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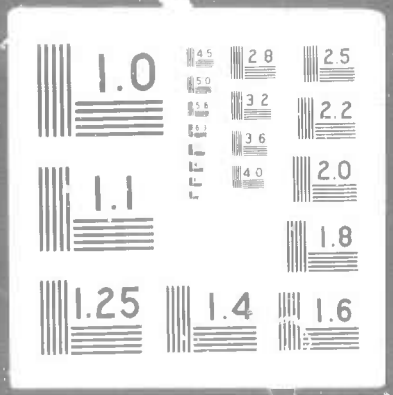

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GRAPHICAL MAN/MACHINE COMMUNICATIONS

University of Utah

TECHNICAL REPORT NO. RADC-TR-68-90
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Principal Investigator

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This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by David Luther, EMIIF under Contract Number AF 30(602)–4277.

Two classes of research activities are being conducted. One is research in information processing system technology, particularly the technology associated with interactive computing. The other is research in application of interactive computing technology to the solution of several significant problems.

The application work reported on is the use of graphics in the solution of partial differential equations in which graphical interactive techniques have been demonstrated to be of very substantial value in the solution of fluid flow problems and curve fitting. Interactive graphical techniques are also being used as a means to extract data from stereoscopic fluoroscopic images of the human heart to permit analysis of its dynamic behavior. Finally, preliminary activity in a rather large scale project to develop a computer aided architectural design system is reported.

Good progress has been made in the development of techniques for producing half-tone photograph like pictures of three dimensional objects whose descriptions are stored in the computer memory. Commonly known hidden surface algorithms for producing such pictures are impractical for objects of large complexity because the amount of computing increases with the square of the object complexity. An algorithm in which the computation is roughly proportional to the first power of the object complexity has been reported. Further research activity is in progress on information storage and retrieval systems and a syntax driven interpreter which is of interest both as an implementation tool for the architectural design project and as a study in computer system organization.

Part I. Summary of Research Activities.

A. The Use of Graphics in the Solution of Partial Differential Equations. Louis A. Schmittroth, Coprincipal Investigator.

Activities have been mainly concerned with creating programming tools to aid in interacting with large Fortran programs.

Charles Brauer has been successful in solving the Navier-Stokes equations of fluid flow on the Univac 1108. The PDP-8-IDI display is being used to monitor the output and to input boundary descriptions with the light pen. One of the main aims of the research is to experiment with the input of the physical boundary conditions from the display. The light pen has proven unsatisfactory for this purpose. Further progress will await the installation of the Sylvania Tablet.

Gary Sandquist has programmed the equations governing the two dimensional time dependent behavior of the neutron flux in a reactor core. This has pointed up the need for a general interpolation program for the output of problems with a sparse mesh. Contours with too few solution points are uninformative. Some research is also being conducted into the control of solution of systems of ordinary equations by finite difference methods. A main calling program and display programs are complete. Another effort to examine the solution of ordinary differential equations in the phase plane has been started and the first displays produced.

D. E. Dallin has started on a program to compute heat transfer coefficients and velocity profiles of a liquid entering a tube. Preliminary numerical analysis is complete and display routines are being developed.

Thomas R. Carter is also working on the Navier-Stokes equations but with a different geometric configuration than that treated by Charles Brauer. Streamlines of the solution are being displayed to monitor the algorithm, but also the ratios of residuals from one interation to the next to provide a way to improve the algorithm.

Scott Bennion has started on a hydrodynamics and radiation diffusion program. This research will use the display for program checkout, control of problem parameters such as time step, solution smoothing, and convergence parameters, and finally, initial problem specification.

Alan Reed has created a small "sub-monitor" for interactive curve fitting using the IDI display. It is general enough to accommodate any input routine, and any fitting algorithm, with a flexible system for specifying which variables of the fitting program are to be controlled from the terminal.

