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ABSTRACT

This module is part of a series designed to be used by life science students for instruction in the application of physical theory to ecosystem operation. Most modules contain computer programs which are built around a particular application of a physical process. PLOT3D is a subroutine package which generates a variety of three dimensional hidden line Cal Comp-type displays. The package features multiple plots per page, with or without annotation, or annotation without plots: multiple pages: automatic scaling: flexible tilting: two dimension interpolation over the image space: choice of size and location of plots on a page: choice of viewing angle and viewing distance: and various options which affect the appearance of the plot. An annotated listing illustrates the control and input data cards for a sample run, along with the associated output. (Author/CS)

PHYSICAL PROCESSES IN TERRESTRIAL AND AQUATIC ECOSYSTEMS

COMPUTER PROGRAMS AND GRAPHICS CAPABILITIES

USER'S GUIDE FOR SUBROUTINE PLOT3D

by

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USER'S GUIDE FOR SUBROUTINE PLOT3D

Identification

PLOT3D - A Subroutine Which Generates Three Dimensional Hidden Line Displays

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Date - April 1978, Center for Quantitative Science in Forestry, Fisheries, and Wildlife, University of Washington, Seattle, Washington 98195

Purpose

PLOT3D is a subroutine package which generates a variety of three dimensional hidden line CalComp-type displays. The package features multiple plots per page, with or without annotation, or annotation without plots; multiple pages; automatic scaling; flexible titling; two dimensional interpolation over the image space; choice of size and location of plots on a page; choice of viewing angle and viewing distance; and various options which affect the appearance of the plot. Each page of plots fits on a standard 8-1/2 x 11 inch page with margins of sufficient size to permit inclusion in three ring binders.

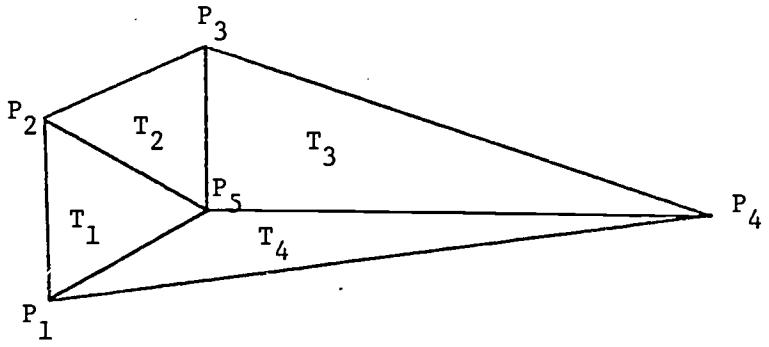
PLOT3D is built around an NX by NY grid of cells called an image space. The image space is filled with numeric values from a binary file of x,y,z coordinates which contains data points as follows:

$$x_1, y_1, z_1$$
$$x_2, y_2, z_2$$
$$\vdots$$
$$x_n, y_n, z_n$$

The x_i, y_i coordinates of each point specify its location in the x,y plane and the z_i coordinate is interpreted as its height. Each x,y coordinate pair locates an

appropriate cell within the NX by NY grid into which the z coordinate value is stored. Multiple z values mapped to a single cell are averaged together. Once the image space is complete, it is sent to an output routine which plots it along with titles and appropriate scaling information.

The image space may either be plotted directly or may be subject to a two dimensional interpolation scheme which converts it into a set of interlocking planar regions. Interpolation may only be applied to data files which are organized in a special way; namely, the data points in a file must form a set of triangles in the x,y plane. Consider the following region which is divided into four contiguous triangles labeled $T_1,\ldots,T_4$ whose vertex points are labeled $P_1,\ldots,P_5$:



Each triangle is defined by three sets of x,y,z coordinates and the data file must be organized as follows:

P_1: x_1, y_1, z_1
P_2: x_2, y_2, z_2 : T_1
P_5: x_5, y_5, z_5

P_2: x_2, y_2, z_2
P_3: x_3, y_3, z_3 : T_2
P_5: x_5, y_5, z_5

P_3: x_3, y_3, z_3
P_4: x_4, y_4, z_4 : T_3
P_5: x_5, y_5, z_5

P_4: x_4, y_4, z_4

P_1: x_1, y_1, z_1 : T_4

P_5: x_5, y_5, z_5

Note that each point occurs at least twice in the data file. Interpolation fits a triangular plane through the z coordinates in each triangle. The points in the plane are Δx and Δy distance apart where Δx and Δy are specified by the user. Both Δx and Δy must be specified since the x and y axes may have radically different scales. This form of interpolation, or point-enrichment, is particularly suitable for displaying the solutions to finite element formulations.

