APPLICATION OF COMPUTER GRAPHICS TO INSTRUCTION

by

David A. Carlson[1] and Clyde E. Work[2]

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[1]Assistant Professor of Engineering Graphics and College Coordinator of Interactive Graphics, College of Engineering, Michigan Technological University.

[2]Professor of Engineering Mechanics and Associate Dean, College of Engineering, Michigan Technological University.

INTRODUCTION

Engineers have always communicated their ideas and information in graphical as well as written and oral forms. Graphical communication via the chalk board, projection screen and handouts, has played a key role in the teaching of engineering and many other disciplines. However, personal imagination, drawing skills and time constraints always limit the extent to which graphics can be used to enhance teaching.

With the advent of powerful high speed digital computers providing graphics capabilities at affordable prices, the opportunity to make significant advances in improving our teaching is now at hand. This paper describes some of the graphics oriented computational machinery that has been assembled at Michigan Technological University, some supporting software and peripheral devices, and some efforts that are being made to utilize it in the classroom.

GENERAL APPROACH AND PHILOSOPHY

Michigan Tech's computer graphics effort approaches graphics usage and capability at three levels.

1) Micro computer based graphics systems for broad usage in the classroom both for demonstration and hands on experience.

These system/lab networks are being developed primarily at the departmental level with requisite software and peripheral devices tailored to individual departmental needs. Apples, TRS-80's, Tetak's, and Cromemcos would be examples.

2) Mini and super mini based graphics systems at the departmental/college level (with emphasis on the latter) for driving sophisticated state of the art graphics-analysis software packages.

These systems are part of a network being developed to meet our needs that require capabilities beyond those of the micro based systems. The student use of these systems and software will be limited mostly to upper division classes. They do, however, provide excellent teaching tools for use at all levels of instruction. Current examples are our IBM 4341 DEC 11/34 and Data General Nova systems.

3) Experimental/research systems dedicated to expanding the current technology base while providing the capabilities for new applications development.

In defining our needs in this manner and as a result of careful planning, the requisite areas of overlap between levels and their capabilities are being developed to facilitate the smooth transition of the learning curve between them. This will provide students with a continuum of exposure, experience, and usage that will give them the background in computer graphics increasingly demanded by industrial recruiters.

Michigan Tech's fundamental philosophy is to devote local and state funds to develop a basic system and use research dollars to extend these capabilities to new and expanding endeavors, applications, and advancements, rather than reinventing capabilities already developed and available

on the open market at competitive prices.

