AD 738293

GRAPHICAL MAN/MACHINE COMMUNICATIONS

David C. Evans

University of Utah

SEMI - ANNUAL TECHNICAL REPORT

1 January 1971 - 31 May 1971

Approved for public release;
distribution unlimited.

This research was supported by the
Advanced Research Projects Agency
of the Department of Defense and was
monitored by Murray Kesselman, RADC
(ISCE), GAFB, N.Y. 13440, under
contract F30602-70-C-0300.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

University of Utah
Salt Lake City, Utah 84112

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

None

3. REPORT TITLE

GRAPHICAL MAN/MACHINE COMMUNICATIONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Semi-Annual Technical Report for period 1 January 1971 to 31 May 1971.

5. AUTHOR(S) (First name, middle initial, last name)

David C. Evans

6. REPORT DATE

June 1971

7a. TOTAL NO. OF PAGES

27

7b. NO. OF REFS

14

8a. CONTRACT OR GRANT NO.

F30602-70-C-0300

b. PROJECT NO.

ARPA Order No. 829

c. Program Code Number 6D30

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

RADC-TR-71-212

10. DISTRIBUTION STATEMENT

Approved for public release;
distribution unlimited

11. SUPPLEMENTARY NOTES

Monitored by Rome Air Development Center, ISCA, Griffiss Air Force Base, New York 13440

12. SPONSORING MILITARY ACTIVITY

Advanced Research Projects Agency
Washington, D.C. 20301

13. ABSTRACT

This document includes a summary of research activities and facilities at the University of Utah under Contract F30602-70-C-0300. Information conveys important research milestones attained during this period by each of the four major research activities:

1 - Computer Graphics Techniques

2 - Computing Systems

3 - Digital Waveform Processing

4 - Applications

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
ARPA network						
computer animation						
computing systems						
curved surfaces						
digital deresonation						
digital waveform processing						
graphics techniques						
half-tone pictures						
hidden line removal						
hydrodynamic/radiation diffusion						
music notation						
nonlinear filtering						
real-time modeling						
shading						
three-dimensional						

PUBLICATION REVIEW

This technical report has been reviewed and is approved.

Murray Kesselman

RADC Project Engineer

TABLE OF CONTENTS

LIST OF FIGURES

PART I. SUMMARY OF RESEARCH ACTIVITIES

The objective of the graphical man/machine communication effort is the development of computers and computing techniques that people may use interactively in real time to extend their problem-solving capability, and to work cooperatively by means of improved communications via computer. This report summarizes the progress made in the four major areas: 1) computer graphics techniques, 2) computing systems, 3) digital waveform processing, and 4) applications.

A brief resume of the overall objective of each major research area is presented, along with highlights of the significant research findings that occurred during the period of 1 January 1971 to 31 May 1971.

A. COMPUTER GRAPHIC TECHNIQUES

The senior investigators in computer graphics techniques are David C. Evans (faculty), Ivan E. Sutherland (faculty), Ronald D. Resch (faculty), and Robert E. Stephenson (faculty). There are two aspects of this research: 1) the development of graphics systems that are readily accessible to computer system users and that may be easily used by them for practical applications, e.g., graphic programming languages and the representation of information for graphic systems; and 2) the development of primary graphic techniques for the realistic dynamic display of three-dimensional objects.

Efforts are directed to the solution of computational problems of real-time windowing, perspective transformations, hidden-surface elimination, and the production of shaded color representations of photograph-like quality. Emphasis is placed upon the capability of the user to interact with the structured data representation of the object being viewed by the graphic system, rather than emphasizing the graphic system as a picture generator by itself.

Computer Display of Curved Surfaces

During this period, a unique method of displaying curved surfaces was developed by Henri Gouraud (graduate student). Gouraud [12] describes a method for producing half-tone pictures of curved surfaces. He uses a small polygon approximation of the surface to solve the hidden parts detection, then computes the shading on each polygon in such a way that discontinuities between adjacent polygons disappear. This restores the apparent smoothness of the surface and greatly increases the realism of the pictures produced with this method.

