INTERACTIVE GRAPHICS USING APPEL'S TECHNIQUE IN TEACHING ENGINEERING DRAWING AND GEOGRAPHY

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ABSTRACT

This paper describes the use of an interactive graphics system in teaching geography and engineering drawing. In the geography application the system is used to show how the strategy used in inferring the shape of a statistical surface from a set of irregularly-spaced sample points can give several contradictory versions of the surface's shape. The concepts of isarithms and contour mapping are introduced as well

The engineering drawing application uses Appel's technique of hidden line deletion to aid in teaching descriptive geometry and orthographic projection.

Classroom experience indicates that there is a limit to the complexity of a teaching aid, and that the instructor sets that limit. If the aid is too complicated it will not be used effectively, though the system designer may not be aware of the complexity. Considerable training seems to be needed before an instructor uses complex aids. The evaluation of such aids is clouded by the tendency of some instructors to concentrate on the computer-orientation of the aid rather than the subject material.

SYSTÈME GRAPHIQUE À ACTION RÉCIPROQUE UTILISANT LA TECHNIQUE D'APPEL DANS L'ENSEIGNEMENT DU DESSIN INDUSTRIEL ET DE LA GÉOGRAPHIE

ABRÉGÉ

Le présent mémoire décrit l'utilisation d'un système graphique à action réciproque dans l'enseignement de la géographie et du dessin industriel. Le système est employé en géographie pour démontrer comment la façon d'illustrer la forme d'une surface statistique d'après un ensemble de points d'échantillonnage espacés de façon irrégulière peut donner plusieurs interprétations contradictoires de la forme de la surface. Les notions d'isolignes et de courbe de niveau sont introduites également.

Le dessin industriel utilise la méthode d'Appel consistant en l'élimination des lignes invisibles pour faciliter l'enseignement de la géométrie descriptive et de la projection orthogonale.

L'expérience dans les classes révèle qu'il y a une limite à la complexité du matériel didactique qui dépend de l'enseignant lui-même. Si le matériel est trop compliqué, il ne sera pas bien employé, bien que le concepteur du système puisse ne pas être conscient de la complexité dudit système. L'évaluation de ce matériel est rendue difficile par la tendance de certains enseignants à se concentrer sur l'orientation informatique du matériel plutôt que sur la matière d'enseignement proprement dite.

"Interactive Graphics using Appel's Technique in Teaching Engineering Drawing and Geography"

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For several years the Department of Electrical Engineering at Queen's University, Kingston, has used an interactive graphics system as a classroom teaching aid in the undergraduate electrical engineering program. This paper discusses the extension of the aid to teaching topics in geography and engineering drawing and some of the results from classroom experience. The present work was supported by a grant from the Ontario Universities' Program for Instructional Development.

1. Background

The hardware, developed by S.R. Penstone, has been described elsewhere (1, 2) so only a brief summary follows. The instructor has in the classroom several television monitors and a control box with 18 digital controls and 1 analog control (Figure 1). The box is cabled to a remote PDP-15 computer which senses the control box outputs and drives a crt display. A closed-circuit TV camera (Figure 2) mounted on a boom in front of the display sends a video image of the display to the classroom.

The system has previously been used for teaching topics for which more conventional aids were rather ineffective. For example, a program to simulate an electrical transmission line was written, and provided real-time simulation of instantaneous voltage and current values at all points along the line.

2. Geography Application

The work in geography was carried out in consultation with Dr. H.W. Castner of the Queen's University Department of Geography. The aim was to introduce geography students to concepts of isarithms, statistical surfaces derived from irregular sample points, and the results of exercising alternate choices of the inferred form of the statistical surface from a single set of samples. The simplest example of these principles is contour mapping, in which the samples are heights of land above sea level at specific geographic co-ordinates and the isarithms are contours of equal elevation. In this case, alternate choice of the shape of the inferred surface may put the ridges and valleys in the wrong places. In a more general sense, the geographer may be interested in a statistical distribution which has no physical reality, such as the distribution of stone houses in Ontario. Here the inferences about the nature of the surface, based on limited and irregular samples, cannot be checked physically so the geographer is specially interested in knowing the results of different inferences from the same sample data.