OVERVIEW OF TWO GRAPHICS SYSTEMS

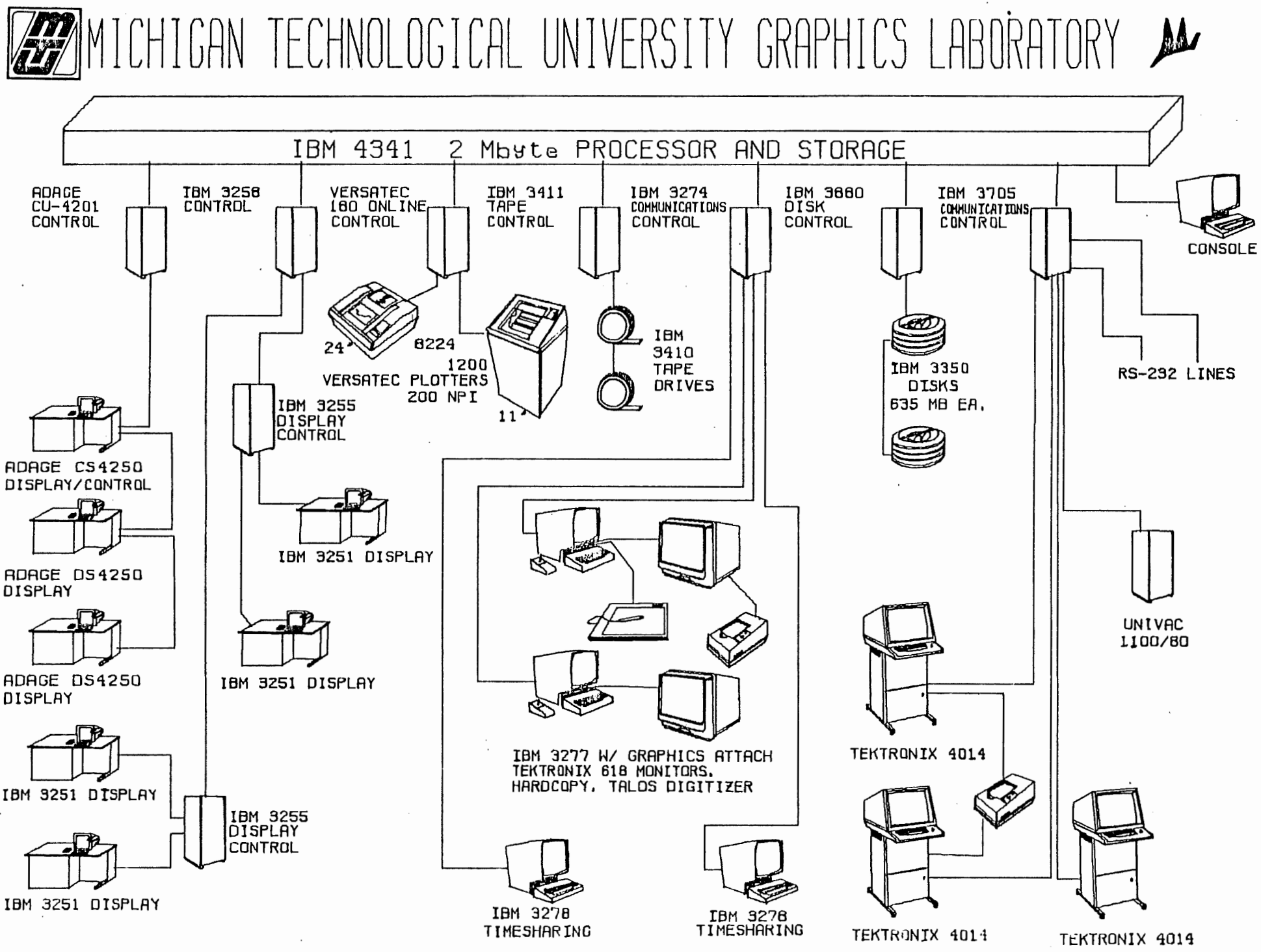
A. IBM Based Graphics Laboratory

The Michigan Tech computer graphics laboratory consists of an IBM 4341 computer system running under the VM operating system with a variety of graphical devices for user interaction. The main computer, housed in the Administration Building, is connected to the laboratory site which is located in the Mechanical Engineering-Engineering Mechanics Building. Input and output lines are available to connect the graphics facility with other computer facilities located directly in the teaching and research laboratories.

The system hardware is described in schematic form in Figure 1. Note that the system currently supports vector refresh (7), storage tube (5), and alpha numeric type devices (5). The vector refresh terminals (IBM 3251's and Adage 4250's) each have a light pen, alpha-numeric keyboard, and a lighted 32 key function keyboard. The storage tube devices are used singly or in pairs as in the IBM 3277 dual screen work stations.

The software available includes the CADAM drawing system, Fortran and APL compilers, and related graphical support libraries. In addition, Michigan Tech is acquiring, through an educational arrangement with Structural Dynamics Research Corporation of Cincinnati, Ohio, its' state of the art analysis software tools for a computer aided engineering thrust in the Mechanical Engineering-Engineering Mechanics

Figure 1.


