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DISPLAY OF COMPLEX THREE DIMENSIONAL FINITE ELEMENT MODELS.(U)

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DISPLAY OF COMPLEX THREE DIMENSIONAL  
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might focus on reducing the amount of user dependence in the algorithm,  
although most reasonable cases currently require no user interaction.

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## FORWARD

This document represents a final report to the Office of Naval Research on Task No. NR 064-554, the Display of Complex Three Dimensional Finite Element Models - Phase III. The main body of the report is a discussion of the computer programs which have been developed during Phase III. This material was prepared by Thomas W. Sederberg and serves as his M. S. Thesis at Brigham Young University. The remaining paragraphs in this forward discuss activities related to the contract that are not discussed in the main body of the report.

### Distribution of MOVIE.BYU

This general purpose computer graphics software package (largely the result of efforts under Phases I and II of this contract), has now been distributed to approximately 160 organizations in the United States, Canada, England, France, Germany, Norway, Israel, and Australia. A complete mailing list of those organizations is included as Appendix C.

### Technical Presentations

Since the award of Phase III of this contract, technical presentations featuring results obtained under this funding have been made by Dr. Christiansen to the following groups. Of course, travel funds came from many sources and some of the presentations were on an informal basis.

1. Envirotech Corporation (Winston-Salem, North Carolina)
2. Waterways Experiment Station, Corps of Engineers (Vicksburg, Miss.)
3. University and College Designers Association - National Conference (Provo, Utah)

4. Engineering Society of Detroit's Third Annual Computer Graphics Conference (Detroit, Michigan)
5. Industrial Design Department, Center for Creative Studies (Detroit, Michigan)
6. Computer Graphics Workshop, University of Arizona (Tucson, Arizona)
7. Graduate Seminar in Computer Science, Brigham Young University (Provo, Utah)
8. 3rd Southwest Graduate Research Conference in Applied Mechanics, University of Texas (Austin, Texas)
9. Department of Creative Arts, Purdue University (Lafayette, Indiana)
10. Raytheon Missile Systems (Bedford, Mass.)
11. Graphics Utah Style - 77 (Snowbird, Utah)
12. Symposium on Computer Methods in Engineering, University of Southern California (Los Angeles, California)
13. Genisco Corporation (Irvine, California)
14. Tektronix Corporation (Wilsonville, Oregon)
15. Shell Development Co. (Houston, Texas)
16. Design and Drafting Seminar, Brigham Young University (Provo, Utah)
17. American Society of Mechanical Engineers, Annual Meeting (Atlanta, Georgia)
18. Art Directors Club (Salt Lake City, Utah)

Since the final report for Phase II, the following technical papers have been published.

Christiansen, H. N., Brown, B. E., and McCleary, L. E., "A General Purpose Computer Graphics Display System for Finite Element Models," 46th Shock and Vibration Bulletin, Part 5, August 1976, pp. 61-66.

Christiansen, H. N., "Computer Graphics - Treatment for the Terminal  
Illness," Preprint 2765 - Development of Computational Methods in Str-  
uctural Analysis and Design: Past, Present, and Future, ASCE, Philadelphia,  
PA, Sept. 1976, pp. VI 1-11.

Christiansen, H. N., "Computer Simulation of Distorted Structural  
Frameworks," Journal of Computers and Structures, Vol. 6, Dec. 1976,  
pp. 497-501.

Christiansen, H. N., and Stephenson, M. B., "MOVIE.BYU - A General  
Purpose Computer Graphics Display System," Proceedings of the Symposium  
on Applications of Computer Methods in Engineering, USC, Aug. 1977.

Recently, three more technical papers (two covering aspects of  
Phases I and II and other concerned with Phase III) have been written  
and submitted for upcoming meetings.

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## Chapter 1

### INTRODUCTION

There has been a disparity between the conventional method of describing topographic surfaces (i.e. contour line definition) and a format of surface description often used in continuous-line computer graphics (i.e. panel definition). The two differ enough that conversion from contours to panels is not a trivial problem. A computer program that performs such a conversion would greatly facilitate continuous tone display of topographical surfaces, or any other surface which is defined by contour lines.

This problem has been addressed by Keppel<sup>1</sup> and alluded to by Fuchs<sup>2</sup>. Keppel's is an highly systematic approach in which he uses graph theory to find the panel arrangement which maximizes the volume enclosed by concave surfaces. Fuchs mentions an approach to the problem as part of an algorithm to reconstruct a surface from data retrieved from a laser scan sensor.

This thesis elaborates on a general conversion system. Following a brief overview of computer graphics, a simple algorithm

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<sup>1</sup>E. Keppel, "Approximating Complex Surfaces by Triangulation of Contour Lines," Journal of Research and Development, IBM Vol. 19, No. 1 (January 1975), 2-11.

<sup>2</sup>Henry Fuchs, "The Automatic Sensing of 3-Dimensional Surface Points from Visual Scenes" (unpublished PhD dissertation, University of Utah, 1975.)

is described which extracts a panel definition from a pair of adjacent contour loops subject to the restriction that the two loops are similarly sized and shaped, and are mutually centered. Next, a mapping procedure is described which greatly relaxes the above restrictions. It is also shown that the conversion from contours to panels is inherently ambiguous (to various degrees) and that occasionally the ambiguity is great enough to require user interaction to guide the conversion algorithm. An important complication addressed in this thesis is the problem of handling cases where one contour loop branches into two or more (or vice versa).

Attention turns next to a contour line definition of the human brain, and special problems encountered in preparing those data for continuous tone display. The final chapters explain the fortran implementation, present an example problem, and show sample pictures of the brain parts.

## Chapter 2

### AN OVERVIEW OF COMPUTER GRAPHICS

The past decade has seen fantastic advances in the field of computer graphics. Today, it is a sheltered person who is not familiar with some form of computer graphics, be it Snoopy calendars or computer ping-pong on one end of the spectrum, or sophisticated airline pilot training simulators on the other end. Display mediums used in graphics are very diverse, and include raster scan cathode ray tubes, cathode ray storage tubes, conventional line printers, plotting machines, and film recorders. Perhaps the most life-like pictures are continuous tone images produced on raster scan cathode ray tubes.

Continuous tone display requires the capability of defining the light intensity of each pixel of a scan line - TV style. There are typically 512 scan lines per picture with 512 pixels per line, and 256 levels of light intensity for each pixel. For a color image, each pixel must know the light intensity for each of the three primary colors. Given the intensity information, a picture can be 'painted' pixel by pixel, scan line by scan line.

Whereas the display itself is strictly a hardware problem, the software problem is chiefly this: What intensity should each of the 250,000 odd pixels have in order to create the desired picture? The preceding question assumes a microscopic perspective, whereas the actual software development proceeds at a macroscopic

level. The overall software problem divides itself into several major sub-problems, such as spatial orientation (translation and rotation of the object), perspective, hidden surface removal, and reflectivity. This brief overview omits discussion of the solution to these problems, but the reader is referred to a sampling of literature addressing these problems.<sup>1,2,3</sup>

One point must be made here, however. Continuous tone graphics concerns itself with surfaces - specifically surfaces of mathematical models. Consequently, only surface definitions, as opposed to line or point definitions, can be used as input data. One way to define an arbitrary surface is to approximate it as a network of discrete polygonal elements (triangles and quadrilaterals) which are defined first by vertices in 3-D space, and further by a connecting perimeter. Such a definition will hereafter be referred as a panel definition.

The continuous tone pictures in this thesis were photographed off a Comtal Image Generator. The display files were generated using MOVIE.BYU - a powerful graphics package written by Dr. Christiansen

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<sup>1</sup>Henry N. Christiansen, "Applications of Continuous Tone Computer-Generated Images in Structural Mechanics," Structural Mechanics Computer Programs - Surveys, Assessments, and Availability, University Press of Virginia, Charlottesville, Virginia, June 1974, pp. 1003-1015.

<sup>2</sup>Henry N. Christiansen, "MOVIE.BYU - A General Purpose Computer Graphics Display System," Proceedings of the Symposium on Applications of Computer Methods in Engineering, University of Southern California, Los Angeles, August 1977.

<sup>3</sup>William M. Newman and Robert F. Sproull, Principles of Interactive Computer Graphics (New York: McGraw-Hill, 1973)

(of Brigham Young University) and Dr. Stephenson (now at the University of Arizona). This thesis focuses on generating panel definitions from contour data in a format compatible with the requirements of MOVIE.BYU.



## Chapter 3

### CONVERTING CONTOURS INTO PANELS

#### A LIMITED TRIANGULATION ALGORITHM

A contour line can be viewed mathematically as the intersection of an arbitrary surface and a plane. In topography, the plane is generally horizontal at a specified elevation. If the surface is closed, its contour lines will likewise be closed loops. A set of contour lines on evenly spaced parallel planes comprise a contour definition of a surface.

Contour lines of an irregular surface, such as found in nature, do not lend themselves to curve fitting, or other attempts at precise mathematical description. The most convenient numerical description of a contour line is perhaps one where the line is approximated as a string of straight line segments. This digitized contour line offers two pieces of information: nodal coordinates, and connectivity of nodes. Connectivity is implied by the sequence in which the nodes are listed.

Triangulation - the process whereby a panel definition of triangular panels is extracted from a contour definition - is greatly facilitated by observing the connectivity inherent in contour data. That connectivity leads us to explicitly note an obvious rule in triangulation: If two nodes of the same contour are to be defined as nodes of the same triangle, they must neighbor each other on their contour line.

Also, no more than two vertices of any triangle may be recruited from the same contour line (except, of course, in the special case where the entire area enclosed by that contour is to be capped off).

Triangulation is most logically carried on between pairs of adjacent contour lines. Consider this pair of contour loops T (top) and B (bottom).

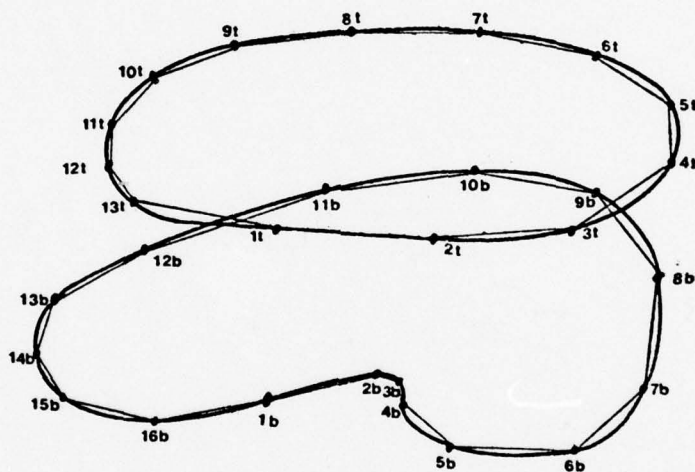


Figure 1

#### Contour Pair Prior To Triangulation

Two requirements must be met before triangulation commences. First, both loops must run in the same rotational direction, and second, the first nodes of each loop must be proximate. Both rules are met by these loops, and they are ready for triangulation.

Perhaps at this point discussion might best center on the finished product.

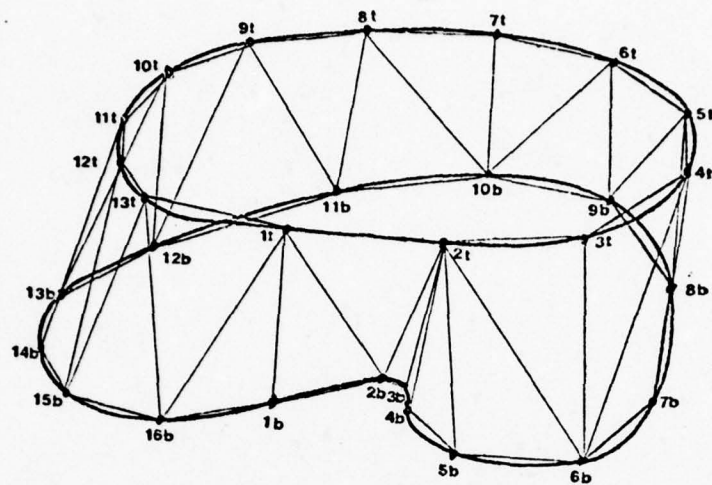


Figure 2

## Triangulated Contour Pair

Observe in figure 2 the triangulated contour pair. If one were to ask oneself "How could a computer algorithm be taught to do this?", a few ideas would assert themselves. First, each contour segment can be considered to be the base of a triangle, with the third vertex being a node from the other contour. Secondly, each triangle appears to be as fat as possible. That is, the third vertex is always very near its counterparts on the other contour line.

