COMPUTER AIDED CINEMATOGRAPHY TECHNIQUES FOR MODEL VALIDATION[a]

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Abstract

Graphical display is a tool for visualizing patterns through quantification of dimensions or parameters that may not be observable by tabular methods. This paper focuses on graphical display where greater than 2 dimensions or parameters are being iteratively evaluated. The specific techniques included in this paper are: (1) two-dimensional plotting of hydrologic flow, with time as a third dimension; (2) three- dimensional plotting of vegetational biomass on a landscape coordinate system; and (3) three-dimensional plotting of carbon monoxide concentrations in a coal gasification facility versus hour-of-day and location with sequential plotting of each day for an extended time period. Each of these examples of cinematography illustrates patterns in data with time- or space-varying parameters. Specific statistical parameters such as the coefficient variation have been used to idenitfy potential patterns of interest. Graphic cinematography is useful for (a) recognition of pattern where a single two-dimensional or three-dimensional display fails to reveal important features, (b) rapid review of data, (c) easy display of various combinations of parameters, and (d) evaluations of large volume temporal data.

Introduction

Graphical display is a tool for visualizing data patterns through quantification of dimensions or parameters that may not be observable by tabular methods. In a recent article in Science 80, Engel (1980) discussed the use of computer graphics for illustrating the fourth dimension to aid mathematicians as well as laymen to visualize objects and patterns that are illusive without computer technology. While his comments are directed toward mathematical treatments, the concept of visual data analysis through computer graphics is quite appropriate. Current research in the Environmental Sciences Division at Oak Ridge National Laboratory uses computer graphics in data analysis evaluation. This paper encourages the use of computer graphics to display data where the evaluation of greater than two dimensions or parameters is being iteratively performed. The specific techniques presented here are (1) two-dimensional plotting of hydrologic flow with time as a third dimension; (2) three-dimensional plotting of vegetational biomass on a landscape coordinate system with view angle rotation; and (3) three-dimensional

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plotting of carbon monoxide concentrations in a coal gasification facility versus hour-of-day and location with sequential plotting of each day for an extended time period. Each of these examples uses cinematography to rapidly illustrate changes in the parameters or dimensions being plotted. In addition, specific statistical parameters such as the coefficient of variation are used to identify potential patterns of special interest. By emphasizing the speed and ease by which cinematographics can be implemented, researchers may find computer graphics useful in their work. Finally, a critical need to identify, analyze, and evaluate complex relations within data sets is satisfied using the tools presented here.

Methods

In this paper, dimension refers to the parameter space along each plot axis and represents a single variable in the sample data. The dimensions chosen for display depend on (1) the investigator's a priori knowledge of potentially related parameters, and (2) his particular training and background which have lead him to formulate the problem to be graphed. Certainly from an ecologist's viewpoint, it makes more sense to relate dimensions such as plant biomass, soil type, and rainfall than it would to a soil geographer who might relate soil type, slope, and rainfall. Thus, the viewpoint of the investigator is used in formulating the dimensions to be graphed. For this paper, three distinct viewpoints each with distinct dimensions were used. The first viewpoint represents a physical scientist's simulation of the circulatory motion of a body of fluid in a square cavity (Yeh, 1980). A computer program simulated the behavior of the fluid in a cavity of fixed width and height through time. The fluid within the cavity was broken down into approximately 400 square compartments wherein the fluid direction in the cavity was represented graphically by an arrow. Every second for a period of 16 minutes, the fluid was depicted on a two-dimensional plot. The 960 plots were then accumulated as a single output file upon which cinematography techniques were used.

The second problem represents an ecologist's view of landscape biomass calculated from an allometric equation where tree diameter is a parameter measured in the field at a fixed sampling points or plots. Biomass was projected for one of a series of years when diameter measurements were made at the fixed sampling points on ORNL's Walker Branch Watershed (Grizzard, et al., 1976). Each sampling point was determined by measuring a fixed distance from a permanent marker near the boundary of the Watershed. The distance in the north-south and east-west directions formed a grid. This grid was then used for the X and Y coordinates of the three-dimensional graph with biomass represented along the third axis. The biomass projection was then rotated through 360 degrees to allow the viewer to identify patterns in the biomass. The rotation simulated an aerial flyover of the landscape where the vegetation was surveyed.

