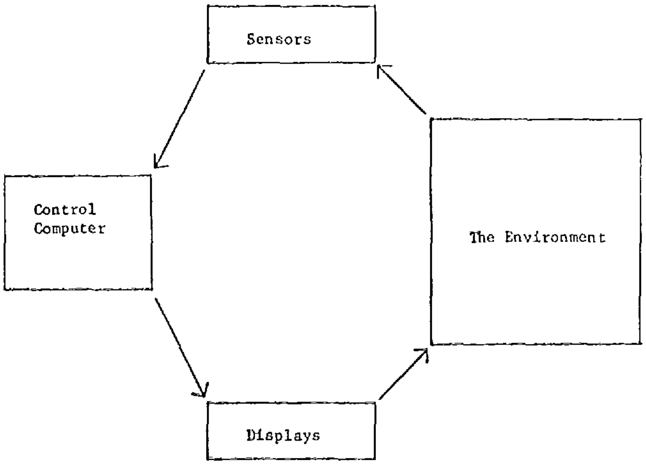
The format was an informal course which I designed and taught at the University of Wisconsin for five years. Students from various fields worked together on computer projects based on the aesthetics of composed man-machine interaction. The project approach seemed desirable for two reasons. First, many students learn better through involvement than through academics. Second, it seemed valuable to conduct a course in which a student's work built on the work of other students to ultimately produce a project which was to be the basis of future work.

The projects were based on the concept of a computer controlled responsive environment. A responsive environment is one in which a computer responds to a person's movements in composed ways through a variety of displays. The concept was new, so that the students were involved in exploring uncharted territory. In addition, the idea was powerful enough to generate interest and general enough to permit the evolution of a great variety of environments.

The Responsive Environment

The environments created as projects in the course consisted of a darkened enclosed space, monitored by a computer capable of perceiving human behavior and responding to it with intelligent visual and auditory displays. (Fig. 1) The computer was used alternately to create direct man-machine dialogues and to mediate interactions among people. For example, in one environment participants attempted to guide a symbol representing themselves through a maze displayed on an 8' X 10' rear projection screen. Grids of hundreds of pressure sensitive floor pads were used to detect people's footsteps as they moved around the environment. On the basis of the information provided by these sensors, the computer was able to foil the participants efforts to walk the maze. In another environment, the computer was used to facilitate interaction among participants which involved drawing on live images projected on a rear projection screen.

The displays in these and other environments consisted of projected images combining live video and computer graphics. Two-way video communication across campus had to be established since the University's Graphic Display Computer was located 1/2 mile from the gallery where the environments were exhibited. The auditory responses used in the environments were generated by elec-



Conceptual Diagram of a Responsive Environment
Fig. 1

tronic synthesizers. In the future, displays can be in any medium which is computer compatible. The level of complexity can range from discrete lights and laser beams to combinations of live video with vector and video graphics. Sound responses can include complex arrangements of electronic sounds and synthesized speech.

Sensing systems can vary from mechanical pressure sensitive floor pads to the use of digitized video images of participants which are fed into the computer in real-time. (Fig. 2)

The equipment used to create these environments included a PDP-12, Adage Graphic Display Computer, PDP-11, rear-view projection screen, television camera, two-way video cable and Moog synthesizer.

Several of the environments are described in detail in "Responsive Environments," included in the AFIPS proceedings for the 1977 National Computer Conference.

Description

Students in computer science, engineering, art, music, dance, psychology and education cooperated in producing the environments which were exhibited to the public. They were afforded the opportunity to use their specialized skills and to interact with students with unfamiliar skills. There were usually ten to fifteen students taking the course for credit. However, as the deadline for an exhibition approached, it was not unusual for the project to generate enough excitement to motivate an additional fifty to one hundred students to work around the clock to finish it.

The process of conceiving and implementing a given exhibit was accompanied by discussions which considered the longer range philosophical issues raised by the environments. Students were asked to consider what constitutes an aesthetic relationship between man and his technology. What aspects of human behavior should the computer be able to perceive? Is it legitimate to manipulate behavior in an aesthetic situation or, alternatively, if the facility is used for psychological experimentation? The interdisciplinary mix of students contributed to the number of perspectives brought to bear on these and related questions.