With these ideas in mind, consider again the untriangulated loops. Referring to figure 3, triangulation commences by defining diagonal  $1t-1b$ . Since contour connectivity requires  $1t-2t$  and  $1b-2b$  as bases of triangles, there are exactly two candidates for the first triangle:  $1t-1b-2t$ , and  $1t-1b-2b$ . Glancing back at the solution,

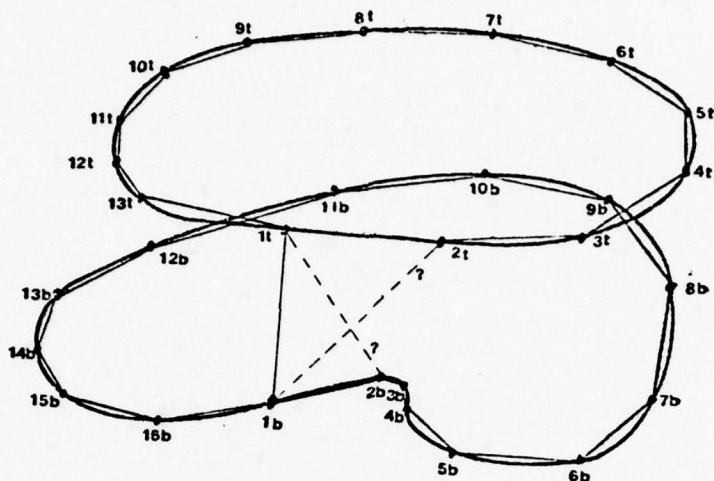


Figure 3

## Commencing Triangulation

it is seen that 1t-1b-2b was selected. Moving on, once again there are exactly two possibilities for the second triangle: 1t-2b-2t, and 1t-2b-3b. This time, triangle 1t-2b-2t is selected. Notice that in each case, there are only two triangles to decide between, and that the triangle with the shortest diagonal is chosen. This procedure continues until both loops have been traversed.

This "shortest diagonal" algorithm is very easily implemented, and works fine as long as the two loops are mutually centered and are of reasonably similar size and shape.

## MAPPING

The basic "shortest diagonal" algorithm fails for mildly complex cases. A typical example is found in this pair of offset contours.

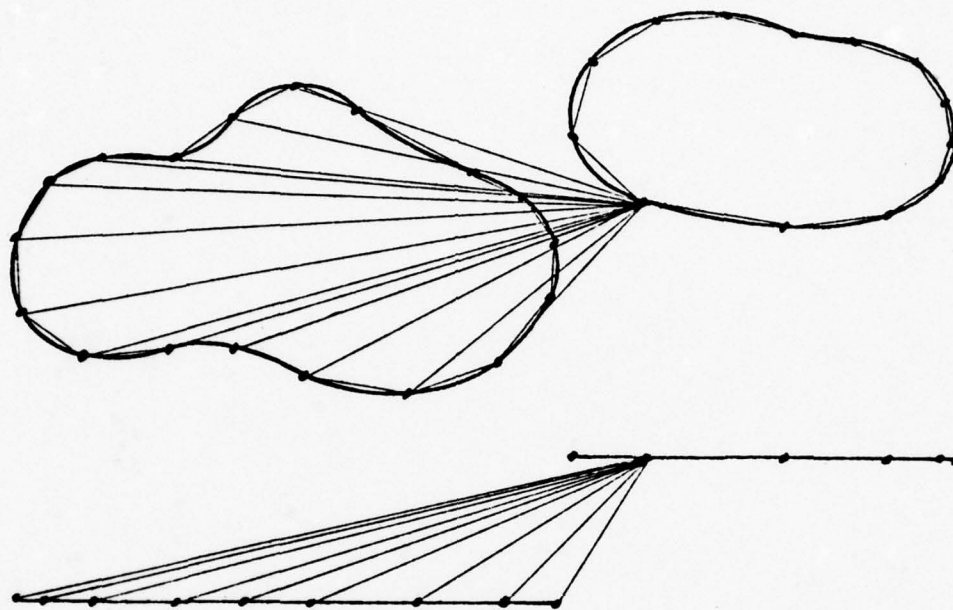


Figure 4  
Failure Example

Here, the shortest diagonal search results in a cone. Rather than abandoning the algorithm, let's consider modifying the contour loops to make them more acceptable. As mentioned, the algorithm prefers contour pairs to be mutually centered, of similar size, and of similar shape. The first two requirements can be met by mapping the loops onto a unit square prior to triangulation. (Mapping also tends to make the shapes more uniform, though not always enough. This problem is addressed in the next section.)

Mapping is easily done using translation and scaling functions. Each contour is mapped consecutively in the following manner:

1. Define the rectangular window which encloses the contour.

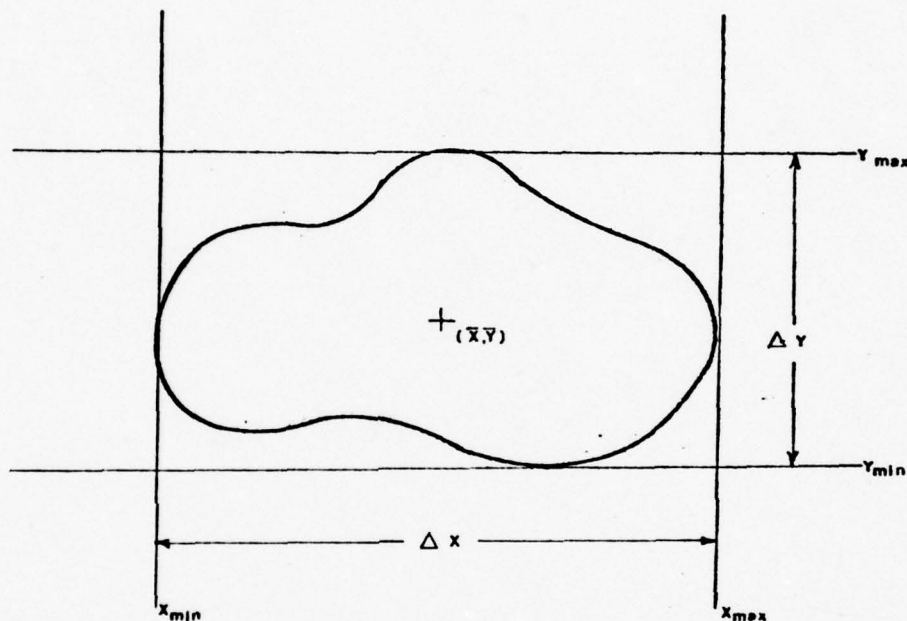


Figure 5

Window Parameters

2. Calculate  $\Delta X, \Delta Y, \bar{X}$ , and  $\bar{Y}$ .
3. Map onto a unit square centered at  $(0,0)$  by translating and scaling the contour such that its window matches the unit square's window. The equations for this are:

$$X' = (X - \bar{X}) / \Delta X$$

$$Y' = (Y - \bar{Y}) / \Delta Y$$

The mapped contour pair looks like this:

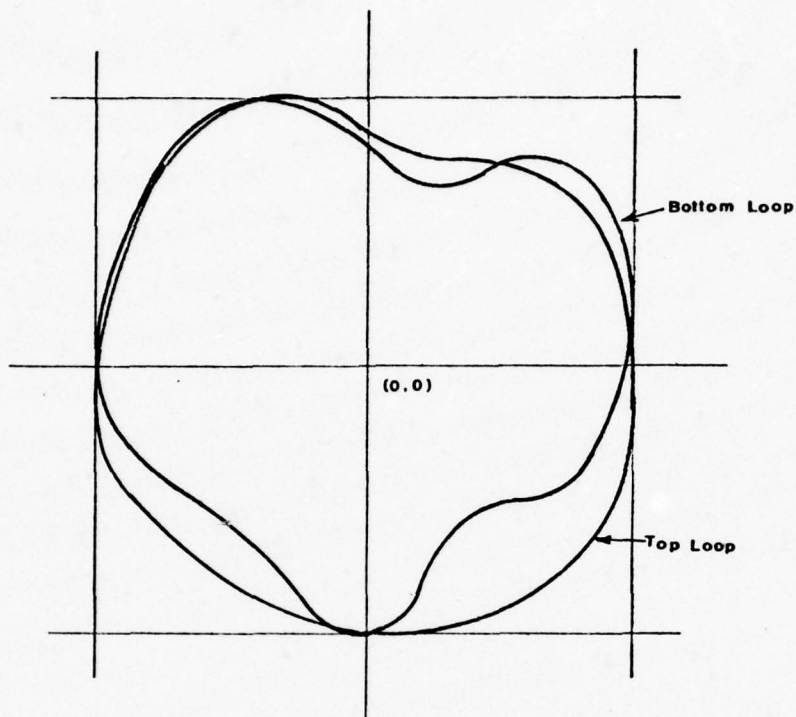


Figure 6

#### Mapped Contour Pair

With both contours thus mapped, they are easily handled by the original algorithm.

A fringe benefit of mapping is that the resulting triangles tend to align themselves with diagonals that are biased in the direction of the offset. This creates a desirable longitudinal texture.

#### ULTIMATE AMBIGUITY

A set of contour lines contains the following mathematical information:

1. Exact coordinates of some points on the surface.
2. Approximate gradients in the X-Y contour plane.
3. A general idea of the range of possible Z-gradients.

A panel definition contains items 1 and 2 and improves on item 3 by pinning down approximate Z components of surface gradients. Consequently, there is a degree of ambiguity inherent in the triangulation problem.

When two loops are similarly shaped, the ambiguity is negligible. To illustrate, consider these two solutions of the same triangulation problem:



Figure 7

*Synonymous Triangulation Interpretations*

Since these two solutions are different, one of them is probably a more exact approximation of the actual surface. But, since the true surface gradients are not available for comparison, and since the two solutions are so similar, either solution is probably adequate. After all, contour lines form a skeletal framework that cast rather rigidly the shape of the surface.



However, as the respective shapes of a contour pair become increasingly divergent, the ambiguity becomes increasingly pronounced. The following convolution provides a good example:

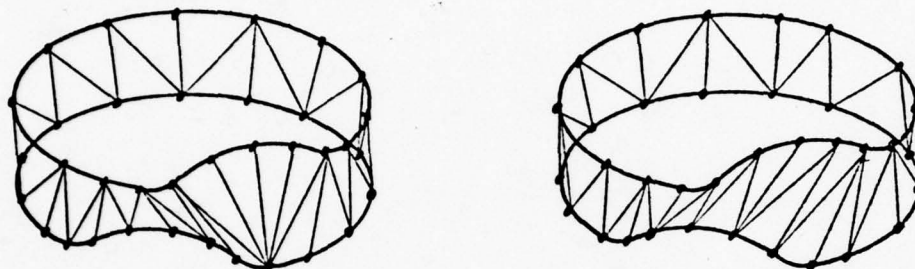


Figure 9

#### Non-Synonymous Triangulation Interpretations

Here, the variation in interpretation is not as tolerable. Both solutions are reasonable, yet one is wrong. Clearly, more information is required to resolve this problem.

There are two ways to provide the needed information. First, one could require the contour planes to be close enough together that there is minimal variation between adjacent contour lines. This approach has the advantage of tending towards an exact description, and the disadvantage of being uneconomical.

The second approach (adopted in this thesis by default) is to request user interaction to guide the triangulation over cases

of excessive ambiguity. This is a more general solution to the problem. Here, the user is called upon to resolve the ambiguity with his knowledge of the true shape of the surface. For the mechanics of how this is implemented in the computer program, refer to the user documentation and the example problem.

#### BRANCHING

An important feature of this algorithm is the capability to handle branching. Consider this simple case where one contour loop branches into two:

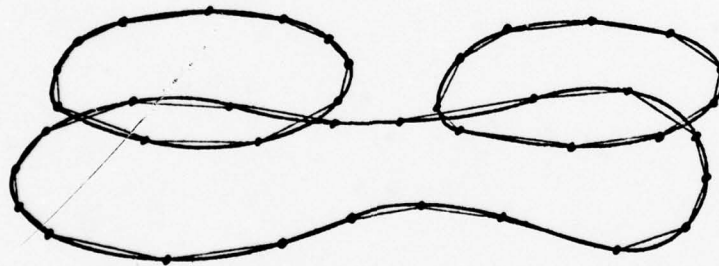


Figure 9

#### Simple Case of Branching

One way to handle this is to respectively treat each contour as if it were alone, neglecting the other branch. The resulting triangulation would appear like this:

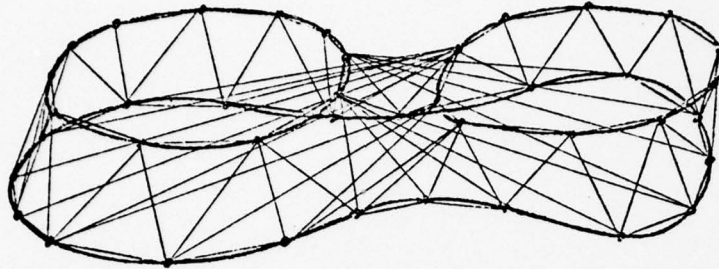


Figure 10

## Uneconomical Handling of Branching

Garbled as it looks, hidden surface elimination cleans it up, and provides a smooth transition between branches.

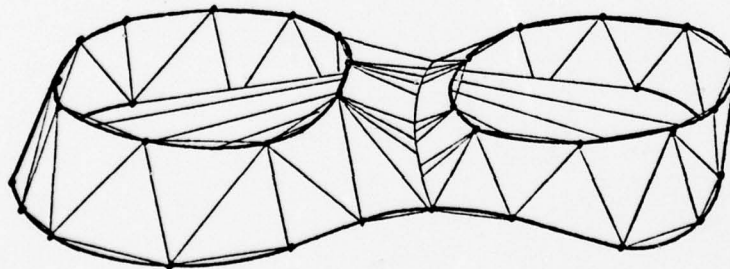


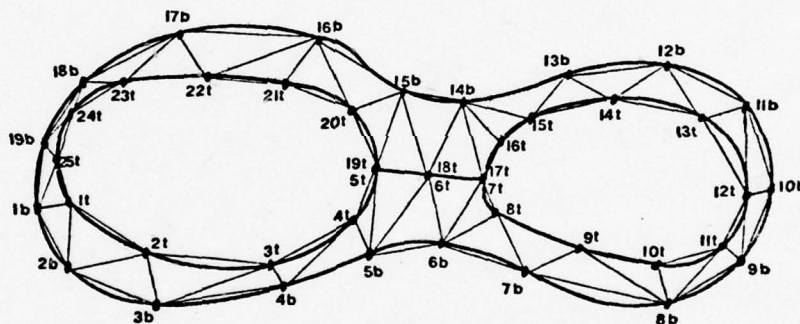
Figure 11

## Preceding View With Hidden Surface Elimination

Drawbacks are that it is uneconomical, and it is unacceptable in even mildly complex branching situations.