Figures 3 to 9 are photographs taken from the crt screen to show some of the features of the geography program. In Fig. 3 a set of sample points is shown as elevations above a sample plane, which the instructor can rotate and tilt to any desired position. The points can be joined to make a faceted surface that approximates the real surface and by rotating and tilting the surface the instructor can allow the class to look up or down the valleys and gain an idea of the overall shape of the surface (Fig. 4). Contours can then be plotted and the view can be tilted to show that they form parallel planes that cut the surface (Fig. 5).

The concept of alternate choice is illustrated by taking a subset of the samples (shown unshaded in Fig. 6). There are several interpolations that can be made between the sample points that form the four corners of the quadrilateral 1-5-2-6. If simple diagonals are used for the interpolation, the contours of Figs. 7 and 8 result - but only one of these choices is consistent with the surrounding areas. Figure 9 shows the result of taking the less likely choice.

In the classroom each student had a sheet showing a sketch of the sample points and a summary of criteria that could be used in deciding which sample points to join in developing the surface.

3. Engineering Drawing Application

The engineering drawing program was based on an earlier version (2) that provided the instructor with a set of objects that he could display in the three primary orthographic views and two auxiliary views (Figure 10). The objects were restricted to the "wire-frame" variety (Figs. 13, 15) since no hidden-line deletion (Figs. 10-12, 14) was included in the program.

Previous experience had suggested that the system could be useful in working with students at either end of the ability spectrum and for answering questions in class that would normally have required much cumbersome construction on the blackboard.

In the new version of the program the instructor had the option of deleting hidden lines at the expense of speed in rotating the object and moving the folding lines of the auxiliary views. The hidden line feature made the system applicable to many more engineering drawing topics than the previous version. The hidden lines were deleted by techniques suggested by Galimberti (3) and Appel (4). The object was defined beforehand using an interactive preparation program as a set of points, faces, and lines. Each face had a normal vector associated with it and for any viewpoint a test of the vectors immediately discarded any planes obscured by their own volume. The remaining "possibly visible" faces were examined for mutual obstruction by starting with the closest point (certain to be visible) and from it developing changes in "quantitative invisibility," defined as the number of faces obscuring a given point on the object from the viewer.

4. Results

The programs have been tested in primary undergraduate courses in geography and engineering drawing, though in the latter case the hidden line features had not yet been added. Fifty-one geography students and 100 engineering drawing students were exposed to the system. Questionnaires were administered afterward but no attempt was made to measure effectiveness quantitatively since exposure was brief.

The answers to the questionnaires were rather ambiguous. While the great majority of students in both groups felt that the system aided 3-D visualization and was well-suited to the subject material, the engineering drawing students were evenly divided on preference for the system versus the blackboard. In choosing between the system and physical models as teaching aids, 26% of the engineering drawing students and 80% of the geography students preferred the system.

Any attempts at evaluating a new aid are subject to the Hawthorne effect: the novelty of any new technique makes it more effective. It is important not to emphasize that the aid is new or to mention that it is computer-driven. More precautions should have been taken to introduce the aid in a low-key manner, but some special emphasis was unavoidable because classes had to be specially scheduled in rooms wired for the system.

The largest problem from the instructor's viewpoint seemed to be the complexity of the system. To exploit the system's power the instructor had to use 18 switches and a potentiometer knob, which required considerable practice. The result was that the classroom presentation was somewhat stilted because the instructor did not feel "at home" with the system and lost the flexibility that the system was intended to provide. Instructors who often used the system became more adept but unless the system is used in a large part of a course the training time would be disproportionately long.

On the whole the system was accepted by the students, in some cases with great enthusiasm. The system approaches the limit of useful complexity for the instructor who does not want to become deeply involved with it. Interest has been expressed in using the system for individual tutorial work for students with perceptual problems.

References

1. S.R. Penstone, J.C. Beal, N.A. Mackay, "Computer Aided Instruction: A Computer-Driven Transmission Line Simulator as an Instructional Tool," 3rd Ontario Universities Computing Conference, February 1972.

2. D.G. Beattie, C.A. Mulvenna, "Results from an Interactive Computer Graphics System for Teaching Descriptive Geometry," ASEE Transactions on Computers in Education, Vol. VI, No. 8, August 1974.