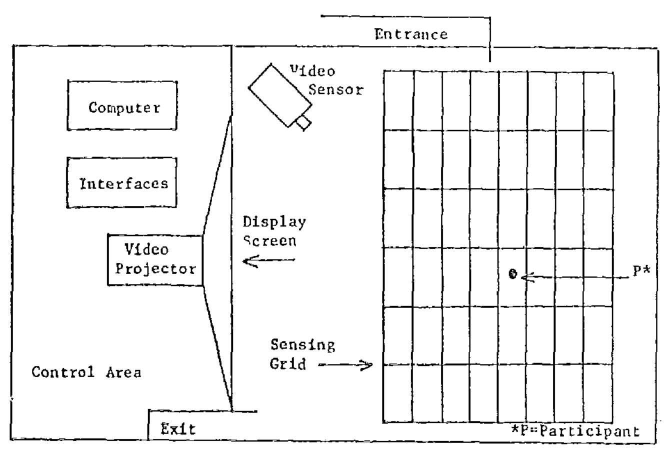
In addition to participating in the discussions, students in the liberal arts and social sciences were encouraged to gain familiarity and confidence in using technical hardware including computers, video and sound synthesizers. The computer was presented as a real-time decision-maker rather than as an off-line data processor. The students were not required to learn how to program, rather to understand the essence of what a computer is and what it can do. They were asked to consider their relationship to machines, as humanists must understand the tools which define their culture if they are to speak for it. Technical students were motivated to develop their own creative abilities and to recognize the aesthetic and philosophical implications of science.

Although a course of this nature is applicable to many fields, it is probably best offered through computer science or engineering departments, as they are the most likely to have an adequate technical base. The course described in this paper was offered through the computer science department.

Evaluation

The course succeeded in generating a high level of energy and enthusiasm. The projects were successful and potentially significant to a number of disciplines. The students were asked to cope with a new kind of course pressure since their efforts were important to other students who were dependent on their output. Perhaps more than in other courses, benefit to the individual depended on his or her willingness to become involved.

Grading was based on two main criteria: the fulfillment of an involvement commitment which the student indicated was possible at the beginning of the year, and the degree to which the parts of the project for which the student was responsible were accomplished.



The Responsive Environment
Fig. 2

For the technical students the course was very successful. In most cases it was the first opportunity they had been given to apply their skills to a concrete purpose. In addition, although a significant number of these students explicitly stated that they were not very creative when they registered, they enjoyed brainstorming ideas for possible interactions and effects within the environments. When discussions became purely philosophical or aesthetic their interest waned, although they did evidence a strong sense of aesthetics concerning the technology itself.

The non-technical students were interested in the process of technology and in the working relationship between the technologist and the machine. They wanted to experience the environments and to compose the interactions. While very few of them became proficient programmers, most learned to operate existing programs and to check out existing circuits. To these students, being surrounded by electronics and computers and probing their inner workings with an oscilloscope was a demystifying and educating experience.

The major problem was that while a laboratory space was committed to the course, it was not equipped with permanent hardware. Consequently, equipment had to be borrowed. It was originally thought that the loan of infrequently used computers and equipment from various campus sources would be sufficient for the needs of the course. However, continuity of effort suffered since software and interface hardware had to be rebuilt from semester to semester. Ultimately a PDP-11 was purchased solely for use on the projects. Independent of these problems, the projects were very ambitious, demanding heroics in terms of time and effort on the part of students and instructor.

Future

The five year experience demonstrated the value of using the concept of a responsive environment as a means of exposing diverse students to the computer through interdisciplinary projects. The course could again be conducted as an interdisciplinary effort, or, as will be discussed in the following paragraphs, it could be tailored to suit the needs of students within a particular discipline.

Computer Science and Engineering

Although it was unforeseen, the course served to highlight an important omission in computer science curriculum. Most computer science departments present the computer solely as a data processing device and fail to introduce either the specialist or non-specialist to the computer as a real-time decision-maker and process controller. This bias permeates not only course instruction but also the understanding of basic concepts and the definition of research problems. For instance, operating systems are typically considered to be like those of university computer centers: timesharing, batch, or dedicated interactive minis. The different constraints of real-time and dedicated systems are seldom considered. This suggests that a similar project course, in a permanent facility, could serve a real need.