Historically, the need for such a technique arose when it became evident that the line drawings previously used were misleading because the spacing of the lines portraying a surface depended not only on its geometry, but also on the behavior of the parameters describing the surface. The shading techniques previously developed at the University of Utah by Romney [1], Warnock [2], and Watkins [3] *seemed* to be "the way to go", but introduced two problems:

1. Hidden parts suppression for curved surfaces is not easily done;
2. Approximation of the surface with small planar polygons, although better than the line drawing method, still conveyed some undesirable visual effect caused by the artificial texture brought about by the parameter spacing.

In attempting to represent a scene, the shading technique is subject to all the psychological illusions present in the visual process. Of interest is a phenomenon thoroughly investigated by Mach [4] which explains how the retina performs some kind of two dimensional filtering on the shading function of a scene. Each neuron, depending on the intensity of the light it receives, interacts with its neighbors and modifies their performances. The result of this interaction will be an attenuation of the low spatial frequencies and an amplification of the high spatial frequencies present in the shading. Discontinuities in the value of the shading give a "fluted" aspect to each of the steps. A discontinuity in the first derivative of the shading gives the illusion of a small bump along the edge between two differently shaded surfaces.

Warnock and Romney had produced pictures of curved surfaces by approximating them with a large number of small planar polygons. Because of the Mach band phenomenon, this method produced pictures in which each small polygon was distinctly visible. Using Watkins' algorithm the author produced pictures of rational Coons patches [5], treating each grid element as a polygon. The polygons thus obtained were not necessarily planar, but the fact that Watkins' algorithm accepts nonplanar polygons was very helpful at that point. As in the case of Warnock's and Romney's pictures, each polygon was very clearly visible and the grid had not disappeared.

From the explanation of the Mach band distortion, it appears that in order to correctly represent the smooth aspect of a curved surface, the shading rule on this surface has to be continuous in value and, if possible, in derivative. One way to achieve this would be to increase the number of polygons approximating the surface, but this is impractical for storage and time reasons. The approach described by Gouraud is to keep the polygon approximation of the surface, but to modify slightly the computation of the shading on each polygon so that continuity exists across polygon boundaries.

The shading rule described gives the illusion of a smooth curved surface when, in fact, this surface is described by a set of small polygons. It was necessary to keep this polygon approximation so that the computation of intersections could be handled easily using existing methods.

The generality and the simplicity of the smooth shading technique developed by Gouraud make it possible to represent with great realism a large new class of objects including: several airplanes (Figures 1 and 2), a car, some mathematical surfaces, and a model of the face of the author's wife (Figures 3 and 4). It is true that in most respects, this model does not do Mrs. Gouraud justice, but nevertheless the likeness between the two compared with the results obtained with previous methods constitutes the best example of the qualities of the smooth shading technique.

Figure 1: Polygon Approximation of a B-58.

Figure 2: B-58 with Smooth Shading.

Figure 3:

Polygon Approximation of Author's Wife.

Figure 4:

The Smooth Shading Technique Applied to the Same Geometric Data as in Figure 3.

Graphics Workshop

During this period, Ivan Sutherland (faculty) and Ron Resch (faculty) conducted a graphics workshop in which 20 graduate students who had completed the required graphics courses in Computer Science made experimental use of the graphic techniques developed under the contract.

The goal of the workshop was to: (1) give the students first-hand experience with graphics state-of-the-art, and (2) to explore practical means to produce desired pictures exercising as much parametric control as possible.

The workshop proved to be a tremendous training ground for future researchers. Students who showed particular aptitudes in this area were given the opportunity to become researchers on the ARPA contract, as new positions were available. The class offered us a new way to build potential researchers in computer graphics while letting them learn about the state of the art to gain practical experience.

One outcome of the class was the development of an off-line picture processing technique. The off-line picture processor is a special program that enables several picture files made by many different students to be run in one sitting, by the computer operator, during non-prime time hours. This makes the pictures much more economical to produce and frees the system during prime

Figure 5: Simplified Model of the Supersonic Transport (SST) Made From Several Quadric Patches.