MICHIGAN TECHNOLOGICAL UNIVERSITY GRAPHICS LABORATORY
IBM 4341 2 Mbyte PROCESSOR AND STORAGE
ADAGE CU-4201 CONTROL
IBM 3258 CONTROL
VERSATEC 180 ONLINE CONTROL
IBM 3411 TAPE CONTROL
IBM 3274 COMMUNICATIONS CONTROL
IBM 3880 DISK CONTROL
IBM 3705 COMMUNICATIONS CONTROL
CONSOLE
24"
8224
1200
VERSATEC PLOTTERS
200 NPI
11"
IBM 3410 TAPE DRIVES
IBM 3350 DISKS 635 MB EA.
RS-232 LINES
IBM 3255 DISPLAY CONTROL
ADAGE CS4250 DISPLAY/CONTROL
ADAGE DS4250 DISPLAY
ADAGE DS4250 DISPLAY
IBM 3251 DISPLAY
IBM 3251 DISPLAY
IBM 3277 W/ GRAPHICS ATTACH TEKTRONIX 618 MONITORS, HARDCOPY, TALOS DIGITIZER
UNIVAC 1100/80
TEKTRONIX 4014
IBM 3251 DISPLAY
IBM 3251 DISPLAY
IBM 3255 DISPLAY CONTROL
IBM 3278 TIMESHARING
IBM 3278 TIMESHARING
TEKTRONIX 4014
TEKTRONIX 4014

Department.

This system and software library is growing and will be replicated in whole or in part as the needs and demands grow throughout the College of Engineering and the University.