3. R. Galimberti, U. Montari, "An Algorithm for Hidden Line Elimination," A.C.M. Communications, Vol. 12 No. 4, April 1968.

4. A. Appel, "The Notion of Quantitative Invisibility and the Machine Rendering of Solids," Proc. of 22nd National Conference, A.C.M., 1967.

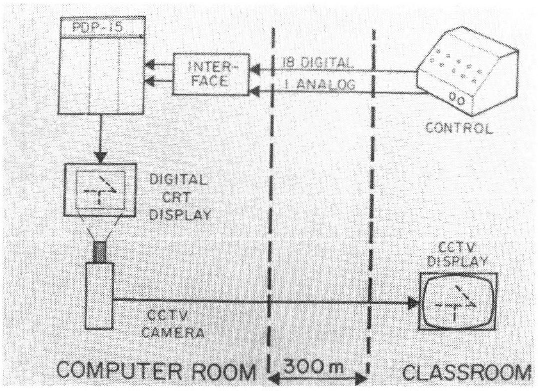

Figure 1
System Block Diagram

Figure 2
Computer, Display & Camera

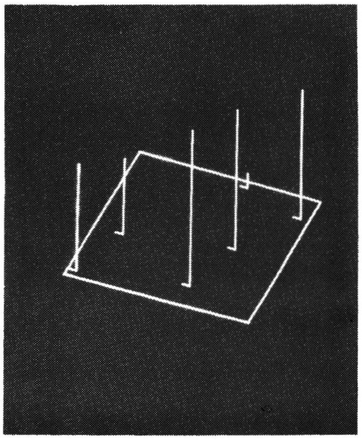

Figure 3
Sample Points

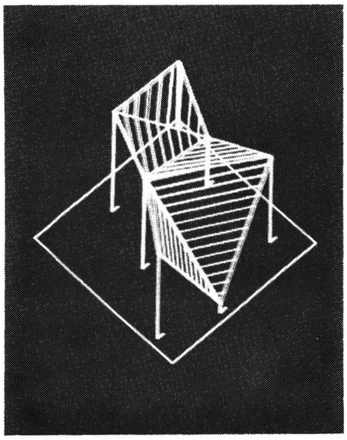

Figure 4
Surface & Contours

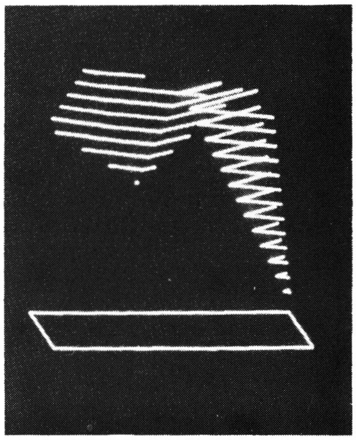

Figure 5
Contours as Edges

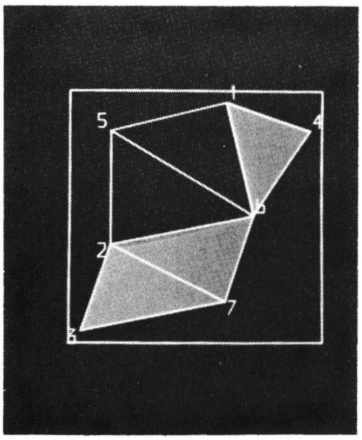

