A COLOR GRAPHICS VIDEO SYSTEM

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ABSTRACT

We have developed an interactive color T.V. video display system for our computer graphics and image processing laboratory in the Electrical Engineering Department at McGill. A Data disc is used for storage and refreshing of a color image which is displayed on a Conrac color T.V. monitor. A high resolution mode plots 776 pixels per raster line while a low resolution mode offers 4096 shades. Software currently supports the interactive creation and filing of pictures as well as the display of wire frame and solid three dimensional objects with shading. In addition our color video system includes a computer-interfaced Hughes scan converter unit with hardware for the pseudocoloring of gray scale images. Pseudocolors may be assigned at a manual station or under program control. The pseudocoloring hardware unit also increases the selection of colors available for high resolution mode in the disc refreshed system. These color graphics facilities are being used in the study of computer models, of algorithms, and of hardware configurations aimed at real time animation in simulators. The system is also being used in the development of a knowledge-based scene analysis system for real and synthetic images.

UN SYSTÈME GRAPHIQUE VIDÉOCOULEUR

ABRÉGÉ

Notre département de génie électrique a mis au point un système d'affichage vidéocouleur de télévision à action réciproque pour notre laboratoire de traitement des graphiques et des images par ordinateur. Une mémoire à disques est utilisée pour emmagasiner et regénérer l'image en couleur qui est visualisée sur un écran de télévision couleur Conrac. Un mode à haute résolution présente 776 éléments dans chaque ligne de trame tandis qu'un mode à basse résolution offre un jeu de 4096 intensités. Le logiciel permet présentement de créer des images à action réciproque et de les emmagasiner ainsi que d'afficher des objets pleins et à contour métallique en trois dimensions avec des nuances. En outre, notre système vidéocouleur comprend un convertisseur de balayage Hughes en ligne avec l'ordinateur doté d'un matériel qui permet de représenter en pseudocouleur les images de l'échelle des gris. Les pseudocouleurs peuvent être assignées manuellement ou automatiquement. Le matériel de pseudocouleur augmente également le jeu de couleurs dans le mode à haute résolution du système de regénération sur disques. Ces graphiques de couleur sont utilisés dans l'étude des modèles par ordinateur, des algorithmes et des configurations du matériel ayant pour but l'animation des images en temps réel. Le système sert aussi à l'établissement d'un système d'analyse fondé sur les connaissances pour l'obtention d'images réelles et synthétiques.

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Introduction

We have been developing facilities for our computer graphics and image processing laboratory in the Electrical Engineering Department at McGill. This laboratory supports both hardware and software development projects with emphasis on general scene analysis of images as well as applications to biomedical sciences and industrial modelling. Many imaging peripherals have been interfaced, the most recent addition being a color TV video system. Although we are presently restricted to an "interactive" display system our current research objectives include "real time" animation hardware for simulation displays.

Historically, we started with a small PDP-8 with 4K of core and developed a disc refreshed graphics controller for a DATA disc to support interactive programs for image analysis and modelling studies. Our facilities improved to include a PDP-15 and a Tektronix 4002A storage tube display. We undertook the development and installation of graphics operating systems such as McGraph and MIIPPS (1), (2). With the addition of a Hughes scan converter memory, a TV column digitizer and a Conrac color monitor, and the development of the necessary interfaces, we now enjoy an interactive video display system with the full color range of the shadow mask display tube and suitable for the display of computer generated images, of true color photographs as well as of pseudo colored images.

Hardware

Our present hardware configuration is summarized in Figure 1. The color video images are displayed on a standard 525 line Conrac color TV monitor. These video displays are driven from two alternate storage systems, the Data disc memory using 12 parallel tracks or the Hughes Model 639 scan converter unit. Both storage systems are interfaced through the PDP-8 computer to the PDP-15. The scan converter being an analog storage medium, favours gray scale images or photographs. It is basically monochrome and is used for pseudo coloring. Its TV raster storage format interfaces very simply with the TV camera input. Due to the inherent picture fading with readout, an accurate color display is maintained for about 5 minutes before being refreshed. Since a change in display is often desired anyway, this refresh requirement is more than offset by the relatively modest cost of this display system. Our scan converter system is capable of displaying eight colors from a repertoire of sixty four possibilities with a resolution of approximately 500 picture elements (pixels) per line.