The final problem dealt with viewing carbon monoxide concentrations at five vertical locations over a 24-hour period in a coal gasification facility. The facility, partially funded by the Department of Energy, is located at the University of Minnesota-Duluth campus and is being studied by ORNL for its potential health and environmental effects (Cowser 1979). At each vertical location a concentration value was recorded at approximately 5-minute intervals via a minicomputer located at the gasifier facility. Carbon monoxide was selected from one of many complex parameters being monitored at the facility. Hourly average concentrations were plotted for each location over a 24-hour period on a single plot. Thirty days were plotted in order to view the CO concentrations over the February-March 1980 operational period.

The maximum carbon monoxide concentration for each hour was calculated and placed in a computer file along with the mean hourly concentration, monitoring location (level) and hour of the day. The maximum carbon monoxide concentration was used to automatically initiate a rotation of the three-dimensional plot through 360 degrees. The computer program compared the maximum carbon monoxide concentration in the data file with a threshold value. If the concentration exceeded the threshold, rotation occurred. This checking process was repeated for each of the days in the data file. If no rotation was performed, only a single view of each day was plotted.

For the problems above, the data were tabulated and summarized statistically using the Statistical Analysis System (SAS) (SAS Institute Inc., 1979). Following inspection, the data were graphed 3-dimensionally using the DISSPLA software (ISSCO 1974). Through the collaborative efforts of Computer Sciences Division of Union Carbide Nuclear Division with ISSCO, subroutines were developed to communicate with an FR80 (Information International Precision Graphics Recorder model FR80 and film processer) device which produces sprocketed film from magnetic disk or tape input. These subroutines control the initialization of the FR80 device by the command CALL FR80 ('S16M') to establish the sprocketed film speed and type and by the command (CALL FR8SET('REPE',n)) to establish the repetition of a plot frame to allow an image to appear the same over a period of time. The argument 'n' in CALL FR8SET instructs the FR80 device to duplicate the plot n times. Thus depending upon film speed, the plot would appear to change only after n frames had passed. For example, if the film speed were 16 frames per second (ca 16 mm) and n were 16, then the viewer would see the identical plot for a period of one second. For each of the above problems the plotting call sequence would appear as follows:

```
CALL FR80('S16M')
[Other plotting initialization calls]

CALL FR8SET ('REPE',16)
[Calls for data plotting]

CALL FR8SET('REPE',0]
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The final call to FR8SET with n = 0 is used to signal the end of a repeated frame.

For a more detailed description of the plotting language used, the recorder is referred to manuals available for purchase from ISSCO (1970) that describe the graphics syntax and capabilities. Additional information on technical aspects of time-lapse graphics is available in a document by Munro (1980).

Results and Discussions

Square Cavity Flow

An example of the first problem where cinematography was used is given in Figure 1. This plot (Figure 1) represents the steady state flow in a square cavity. For this particular problem 960 plots were generated. For the researcher to inspect each plot manually to verify that the flow conditions were occurring as was predicted, would require excessive amounts of time and space, especially with a number of case studies to consider. The use of cinematography was very useful in inspecting the behavior of the model and the steady state conditions in the cavity.

Biomass Projection

Two views of the three-dimensional biomass projection are provided in Figures 2 and 3. Figure 2 represents a view toward the northeast direction - from the base of the watershed. Figure 3 represents a view toward the southwesterly direction or from the top of the watershed. This represents a 180 degree rotation. While this single projection being rotated through 360 degrees illustrates the biomass clusterings, the cinematography is even more useful when a series of years are projected and rotated. The addition of another dimension to the projection would provide even greater definition of the actual landscape. For example, color representing different vegetation types would be very useful in analyzing the landscape pattern and illustrating the landscape change through time.

Carbon Monoxide Concentrations

Examples of the three-dimensional plots of carbon monoxide concentrations are given in Figures 4 and 5 where Figure 5 represents the data upon which rotation was automatically performed. The interrogation of these data using tabular methods was performed and it was noted that the pattern of increasing concentrations in the gasifier with increasing height or monitoring level was not readily apparent until the cinematography techniques were used. There was such a large volume of data to interpret that remembering values from one table to the next proved impossible. By placing the different projections on film, in 3-4 minutes the entire data set could be viewed. With stop action of the projector, a particular day could be held even longer. Another dimension would be added to this graphical technique which would allow certain values to be accentuated. Color could be used to indicate those concentrations that exceeded the threshold values.