A more economical, and more general, approach to branching is outlined in this thesis. The idea is to treat all branches as one continuous closed loop by introducing a new node midway between the closest nodes on the branches and renumbering the nodes of the branches and the new node(s) such that they can be considered as being one loop. The Z coordinate of the new node is the average of the Z coordinate of the two levels involved.

Plan



Elevation

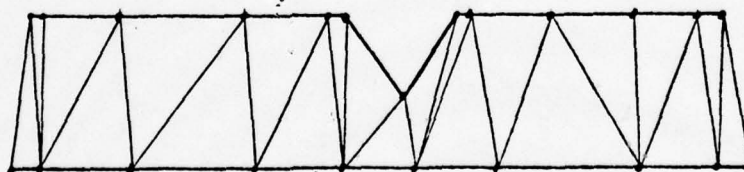


Figure 12

Preferred Handling of Branching

As seen from figure 12, the new node and its immediate neighbors are numbered twice to give the effect of one continuous loop. Triangulation can now proceed as normal. The scheme is easily expanded to handle more than one branch.

Often, there are several contour loops on adjacent planes, posing the problem of loop connectivity. Which loops should be triangulated one-on-one, and which are cases of branching? Judgment, in clear cut cases, can be made on the basis of window overlap.

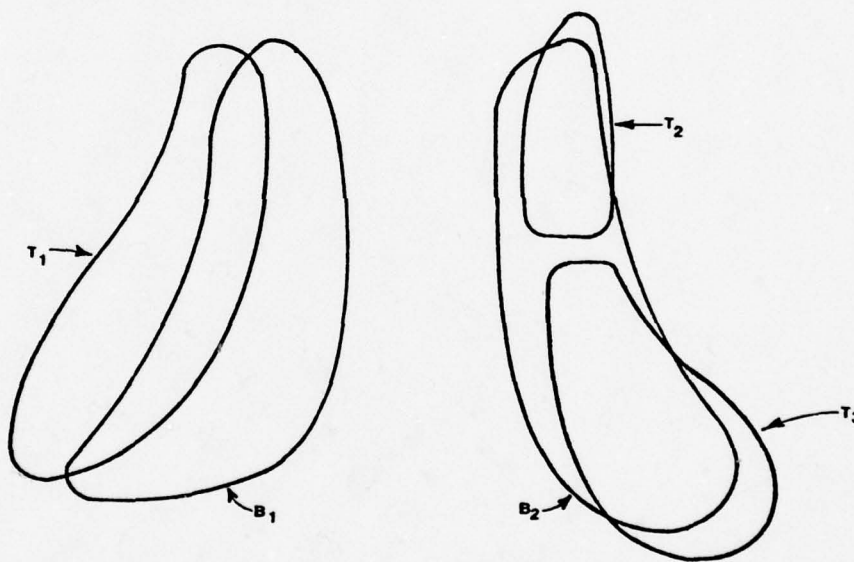


Figure 13

#### Typical Problem in Connectivity

Here,  $T_1$  and  $B_1$  clearly go together, and  $B_2$  clearly branches into  $T_2$  and  $T_3$ . Window overlap is best found by default: IF they don't not overlap, they overlap.

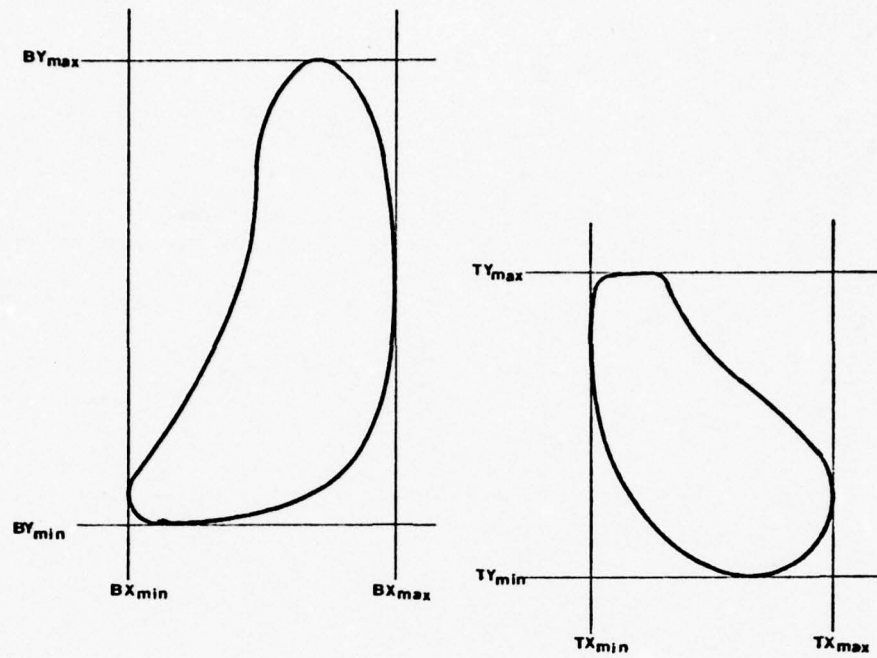


Figure 14

## Overlap Test

The rectangular windows definitely do not overlap if:

$$TY_{\max} < BY_{\min} \quad \text{or}$$

$$TY_{\min} > BY_{\max} \quad \text{or}$$

$$TX_{\max} < BX_{\min} \quad \text{or}$$

$$TX_{\min} > BX_{\max}$$

On the other hand, if all four inequalities are false, the windows necessarily overlap.

The algorithm works well for mildly complex cases, with optional user interaction capabilities to handle complex branchings.

## Chapter 4

### BRAIN CONTOUR DATA

#### ORIGIN AND DESCRIPTION

The brain data to be used for example purposes in this thesis has an interesting history. In 1967, the first of several movies was made of a human brain at the University of California at San Diego. Using the process of cinemorphology, an entire human brain was placed in a microtome capable of shaving off a slice 25 microns thick. After each slice, a frame of movie film was shot. The entire brain was sliced through, with each successive newly exposed surface recorded on film. Every nth frame of the movie was exploded photographically and outlines traced of each distinct brain structure. Figure 15 shows a cortex contour. In all, 22 separate structures were recorded. The contour outlines were laid on an acoustic tablet and a graduate student (of course!) selected appropriate nodes with the acoustic pen. The nodes were then digitized and recorded.

This digitized data base was accessed by a line drawing graphics package which can produce real time line drawing movies (in color!) on an Evans and Sutherland Picture System.

Each contour plane is referred to as a "page", and there are 98 pages total, ranging from page 3 at the top of the cortex to page 100 at the bottom of the brain stem. The data base is

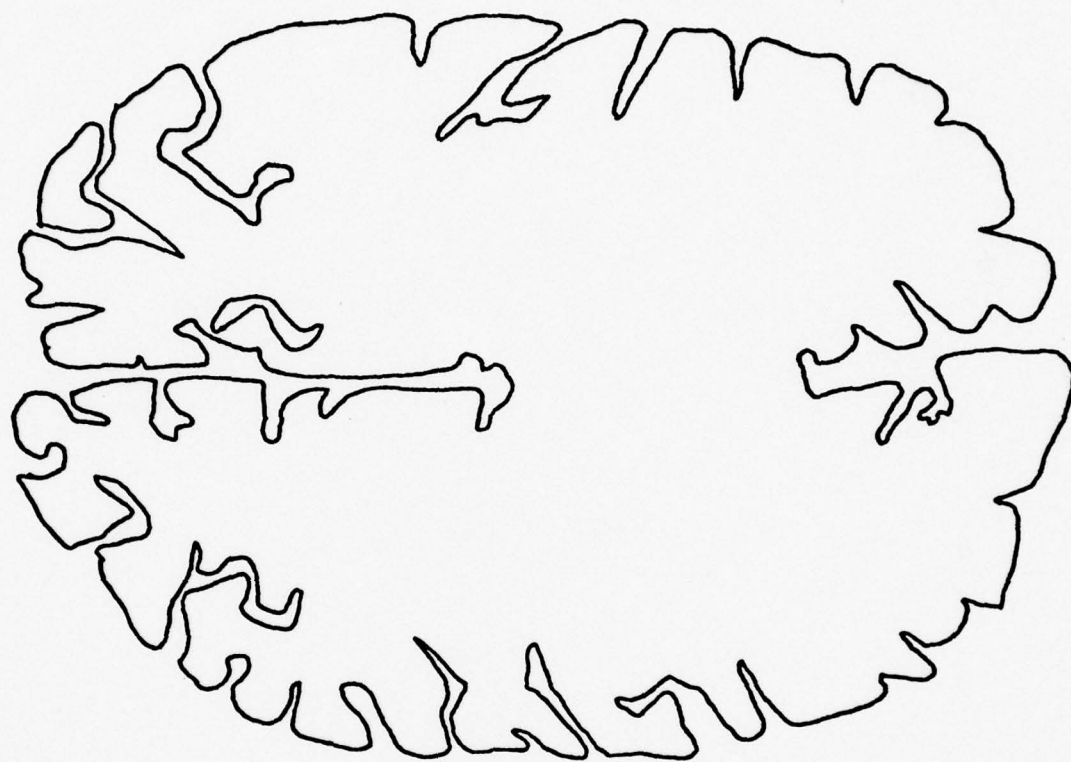


Figure 15

Contour Line of Brain Cortex

massive - totaling 78,651 nodes. Table 1 shows the number of nodes per structure, as well as their page limits. Pages are spaced approximately  $1/25''$  apart, corresponding to a brain that is roughly 4" tall.



Table 1

## INDEX TO BRAIN DATA

	STRUCTURE	PAGES	NODES
1	Cortex	3-78	52,870
2	Caudate	30-61	1,922
3	Ventricles	30-84	4,707
4	Fornix	35-57	1,081
5	Putamen	37-54	1,075
6	Thalamus	38-58	1,248
7	Corpus Callosum	41-46	35
8	Globus Pallidus	43-52	725
9	Hippocampus	47-66	1,576
10	Hypothalamus	50-61	400
11	Pineal Body	51-55	92
12	Subthalamic Nucleus	50-56	142
13	Red Nucleus	52-60	238
14	Brain Stem	54-100	1,960
15	Amygdala	55-63	395
16	Substantia Nigra	56-62	243
17	Cerebellum	59-99	6,800
18	Optic Chiasm	60-62	78
19	Mammillary Bodies	57-59	87
20	Mesopallium	19-69	2,385
21	Mammillothalamic Tract	43-56	303
22	Septum	42-49	289

## BRAIN DATA FORMAT TRANSMUTATION

The brain contour data arrived at BYU on magnetic tape as 16bit integers in binary format. The data are grouped into 22 structures, which in turn are divided into segments. A segment is a string of contour points and a contour line is formed from one or several segments. Segments represent portions of surfaces which are shared by two structures. Hence, a contour line that is composed of say 5 segments is bordered by 5 neighbors.

Segment definition, which was initially imposed on the data to facilitate line drawing display, somewhat hampers triangulation because all contours must be reconstructed from their constituent segments before triangulation can commence. The problem is aggravated because the segments are randomly sequenced and, furthermore, no convention is observed in clockwise and counterclockwise ordering of nodes.

Segment definition is illustrated by this typical configuration where 3 closed contour loops are defined by 6 segments:

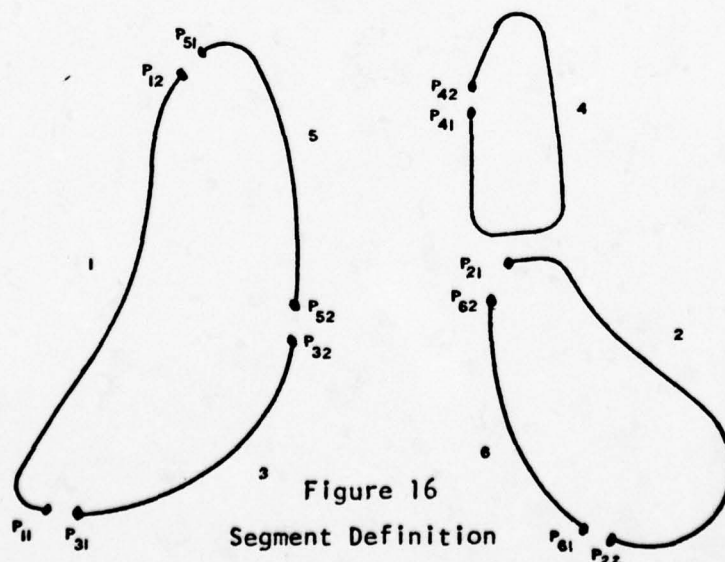


Figure 16  
Segment Definition

Notation wise,  $P_{n1}$  is the first node of segment  $n$  and  $P_{n2}$  the last node of segment  $n$ . The transmutation algorithm begins by assigning segment 1 to loop 1. A search is made for the nearest neighbor of  $P_{12}$  which is  $P_{51}$ , and segment 5 is appended to segment 1. Next, the nearest neighbor of  $P_{52}$  is sought. Its nearest neighbor is  $P_{32}$ . This indicates that segment 3 is sequenced in an order contrary to that of segments 1 and 5. Consequently, segment 3 is joined to loop 1 in reverse order. Since  $P_{31}$  neighbors  $P_{11}$ , the loop is complete. A flag is set for loops 1, 3 and 5 preventing future assignment. This logic repeats until all segments are joined to a loop.