B. Left Ventricular Dynamics Project. Homer K. Warner, Coprincipal Investigator.

The object of this research is to develop means to extract data from stereoscopic fluoroscope images of the human heart to permit analysis of its dynamic behavior. By the use of radiopaque dye in the blood stereoscopic images of the left ventrical are obtained. The general strategy for data extraction is for a human operation to mark the boundaries of the image of the chamber by means of a Sylvania Tablet stylus input for extraction of data from the first frame and for a computer program to track the changing image on subsequent frames. The work has been organized into three phases:

Phase I. In this initial phase, Mr. Richard Robb has written programs through which he can generate from the 1108 computer a variety of solid images on the scope display with these images overlying one another. Other

programs allow him to trace out the border of one of these images with a light pen and select a few points on either side of this border at each vertical position and retain these for later processing. The object of this phase is to familiarize him with the 1108 and the display system and to provide the initial image border approximation which will form the starting point of the subsequent pattern recognition.

Phase II. The object of this is to obtain, in digital form, the image from a 35mm movie film of the fluoroscopic image of the chest following injection of radiopaque media into the left ventricle. Films have been obtained from two experiments done at the Dee Memorial Hospital in Ogden but as yet no successful digital representation has been accomplished.

Phase III. This phase represents the design of the "ultimate" system for which Phase I and Phase II are preparation. A video disc has been ordered from MVR Corporation in Palo Alto. Video images will be recorded for approximately 30 seconds following injection of opaque dye using a television camera focused through an image intensifier on a fluoroscopic screen and a video tape recorder. This data will be copied from tape to disc; a single image on the disc will be replayed over and over and displayed on a monitor television screen. A device will be built which will permit an operator to define the borders of the heart causing the X and Y coordinates of each point on this borderline to be stored in computer memory as a line count and a delay. This matrix of points will then form a "mask" for digitizing this and subsequent frames including only points approximately 1 cm either side of the borderline drawn by the operator. Thus, a tremendous data reduction will be performed prior to digitization. This work is under the direction of Wayne K. Wiscomb.

C. Computer Aided Architectural Design System. Stephen L. Macdonald, Coprincipal Investigator.

Much of the first official six months of this project has been devoted to exposing ourselves and our staff to as many of the technical possibilities of input, processing, storage and output as was consistent with the progress of new ideas. In the past three months, considerable progress has been made in the writing of what we have termed English Algorithms to describe various aspects of the work we wish to perform. These have been done with the cooperation of Stephen Carr of Computer Science and Mr. David Luther on loan from the Rome Air Force Base. The following general ideas have been in progress:

1) Input - A fairly comprehensive study of Topographic Input for Computer Graphics - The State of the Art has been essentially completed and will be available shortly. From this has emerged a new idea based on many related projects to obtain direct input data through the use of a laser flash on which is superimposed a microwave ramp which is then focused as a returning light on a lasing diode array. The measurement of the intensity of light on each diode would then give a gridwork of elevations which could be converted to contours.

2) Processing - What we hope will evolve as a totally comprehensive design system is being formulated, based on three-dimensional geometric shapes which can be manipulated to almost any Space Form. The words Space Form have been used rather than Geometric Primitives or Geometric Shapes because of their implications to designers. These coupled with manipulative curves, section capability, zooming, primitive constraints, rotational ability, dimensioning, and various uses of a light pen and five-key typewriter presently constitute the entire design system. Parts of this process such as The Manipulation of Space Forms, The Manipulation of Curves, Linking Maneuvers for Handling

and Translation, Sectioning, Grouping by Zooming, and Dimensioning have all been tentatively written but not finalized. Other considerations such as Basic or Primitive Constraints, Designating Materials and Attributes, and the study of a comprehensive structural system are now in progress.

A Pert program is being developed for the architectural phase of the project.

3) Storage - Data Storage as it applies to architecture and other design processes involving large volumes of information has been tentatively conceived both for Architecture and the Machine as a completely open-ended system. No interim papers have been written on these yet.

4) Output - Work is now in progress to develop a cutting machine which can produce models directly from graphic computer designs. Systems under consideration are: 4.1 Hot cutting of various density urethane foams, 4.2 Vibration cutting of glass or ceramic foam, and 4.3 The nozzle application of a rapid setting plaster material in the presence of carbon dioxide gas or air.