For each of the above examples, three-dimensional graphics was a significant factor in reducing the time spent in analyzing raw data for patterns. In addition, certain patterns may have gone unnoticed had cinematography techniques not been used to rapidly rotate the data. The application of cinematography techniques is useful in areas where large amounts of data or complex relationships may exist. Cinematography allows the researchers to view the raw data as opposed to some transformed vectors which might be used in a discriminant function or principal component analysis.

The automatic rotation of the data is a procedure that might prove even more fruitful where outlier detection was the objective. A suitable algorithm could be incorporated in the computer program to evaluate probable outliers and with color patterns these outliers could be graphed to show patterns in the data. In this study, the maximum carbon monoxide concentration was used as a criterion for rotation because of its appropriateness in comparison with threshold limit values as set by occupational safety and health standards.

For the purposes of pattern recognition in n-dimensions, we feel cinematography has merits and should be emphasized where complex patterns and large volumes of data occur. Certainly, it is infeasible if graphical computer hardware is not available to initiate such analyses. However, where budgets will allow for acquisition of appropriate hardware, these techniques should be useful.

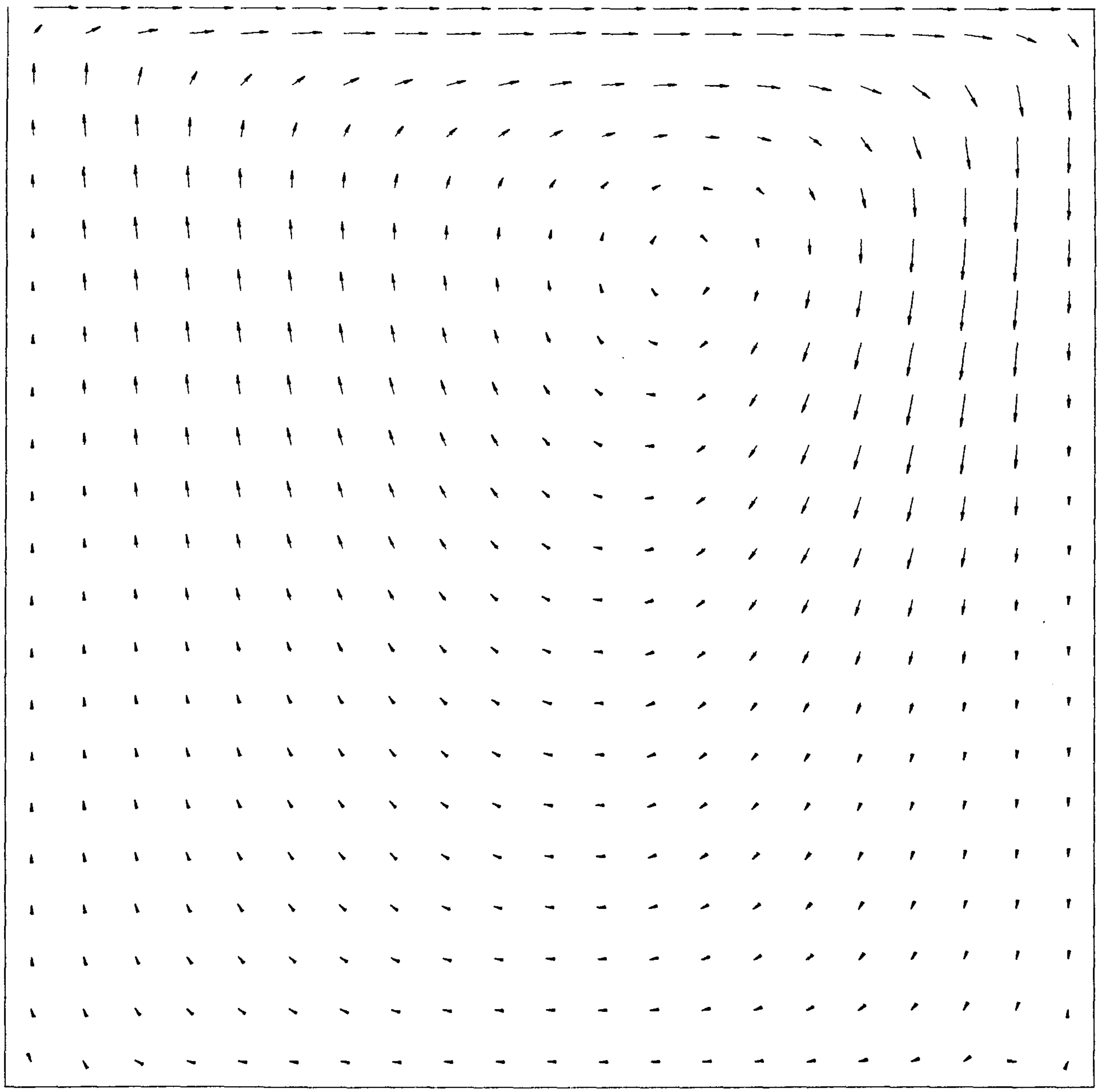

Figure 1. Graphical representation of steady state flow of a fluid through a square cavity of constant height and width. This plot represents one frame of a total of 960 used in the cinematography techniques presented via a 16 mm movie.