While it is universally recognized that the economics of computer technology is undergoing a cataclysmic change, it may be less obvious that this implies a revolution in architecture. All of the traditional tradeoffs between hardware and software have to be reconsidered. Hardware and software skills must be united at both the basic level of microprocessor applications and at the most sophisticated levels of systems design.

The environment is an ideal testbed for microprocessor and parallel processing solutions to these problems. The student quickly becomes aware that the much vaunted speed of the computer is a myth. The resources of any single processor can be quickly consumed by controlling any facet of the environment. Parallel processors and special purpose hardware are a necessity. In addition, the distribution of system control presents a number of options instructive to the software student. Although these methods will not be universally applicable, their uniqueness gives the student a richer understanding of what operating systems are and can be.

The process of creating a responsive environment poses a number of additional problems of common interest to the engineer and computer scientist in the areas of robotics, pattern recognition and graphics.

The responsive environment is essentially an immobile robot which must sense behavior and respond to it. However, unlike many research approaches to robots, the environment accepts the requirement of real-time response. This dynamic approach focusses less on the cognitive and reflective aspects of artificial intelligence and more on the level of intelligence required to interact in the present. Since less time is available for processing, presumably less intelligence is possible for either man or machine in this situation. However, while men do not typically prove new theorems while they are physically involved, they can behave in a way which is recognizably intelligent. It is this level of intelligence to which the environment aspires.

The emphasis on real-time changes the nature of the problem of pattern recognition. It requires analyzing dynamic patterns into smaller gestures which the computer can understand and respond to in a meaningful manner. The total sensing-display system provides a means of working with real-time graphics and with video for input, display and transmission. Finally, the engineering and computer science student are asked to judge the quality of the man-machine interface by aesthetic criteria as well as practicality. They are encouraged to play with many possible approaches and to invent new ones.

Psychology and Education

For students in psychology and education the responsive environment offers a unique opportunity for experimentation and a strong motivation to understand the capabilities of the computer. The environment is a flexible tool for presenting stimuli and eliciting and analyzing behavior. It can be used as a generalized Skinner Box capable of automating experiments since it has the capacity to simultaneously generate patterns of stimuli and reinforcers and to record statistics without interfering with the experience. Students can study perception as an aspect of human activity rather than as an isolated behavior or devise diagnostic tests which do not demand that the subject have verbal facility.

New kinds of learning and student-teacher relationships can be explored. The education student would have the opportunity to observe the child in a learning situation dependent on physical activity rather than traditional passivity. The presence of a commanding 8' X 10' video display, capable of reversing the relative sizes of child and teacher, can create evocative alterations in their respective roles. (Fig. 3) Finally, the ability of the educator to compose interactions within the environment suggests the possibility of developing learning vignettes which could be used to teach a variety of concepts and skills.

Both the education and psychology student would have the use of a potent tool for exploring and molding human behavior.

Art, Music and Dance

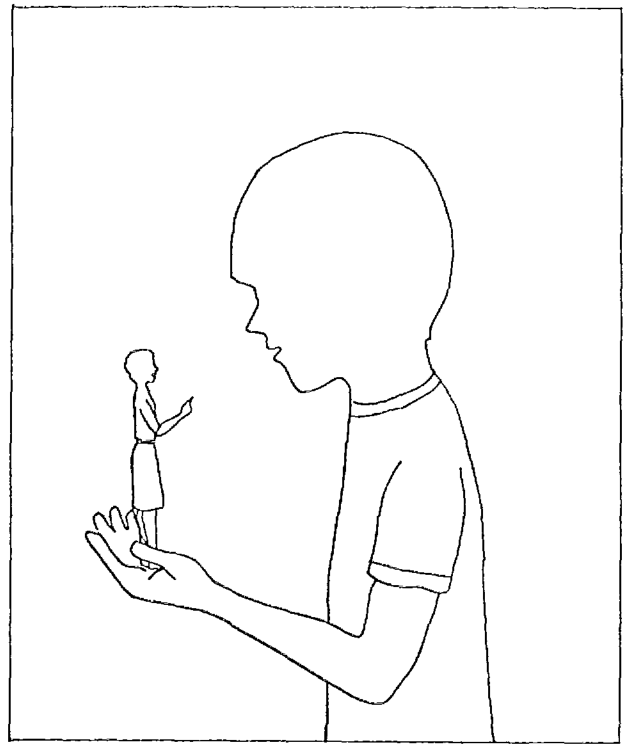
Students in art, music and dance are offered the opportunity to learn about the computer while using a unique aesthetic medium. Visual artists can create exciting real-time visual displays which demand an active viewer. Musicians have the use of a complex instrument which requires that they guide and incorporate the unpredictable actions of the participant into the piece. The dancer can expand his role by composing music through his movements rather than responding to compositions written by someone else.