On the other hand, our Data disc system uses digital storage and is therefore permanent. It operates in two mutually exclusive modes: a high resolution mode plotting 776 pixels per line, and a low resolution mode plotting 194 pixels per line. The low resolution mode offers 16 intensity levels on each of the three channels (red, green, blue) giving 4096 possible colors to a pixel. In the high resolution mode, we are limited to eight color choices, from a selection of 64 possibilities. To display video images, extensive and intricate data manipulations are required to accomplish raster conversion, horizontal and vertical blanking, color assignment using parallel tracks, and formatting translations from 18 bit parallel to 12 bit parallel to 8 bit serial packing. This larger software overhead as well as the higher cost of the interfaced video disc are two drawbacks of the Data disc system compared to the scan converter system.

Scan Converter System

We shall now outline some of the hardware functions in more detail starting with the scan converter system. Standard interfacing to the PDP-8 allows us to control the scan converter unit permitting us to prime, erase, store an image from a television camera, store a picture from the computer given as X-Y deflections and Z intensities, read Z intensity at a selected X-Y position, and display TV video to monitors. The gray scale video feeds a Conrac model RVC-17 black and white monitor directly and the Conrac RHM-19 color monitor through the pseudo coloring hardware as shown in Figure 1. Figure 2 shows a complete block diagram of the pseudo coloring interface. The pseudo color hardware operates in three modes: normal, filtered, and intensity modulated. In the normal mode, the scan converter video output is coupled directly for pseudo color mapping. In the filtered mode, the video input to the pseudo color hardware is first low pass filtered to remove much of the noise caused by the scan converter. The tradeoff is a reduction in horizontal resolution from 500 pixels to about 250. In the previous two modes, the quantization of a continuous gray scale into eight discrete steps tends to destroy some of the original video information. The third mode uses the original monochrome signal to modulate in intensity or brightness, the various colors being displayed. Thus more of the original information is retained.

In operation, composite video from the scan converter, corresponding to the monochrome stored image, is applied to the three bit A to D converter. Signal levels are adjusted so that the binary code 000 results from a video level of black or blanking, 111 results from a fully saturated white level, and the six intermediate combinations from the appropriate shades of gray. The three bit A/D output becomes the selector address for the random access memory. Alternatively, the three bit code of the video output from the Data disc in the high resolution mode can be selected for color assignment. A six bit color word is outputted from memory for each of the eight addresses. The color words are loaded into the pseudo color memory by the color encoder which may be driven from the manual station or by software. This six bit color word is broken into three two bit codes which form the inputs to the three D/A converters driving the red, green and blue guns respectively. Six bits allow a color repertoire of 64 different shades. Changing the gray level color assignment involves changing the contents of a six bit word in the random access memory, without reprocessing of the stored image. This property allows instantaneous on-line coloring of the picture. The eye's ability to discriminate many more colors of varying hue, saturation and brightness than shades of gray makes pseudo coloring useful in many applications such as in studying features of X-Ray photographs.

Data Disc System

Although the digital hardware for the Data disc color video system is more complex than for the scan converter system, it is quite conventional consisting of the synchronizing, unpacking and driver blocks shown in Figure 1. The sync section is driven from two clock waveforms which designate track origin and bit positions. Counters and monostables are used to synthesize the standard NTSC synchronizing waveforms for 525 lines and 2:1 interlace. The unpacking section reads 12 bit words from parallel disc tracks and supplies three 4 bit words to the video drivers every 330 nsec.. This low resolution mode offers 4096 colors to a pixel. In the high resolution mode, the three channels are driven by one bit words every 82 nsec.. With this three bit code, each pixel may take on one of eight colors. The pseudo color memory allows the eight colors to be chosen from a repertoire of 64 as explained.