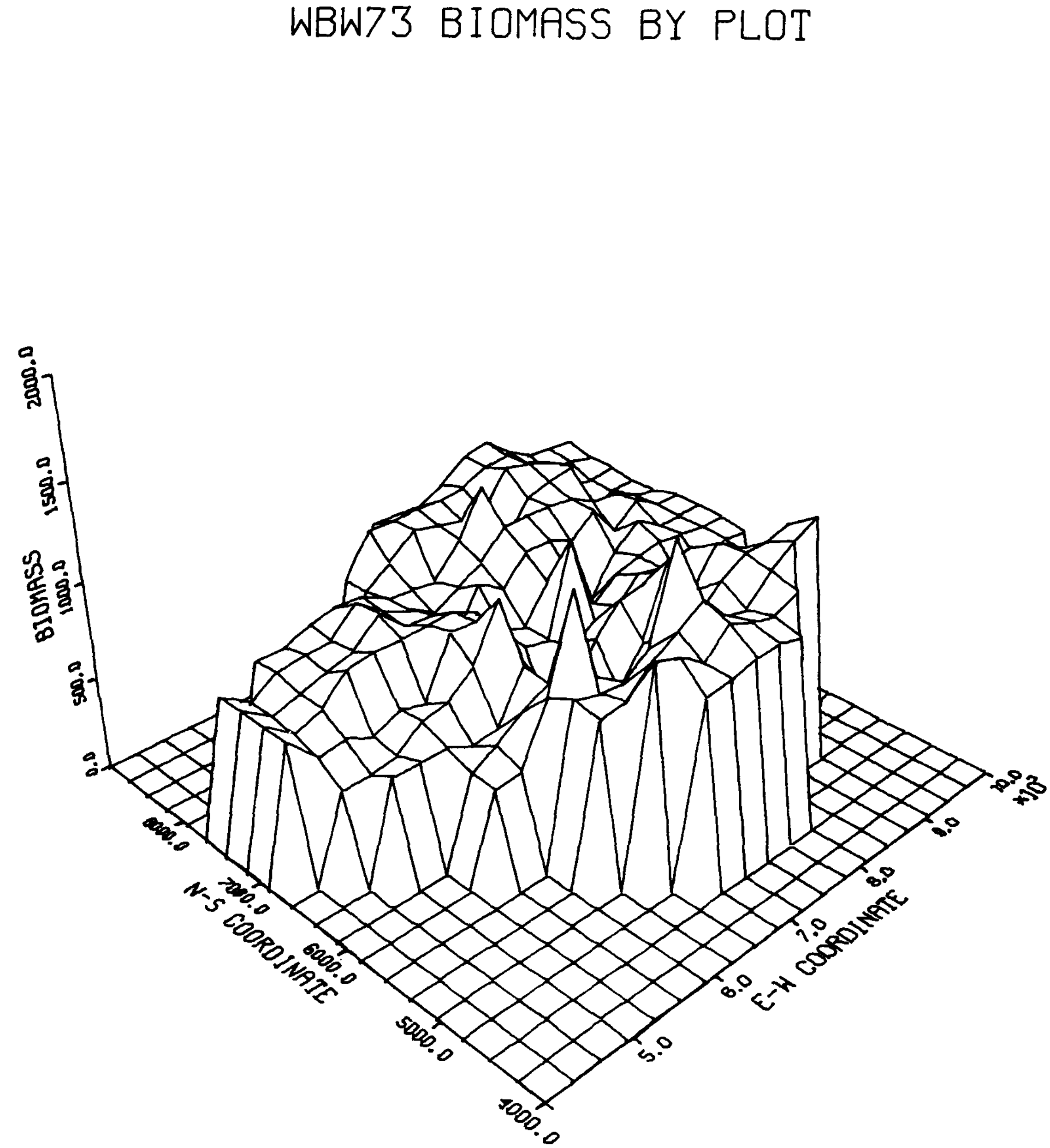

Figure 2. Northeasterly view of biomass on Walker Branch Watershed for 1973.