It is important to impose the convention that loops run uniformly in a clockwise (or counter-clockwise) direction. To enforce this convention, all nodal angles of a contour line are summed for monitoring in the following manner:

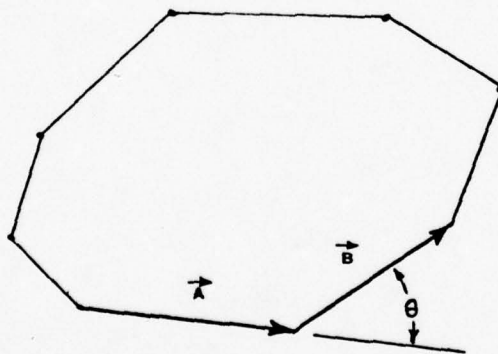


Figure 17

Determining Direction of Rotation

Theta is the angle by which each succedent vector deviates from a straight line. The sum of all such angles will be 360 degrees for counterclockwise sequencing and -360 degrees for clockwise. Theta is computed from vector cross and dot products.

$$\sin\theta = \frac{\vec{A} \times \vec{B}}{AB}$$

$$\cos\theta = \frac{\vec{A} \cdot \vec{B}}{AB}$$

$$\theta = \begin{cases} \sin^{-1}(\sin\theta) & \cos\theta > 0, \\ \sin^{-1}(\sin\theta) + 90 & \cos\theta < 0 \text{ and } \sin\theta > 0, \\ \sin^{-1}(\sin\theta) - 90 & \cos\theta < 0 \text{ and } \sin\theta < 0. \end{cases}$$

In a few instances, the brain data invalidates this approach by having a contour line cross itself like this:

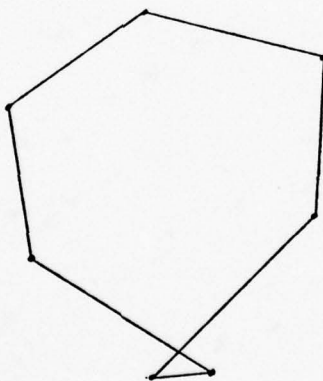


Figure 18

Brain Contour Error

This error causes a figure 8 which results in  $\Sigma\theta$  approaching 0. Often, this causes a violation of the rotation convention.

Chapter 5

ECONOMIZING

NODE ELIMINATION

If a data base is too refined (i.e. contains nodes you could do without) it is desirable for reasons of economy to eliminate the less essential nodes. Consider this node:

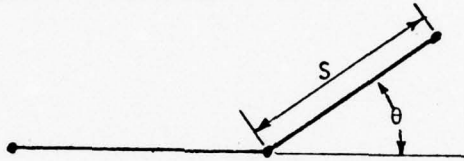


Figure 19

Node Elimination Parameters

The node is accepted (or rejected) upon the following criteria:

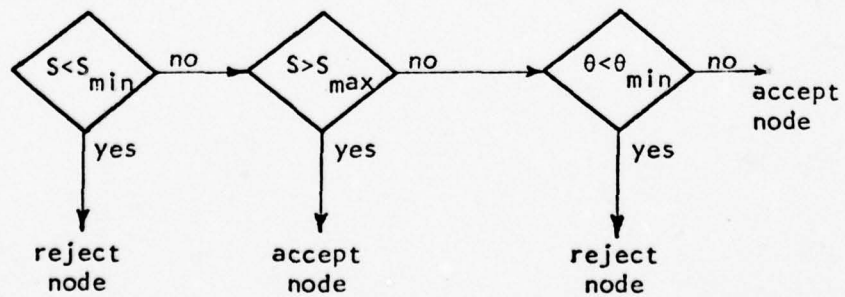


Figure 20

Node Reduction Flow Chart

$S_{min}$ ,  $S_{max}$  and  $\theta_{min}$  are user definable parameters. Every node is screened using this logic. To assure acceptance of every node, all three parameters may be set to zero.

This is a logical place to interject a few thoughts on interpolation of new nodes. Since a digitized contour line is an approximation comprised of a series of straight line segments, it is reasonable to assume, and important to prescribe, that nodes are selected such that the digitized approximation does not deviate intolerably from the actual contour line. This would imply a correlation between nodal density and contour line curvature. That correlation suggests that it is desirable to re-distribute nodes around the contour loop according to a curvature vs. node density function using curve fitting procedures. This is an appealing thought, since it would reduce angularity in the continuous tone display. This would be great, provided the actual surface isn't angular. Of course, however, that assumption is not always valid. Take, for example, a simple four node contour definition of a square. If curve fitting were imposed in an attempt to extrapolate extra nodes, the result would tend towards a circle. Angularity is reduced at the expense of accuracy. In conclusion, the burden of providing acceptable data rests with the person who actually does the digitizing.

#### QUADRILATERAL FORMATION

For economy of storage, it is desirable to join pairs of adjacent triangles together into quadrilaterals. Not all adjoining triangles are thus combined. The decision is made on the basis of how warped the resulting quadrilateral would be, that is, the angle

by which the two triangles are out of plane. That angle is easily found using vector algebra.

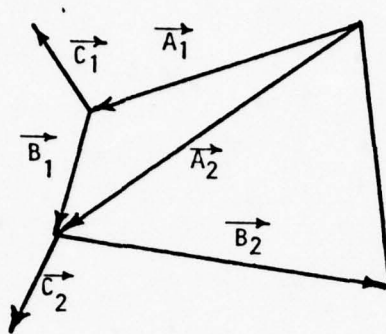


Figure 21

Warp Angle Determination

$$\vec{C} = \vec{A} \times \vec{B}$$

$$\sin \alpha = \frac{\vec{C}_1 \cdot \vec{C}_2}{C_1 C_2}$$

If  $\sin \alpha < \sin \alpha_{\max}$ , the two triangles are redefined as a quadrilateral.  $\alpha_{\max}$  is user definable and defaults to 45 degrees.

## Chapter 6

### FORTRAN IMPLIMENTATION

A few explanatory remarks are offered here to the reader who is bent on deciphering the source code.

As mentioned, the brain data arrived at Brigham Young University in the form of 16 bit integers on tape in binary format. To facilitate use on the DEC-10 computer, these data were re-formatted into 7 bit ASCII data files, one file for each of the 22 structures, with 8 integers per line. The first two integers of a file comprise the "structure heading", the first integer being the structure number, and the second being the number of segments in the structure. These two integers are ignored by the triangulation program.

The next four integers form the segment header of the first segment. The first integer of the segment header is the page number or horizontal level of the segment. The page numbers range from -3 to -99. The Z coordinate of the segment is computed from the formula  $RZ = -(Z+51) * 450 * SCALE$  where RZ is the Z coordinate, Z is the page number, and SCALE is the scale factor. The second and third integers in the segment header are ignored. The fourth integer, NPL, is the number of nodes in the segment.

Immediately following the segment header are the X-Y coordinates of the segment nodes, totalling NPL pairs. The next segment header immediately follows the last node of the preceding segment, so there is an uninterrupted string of integers from start to



finish in the data file. Nodes of all segments of the same page are stored in array P2. The segments are joined together to create closed loops (as described in chapter 4) and stored in array P3. Node elimination is imposed, and the nodes are finally stored for triangulation in array P.

Two pointers are used in accessing the nodes in array P. The Loop Pointer - LPP - indexes the global loop numbers of the first loop on any contour level. Pointer P1 addresses the global node number of the first node on a loop. For example, the X coordinate of the  $n^{\text{th}}$  node of the  $j^{\text{th}}$  loop on the  $k^{\text{th}}$  contour level would be:

$$P((P1(LPP(k)+(j-1))+n-1)),1)$$

Knowing these conventions, the fortran coding should be relatively lucid. The coding, written for use on a DEC-10 system, is given in the appendix. An additional assembly language Tektronix interface, GRTEK.REL, must also be loaded.

Chapter 7

EXAMPLE PROBLEM

A simple yet dramatic example of branching is provided by the caudates - the symmetric pair of brain structures shown below.

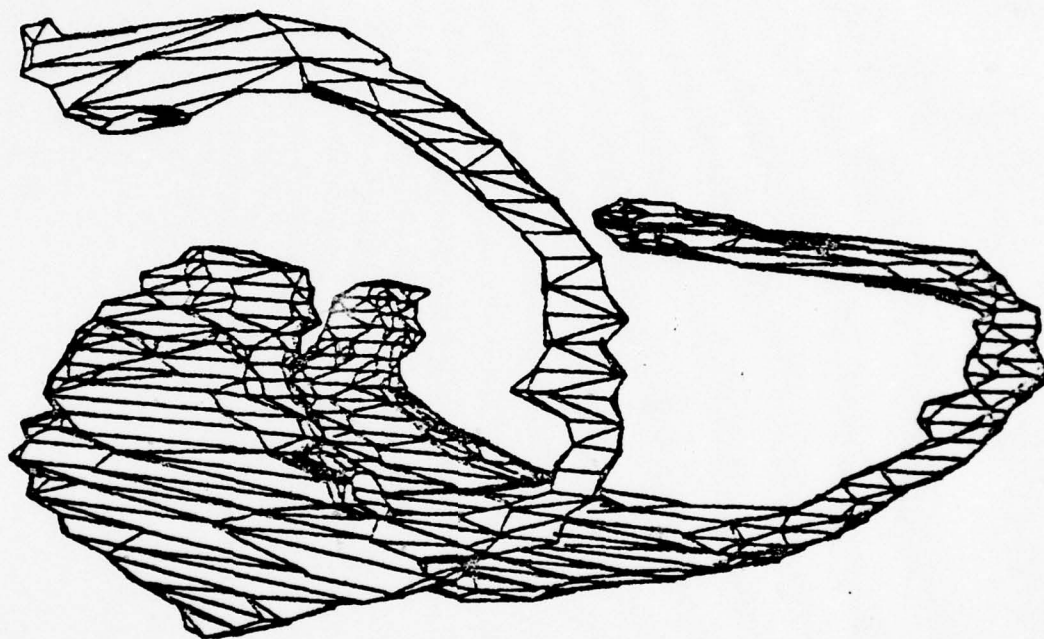


Figure 22

Caudates

Triangulation of the caudates occurred as follows. User statements in the computer dialogue have been underlined to distinguish them from computer generated prompts. Referring to figure 23 the computer begins by asking if the data it is about to read is brain data. It is, and the caudate data file name, B2, is given. Next, the menu of commands is printed, of which PARAMENTERS is

BRAIN DATA? Y  
FILENAME OF INPUT DATA? I2  
READ> HELP  
PARAMETERS, TOTALS, LEVEL, SCALE, EXIT  
BRANCH, MANUAL, CLOSE, DEVICE, KLOCKWISE  
READ> P  
MINIMUM SEGMENT ANGLE= 15  
MIN. & MAX. SEGMENT LENGTHS: .3, 2  
READ> L  
Z-SPACING= 1  
LEVEL RANGE= 1, 60  
DATA ENDED AFTER LEVEL 32  
BRANCH> HELP  
AUTOMATIC, WARP, MANUAL, INSPECT, SINGLE, CAP, EXIT, TOTALS  
BRANCH> T  
955 NODES. 1 ELEMENTS  
BRANCH> A  
START WITH WHICH LEVEL? 1  
POST-EDIT? Y

Figure 23  
Computer Dialogue

selected. We opt to set the minimum segment angle to 15 degrees,  $S_{\min}$  to .3 and  $S_{\max}$  to 2. (These parameters are explained on page 26). Having returned to the READ> prompt, we now choose to read in the data, being satisfied with the default values for SCALE, CLOSE, and KLOCKWISE. After setting the LEVEL parameters, the computer goes to work reading in contour segments, reconstructing them into loops, thinning them out, and assuring that all loops run in a clockwise

direction. The algorithm encounters end of file before 60 levels are read in, and informs us that all 32 available levels have been read in and processed. The TOTALS command receives the response that there are 955 nodes in array P, which means that over half of the available 1922 nodes have been thinned out by the node elimination algorithm.

The Caudates are quite regular, requiring little or no interaction to triangulate properly, so the AUTOMATIC option is invoked beginning, as usual, with level 1. As a safeguard, post-editing is requested. If the data were unquestionably obedient, the post-editing could justifiably be circumvented, but this way good results are guaranteed.

The algorithm now proceeds to first determine connectivity, then to triangulate all loops implicated in the the window overlap connectivity check, and finally to display the resulting panel definition. The user glances at each successive display and grants acceptance with a carriage return, or occasionally rejects the triangulation, as the case may be. (Usually it is immediately clear when triangulation is unacceptable. Normally, failure occurs in areas where the two loops are excessively dissimilar, and the resulting panels are often bizzare).

Two of several simple one-on-one triangulations are shown in figures 25 and 26, each of which is accepted. However, the branching loops in figure 27 are triangulated incorrectly, and a change is requested. This change is granted through erasure of the screen, re-drawing of the untriangulated loops, and issuing of the TRIANGULATE> prompt. The INTERACTIVE command is given. As always,

only the first letter of the command is required. Referring to figure 28 the nodes are numbered for identification - even for the top loop and odd for the bottom.