Input

This write-up assumes that PLOT3D is already incorporated as a subroutine in an existing program which uses the format-free input package (Gales and Anderson 1978; Anderson and Gales 1978).

The user assignable variables in PLOT3D are XMIN, XMAX, YMIN, YMAX, ZMIN, ZMAX, XRICH, YRICH, DFAULT, XVIEW, YVIEW, ZVIEW, XC, YC, XSIZE, YSIZE, NX, NY, LBOX, LHIDE, PAGE, TITLE, and LOCTIT, and are described as follows:

INPUT TABLE

NAME	TYPE	RESTRICTIONS	DESCRIPTION
XMIN XMAX YMIN YMAX ZMIN ZMAX	Real	$\geq -10^{29}$ $\leq 10^{29}$	XMIN, XMAX, YMIN, YMAX, ZMIN, and ZMAX define a three-dimensional window which encloses all the data in the image space to be displayed. Data outside the window are not shown. If one or more of the following conditions hold: XMIN $\geq$ XMAX, YMIN $\geq$ YMAX, ZMIN $\geq$ ZMAX the computer considers the limits to be unspecified by the user and computes new limits for the axis or axes in question which are sufficient to include all the data along that axis or axes in the image space.

NAME	TYPE	RESTRICTIONS	DESCRIPTION
XRICH YRICH	Real	≥ 0	XRICH and YRICH are the Δx and Δy increments used in two-dimensional interpolation (enrichment). If either is zero, no enrichment takes place. The user should note that the values of XRICH and YRICH should be coordinated not only with the data, but also with the size of the window set by XMIN, XMAX, YMIN, and YMAX. If either is too small, the computer will consume too much computer time, whereas large values of XRICH or YRICH will adversely affect the appearance of the plot. Note that interpolation should only be applied to data which are correctly organized on the binary data file.
DFAULT	Real	$\geq -10^{29}$ $\leq 10^{29}$	DFAULT is the default value assigned to all cells in the image space. DFAULT is usually set to zero.
XVIEW YVIEW ZVIEW	Real	|XVIEW| > XSIZE |YVIEW| > YSIZE |ZVIEW| > XSIZE |ZVIEW| > YSIZE	The point of view in space, in inches, from which the plot is seen by the user. Normally, XVIEW and YVIEW should be negative, indicating that the observer is behind the plot so that it appears in front of him, while ZVIEW should be positive, indicating that the observer is above the plot looking down. The user may have to experiment with different values for these viewpoints in order to obtain the desired view of the plot.
XC YC	Real	$0.5 \leq XC \leq 8$ $0.5 \leq YC \leq 10.5$	The location on a page of the lower left corner of a box which encloses the plot. The distances are in inches from the lower left corner of the page.
XSIZE YSIZE	Real	XSIZE $\geq .1$ XC + XSIZE ≤ 8 YSIZE $\geq .1$ YC + YSIZE ≤ 10.5	The size of a box, in inches, which is to contain the plot.
NX NY	Integer	$2 \leq NX \leq 30$ $2 \leq NY \leq 30$	The number of grid cells in the image space along the x and y axes.
LBOX	Integer	0, 1, 2, or 3	The box control for subroutine PICTURE. This parameter controls the structure of the three-dimensional window, or box, which contains the plot. The options are: LBOX = 0: No box lines. LBOX = 1: Surface and box lines. LBOX = 2: Surface, box, and side bars. LBOX = 3: Surface, box, side bars and labels. Normally, LBOX = 3.