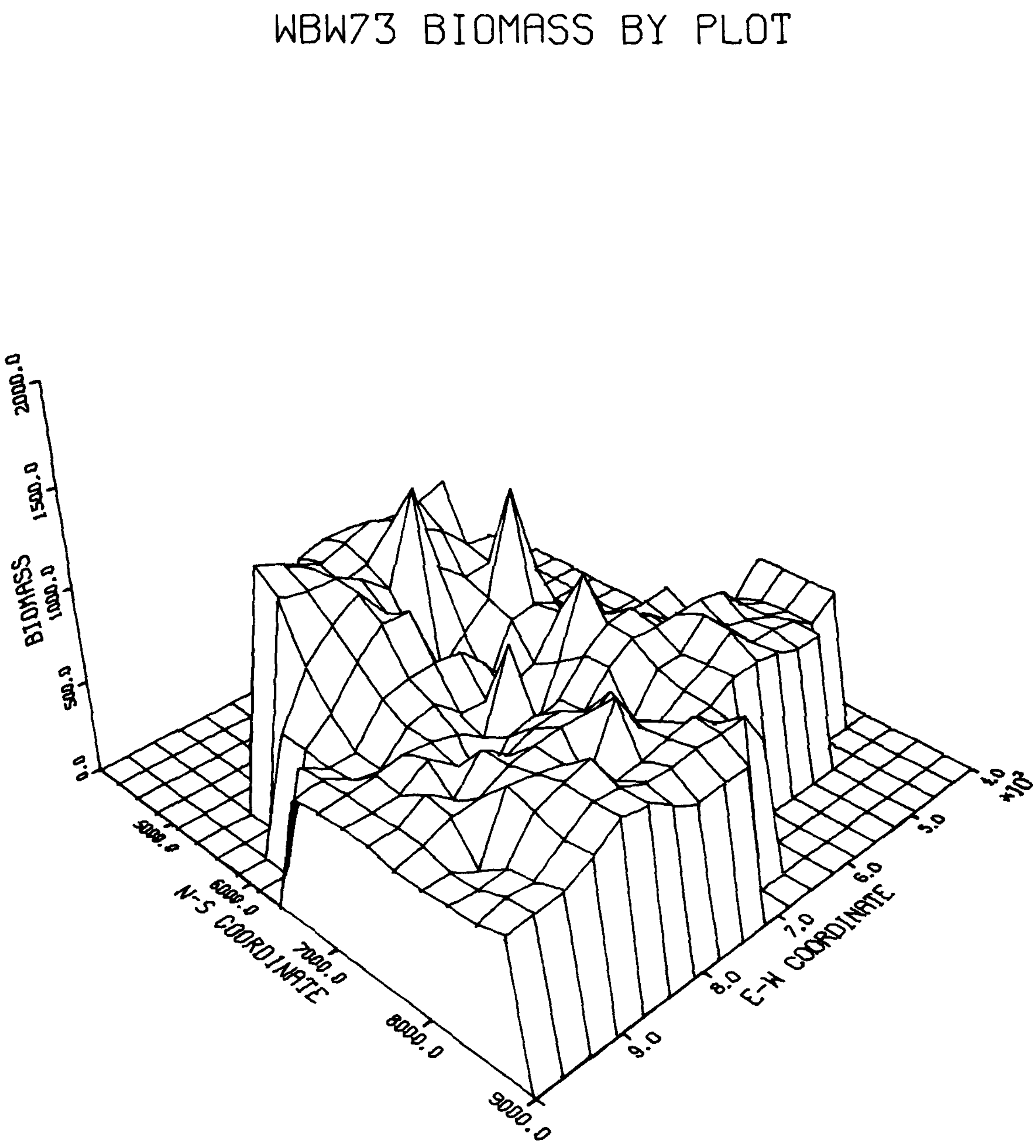

Figure 3. Southwesterly view of biomass on Walker Branch Watershed for 1973.