For students of all the arts, the environment provides the opportunity to participate in the definition of a new medium. This affords an exciting alternative to students who must spend most of their time making weak imitations of well established art forms.

Facility

An ideal facility should include not only the means of controlling the responsive environment, but also the support equipment required to maintain the facility, develop new interactions and analyze the results. The allotted space should be large enough to encourage free movement and to view large rear screen projections. In addition an area is needed for hardware and software development. (Fig. 4)

Test equipment should include a logic analyzer and at least one fast (100 mhz) oscilloscope for digital video circuitry. A computer with a significant software development capability, i.e. several languages, considerable mass storage, printer and several alphanumeric displays, is also desirable. The purpose of this machine would be to edit and compile programs for the computers that actually control the environment. It should be able to communicate with them at full bus rates and be capable of communication with a machine that has a significant arithmetic processing capability for analyzing experiences and learning from them. This communication does



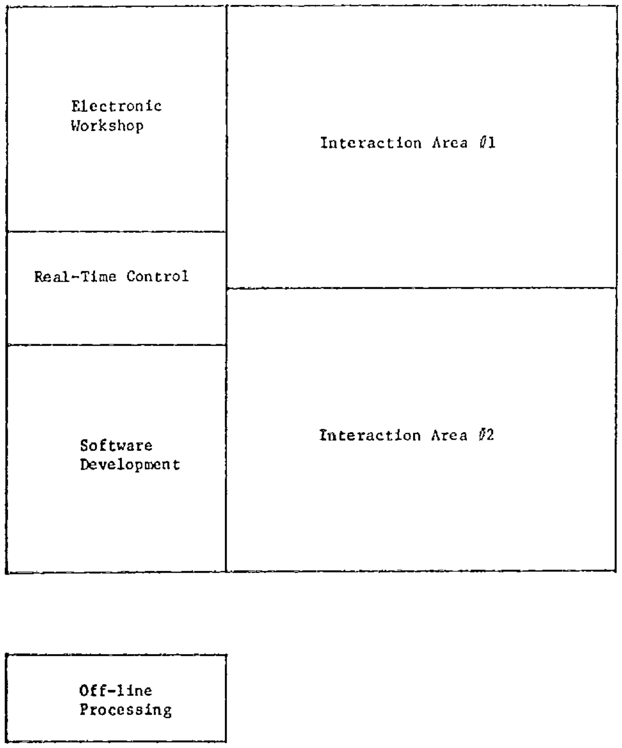
Child and Teacher on Video Display Screen
Fig. 3

not have to be fast. In fact, compatible disk or tape media would be sufficient.

The facility should be connected to a two-way video cable system which would allow its capability to be remoted and also allow it to tap additional immovable resources which might exist at various sites around the campus. The facility would also require a number of black and white television cameras and at least one color video tape recorder and two rear-screen black and white video projectors. Color projectors would be ideal, although the rear-screen variety may still be prohibitively expensive.

A family of standard interface modules would be required to provide discrete and serial I/O, analogue I/O, AC control, optoisolation and small signal amplifiers. These should be plug compatible with each other, so composite functions could easily be created. These interfaces should be protected from the errors of novice students and provide a means of simplifying the addition of new capabilities. Similarly, video control signals should be bussed so they are readily available for new circuits.