Figure 6: A Lamp Shade Described with Quadratic Equations.

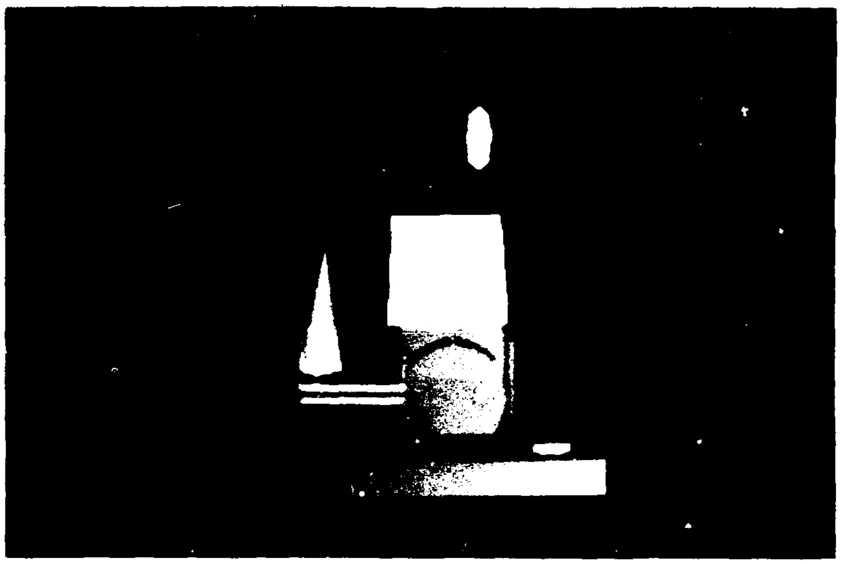

Figure 7: A Graphical Presentation of the Pole and Barn Relativity Paradox.

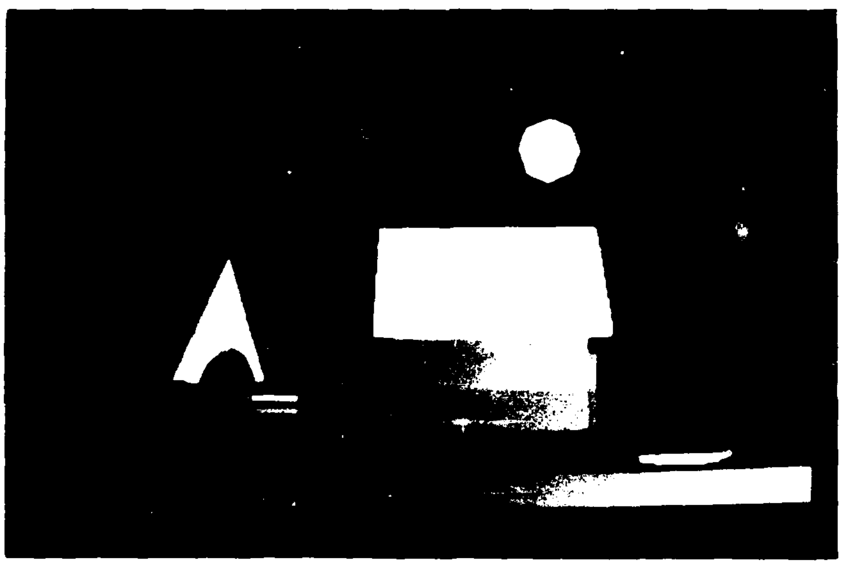

Figure 8: A Graphical Presentation of the Pole and Barn Relativity Paradox.

time hours for other research activities. Figures 5-8 are samples of the pictures produced by the students.

As indicated by the sample photos shown, the students refined, developed, and perfected the system to make pictures. Once individual problems are solved and basic techniques are developed, they can then be applied to problems in any area, i.e., pilot training, terrain familiarization, etc.