Software System

We shall now discuss the graphics package which supports the creation, editing and display of computer generated images of three dimensional solid objects on our color video system. The program presently runs under the DOS operating system on the PDP-15 and executes interactively with the Tektronix 4002A console and the Data disc video system. Figure 3 shows the functional relationships between the different blocks. First the user may prepare source files under the DOS Editor. These files of ASCII characters contain any of the McGral graphics language statements to be described presently. Source files are entered to form a library. The graphics interpreter program responds to certain statements entered by the keyboard to generate binary picture files (BIN) which may be placed back in the disc library. Such commands may involve processing other referenced library files. Binary picture files (BIN) consist basically of picture end point definitions, polygon definitions, and coloring data. Source files (ASCII), on the other hand, are general and may contain any command statements including commands and data for picture manipulations such as translations, rotations, or scaling. Certain commands cause the interpreter to execute and generate display files (RAS) of two varieties: solid surface and wire frame files. Basically this involves processing the picture file defined in world or "scene" coordinates and generating a display file (RAS) in the viewer or "eye" coordinates for subsequent display. This involves processing for the desired viewing position and angle, clipping to the desired viewing window, and transforming for perspective. Such display files (RAS) may also be entered into the library. Output commands operate on display files (RAS) and produce the desired color image on the TV monitor. These involve routines for raster conversion, hidden surfaces, memory management, buffer stuffing and transmission. Finally a set of maintenance commands assist in the general filing process and overall control.

Applications

We have applied our three dimensional graphics system to an aircraft simulator display study. Figure 4 shows a computer generated airport scene using wire frames. Solid images are displayed with an implementation of Watkins hidden surface eliminator algorithm (3). Pixels at polygon edges are shaded using the "area times color" rule to minimize quantization effects. The user may specify one of four shading rules to be applied to each polygon in the display: no shading, shading with distance, shading with angle, shading with distance and angle. These implementations invoke Gouraud's algorithm (4) based on linear color interpolations to avoid detailed calculations at every pixel. Flashbulb lighting effects are also possible. Figure 5 shows a solid rendition of an airport scene. Computation times range around one to five minutes depending on image complexity. Images may presently contain a maximum of 1900 polygons per frame and 100 polygons per scan line. Hard copy is obtained using Polaroid color and 35mm film. We are currently extending our system to include PDP-15 core refresh with a direct memory access interface. This will simplify and therefore reduce the time required in outputting the picture. Some animation will also be possible. The system will also be used in the development of a knowledge based scene analysis system for real and synthetic images.

References

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(3) Newman, W.M., and Sproull, R.F., Principle of Interactive Computer Graphics, McGraw Hill, 1973.

(4) Gouraud, H., Continuous Shading of Curved Surfaces, IEEE Transactions on Computers, Vol. C20, No. 6, 623, June 1971.