D. Computer Graphic Techniques. David C. Evans, Principal Investigator.

The urgent need for realistic pictures of three dimensional objects and constructs is evident in many fields. The object of this research has been to develop means to produce photograph like pictures of complex illuminated objects at reasonable cost. In order to do this three important problems must be solved:

1) A good means must be found so that only visible surfaces are displayed.
2) Halftone shading determined by incident light must be provided; much information about the object is provided by this means.

3) A good model for representing arbitrary shaped surfaces must be provided.

Reasonable solutions to these three problems have been found. The usual means of solving the hidden surface problem are satisfactory for only simple objects because the amount of computation required typically grows in proportion to the square of the object complexity. By means of the ingenious use of sorting a new algorithm has been designed and tested in which the amount of computing is greatly reduced and increases only about linearly with object complexity thus making the generation of pictures of very complex objects practical for the first time.

Halftone shading computations have been made reasonable by assuming only first order illumination from a single light source located at the eye of the viewer. This illumination is not the most artistic but pictures produced have been pleasing to look at. The illumination is similar to the single flash illumination of many press photographs.

Rather than building objects from solid objects as has been done, objects are approximated by plane triangular surfaces. Any developable surface can be approximated arbitrarily accurately by small but finite triangles. Computer programs implementing these algorithms have been developed and demonstrated. This work has been described in a paper by Wylie, Romney, Evans, and Erdahl which was presented at the Fall Joint Computer Conference.[1]

Further work in this area is continuing toward improved visual picture quality, better hidden surface algorithms, and general synthesis of synthetic video signals in real time.

An additional graphical technique that is being developed is on line recognition of cursive handwriting. This work is by Mr. Y. T. Kim and will be reported in more detail as the work progresses.

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[1] "Half-Tone Perspective Drawings by Computer," Chris Wylie, Gordon Romney, David C. Evans, Alan Erdahl. AFIPS Conference Proceedings, Fall Joint Computer Conference, 1967, vol. 31, pp. 49-58.

E. Information Processing Systems. David C. Evans, Principal Investigator.

Two general tools which will be used in the architecture design system and other activities of the project are under development.

A syntax driven interpreter which is not only intended to be directly usable as a programming tool but which is also a model for a new computing system is under development by Alan C. Kay.

An information storage system based in part on ideas described earlier by Evans and Leclerc[2] and by Feldman and Rovner[3] is being designed and constructed. An early software simulation of the system is now being designed. Final implementation of this system will include some hardware modification of the UNIVAC 1108 computer of the University of Utah Computer Center.

Further report of these projects will be made as they progress.

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[2]David C. Evans and Jean Yves Leclerc, "Address Mapping and the Control of Access in an Interactive Computer," Spring Joint Computer Conference, 1967, pp. 23-30.

[3]P. D. Rovner and J. A. Feldman, "An Associative Processing System for Conventional Digital Computer," M.I.T. Lincoln Labs Group 23, Technical Note 1967-19, 6 June 1967.

Part II. Description of Facilities.

The central computing facility employed for this research is the Univac 1108 system of the University of Utah Computer Center. This facility is equipped with 131 thousand 36 bit words of core memory and has 6 FH432 high speed drums (1.5 million words at 4 msec average access time) and a Fastrand II (131 million characters at 100 msec access time) as auxiliary memory units.

The laboratory in which the research is done is provided with a Univac type 1004 as a card reader and printer terminal connected by 202 B dataset. The general purpose graphic facility is an Information Displays Inc. display serviced by a local PDP-8 computer which is connected directly to an 1108 channel. The halftone pictures are made using a laboratory oscillograph which is driven by digital to analog convertors attached to the PDP-8.

Part III. Index of Technical Reports.

A. "Half-Tone Perspective Drawings by Computer"
Chris Wylie, Gordon Romney, David C. Evans, Alan Erdahl. Presented at the Fall Joint Computer Conference, Anaheim, California, November 14-16, 1967.