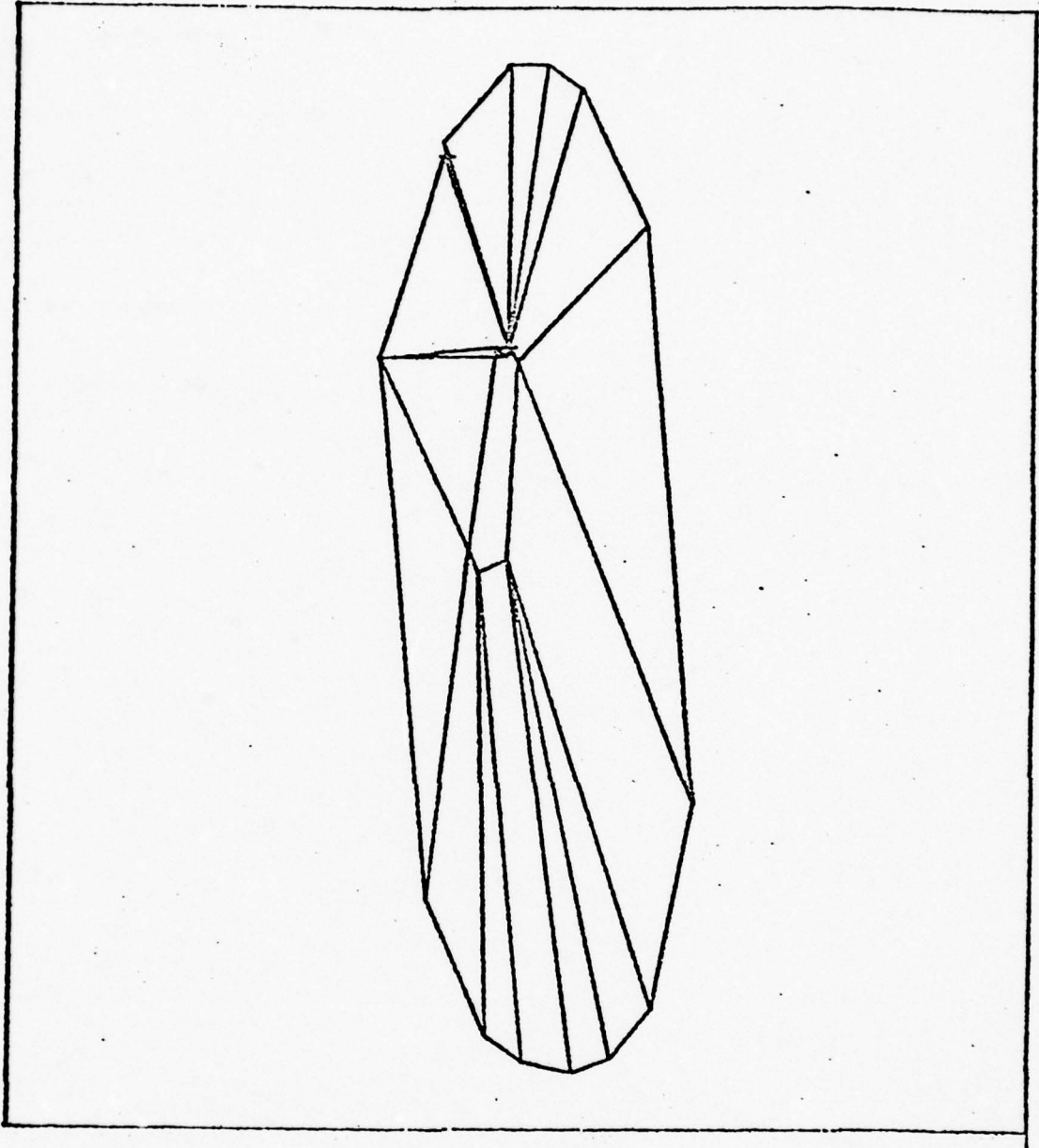
The INTERACTIVE command allows the triangulation to be controlled by allowing specification of nodal delimiters between which triangulation will occur. For example, if the delimiters 1,1 for the top and 1,2 for the bottom were chosen, only one triangle would be formed. Basically the selection of delimiters is a trial and error process. The user delimits as large a span as reasonable. If the resulting triangulation is adequate, great! If not, try again with a smaller span. A general rule might be to proceed quickly over sections where the two contours are similar, and cautiously over sections where they are dissimilar.



Figure 24

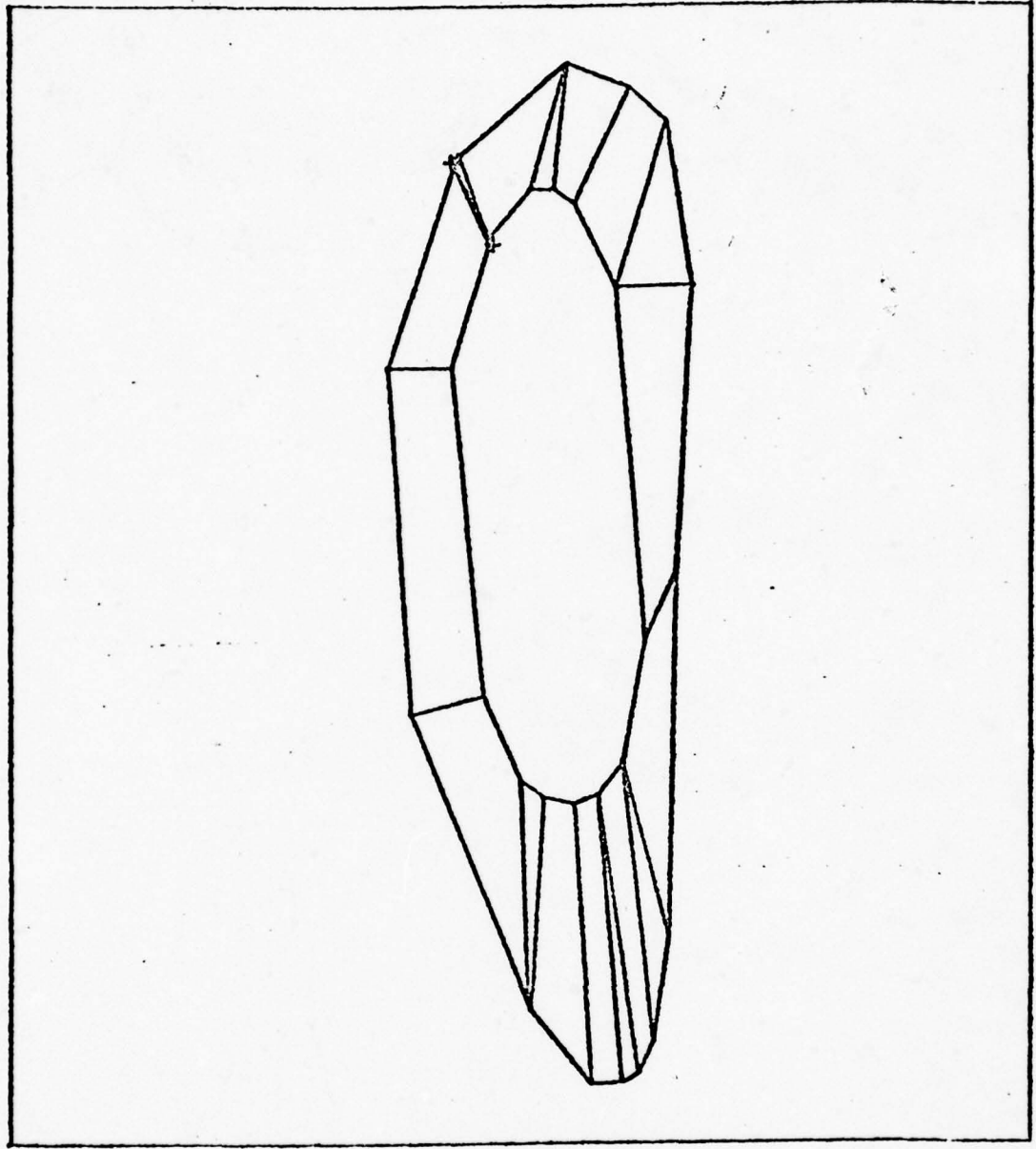
Continuous Tone Rendering  
of Caudates

Referring to figure 26, the triangulation was successful through node 17 of the bottom loop, but then failed to traverse the branch properly. This suggests the selection of delimiters 1,28 for the top and 1,17 for the bottom. The resulting triangulation shown in figure 28 looks good. Now, one more span (top:28,33 ; and bottom:17,20) should suffice, and figure 29 confirms the hope. Now that the entire circuit is complete, AUTOMATIC mode is re-entered and triangulation proceeds smoothly to the conclusion. Upon exiting from the program, the panel definition is written into a disk file, available for display using MOVIE.BYU. A continuous tone image created by that panel definition is shown in figure 24.