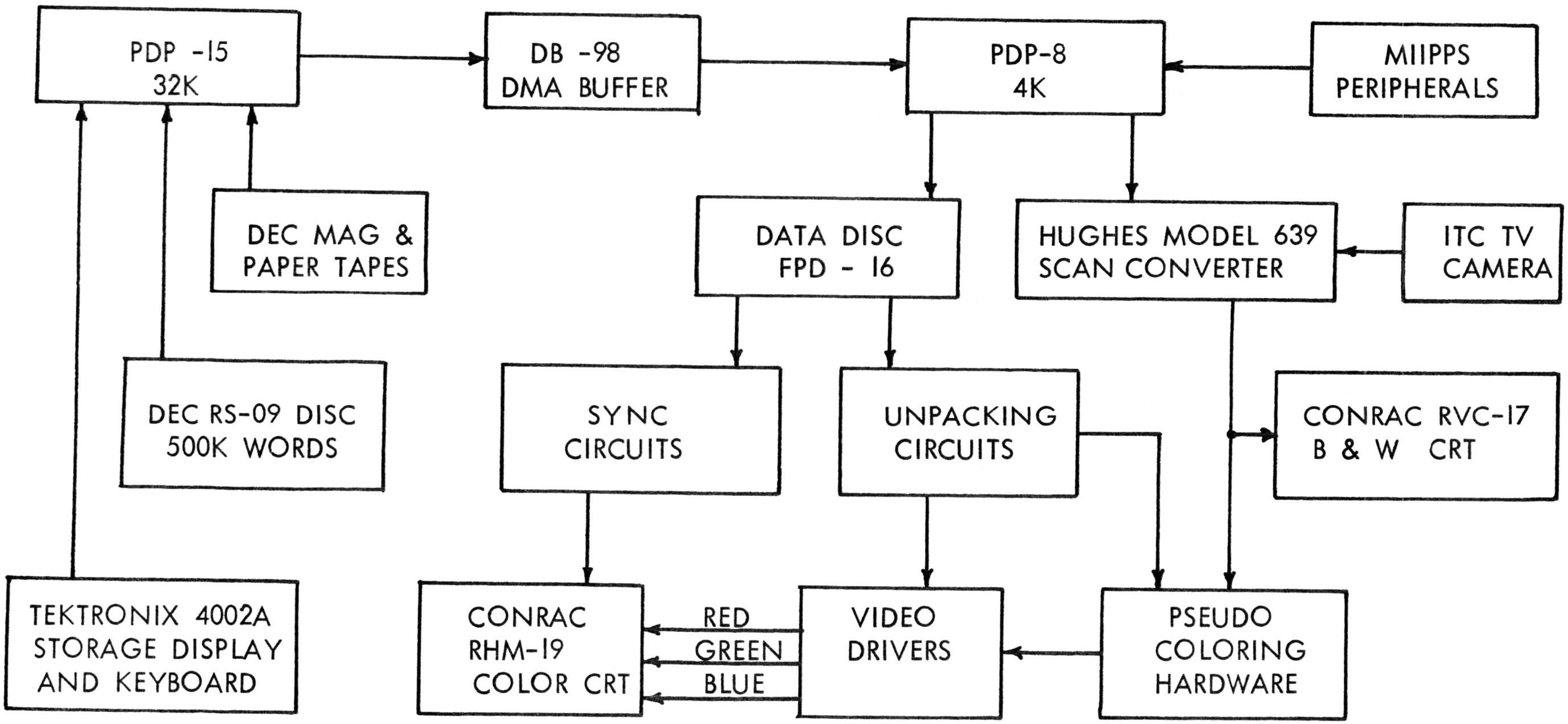

FIGURE 1 : HARDWARE ARRANGEMENT OF THE COLOR GRAPHICS SYSTEM

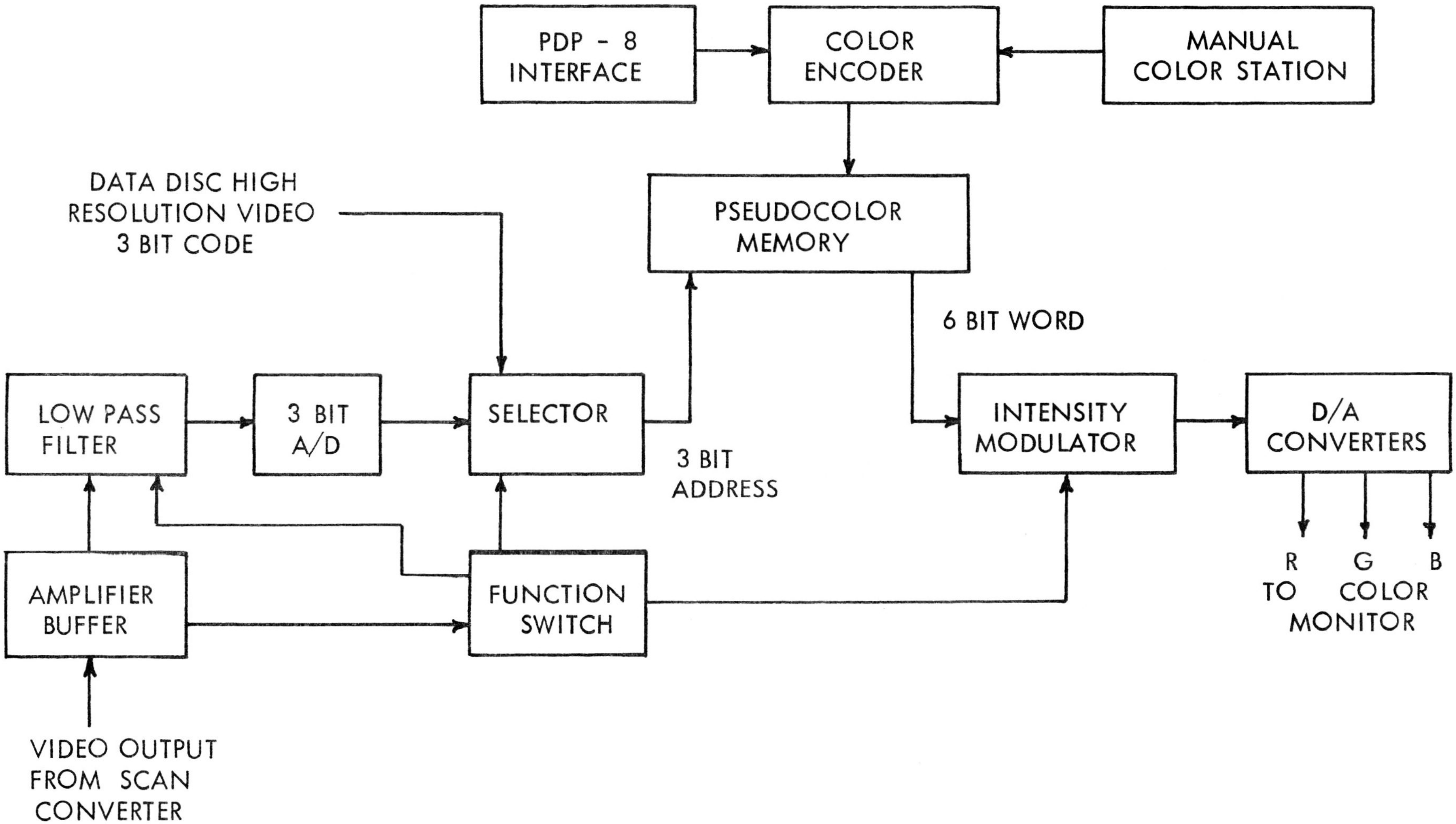