NAME	TYPE	RESTRICTIONS	DESCRIPTION
LHIDE	Integer	0, 1, 2, -1, -2	The hidden line control parameter for subroutine PICTURE. The options are: LHIDE = 0: No hidden lines removed. LHIDE = 1: Hidden lines of plot but not of box are removed. LHIDE = 2: All hidden lines are removed. LHIDE < 0: Visible portions of the underside are also plotted. Normally, LHIDE = 2.
PAGE	Logical	T or F	If PAGE = T (true), then the current page is skipped and the current plot is written on the next page. If PAGE = F (false), the current plot is written on the current page.
TITLE	Logical	T or F	If TITLE = T (true), then the current plot consists of plot titles only, with no plot. If TITLE = F (false), then both plot and plot titles are written. Note that in the former case, the entire area defined by XSIZE, YSIZE is available for plot titles (or any other text), whereas in the latter case, the plot titles are either squeezed in near the top of the area defined by XSIZE, YSIZE, or just above it (see LOCTIT).
LOCTIT	Logical	T or F	If LOCTIT is T (true), then the plot titles will be contained wholly within the region defined by XC, YC, XSIZE, and YSIZE. If LOCTIT is F (False), the plot titles are placed above and outside this region.

Output

The output for PLOT3D consists of one or more plots per page. Each plot normally contains up to four lines of annotation near, or above, the top of the plot, along with x, y, and z axis labels.

Restrictions

The two-dimensional interpolation function should only be used on data which are correctly organized on the binary file of x, y, z coordinates.

Error Messages

PLOT3D issues three types of fatal error messages: input parameter errors, errors due to zero width windows, and errors arising from enrichment of faulty data, in addition to warnings when z axis values lie outside the range defined by ZMIN, ZMAX.

The first type of errors is of the form:

-----ERROR NO. x IN SUBROUTINE PLOT3D-----

yy...y OUT OF RANGE

yy...y = dd...d

where x is 1 through 6, yy...y is the name of the variable, and dd...d is its value. The second type is of the form:

-----ERROR NO. x IN SUBROUTINE PLOT3D-----

COMPUTED α-axis IS ZERO WIDTH

AT α = dd...d

where x is 7, 8, or 9, α is X, Y, or Z and dd...d is the x, y, or z axis value. The third type is of the form:

-----ERROR NO. 10 IN SUBROUTINE PLOT3D-----

TRIANGULAR REGION IS MALFORMED

ITS POINTS ARE

(x_1,y_1,z_1), (x_2,y_2,z_2), (x_3,y_3,z_3)

-----ERROR NO. 11 IN SUBROUTINE PLOT3D---

END OF FILE ENCOUNTERED BEFORE

A TRIANGLE IS COMPLETE

The warning messages are of the form:

-----WARNING Z VALUES OUT OF RANGE-----

n Z VALUES LESS THAN z_1

m Z VALUES GREATER THAN z_2

SMALLEST Z VALUE = x_1

LARGEST Z VALUE = x_2

COMPUTATION CONTINUES

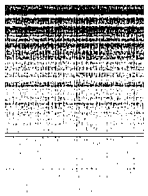
where z_1 and z_2 are ZMIN and ZMAX, respectively, n and m are the number of z axis values less than ZMIN and greater than ZMAX, in the image space, and x_1 and x_2 are the smallest and largest z values encountered.

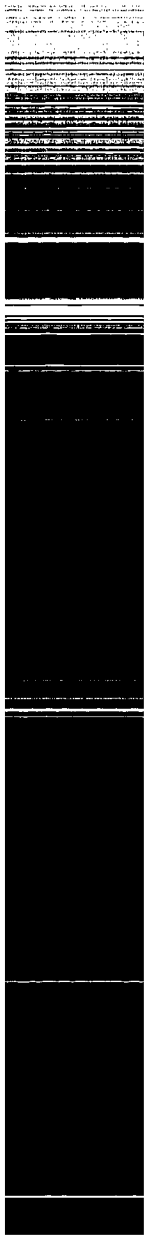
Errors 1 through 6 occur if the input parameters have improper values, errors 7 through 9 occur if the user is letting PLOT3D determine its own window size (by setting XMIN $\geq$ XMAX and/or YMIN $\geq$ YMAX and/or ZMIN $\geq$ ZMAX) and all x coordinates are equal, or all y coordinates are equal, or all z coordinates are equal (for example, if only one point occurs in the image space). Error 10 occurs if the three vertex points of a triangle form a single line, and error 11 occurs if the last triangle possessed only one or two vertex points.