B. COMPUTING SYSTEMS

Computing systems senior investigators are: Roy A. Keir (faculty), and Charles L. Seitz (faculty). These investigators have as their common interest real computing systems with radically improved characteristics for direct use by people, such as: communication devices, simulation and modeling devices, and computational instruments. Emphasis is not primarily on raw computational capacity, but rather on system problems of the direct use of these machines by people in a natural way so that procedures may be easily described and information may be simply represented.

Experimental Computer Organization Laboratory

The major efforts of this laboratory during the past five months were concentrated on developing the Meta-4 computer for use as a base for testing novel computer organizations. Digital Scientific Corporation has failed to meet its commitment to bring the machine up to its advertised capability, and further postponement will cause re-examination of the desirability of final acceptance. A decision to refuse acceptance of the machine would mean the waste of considerable effort expended during this period in developing input-output equipment and PDP-10 support programs for this machine.

An assembler for Meta-4 ROM control programs is nearly complete and has been run successfully in its partially completed form on the PDP-10. A simulator has also been completed in part, but has not received extensive testing.

Teletype input is working, and block transfers to and from the salvaged video disk have been demonstrated. Work has begun on handlers for the Tektronix 611 storage scope and a general purpose input interface.

The work of E. Eastman on data structures and their processors has advanced, though slowly, and now permits creation, tracing, and modification of list structures in a manner compatible with hardware implementation. Extension of this work to structures more complicated than lists is under way, and an APL interpreter based on similar principles is well along.

C. DIGITAL WAVEFORM PROCESSING

Recent research performed at Utah under the direction of Dr. Thomas G. Stockham, Jr., into the problem of eliminating blur and reverberation from digital signals has led to the invention of a statistical deconvolution method based on the theory of homomorphic filtering. Several applications have been considered theoretically with practical experience having been gained to varying degrees in each. These applications include the digital deresonation of acoustic recordings, the sharpening of electrocardiographic waves for more precise determination of waveshape and rhythm, the dereverberation of geological soundings, the removal of uncertain blur from photographs, and the elimination of multipath in communications. The maximum of experience has been gained on the first of these, the least on the last. Active Ph.D. thesis research on the subject of homomorphic image deblurring has begun at M.I.T. as a result of the acoustic dereverberation experiments at Utah as described in a lecture to students at M.I.T. in the spring of 1970. This progress report will concentrate on advances made in the first area. That application involves the removal of recording horn resonances from old acoustic discs. A major distortion in these discs is the convolution of the recording horn impulse response with the voice waveform. This impulse response is estimated by chopping the recorded signal into many one-second intervals and averaging logarithms of the corresponding Fourier transforms. Since the homomorphic theory tells us that the convolutional distortion of the original voice waveform appears as a sum rather than a convolution after the transformation just described, averaging several such segments will tend to cause the recording horn impulse response to emerge in the form of its log Fourier transform. Thereafter, it can be removed in a digital convolution involving a computed system inverse. The resulting inhance sound is generally considered far more acceptable and informative than the original, although a slight increase in apparent surface noise is induced.

A slightly hidden defect in the above analysis is that when the average of the Fourier transforms of the sections of music is formed, this average not only includes the contribution due to the impulse response of the horn, but also contains the frequency biases of the human voice. At first it was thought that these biases were relatively inconsequential and could be ignored in the restoration process. In the last quarter it was decided to check this assumption by making the same averaging measurements on an unreverberated segment of music as had been made on the reverberated ones. The average of the logarithm of the Fourier transform of the unreverberated music should contain only the frequency biases due to human voice. Once obtained, the human voice frequency bias information was reinserted at the appropriate point in the deconvolution process outlined above, to achieve a much upgraded result. Restoration studies concentrating on the voice of Enrico Caruso have produced a great deal of increased insight into the performance of this artist, and have exemplified the effectiveness of this deconvolution technique.

The social and artistic value of the research is not less exciting than the furtherance that has been given to our understanding of the other applications of statistical convolution described earlier. For example, it is felt that the notion of restoring spectral bias is a key issue in homomorphic image deblurring, a most promising powerful technique.