DAY= 03FEB80   MAX CO= 90.3

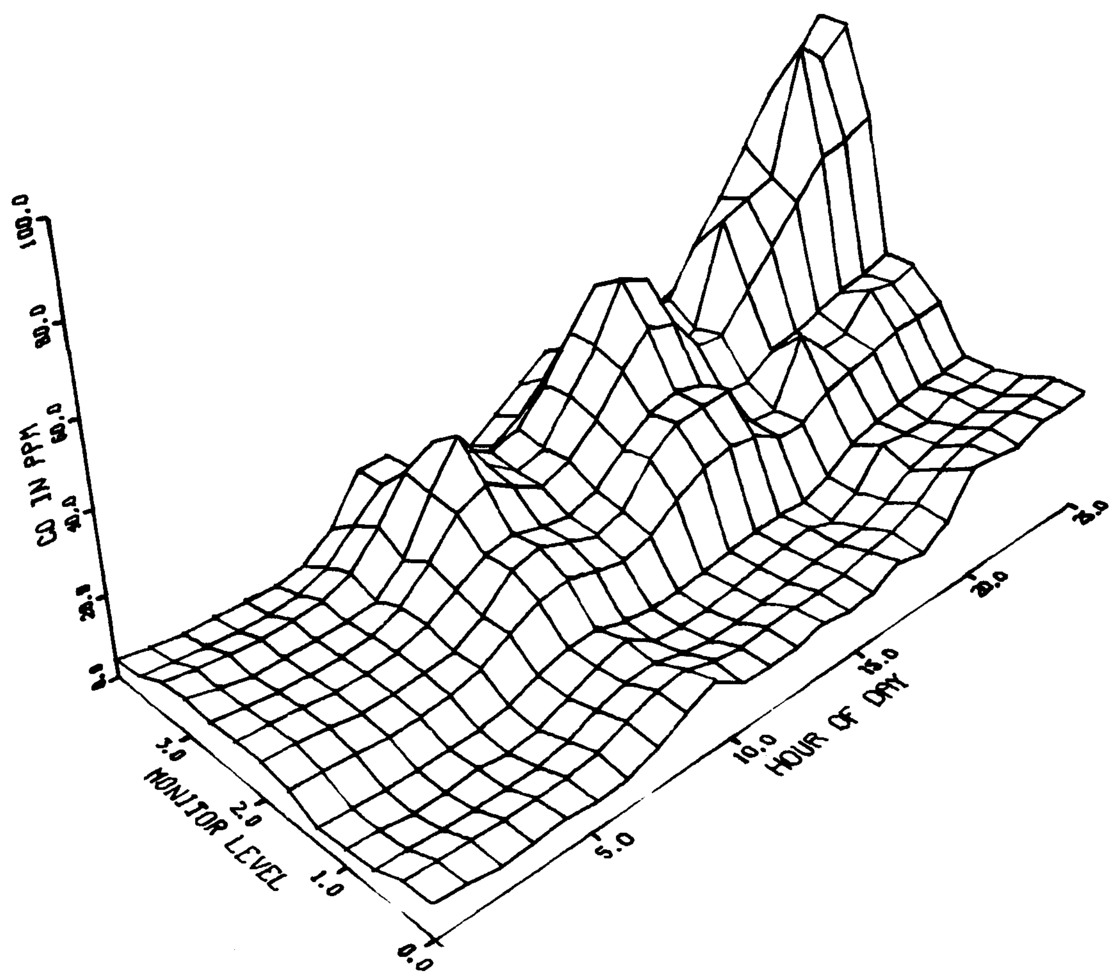

Figure 4. Carbon monoxide concentrations at 5 vertical locations over a 24-hour period for February 3, 1980, at the University of Minnesota Duluth Gasifier Facility.