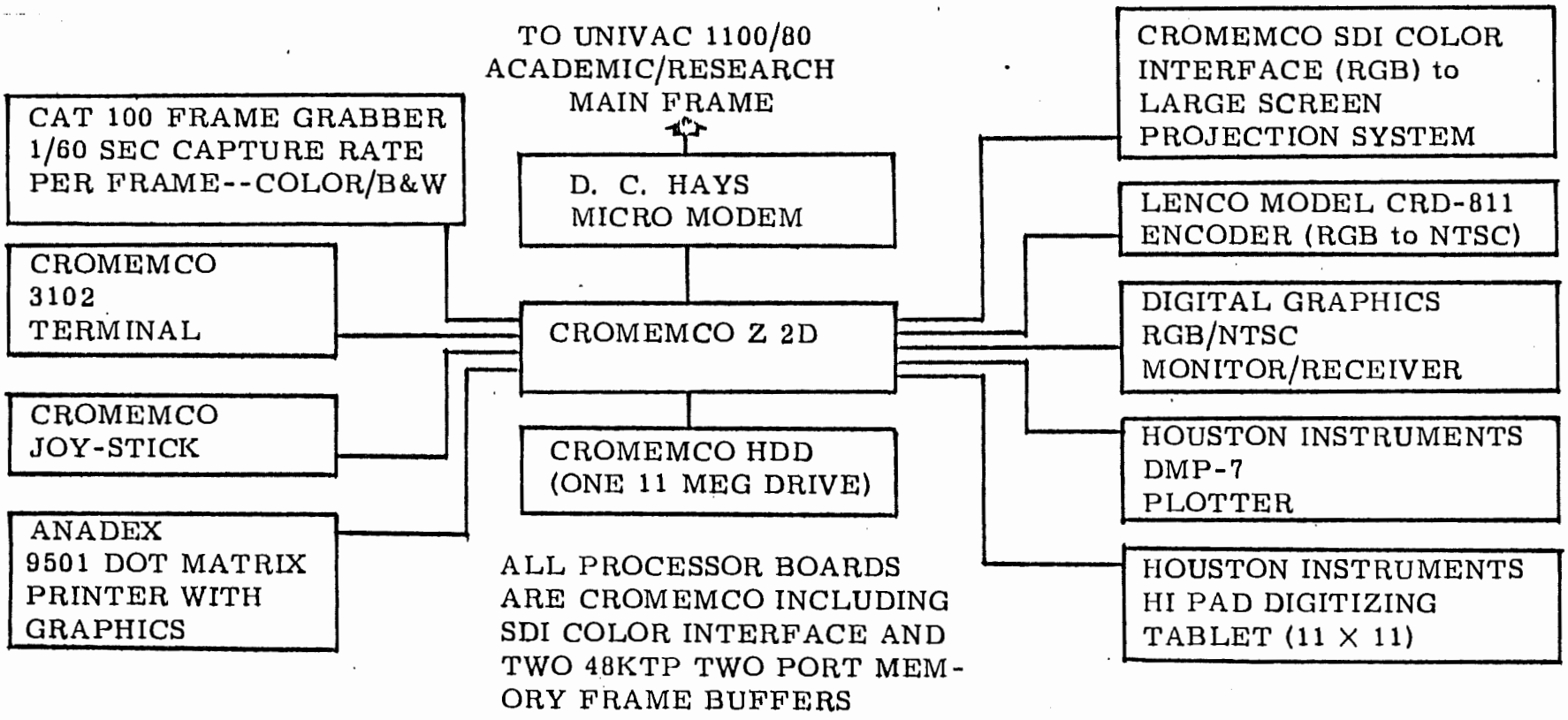
B. Cromemco System

The heart of our microprocessor based color interactive graphics development system is a Cromemco Z-2D processor with 128K of memory and an eleven megabyte hard disk. The graphics output is handled through a Cromemco SDI interface and two 48K two port frame buffers driving an RGB monitor. Peripheral devices include an 11" x 11" digitizing tablet, 11" x 17" pen plotter, joy stick, and dot matrix printer with graphics capability. There is also an Aquastar IIIB large screen projector and a Lenco RGB to NTSC encoder. For a complete schematic of this system see Figure 2. A complete breakdown of system hardware is presented in the listing in Appendix **A.**

In addition to the hardware identified above, the system includes a variety of software, partly purchased and partly developed at Michigan Tech. Currently most of our program development work is written in Fortran IV (ANSI 66 Standard) with some routines in Z·80 assembly language and BASIC. A complete itemization of system software is given in Appendix **B.**

FIGURE 2

MICHIGAN TECHNOLOGICAL UNIVERSITY
CROMEMCO MICROPROCESSOR GRAPHICS SYSTEM



CURRENT EDUCATIONAL APPLICATIONS

Current applications at Michigan Tech are being approached at a variety of levels with efforts being made to achieve an optimal match between the capabilities required for each application and the various systems available. In line with the university goals for interactive graphics, our facilities and software are being directed not only at research but also toward extensive use in the classroom as a demonstration tool and to provide hands-on experience where it seems appropriate. There is also an emphasis to market the developed technology to industry, other academic institutions, and various interested users. The discussion which follows provides a brief summary of three such projects.

First a small three dimensional software package was written for interactive use in our beginning graphics class, **ME 103 Engineering Communication in Design.** This was supported by an internal faculty research development grant.[1] The software which runs on and utilizes the capabilities of the Cromemco system allows the user to construct and display 3D wire frame objects for use in teaching the fundamentals of spatial visualization so necessary for engineers. By being able to display these objects in both pictorial (isometric, oblique, axanomeric, perspective) as well as orthorgraphic formats, the viewer and instructor can play to meaningful "what if" games and see immediate results. The objects can

[1]"Evaluation of the Potential of a Low Cost Micro Computer Based Interactive Graphics System for Teaching Spatial Visualization in Engineering in Engineering Graphics," MTU F.D.C. Report, David A. Carlson, 1981.

be constructed and/or modified and saved for future use. Rotation about the X, Y, and Z axis allows the various sides to be seen in much the same manner we would view real objects. Because of an easy, flexible editing system within the software package, an individual can build, in a minimum amount of time, a library of objects for use in the classroom. Hard copy can be obtained with either the pen plotter or the dot matrix printer.