FIGURE 2 : BLOCK DIAGRAM OF THE PSEUDO COLORING SYSTEM

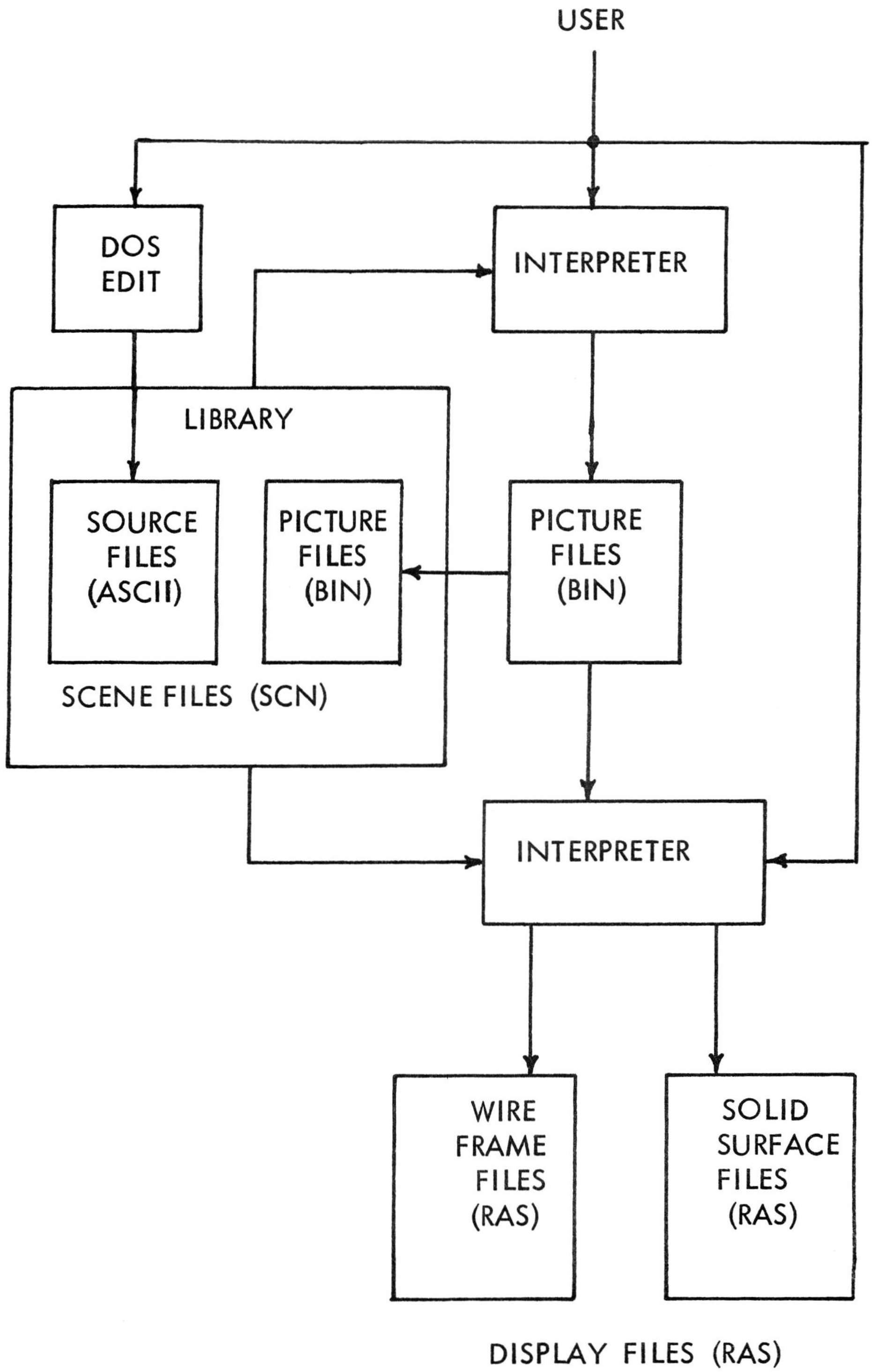

FIGURE 3 : BLOCK DIAGRAM OF 3-D SOFTWARE SYSTEM