CHANGES? NO

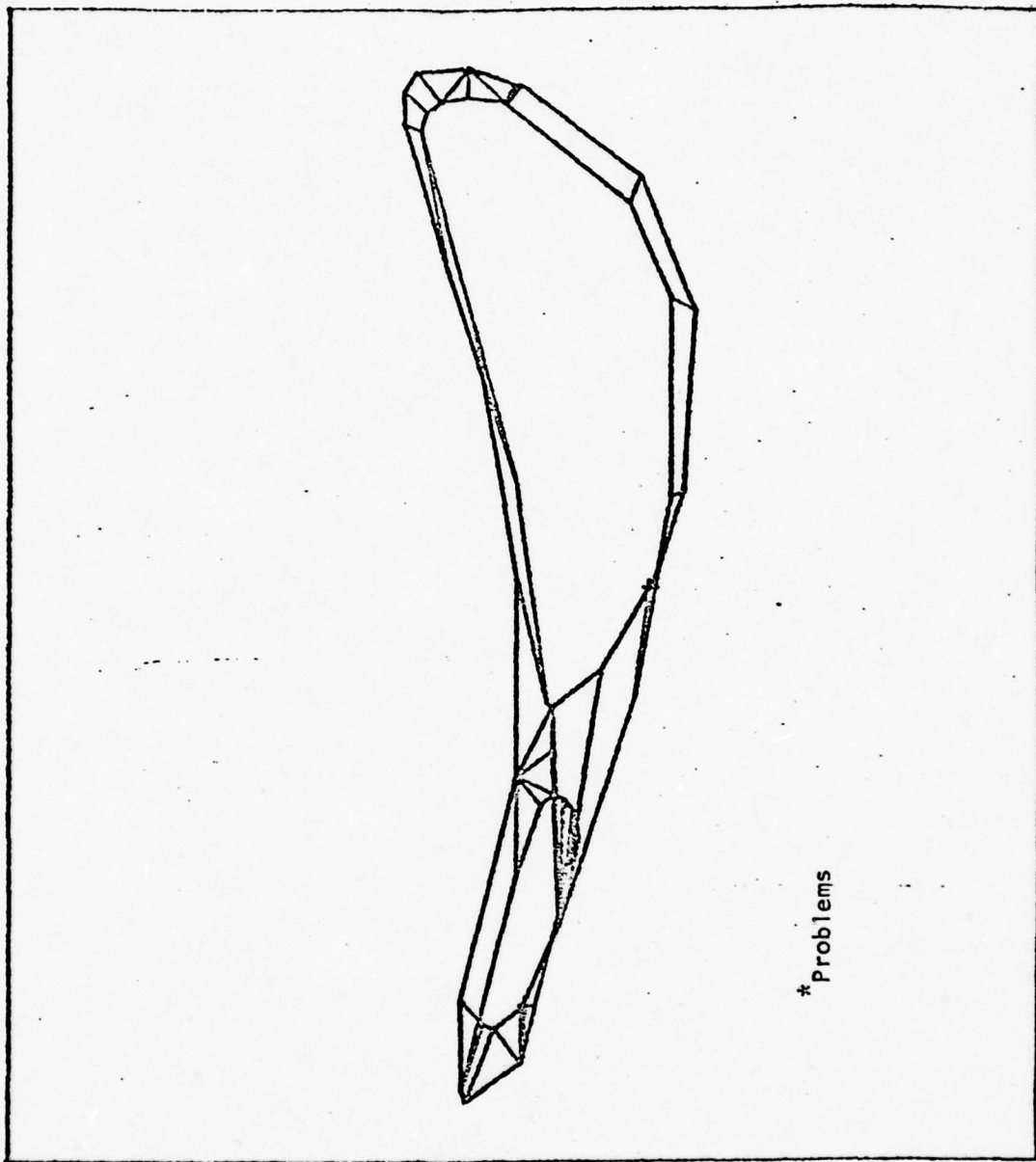
Figure 25  
Example



CHANGES? NO

Figure 26  
Example

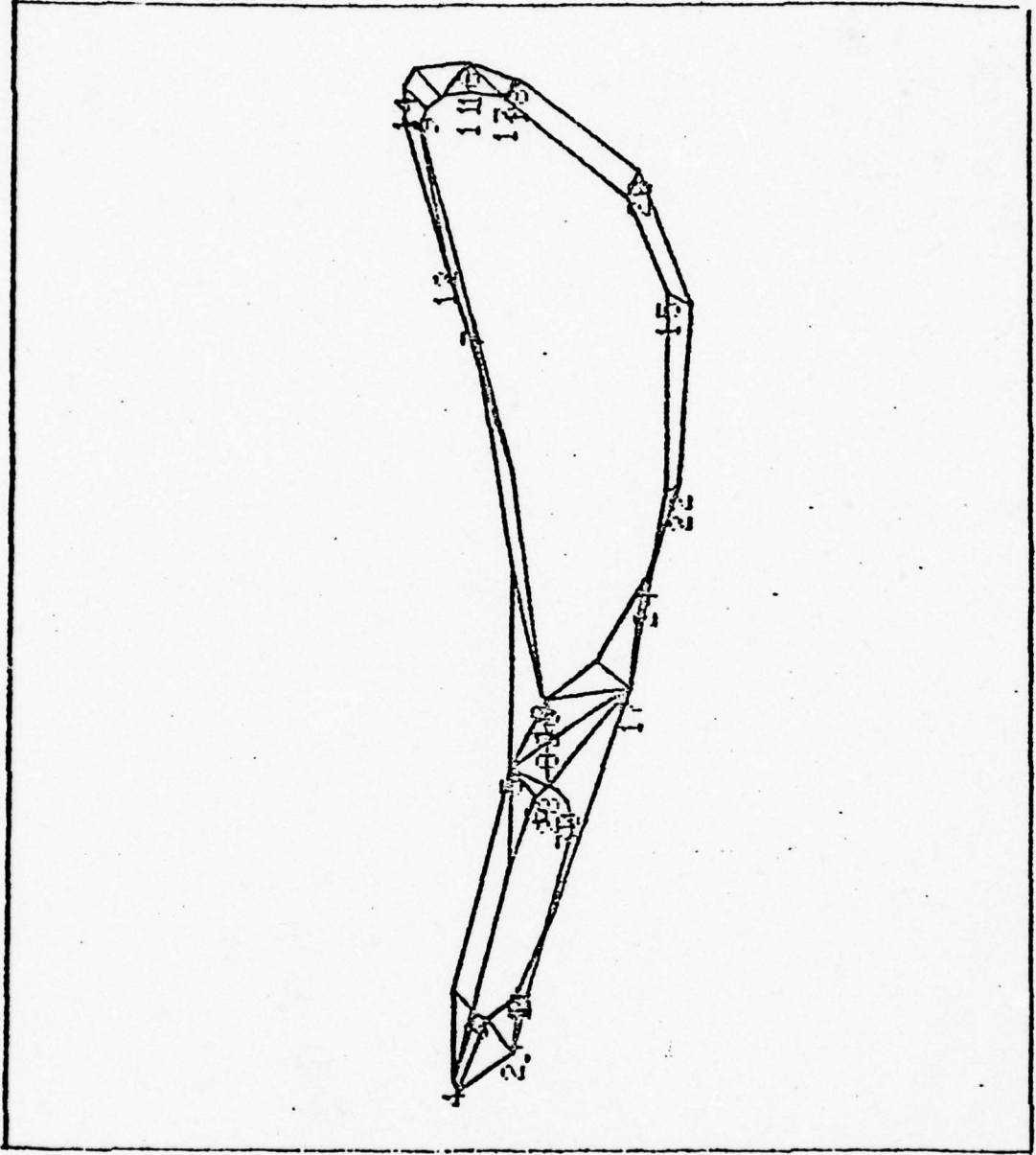




\* Problems

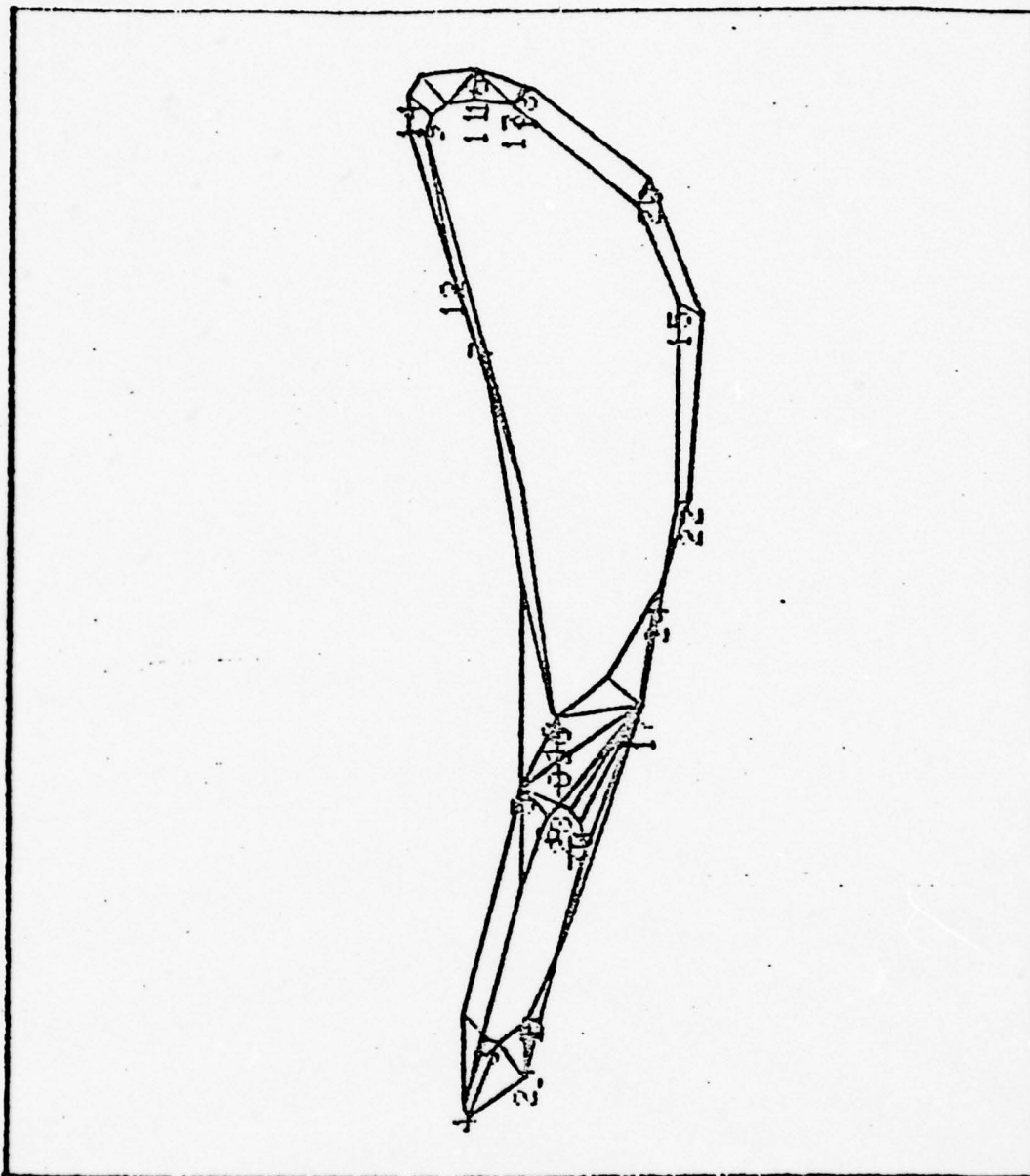
CHANGES? YES

Figure 27  
Example



TRIANGULATE>I  
TOP: 1-33  
1,28  
BOTTOM: 1-20  
1,17  
CHANGES? NO

Figure 28  
Example



TOP: 28-33  
28,33  
BOTTOM: 17-20  
17,20  
CHANGES? NO

Figure 29  
Example

## Chapter 8

### PICTURES

This chapter presents examples of the finished product. It is difficult to judge how true to life the images are, due to the highly esoteric nature of the subject matter. Nonetheless, it is generally evident that the triangulation algorithm has performed reasonably.

The first structure presented is the Brain Stem. The Brain Stem was a straightforward triangulation problem. There are no branches, and there is no serious variation in the shape of its respective contours. The only difficulty was a case of illegal rotational direction, as described on page 25. Other than that, the entire triangulation was handled automatically. Two panel definitions were generated for the brain stem. The first file was made with  $S_{\min} = S_{\max} = \theta_{\min} = 0$ , Z-SPACING=1, and LEVEL RANGE =5,36. The resulting panel definition had 1609 nodes and 1991 panels. The second brain stem panel definition has 378 nodes and 492 panels. It was generated with  $S_{\min} = .2$ ,  $S_{\max} = 1$ ,  $\theta_{\min} = 15$ , Z-SPACING =4, and LEVEL RANGE =5,40. Line drawings are shown in figures 30 and 31, and continuous tone images in figures 34 and 35.

The next pair of images, figures 36 and 37 are detailed studies of the thalamus. Here, 4 loops branch into 2, then 2 into 1. Figure 37 has a more biological look due to Gouraud smooth surface simulation.

Figure 38 is a striking composition of 6 different structures, each in proper relative orientation. The structures are identified in figure 32 and figure 33 shows a line drawing. To enable so many parts, the larger structures have coarser panel definitions.

All of the preceding examples were triangulated with virtually no user interaction. The cortex slice, in figure 39 was not so oblidging. This image is presented to demonstrate the degree of complexity the algorithm can accomodate. To help orient the reader, this image represents about a  $\frac{1}{2}$ " thick slice of the cortex, centered about  $\frac{1}{2}$ " from the top of the brain. The many oddly shaped holes are due to the fact that the top most convolutions are decapitated in this view. This panel definition - shown here with smooth shading - consists of 1752 nodes with 1778 panels. This particular data did not cooperate with the automatic algorithm, and required nearly 2 hours time to interactively triangulate. The difficulty was not so much the complexity of the shapes, but the dissimilarity between adjacent contours. Also, the data had a disproportionate number of glitches. Nonetheless, the continuous tone image is quite convincing.

One final image is the panoramic shot of Mt. Timpanogos as it might be seen from an airplane flying to the west of Timp. This is submitted to illustrate a possible application of triangulation to display of topographic surfaces.