The hardware controlling the operation of the environments would consist of a number of processors arranged in a hierarchical structure. (Fig. 5) An Executive Processor would run the operating software for the system as a whole. It alone would be aware of the compositional rules governing the interactions. It would initiate actions on subordinate processors and be notified when they were completed. It would not, however, be involved in the actual moment-by-moment responses of the environment. Rather, it would establish a set of expectations and reflex responses in the subordinate processors, which



The Laboratory Facility
Fig. 4

would actually recognize behavior and select and effect the appropriate response.

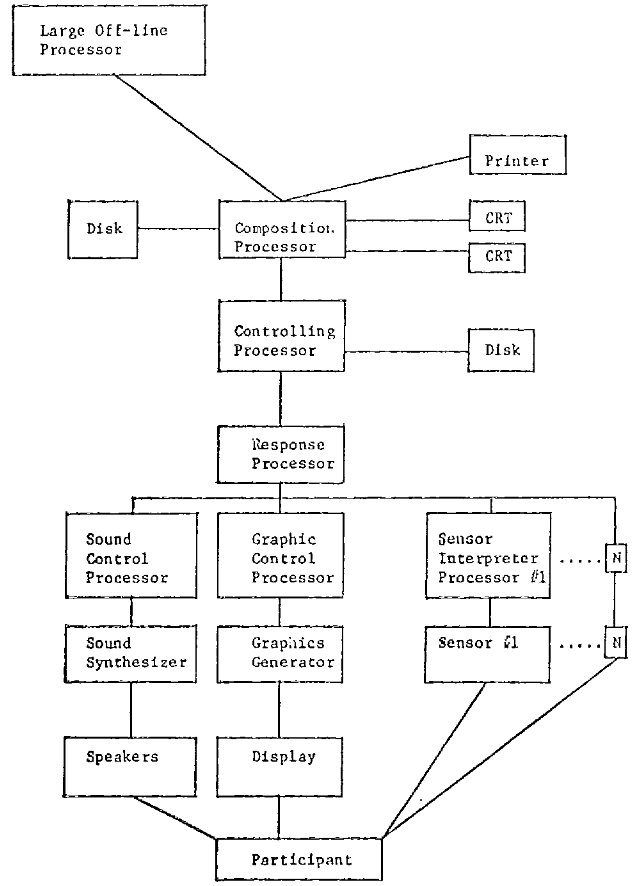
Below this processor would be the Utility Processor and Response Processor. The Utility Processor would stage block transfers between processors, devices and mass storage by means of a multichannel, general purpose DMA processor operating on a 24 bit interface bus connecting all processors and devices.

The Response Processor is the top level of real-time reflex processing. Given a set of expectations, it analyzes the outputs of the various perceptual processors and initiates the desired response on the appropriate graphics or auditory display processor. It also reports the action it has taken to the Executive.

The Perceptual Processors may consist of a variety of specialized machines sensitive to aspects of human behavior. In the past, as mentioned earlier, a grid of 400 pressure sensors was used. Currently, a circuit which digitizes the outline of the participant's video image is being used. The ease of the decision processing at the higher levels depends on the sophistication of the determinations that can be made rapidly at the hardware level.

The graphics processing would require several generators for video graphics elements, processors for saving and modifying live video inputs and elaborate means for combining all of these ingredients into a completely plastic computer video medium involving all of the effects available to both computer and analogue processing.

Sound synthesis in the course has been limited to computer control of conventional synthesizers such as the MOOG. However, at the present time, a very fast digital synthesizer capable of generating extremely complex waveforms is nearing completion. Speech synthesis is an additional option which should be considered in the future.



System Block Diagram
Fig. 5

Conclusion

Such a facility would be an extremely rich vehicle for doing significant work in a number of fields. It would also create a new kind of computer event which would enrich campus and community life.

This type of facility provides an opportunity for students within the University to learn about computers, but it is also a means of reaching those beyond formal academics. The people from the community, who visited the exhibits, were introduced to a non-numeric entity which seemed capable of whimsey and engaged them in a completely individualized interaction, providing a positive exposure to the computer.