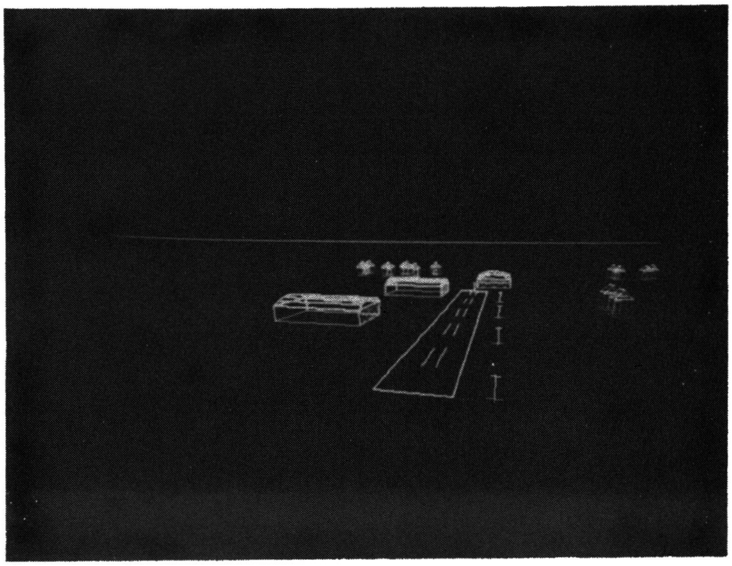

FIGURE 4: A WIRE FRAME AIRPORT DISPLAY

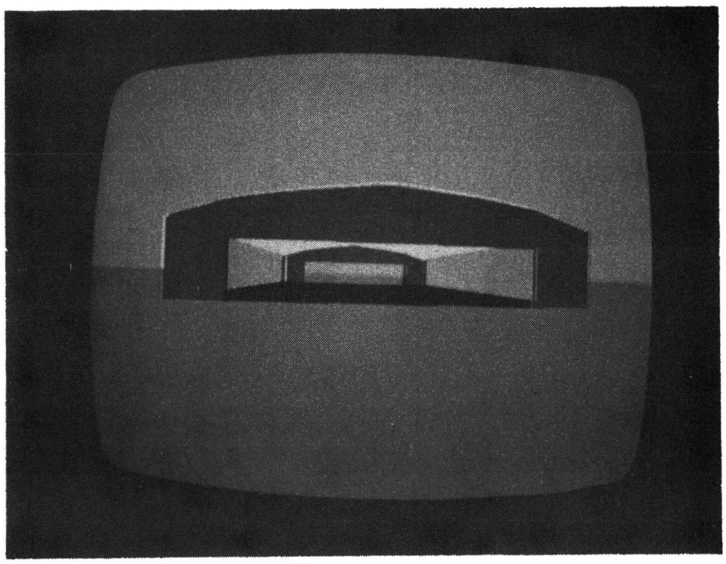

FIGURE 5 : A SOLID SURFACE AIRPORT DISPLAY