The IBM graphics system is being used in conjunction with the CADAM software from the Lockheed Corporation during the fall quarter, 1981 to teach ninety-six senior mechanical engineering students registered for **ME 441 Special Topics in Design** the fundamentals of this software package. Each student spends approximately two hours per week at a graphics terminal learning to manipulate the intricacies of the Lockheed system. Half of this time is in a formal structured lab and the remainder is arranged to fit the students' individual schedule. The goals of the course are first to expose the student to and give hands-on experience with leading edge technology in computer graphics for CAD and secondly to prepare the majority of them (approximately 70) for their second course in the senior elective sequence in engineering design. In that course they will be applying this tool extensively to solve actual design problems and to complete a design project.

A third type of system with graphics capability is currently being utilized as a teaching tool as well as a research and experimental analysis device. This is the

Zonic™ fast forier front end to a DEC 11/34 based minicomputer system. Through the use of software called Model Plus developed by Structural Dynamics Research Corporation (SDRC), vibrations data obtained experimentally is quickly analyzed, displayed and used to drive animation routines that accurately reflect the physical movement of real objects or systems.

CURRENT DEVELOPMENT EFFORTS - FUTURE DIRECTIONS

To make it possible for classes to view the graphics generated by the computer, the Aquastar IIIB video projection system developed and manufactured by Electronics Systems Products, has been acquired. This system produces a brilliant sharp image of 400 lumens on either a flat or curved screen from 4 to 20 feet wide. It is remote controlled and capable of front or rear projection. Its compact size, 78 lb. weight, and flexible focusing system make it useful in a variety of configurations.

The system accepts and projects signals from a wide variety of color as well as black and white video sources including: videotape players, computer generated graphic outputs in RGB format, video cameras, video disk players and VHF/UHF Tuners.

The Aquastar IIIB is a part of a semi portable system which can be moved in and out of classrooms and lecture halls where computer graphics are to be used to enhance instruction. Our ultimate ultimate goal is to install several units in lecture facilities (100 students or more) as a cost effec-

tive alternative to sets of small (19 to 25 Inch) TV monitors.

An interactive graphics classroom is being developed to use the Aquastar IIIB in its rear screen projection mode. This arrangement will provide the teacher with direct computer generated graphics and videwo input through direct coupled video camera, pre-recorded cassettes and video disk (under computer control) as well as pictures digitized through a video sampler or frame grabber. Up to 115 students at a time will be able to view the material being presented at this site. It will allow the teacher to use and develop the interactive software required to play the "what if" games to enhance and increase understanding of the subject. Through the use of interactive computer graphics we can now generate pictures at a sufficient rate and quality to use the computer in this mode of operation as a tool to increase productivity in teaching.

Production of the software required for interactive teaching is very time consuming. However, by exercising care in about how we write such programs we expect to be able to reuse portions of existing code by incorporating them in new software applications. Such forethought will often avoid the time spent reinventing basic routines such as drivers, I/O routines, plot libraries and other such items. The major advantage of software for education is that it can be utilized to reduce the repetition inherent in teaching the same subject matter again and again and at the same time provide opportunities for increasing the quality of

instruction. We will not replace teachers. However, we can use these tools to increase the quality and effectiveness of what they do and in some instances significantly increase their productivity significantly. Given the economic constraints facing higher education, technology properly applied promises to provide reasonable alternatives to some past practices and limitations.

In order to facilitate developing this kind of software/system at Michigan Tech we have established the position of Coordinator for Interactive Graphics for the College of Engineering. He provides a focal point for this endeavor and establishes a mechanism for coordination of effort as well as efficient use and development of resources. In addition to laboratory and system development, we are initiating a software/system support service for educational software-projects. This is currently being achieved through the addition of full time professional personnel to help fill the needs of faculty for expertise in the areas of graphic systems and software development. As projects become increasingly complex, team efforts are required to meet goals efficiently.