Sample Run

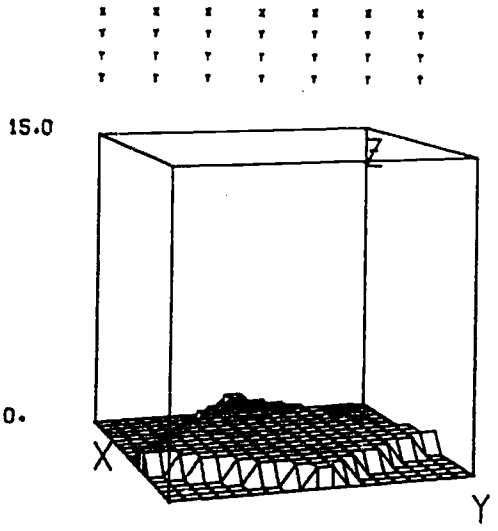
The annotated listing on the next few pages illustrates the control and input data cards for a sample run, along with the associated output. The output consists of a set of plots and annotation on one page which show the effects of various plot options applied to a single file of x, y, z coordinates.

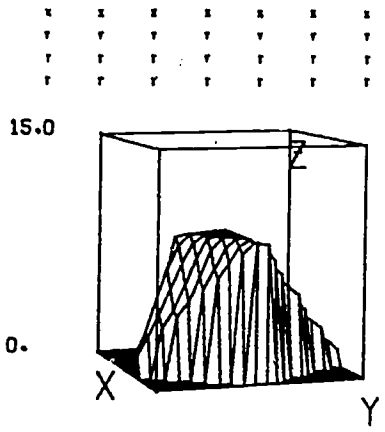
```
XPL3D,CM50000,T35,P2.          PLOT3D TEST
ACCOUNT,XXXXXXXX,XXXXXX.
COMMENT.
COMMENT.*************************************************************
COMMENT.* THE ABOVE CARDS IDENTIFY THE JOB, SPECIFY THE MEMORY       *
COMMENT.* REQUIREMENTS (50000 OCTAL), ESTIMATE THE CENTRAL PROCESSOR *
COMMENT.* TIME (35 SECONDS), AND SPECIFY THE USERS ACCOUNT           *
COMMENT.*************************************************************
COMMENT.
MNF,E=0,R=7,J.
COMMENT.
COMMENT.*************************************************************
COMMENT.* THE ABOVE CARD CALLS THE MINNESOTA FORTRAN COMPILER TO     *
COMMENT.* COMPILE THE EXECUTION PROGRAM FOR PLOT3D                   *
COMMENT.*************************************************************
COMMENT.
ATTACH,BPL3D,ID=BPL3D.
COMMENT.
COMMENT.*************************************************************
COMMENT.* THE ABOVE CARD ATTACHES THE PLOTTING ROUTINE IN BINARY FORM *
COMMENT.*************************************************************
COMMENT.
ATTACH,BFF,ID=BFF.
COMMENT.
COMMENT.*************************************************************
COMMENT.* THE ABOVE CARD ATTACHES THE FREE-FORMAT INPUT ROUTINES IN   *
COMMENT.* BINARY FORM.                                               *
COMMENT.*************************************************************
COMMENT.
ATTACH,GRAFTN.
LIBRARY,GRAFTN.
COMMENT.
COMMENT.*****************************************
COMMENT.* THE ABOVE CARDS ATTACH THE LIBRARY   *
COMMENT.* ROUTINES FOR PL3D AND DESIGNATE THAT *
COMMENT.* FILE AS THE CURRENT LIBRARY.         *
COMMENT.*****************************************
COMMENT.
LOAD,BFF.
LOAD,BPL3D.
LOAD,LGO.
EXECUTE,XPL3D.
COMMENT.
COMMENT.*************************************************************
COMMENT.* THE ABOVE CARDS LOAD THE EXECUTION, INPUT AND PLOT ROUTINES *
COMMENT.* AND CAUSE CONTROL TO BE PASSED TO XPL3D FOR EXECUTION      *
COMMENT.*************************************************************
CATALOG,TAPE99,RP=5.
COMMENT.
COMMENT.*****************************************
COMMENT.* THE ABOVE CARD SAVES THE PLOTTING    *
COMMENT.* TAPE,-TAPE99-, SO THAT THE PLOTS MAY *
COMMENT.* BE PREVIEWED BEFORE BEING SENT TO    *
COMMENT.* THE PLOT QUEUE.                      *
COMMENT.*****************************************
COMMENT.
COMMENT.*************************************************************
COMMENT.* THE BELOW CARDS ARE THE EXECUTION PROGRAM XPL3D            *
COMMENT.*************************************************************
COMMENT.
```