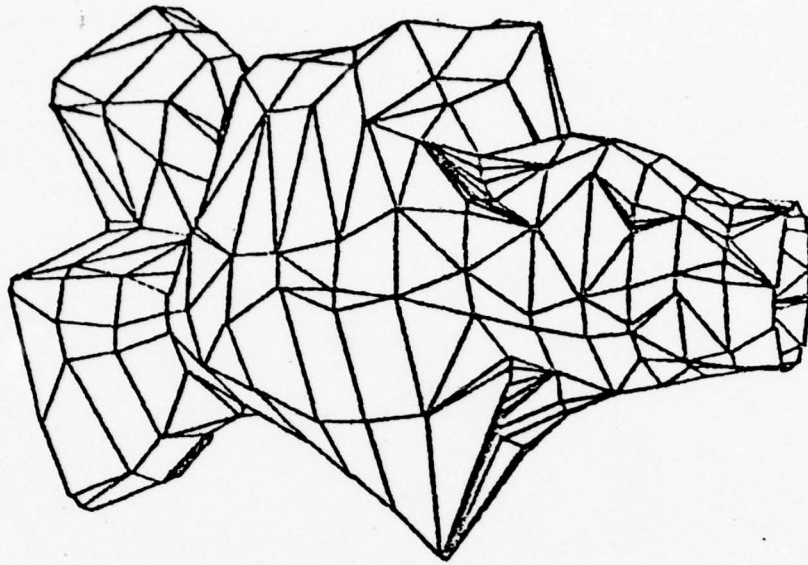


Figure 31

Brain Stem - 492 Panels

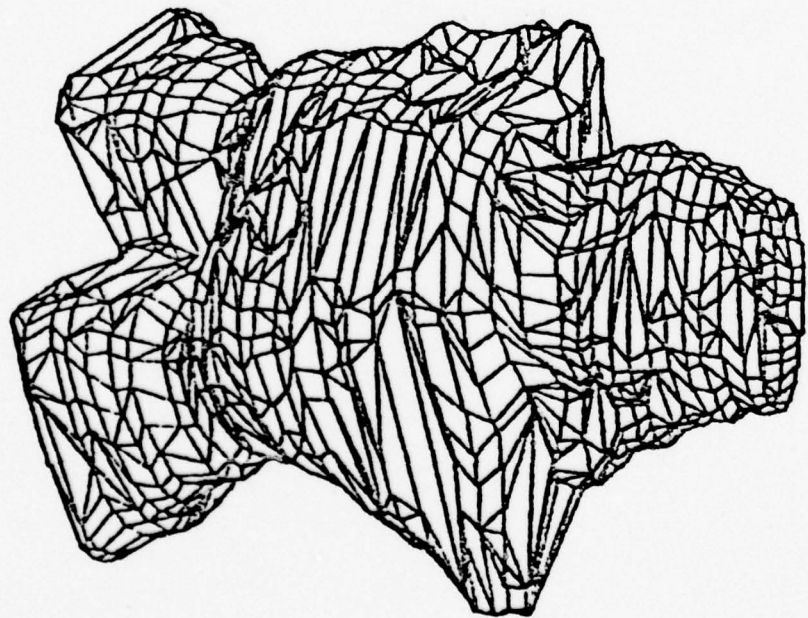


Figure 30

Brain Stem - 1991 Panels

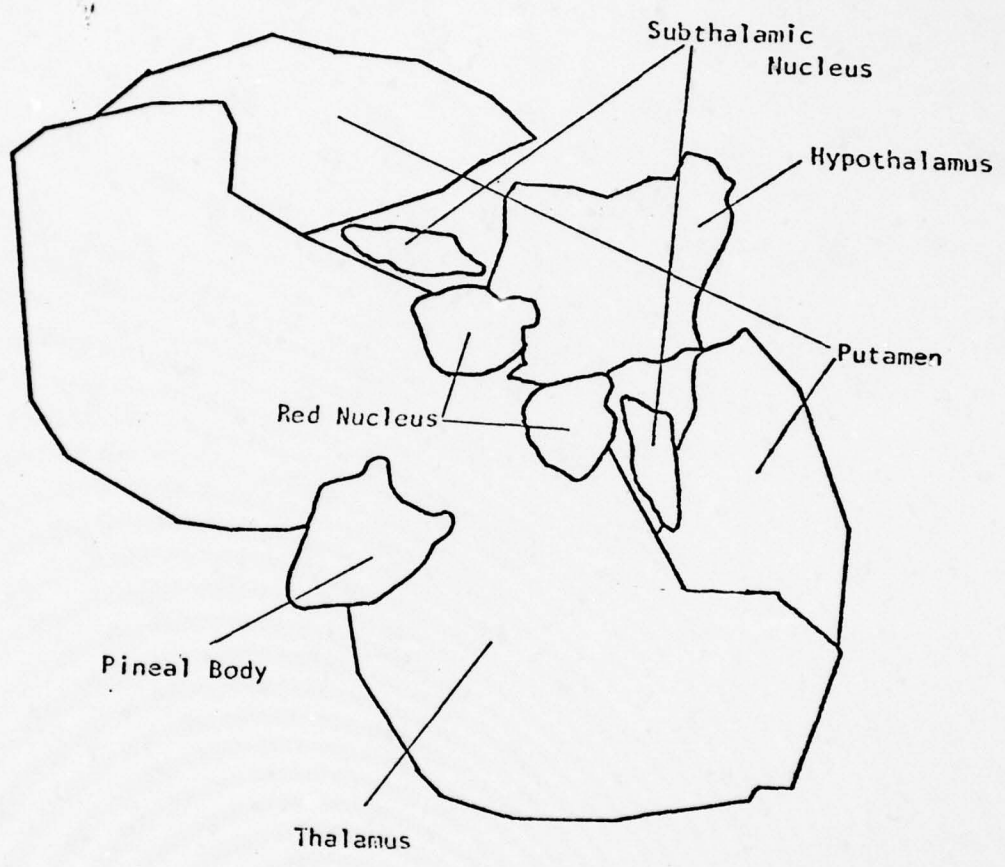


Figure 32  
Labelled Composite View

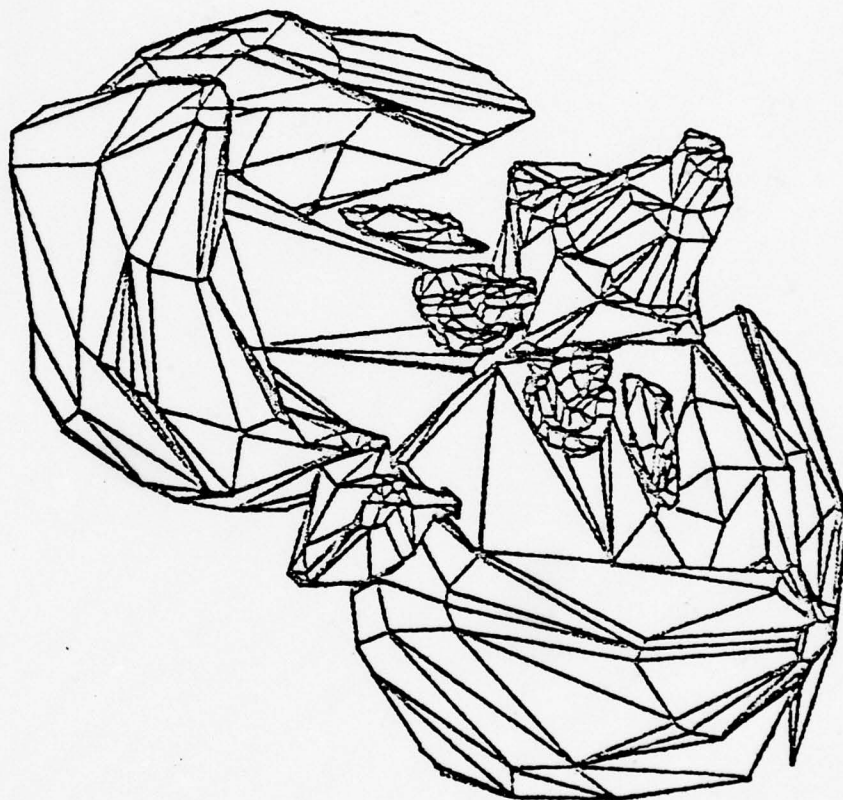


Figure 33  
Composite View  
Line Drawing



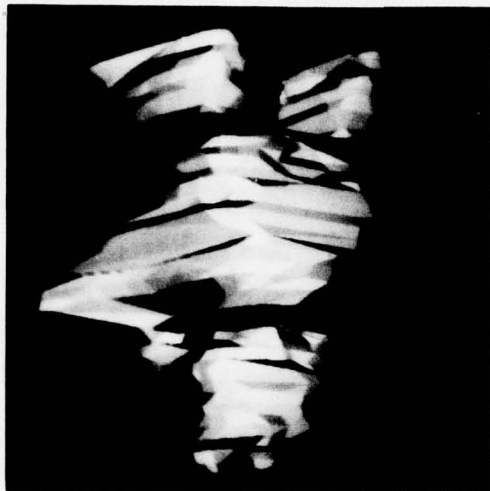


Figure 34

Brain Stem with  
1991 Panels



Figure 35

Brain Stem with  
492 Panels

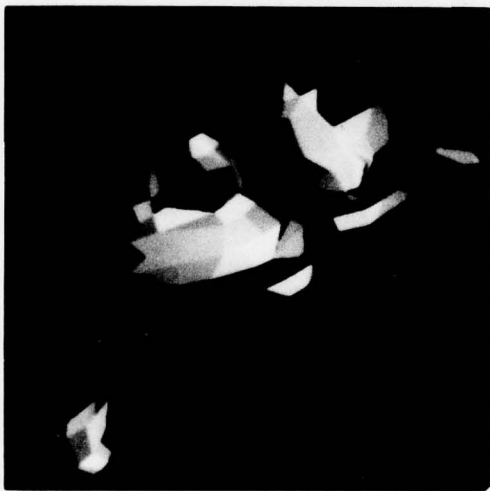


Figure 36

Thalamus with  
Flat Shading



Figure 37

Thalamus with  
Smooth Shading



Figure 38  
Composite View



Figure 39  
Cortex Slice



Figure 40  
Mount Timpanogos - Flat Shading



Figure 41  
Mount Timpanogos - Smooth Shading

## Chapter 9

### CONCLUSIONS

This thesis purports to present a general solution to the problem of converting a contour definition of an arbitrary surface into a panel definition. That assertion is rigorously tested by the brain data, and experience with that highly complex data base lends credence to the claim of a general solution. Total user interaction capabilities virtually guarantee a general algorithm.

Work might be done on reducing the amount of user dependence in the algorithm, though most reasonable cases require no interaction at all. Also, it would be helpful to improve graphical interaction by using, for example, a tablet to input interaction parameters. Study might also be made on how the economy parameters ( $S_{\min}$ ,  $S_{\max}$ ,  $\theta_{\min}$ , and  $\alpha_{\max}$ ) effect the continuous tone image.

#### BIBLIOGRAPHY

- Christiansen, Henry N. "Applications of Continuous Tone Computer-Generated Images in Structural Mechanics," Structural Mechanics Computer Programs - Surveys, Assessments, and Availability, University Press of Virginia, Charlottesville, Virginia, June 1974, pp. 1003-1015.
- \_\_\_\_\_. "MOVIE.BYU - A General Purpose Computer Graphics Display System," Proceedings of the Symposium on Applications of Computer Methods in Engineering, University of Southern California, Los Angeles, August 1977.
- Fuchs, Henry. "The Automatic Sensing of 3-Dimensional Surface Points from Visual Scenes." Unpublished PhD dissertation, University of Utah, 1975.
- Keppel, E. "Approximating Complex Surfaces by Triangulation of Contour Lines," Journal of Research and Development, IBM Vol. 19, No. 1 (January 1975), 2-11.
- Newman, William M., and Robert F. Sproull. Principles of Interactive Computer Graphics. New York: McGraw-Hill, 1973.

APPENDIX A  
COMPUTER PROGRAM

```

COMMON/C/NL(2),LPSTK(2,5),NPT,NJ,DZ,BD,TEKT,PE,
1  FX(100,4),P1(100),TRIC,IPL(2,5,10),NIPL(5),IPLI,NPMAX,IP(4,2000)
COMMON/NOE/PP(1100,3),P3(1100,3)
COMMON/TEK/XHAF,YRAF,SF,P(2000,3),IYD2
INTEGER LPP(40),F1,FIRST,NPI(5),NPIC(5),NPLA(2,5)
INTEGER LT(40),C(8,8),NPL(40),NPLM(40),NCCNC(40),SURR(8,40)
REAL E(4),ID(8)
LOGICAL FLAG(40),CLOSE,DATAF,TEKT,BD,CW,PE
INTEGER ZS,PP,SP,EP,DP,CN,RC,TO,R0,RRANCH(10),STACK(10)
DATA SAS,SMINT,SMAXT,WANG,DZ,SCALE/.3,.01,1.,.7,.45,.0001/
DATA ZS,KP,L,DP,LIC,PNI,NP1,IZP/1,0,1,2,1,0,1,0/
DATA NLA,NLP,NLV,NP,LT(1),P1(1),IYD2/0,0,0,0,0,1,0/
DATA LPP(1),IPLI,NPMAX/1,1,2/
DATA TEKT,CLOSE,DATAF,ED,CW/.TRUE...TRUE...TRUE...TRUE...TRUE;/
DATA NIPL/1,0,0,0,0,0/
IPL(1,1,1)=1
SMIN=(DZ*SMINT)**2.
SMAX=(DZ*SMAXT)**2.
C INPUT SPECS
TYPE 1
1  FORMAT(' BRAIN DATA? ',S)
ACCEPT 10,ANS
IF(ANS.EQ.'Y')GO TO 2
BD=.FALSE.
SAS=0.
SMIN=0.
SMAX=10
SCALE=1.
2  TYPE 3
3  FORMAT(' FILENAME OF INPUT DATA? ',S)
ACCEPT 4,INAME
4  FORMAT(A5)
OPEN(UNIT=21,FILE=INAME)
C INITIALIZE DISK
HEAD(21,5)A,R,TZ1
BACKSPACE 21
5  FORMAT(8G)
C ACCEPT READ COMMANDS
GO TO 8
TYPE 7,NLA
7  FORMAT(' LAST LEVEL WAS ',I2)
8  TYPE 9
9  FORMAT(' READ> ',S)
ACCEPT 10,RC
10  FORMAT(A1)
IF(RC.EG.'B')GO TO 76
IF(RC.EG.'P')GO TO 20
IF(RC.EG.'L'.OR.RC.EQ.'M')GO TO 25
IF(RC.EG.'S')GO TO 18
IF(RC.EG.'T')TYPE 24,NJ,NPT
IF(RC.EG.'E')GO TO 139
IF(RC.EG.'K')GO TO 16
IF(RC.EG.'C')GO TO 14
IF(RC.EG.'D')GO TO 12
IF(RC.EG.'T')GO TO 8
TYPE 11
11  FORMAT(' PARAMETERS,TOTALS,LEVEL,SCALE,EXIT,BRANCH,
1  MANUAL,CLOSE,DEVICE,KLOCKWISE')
GO TO 8
C SET DEVICE

```

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12     TYPE 13
13     FORMAT(' TEKTRONIX SCOPE? ',S)
        ACCEPT 10,ANS
        TEKT=.FALSE.
        IF(ANS.EQ.'Y')TEKT=.TRUE.
        GO TO 8
C     SET 'CLOSE' FLAG
14     TYPE 15
15     FORMAT(' CLOSE ALL LOOPS? ',S)
        ACCEPT 10,ANS
        CLOSE=.FALSE.
        IF(ANS.EQ.'Y')CLOSE=.TRUE.
C     SET CLOCKWISE FLAG
        GO TO 8
16     TYPE 17
17     FORMAT(' CLOCKWISE ORDERING? ',S)
        ACCEPT 10,ANS
        CW=.FALSE.
        IF(ANS.EQ.'Y')CW=.TRUE.
        GO TO 16
C     SET SCALE FACTOR
18     TYPE 19
19     FORMAT(' SCALE FACTOR= ',S)
        ACCEPT *,SCALE
        DZ=ZS*450.*SCALE
        SMIN=(DZ*SMINT)**2.
        SMAX=(DZ*SMAXT)**2.
        GO TO 8
C     SET PARAMETERS
20     TYPE 21
21     FORMAT(' MINIMUM SEGMENT ANGLE= ',S)
        ACCEPT *,SANG
        SAS=SIND(SANG)
        TYPE 22
22     FORMAT(' MIN. R MAX. SEGMENT LENGTHS: ',S)
        ACCEPT *,SMINT,SMAXT
        SMIN=(DZ*SMINT)**2.
        SMAX=(DZ*SMAXT)**2.
        GO TO 8
C     TOTALS
24     FORMAT(1H ,I4,' NODES ',I4,' ELEMENTS')
C     SET SPACING AND RANGE
25     TYPE 26
26     FORMAT(' Z-SPACING= ',S)
        READ(5,*,END=8,ERR=8)ZS
        DZ=.45*ZS
        IZP=ZS-1
        TYPE 27
27     FORMAT(' LEVEL RANGE= ',S)
        READ(5,*,END=8,ERR=8)NLS,NLF
        LIND=NLV+1
C     INITIALIZE
28     READ(21,5,END=69)(ID(J),J=1,DP),TZ
        BACKSPACE 21
        IF(DP.EQ.8)BACKSPACE 21
        IF(TZ1.EQ.TZ)GO TO 29
        NLA=NLA+1
        IF(NLA.GE.NLF)GO TO 31
        TZ1=TZ
        IZP=IZP+1