Resource dollars can be spent only once in efforts to establish new directions for educational and research development. The costs of mistakes in judgement are increasing but timidity and apathy towards moving ahead are likely to be the most costly errors of all. The application of graphics through the use of the computer can and will impact education in general and engineering education in

particular by providing tools to explain our increasingly complex technology.

Among the initial applications of computer graphics to enhance learning of students in engineering courses of a non-graphics nature is the animation of motions for a dynamics class. The program first to be developed is designed to help the student visualize the many vectors with which he sometimes feels inundated. The Cromemco system will will be used to display an animated sequence showing a body in motion, the trajectory of an arbitrary point on the body, the velocity vector and/or the acceleration vector and how they vary with time and position. Dimensions and kinematic parameters may be changed to illustrate their influence on the ensuing motion.

It is intended that a set of such programs be developed for a variety of courses with interchange of examples among interested faculty members stimulating the imagination of others. Support staff will assist faculty members in the implementation of the ideas they generate.

CONCLUSIONS

Computer graphics is a reality at Michigan Tech. The variety of hardware and software already in place is being expanded and utilized with increasing speed and diversity. Its use is expected to improve the quality and productivity of the educational process as well as familiarizing students with technology with which they will deal on the job.

APPENDIX A CROMEMCO SYSTEM HARDWARE

ITEM		DESCRIPTION
1. Cromemco Z·2D		Z·80A Based Microcomputer with two 5 1/4" quad density floppy disk drives. The 21 slot motherboard contains the following cards:
	ZPU Card	Z·80A Processor
	16FDC Card	Quad density floppy disk controller
	2-64K Z Cards	64k of dynamic RAM each-128k total
	2-SDI Cards	Graphics Interface Cards: Medium and High Resolution
	2-48K TP Cards	48K Two Port Frame Buffers
	Tvart Card	2 Parallel/2 serial communications ports
	PRI Card	Letter quality/dot matrix printer
	D+7A I/O Card	A/D and D/A interface
	WDI Card	Hard disk drive controller and interface
	D.C. Hays S·100 Micromodem - Auto Originate and Answer Modem	

2. Cromemco 3102A Terminal
3. Cromemco HDD 11 Megabyte Hard Disk Drive
4. Cromemco Joystick
5. Digital Graphic RGB Monitor
6. Houston Instruments Hi·Pad 11" x 11" Digitizer with cursor
7. Houston Instruments Hi-Plot DMP-7 11" x 11" pen Plotter with Plotter with 8 color pen option
8. Anadex 9501 Dot matrix printer with graphics capability and ZK buffer.
9. Aquastar IIIB RGB/NTSC large screen projector
10. Lenco Model 811 Encoder RGB to NTSC conversion

APPENDIX B CROMEMCO SYSTEM SOFTWARE

ITEM*	DESCRIPTION
1. CDOS	Cromemco Disk Operating System
2. CROMIX	Cromemco Multi User-Multi Tasking Operating System
3. FORTRAN	FORTRAN Compiler
4. 16K Extended BASIC	BASIC Interpreter
5. 32K Structured BASIC	Structured BASIC Interpreter
6. Z80 Macro Assembler	
7. Trace System Simulator	
8. Data Base Management System	
9. SDI Graphics	
10. WORDSTAR	Word Processing from MicroPro™
11. Overlay Linker	
12. Slidemaster	Cromemco developed paint and graphics software tablet driven
13. PRE	Preprocessor-FORTRAN N to FORTRAN IV (ANSI 66 Standard)
14. PRTSET	Anadex Printer Driver
15. HRPLOT	High resolution screen dump
16. MRPLOT	Medium resolution screen dump
17. PLOTLIB	Pen Plotter Library and low level driver
18. PREASIGN	Preallocates file space
19. TERM	Terminal Software for two way communications between Cromemco and Univac 1100/80
20. GDS	3-D Point oriented graphics software with editing input routine and plotting capability

*Items 1-12 are Cromemco items, 13-20 were developed at MTU.