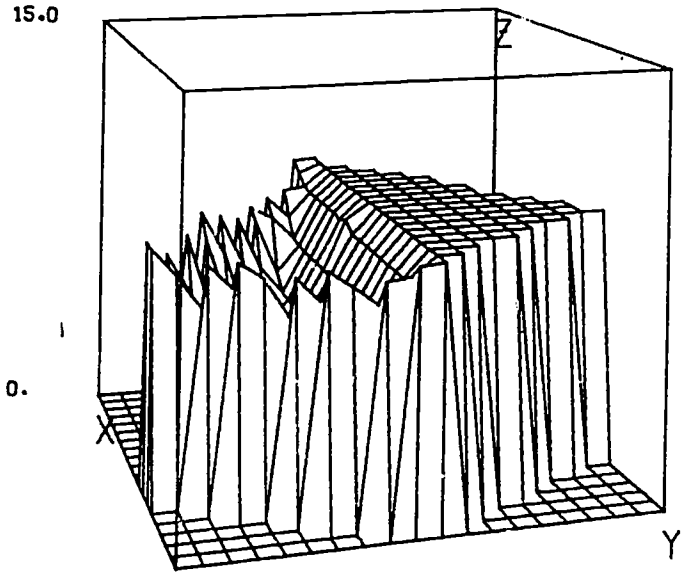




```
*EOR
---- PROGRAM GOES HERE ----
*EOR
 /*
  /* INITIAL PLOT PARAMETERS */
 /*
  XMIN = 1.0,  XMAX = 5.0,  YMIN = 1.0, YMAX = 4.0,
  ZMIN = 0.0,  ZMAX = 15.0,  XRICH = 0.05,  YRICH = 0.05, DEAULT = C.C,
  XVIEW = 5.0,  YVIEW = 13.228, NX = 20, NY = 20,
  ZVIEW = 30.0,
  LBOX = 3,  LHIDE = 2     $
 /*
 /* PARAMETERS FOR PLOT 1 */
 /*
   XC = 1.5,  YC = 8.0,  XSIZE = 2.0, YSIZE = 2.0,
    TITLE = .F.,  LOCTIT = .F.    $
 /*
 /* PARAMETERS FOR PLOT 2 */
 /*
    XC = 5.0,  LOCTIT = .T.   $
 /*
 /* PARAMETERS FOR PLOT 3 */
 /*
    XC = 3.0,  YC = 3.5,  XSIZE = 3.0,  YSIZE = 3.0,  LOCTIT = .F.   $
 /*
 /* PAPAMETERS FOR PLOT 4 */
 /*
    XC = 3.0,  YC = 1.5, XSIZE = 5.0,  YSIZE = 1.0,
    TITLE = .T.     $
*EOR
*EOF
```


15.0
0.
Z
X
Y


15.0
0.
Z
X
Y


15.0
0.
Z
X
Y

Acknowledgments

We are indebted to Dr. Melvin L. Prueitt of the Los Alamos Scientific Laboratory for the original PICTURE program which is used in PLOT3D as a subroutine.

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