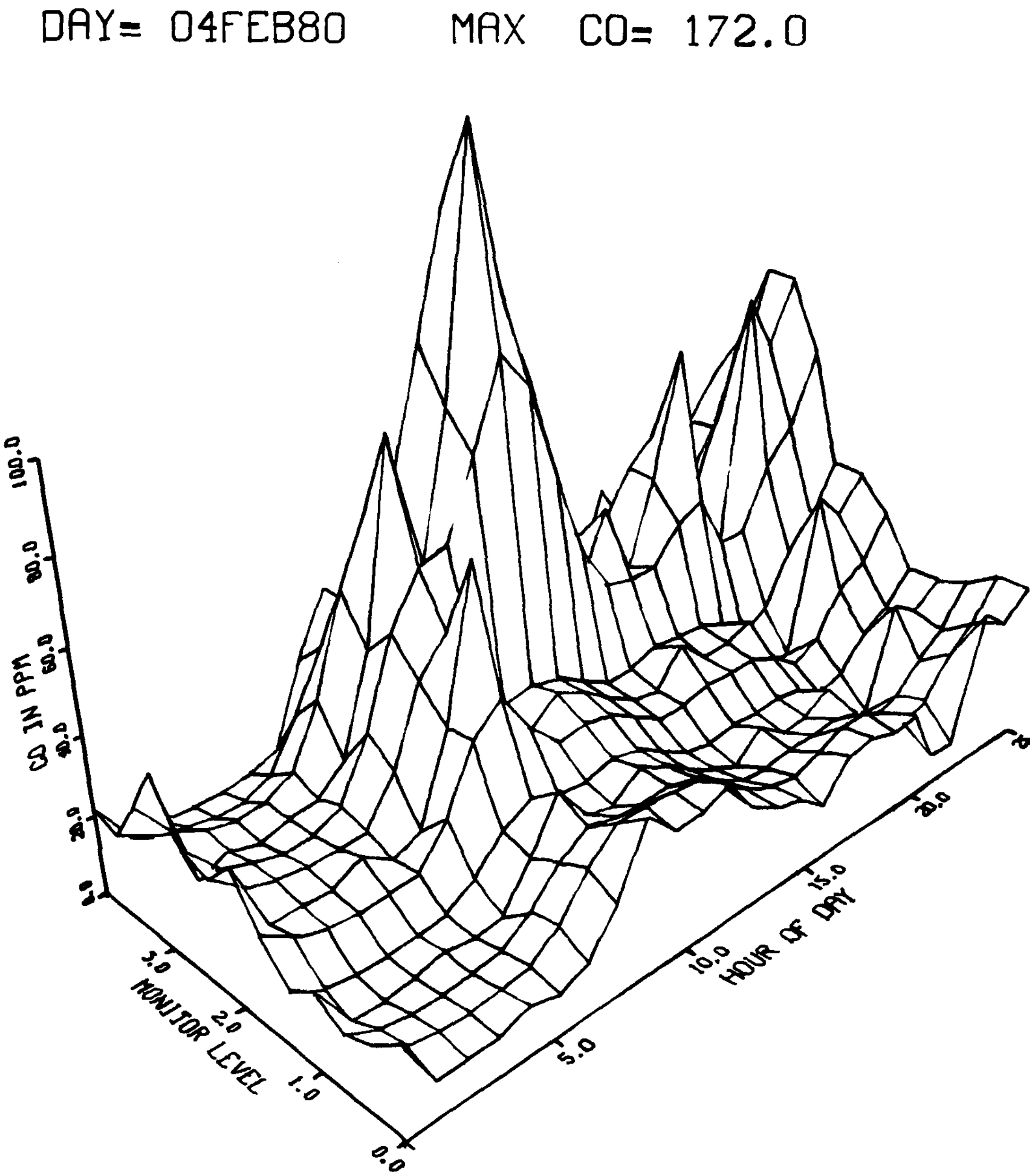

Figure 5. Carbon monoxide concentrations at 5 vertical locations over a 24-hour period for February 4, 1980, at the University of Minnesota Duluth Gasifier Facility.

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