D. APPLICATIONS

The applications area includes a small set of carefully selected problem areas that will provide feedback to the researchers in the first three research categories and will provide a mechanism for publication of newly learned techniques to people outside the relatively closed community of computer science researchers.

Involved in the applications activity are Winfred O. Carter (faculty), Henry N. Christiansen (faculty), Harvey S. Greenfield (faculty), William J. Hankley (faculty), Anthony C. Hearn (faculty), Louis A. Schmittroth (Adjunct Professor), and Robert E. Stephenson (faculty). Applications are in the field of computer-aided design, techniques for solving mathematical problems, the modeling of complex geometrical structures, the modeling of a collection of fluid-flow problems (including the flow of blood in the human circulatory system), and the use of computers in education. There are a large number of senior investigators listed in connection with these application problems, but these problems are in the main supported jointly by the University of Utah and other agencies including the National Institutes of Health; hence this work does not represent an unreasonable fraction of the total resources.

A Method of Solution for Hydrodynamics and Radiation Diffusion as a Multi-Material Problem in One Dimension

In this research [14], Scott Thomas Bennion, graduate student, formulates and reports upon the implementation of a numerical system for the solution of hydrodynamics and radiation diffusion as a multi-material problem in one dimension. A parametric system is developed in which the program parameters may be dynamically altered and studied as to their worth and effectiveness. The system is designed specifically for use within an interactive man-machine environment wherein the user becomes an integral part of the final solution.

The largest and fastest computers have always been used for the solution of partial differential equations, especially nonlinear equations which are used to describe some physical phenomenon in time and space. Computer programs for this class of problems are large, and their creation requires a joint effort of many individuals over long periods of time, most of which is consumed by the debugging process. Once such a program has been developed, its use requires a great deal of data to specify the desired physical system. It also requires an intimate knowledge of the workings of the program and a vast amount of intuition and experience into the mechanics of the physical processes involved.

Even without difficulties, such problems run for hours at a time on the most modern computers in the typical batch mode. At some time after what may develop into days and weeks of aborts, restarts, parameter changes, program patches, reconfigurations and the like, the user finally acquires several edge feet of printed output, and perhaps a few computer generated graphs which represent the solution to his problem. He must then examine, plot and otherwise become familiar with this output data and make judgments as to its validity and applicability within the constraint of the system being designed or simulated.

With the advent of multiprogramming, time-sharing, and real-time problem solving at a remote console, new hardware and software tools are being developed to allow the programmer and the user to become an active part of the checkout and running process of a program. While this document reports on the developments of a medium size program within the rudiments of such an interactive environment, its primary emphasis is placed upon the derivation of a numerical system for the solution of hydrodynamics and radiation diffusion as a multi-material problem in one dimension. The system is developed parametrically in a very general form. Thus, the user is able to dynamically configure the system into a form best suited for his immediate needs through the program parameters. The technique is not unlike that of adjusting and tuning a fine piece of complex mechanical equipment. It also inherits many of the disadvantages of such mechanical systems, primarily the difficulty of dynamically changing the program.

In conclusion, the model developed by Bennion and the subsequent calculations indicate that the numerical methods are reasonable and are capable of giving valid results. With the advent of better computing tools, the solution techniques appear even more palatable. The development of the straight-forward radiation diffusion scheme was an early (five years ago) revolt against the first order expansion techniques as used by [10]. The results seem to bear out the fact that these equations are at least as good as those used in the past. Other recent analysis and work done, notably by Burton Wendroff [11], seems to indicate that this approach has a great deal of promise.

PART II. FACILITIES

During this period, the decision was made to upgrade the PDP-10 computing system through the addition of TENEX software and paging hardware. The first changes in the system will begin in June with TENEX installation expected in July.

We recently acquired a DX-10 interface from System Concepts to solve bandwidth problems between the time-sharing PDP-10 and the PDP-9. These problems were caused by the transmission of large quantities of graphic information from the PDP-10 to the PDP-9 for display on the Univac 1559 scopes.