Figure 6
Alternate Choice

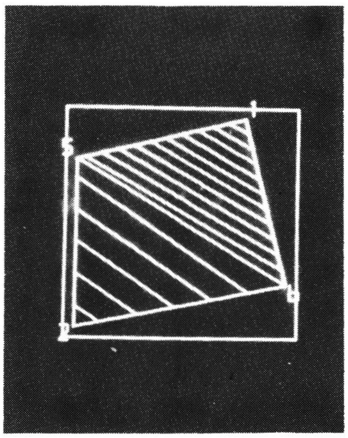

Figure 7
First Choice

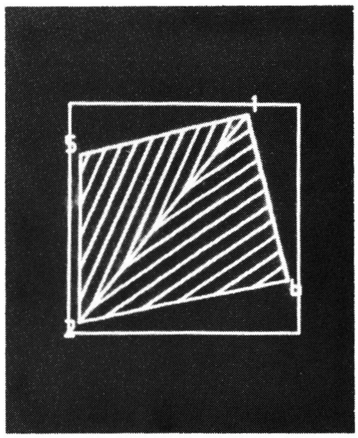

Figure 8
Second Choice

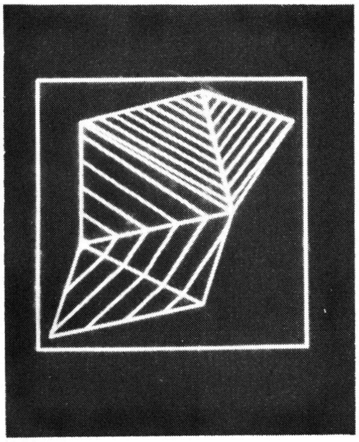

Figure 9
Complete Surface

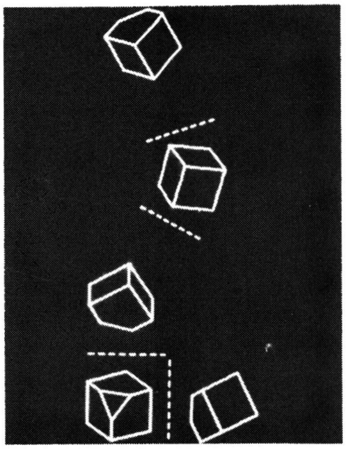

Figure 10
Five Views

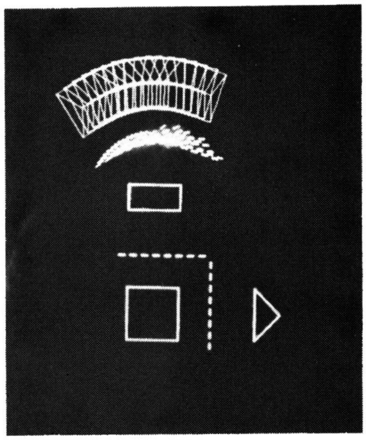

Figure 11
Rotating a View

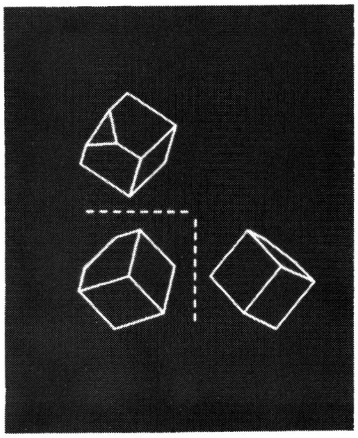

Figure 12
Lines Hidden

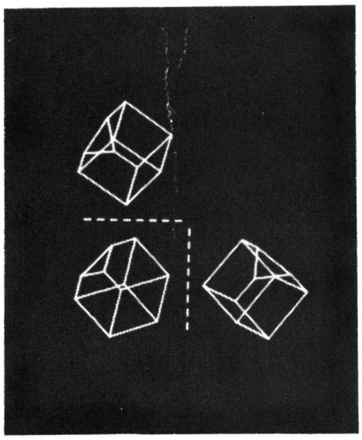

Figure 13
Wire Frame

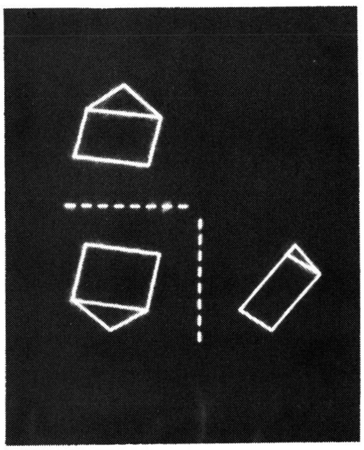

Figure 14
Lines Hidden

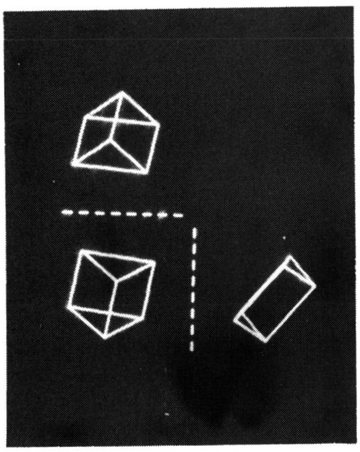

Figure 15
Wire Frame