This paper is a brief description of an algorithm for the creation of two-dimensional, half-tone pictures of perspective projections of three-dimensional objects. Only the visible surfaces are displayed; all hidden surfaces are erased. This process is independent of the orientation of the object. The inclusion of half-tone shading was considered important because the illumination of an object gives a viewer much information about the three-dimensionality of the object. A FORTRAN IV program is working on a Univac 1108. Preliminary results indicate that this approach is not only possible, but practical for complex objects.

B. "GS -- Graphics System"
C. Stephen Carr and Lee Copeland

GS is a sub-monitor operating in the 1108 under the 1108 Executive. Its purpose is to make the display hardware easier to use as a peripheral unit to the 1108 computer by providing certain services and a stable programming interface which can be maintained as the graphical equipment is modified. The general services provided include communication with the PDP teletype, display file processing, light button declaration and monitoring, pen tracking and pointing, file manipulation, and control of program swapping in the 1108 computer. The document is a reference manual intended for programmers who are familiar with the 1108, Exec II, and Fortran or Algol.

C. "Unidec Assembler"
C. Stephen Carr

The Unidec Assembler is an assembly program operating on the 1108 computer to produce absolute machine language code for the PDP-8 computer. In our installation the PDP-8 computer is connected directly to an 1108 channel. While the assembly language is similar to that of Macro-8 the syntax and operation of Unidec differs sufficiently from that of Macro-8 to warrant a separate users' manual. The systems are sufficiently similar, however, that one familiar with Macro-8 will have little difficulty learning to use Unidec.

D. "SPEED Speedy Editor"
C. Stephen Carr

SPEED is a typewriter oriented text editor which operates on the UNIVAC 1108. It is intended for use with the Graphics System and is operated from the teletype of the peripheral PDP-8. The region of text being modified is displayed at all times on the Cathode Ray Tube.

E. "DEBUG Conversational Debugger"
C. Stephen Carr

DEBUG is the first of a series of conversational programming tools which are being developed to facilitate the research programming work of our project. The ideas represented here are not original nor are they intended to be. The frontiers of conversational programming may be advanced when a display debugging system is designed and implemented. In the meantime, progress depends on the tools available -- DEBUG is such a tool.

DEBUG currently operates on the 1108 on-line typewriter. Binary decks are available which are loaded with the user's program. With the advent of demand mode processing, DEBUG will operate in an identical fashion from the teletypewriter of the PDP-8. DEBUG is used to examine and modify programs in the 1108 core storage, to execute instructions one at a time, and to control execution of the user's program.

F. "1108 Segment Storage System"
C. Stephen Carr and Alan C. Kay

Present day computing systems make too great a distinction between core storage, fast drums, and mass storage. Low level physical device handling subroutines are provided, but they are not at the level which users wish to interface with storage hardware.

The 1108 Segment Storage System (S^3) provides the user with a large virtual memory where segments move automatically to appropriate storage levels as required. S^3 manages user data at four levels: (1) core, (2) fast drums, (3) Fastrand, and (4) tapes. At the start of a run, all data resides at levels three and four. On demand, segments of data or procedure are automatically moved to core (level one) for random access. When additional space is required in core, a segment is dropped to the fast drums (level two) to make room at the top. When space at level two is exhausted, a segment is dropped from level two to level three, and so on.

The second important service performed by S^3 is organization of the total storage space as a variable number of variable length segments bound together as required. The length of each segment varies dynamically with the user's requirements.

G. "Three-Dimensional Input for Computer Graphics"
Jay A. Schadel and Stephen L. Macdonald

This paper states the need for three-dimensional input for architectural work using computer graphics. The paper consists of two sections. The first deals with laser scanning; x, y being a mechanical scan, and z being a modulated laser source timing the reflected laser beam. The second section explains the use of photogrammetry for x, y, z information. (Photogrammetry is the science of measuring using photographs.) Examples are given comparing old methods of ground survey with photogrammetry.

This report is a revised edition of the semi-annual technical report that was distributed earlier for the period ending 30 November, 1967.