The previous connection was an I/O buss connection through a DEC DA-10. The DX-10 is designed to be a memory buss connection, thus requiring less CPU time for data transmission. New software has been put into the PDP-9 and PDP-10 to use this new hardware. The software is currently operational and the system is now performing with the expected improved transmission characteristics.

ARPA NETWORK

The Network Control Program was written and checked out for both the first and second protocols. The Initial Connection Protocol was implemented and tested. We have very recently been able to log into the TENEX System at BBN, and they have logged into our system, however we have been unsuccessful in logging into anyone else. Our plans for using the network have been delayed significantly by the lack of software at other network sites.

The NCP was written as a user program rather than as part of the executive system. In addition, it was written in a high level language rather than assembly code. This permitted quick implementation and easy debugging at the expense of some efficiency. This implementation was made possible by the existence of an interprocess communication subsystem developed and implemented by our PDP-10 systems programming group.

PART III. PUBLICATIONS AND PRESENTATIONS

1 January 1971 to 31 May 1971

Following is a listing of presentations and publications made by Computer Science Department personnel during the reporting period related to ARPA sponsored projects and/or activities. This listing is included merely to indicate the scope of exposure our work has had during this period and not as a means of announcing new research discoveries made under the contract. All significant information contained in either the presentations or written articles has been previously reported on an individual basis.

Evans, D. C. "Computers in Industry", talk given at the General Motors Technical Center, Warren, Michigan, March 23, 1971.

Gouraud, Henri "Continuous Shading of Curved Surfaces", _IEEE Transactions on Computers_, Vol. C-20, No. 6, June 1971, page 623.

Greenfield, H. S. "Computer Graphics and the Application to the Artificial Heart", presented at the Physics Colloquim Series, Utah State University, Logan, Utah, May 3, 1971.

________________ "Hemodynamic Basis of Atherosclerosis", presented at the Intermountain Regional Medical Program Course (Hemodynamic Basis of Cardiologic Practice), Salt Lake City, Utah, May 3, 1971.

________________ "New Job for the Busy Computer: Designing Artificial Heart Valves", <u>Electronic Design</u>, Vol. 3, February 1971, page 27.

________________ "Rheology of Blood Flow", Series of ten lectures, Cardiovascular Research and Training Institute, University of Utah, Winter Quarter 1970-1971.

________________ World Book Encyclopedia: Science Annual 1971, under Computer Section: Computer Simulation Significant Advance (H. Greenfield's Investigations), page 291.

________________, and T. M. Cannon "Adaptability of Computer Graphics to Studies of Atherosclerosis Pathogenesis", presented at the Sixth Annual Meeting, Association for Advancement of Medical Instrumentation, March 18-20, 1971, Los Angeles, California.

________________, D. Vickers, I. Sutherland, W. Kolff and K. Reemtsma "Moving Computer Graphics Images Seen from Inside the Vascular System", 1971 Proceedings of American Society for Artificial Internal Organs.

Hearn, A. C. "Applications of Symbol Manipulation in Theoretical Physics", <u>Proceedings of Second Symposium on Symbolic and Algebraic Manipulation</u>, International Hotel, Los Angeles, California, March 23-25, 1971.

____________ "REDUCE 2", A Program and Language for Algebraic Manipulation", <u>Proceedings of the Second Symposium on Symbolic and Algebraic Manipulation</u>, International Hotel, Los Angeles, California, March 23-25, 1971.

Lee, R. M. "Using a Computer Display to Model a Complex Vibrating Surface", <u>The Journal of the Acoustical Society of America</u>, Vol. 49, No. 1 (Part 1), January 1971.

Seitz, C. L. "Asynchronous Machines Exhibiting Concurrency", Project MAC Conference on Concurrent Systems and Parallel Computation, 1970 ACM Conference Record.

Stephenson, R. E. and R. P. Burton "Computer Animation of Halftone Images for the Display of Calculated Molecular Motion and Structure", The Proceedings of the Purdue 1971 Symposium on Applications of Computers to Electrical Engineering Education, April 26-28, 1971, page 118.

__________, and K. F. Brown "Improved Understanding of Circuit Behavior by Computer Manipulation of Primitives", The Proceedings of the Purdue 1971 Symposium on Applications of Computers to Electrical Engineering Education, April 26-28, 1971, page 446.

Stockham, T. G., Jr. "Digital Deresonation of Acoustical Recordings", talk given at the Eighty-First Meeting of the Acoustical Society of America, Washington, D.C., April 1971.

__________ "Enrico Caruso Revisited: Digitally", talk given at the Artificial Intelligence - Computer Science Seminar, Department of Computer Science, Stanford University, April 1971.

__________ "New Directions for Communications Theory in Digital Signal Processing", talk given at the IEEE Workshop on New Directions in Communications Theory, St. Petersburg, Florida, April 1971.

__________ "Nonlinear Processing of Images", talk given at The C-Division Seminar, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, January 1971.

__________ "Some Activities in Digital Picture Processing and Processing of Acoustic Signals", talk given at the Communications and Computer Seminar. Department of Electrical Engineering, University of Southern California, March 17, 1971.

__________ "Some Activities in Digital Picture Processing", talk given at the Bell Telephone Laboratories, Murray Hill, New Jersey, January 1971.

__________ "Some Activities in Digital Processing of Acoustic Signals", talk given at the Bell Telephone Laboratories, Murray Hill, New Jersey, January 1971.

Vickers, D. L. "Computer Graphics and the Head-Mounted Display", talk given at the Fifty-Fourth Annual Meeting of the Mathematical Association of America, Rocky Mountain Section, Ogden, Utah, May 7, 1971.

__________ "The Head-Mounted Display as a Tool", talk given at the Bio Engineering - Bio Physics Seminar, LDS Hospital, Salt Lake City, Utah, February 9, 1971.

BIBLIOGRAPHY

1. G. W. Romney, "Computer Assisted Assembly and Rendering of Solids," Department of Computer Science, University of Utah Technical Report TR 4-20, 1970.

2. J. E. Warnock, "A Hidden Surface Algorithm for Computer Generated Halftone Pictures," Department of Computer Science, University of Utah Technical Report 4-15, June 1969.

3. G. S. Watkins, "A Real Time Visible Surface Algorithm," Department of Computer Science, University of Utah Technical Report UTEC-CSc-70-101, July 1970.

4. F. Ratliff, *Mach Bands: Quantitative Studies on Neural Networks in the Retina,* San Francisco: Holden-Day Publishers, 1965.

5. S. A. Coons, "Surface for Computer-Aided Design of Space Forms," M.I.T., Cambridge, Mass., Project MAC, Report MAC-TR-41, June 1967.

6. K. W. Whitelock, "The Musigraph - A Graphic Music Recorder," Masters Thesis, University of Utah, 1949.

7. L. A. Hiller and R. A. Baker, "Automated Music Printing," *Journal of Music Theory,* 9:(1)129, 1965.

8. Tektronix, Inc., "Permanent Copies from the Tektronix T4002..." *Datamation,* 17:(8)82, 1971.

9. L. A. Hiller, Personal Telephone Conversation, March, 1971.

10. A. N. Cox, R. R. Brownlee, and D. D. Eilers, "Time Dependent Method for Computation of Radiation Diffusion and Hydrodynamics," *Astrophysics Journal,* 144, pp. 1024-1037, 1966.

11. B. Wendroff, "The Initial Value Problem," University of Denver Report MS-6904, 1969.

12. H. Gouraud, "Computer Display of Curved Surfaces," Department of Computer Science, University of Utah Technical Report UTEC-CSc-71-113, June 1971.

13. P. Knowlton, "Interactive Communication and Display of Keyboard Music," Ph.D. Thesis, Dept. of Electrical Engineering, Division of Computer Science, University of Utah, June 1971.

14. S. Bennion, "A Method of Solution for Hydrodynamics and Radiation Diffusion as a Multi-Material Problem in One Dimension," Department of Computer Science, University of Utah Technical Report UTEC-CSc-71-114, June 1971.