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```

                IF((I7P.GE.ZS).AND.(NLA.GE.NLS))GO TO 31
                NP=0
                KP=0
29              KP=KP+1
C READ FROM DISK
                READ(21,5,FND=69)(ID(J),J=1,DP),Z,A,DUM,NPL(KP)
                1,(((P2(J+NP,I)),I=1,2),J=1,NPL(KP))
                NP=NP+NPL(KP)
                LT(KP+1)=LT(KP)+NPL(KP)
                BACKSPACE 21
C SET DATA FILE POINTER
                DP=2*NPL(KP)+DP+12
30              DP=DP-8
                IF(DP.GT.8)GO TO 30
                GO TO 28
C CHECK SEGMENT INTERCONNECTIVITY
31              LC=1
                NP3=0
                IF(RC.NE.'M')GO TO 37
C GRAPHICS FOR MANUAL RE-CONSTRUCTION OF LOOPS
C FIND WINDOW
                E(1)=P2(1,1)
                E(2)=E(1)
                E(3)=P2(1,2)
                E(4)=E(3)
                DO 32 I=2,NP
                IF(P2(I,1).LT.E(1))E(1)=P2(I,1)
                IF(P2(I,1).GT.E(2))E(2)=P2(I,1)
                IF(P2(I,2).LT.E(3))E(3)=P2(I,2)
32              IF(P2(I,2).GT.E(4))E(4)=P2(I,2)
                DX=E(2)-E(1)
                DY=E(4)-E(3)
                XBAR=(E(2)+E(1))/2.
                YBAR=(E(4)+E(3))/2.
                SF=DX
                IF(DY.GT.SF)SF=DY
                SF=700./SF
C PAINT & LABEL SEGMENTS
                IF(.NOT.TEKT)GO TO 37
                CALL BOX
                DO 36 I=1,KP
                IND1=LT(I)+1
                IND2=LT(I+1)
                IX1=SF*(P2(IND1,1)-XBAR)+634
                IY1=SF*(P2(IND1,2)-YBAR)+390
                CALL MVTO(IX1,IY1)
                DO 33 J=IND1,IND2
                IX=SF*(P2(J,1)-XBAR)+634
                IY=SF*(P2(J,2)-YBAR)+390
33              CALL VCTO(IX,IY)
                IX=SF*(P2(IND1+1,1)-XBAR)+624
                IY=SF*(P2(IND1+1,2)-YBAR)+380
                CALL MVTO(IX,IY)
                CALL MVTO(IX,IY)
                CALL ALPDE
                TYPE 34,I
34              FORMAT(IH+,S,I2,'I')
                IX=SF*(P2(IND2-1,1)-XBAR)+424
                IY=SF*(P2(IND2-1,2)-YBAR)+380
                CALL MVTO(IX,IY)

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CALL ALMODE
TYPE 35,I
35  FORMAT(1H+,S,I2,'2')
36  CONTINUE
    CALL MVT0(0,767)
    CALL ALMODE
37  IF(<P.EG.1.AND.RC.NE.'M')GO TO 51
    IF(.NOT.RD)GO TO 51
    DO 38 I=1,KP
38  FLAG(I)=.FALSE.
    DO 50 IL=1,KP
    IF(FLAG(IL))GO TO 50
    JPC=1
    JLC=IL
    DO 39 I=1,NPL(IL)
    NP3=NP3+1
    DO 39 J=1,2
39  P3(NP3,J)=P2(LT(IL)+I,J)*SCALE
    NPL(LC)=NPL(IL)
C  FIND THE CLOSEST ENDPINT
40  IF(RC.NE.'M')GO TO 43
    JP=2
    IF(JPC.EQ.2)JP=1
    TYPE 41,JLC,JP
41  FORMAT(' JOIN ',2I1,' TO ',S)
    ACCEPT 42,JLC,JPC
42  FORMAT(2I1)
    IF(JLC.NE.0)GO TO 45
    GO TO 50
43  DM=1F+35
    Y1=P3(NP3,1)/SCALE
    Y1=P3(NP3,2)/SCALE
    DO 44 JL=1,KP
    IF(FLAG(JL))GO TO 44
    DO 44 JP=1,2
    IF((JL.EQ.IL).AND.(JP.EQ.2))GO TO 44
    JPR=JP
    IF(JP.EQ.?)JPR=NPL(JL)
    DIST=(Y1-P2(LT(JL)+JPR,1))**2.+(Y1-P2(LT(JL)+JPR,2))**2.
    IF(DIST.GT.DM)GO TO 44
    JLC=JL
    JPC=JP
    DM=DIST
44  CONTINUE
45  FLAG(JLC)=.TRUE.
    IF(JLC.NE.IL)GO TO 46
    LC=LC+1
    GO TO 50
46  IF(JPC.EQ.2)GO TO 48
    DO 47 I=1,NPL(JLC)
    NP3=NP3+1
    DO 47 J=1,2
47  P3(NP3,J)=P2(LT(JLC)+I,J)*SCALE
    NPL(LC)=NPL(LC)+NPL(JLC)
    GO TO 40
48  DO 49 I=1,NPL(JLC)
    II=NPL(JLC)+1-I
    DO 49 J=1,2
49  P3(NP3+II,J)=P2(LT(JLC)+I,J)*SCALE
    NP3=NP3+NPL(JLC)

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```

NPL(LC)=NPL(LC)+NPL(JLC)
GO TO 40
50 CONTINUE
GO TO 53
51 DO 52 I=1,NP
DO 52 J=1,2
52 P3(I,J)=P2(I,J)*SCALE
LC=KP+1
C RESET FLAGS
53 LC=LC-1
NLV=NLV+1
LPP(NLV+1)=LC+LPP(NLV)
C THINNING OUT
FIRST=0
RZ=-(Z+51)*450*SCALE
IF(.NOT.HD)RZ=Z*SCALE
DO 67 M=1,LC
RP=1
NLP=NLP+1
SP=2
EP=1
DC=0.
N=P1(NLP)-1
P(N+1,1)=P3(FIRST+1,1)
P(N+1,2)=P3(FIRST+1,2)
P(N+1,3)=RZ
C INITIALIZE WINDOW MATRIX
EX(NLP,1)=P3(FIRST+1,1)
EX(NLP,2)=P3(FIRST+1,1)
EX(NLP,3)=P3(FIRST+1,2)
EX(NLP,4)=P3(FIRST+1,2)
IF(NPL(M).GT.2)GO TO 54
P1(NLP+1)=P1(NLP)+NPL(M)
IF(NPL(M).EQ.1)GC TO 67
P(N+2,1)=P3(FIRST+2,1)
P(N+2,2)=P3(FIRST+2,2)
P(N+2,3)=RZ
54 XA=P3(FIRST+RP+EP,1)-P3(FIRST+RP,1)
YA=P3(FIRST+RP+EP,2)-P3(FIRST+RP,2)
AL=XA*XA+YA*YA
IF(AL.LT.SMIN)GO TO 56
55 XR=P3(FIRST+RP+EP+1,1)-P3(FIRST+RP+EP,1)
YR=P3(FIRST+RP+EP+1,2)-P3(FIRST+RP+EP,2)
BL=XR*XR+YR*YR
IF(BL*AL.EQ.0.)GO TO 56
ST=(XA*YR-XR*YA)/SQRT(AL*BL)
IF(ST.LT.-1.)ST=-1.
IF(ST.GT.1.)ST=1.
IF(ABS(ST).GT.SAS)GO TO 57
C ANGLE OF SEGMENT LENGTH IS TOO SMALL. ELIMINATE THE NODE.
IF(((XA+YB)**2.+(YA+YR)**2.).GT.SMAX)GO TO 57
56 EP=EP+1
IF((RP+EP).EQ.NPL(M))GC TO 5A
GO TO 54
C ACCEPT THE NODE.
57 P(N+SP,1)=P3(FIRST+RP+EP,1)
P(N+SP,2)=P3(FIRST+RP+EP,2)
P(N+SP,3)=RZ
C SUM ANGLES TO DETERMINE DIRECTION OF ROTATION
DC=DC+ASIN(ST)

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IF((YA+YR+YA+YP).GF.0.)GO TO 571
IF(ST.LT.0.)DC=DC-1.5708
IF(ST.GT.0.)DC=DC+1.5708
C DETERMINE LOCP EXTRAMES.
571 IF(P(N+SP,1).LT.FX(NLP,1))EX(NLP,1)=P(N+SP,1)
IF(P(N+SP,1).GT.EX(NLP,2))EX(NLP,2)=P(N+SP,1)
IF(P(N+SP,2).LT.FX(NLP,3))EX(NLP,3)=P(N+SP,2)
IF(P(N+SP,2).GT.EX(NLP,4))EX(NLP,4)=P(N+SP,2)
XA=XB
YA=YB
AL=BL
PP=RP+EP
SP=SP+1
IF(PP.EQ.(NPL(M)-1))GO TO 58
EP=1
GO TO 55
C ENDPOINTS
58 NSP=SP
DO 59 I=1,2
59 IF(P3(FIRST+NPL(M),I).NE.F(N+1,I))GO TO 60
NSP=NSP-1
GO TO 62
60 DO 61 I=1,2
61 P(N+SP,I)=P3(FIRST+NPL(M),I)
P(N+SP,3)=RZ
62 IF(.NOT.CLOSE)GO TO 64
NSP=NSP+1
DO 63 I=1,2
63 P(N+NSP,I)=P(N+1,I)
P(N+NSP,3)=RZ
64 P1(NLP+1)=P1(NLP)+NSP
C INSURE CLOCKWISE ORDERING
IF(DC.LT.0..AND.CW)GO TO 67
IF((DC.GT.0.).AND.(.NOT.CW))GO TO 67
DO 65 I=1,NSP
DO 65 J=1,2
65 P2(I,J)=P(N+I,J)
DO 66 I=1,NSP
DO 66 J=1,2
II=NSP+1-I
66 P(N+II,J)=P2(I,J)
67 FIRST=FIRST+NPL(M)
C RESET POINTERS
68 KP=0
IZP=0
NP=0
IF(NLA.LT.NLF)GO TO 28
GO TO 71
69 TYPE 70,NLA
70 FORMAT(' DATA ENDED AFTER LEVEL ',I2)
DATAF=.FALSE.
71 NJ=N+NSP
C DETERMINE CONCENTRICITY
DO 75 M=1,NLV
NCONC(M)=0
LI1=LPP(M)
LI2=LPP(M+1)-1
DO 75 I=LI1,LI2
DO 75 J=LI1,LI2
IF(I.EQ.J)GO TO 75

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C CHECK FOR TRIVIAL REJECTION
DO 72 K=1,3,2
IF(EX(J,K+1).LT.EX(I,K))GO TO 75
72 IF(EX(J,K).GT.EX(I,K+1))GO TO 75
I1=-1
73 I1=I1+1
C SEE IF J SCRIBES A 360 DEGREE ARC AROUND I
ANG=0.
XC=P(P1(I)+I1,1)
YC=P(P1(I)+I1,2)
XB=P(P1(J),1)-XC
YB=P(P1(J),2)-YC
RL=YB*XB+YB*YB
IF(RL.EC.0.)GO TO 73
DO 74 J1=P1(J),P1(J+1)-1
XA=YB
YA=YB
AL=BL
XB=P(J+1,1)-XC
YB=P(J+1,2)-YC
RL=XB*XB+YB*YB
IF(RL.EC.0.)GO TO 73
SINE=(XA*YB-XB*YA)/SORT(AL*BL)
74 ANG=ANG+ASIN(SINE)
ANG=ABS(ANG)
IF(ANG.LT.1)GO TO 75
NCONC(M)=NCONC(M)+1
SURR(NCONC(M),M)=I
75 CONTINUE
C ACCEPT COMMANDS
76 TYPE 77
77 FORMAT(' BRANCH> ',S)
ACCEPT 10,TRIC
TRIC1=TRIC
IF(TRIC.EQ.'A')GO TO 92
IF(TRIC.EQ.'W')GO TO 79
IF(TRIC.EQ.'M')GO TO 92
IF(TRIC.EQ.'T')TYPE 24,NJ,NPT
IF(TRIC.EQ.'I')GO TO 92
IF(TRIC.EQ.'C')GO TO 81
IF(TRIC.EQ.'S')GO TO 110
IF(TRIC.EQ.'E')GO TO 139
IF(TRIC.EQ.'T')GO TO 76
TYPE 78
78 FORMAT(' AUTOMATIC,WARP,MANUAL,INSPECT,SINGLE,CAP,EXIT,TOTALS ')
GO TO 76
C CHANGE WARP ANGLE
79 TYPE 80
80 FORMAT(' MAX,WARP ANGLE= ',S)
READ(S,*,END=76,ERR=76)ANG
WANG=COSD(ANG)
GO TO 76
C CAP
81 TYPE 82
82 FORMAT(' GLOBAL LOOP NUMBER:',S)
READ(S,114,END=76,ERR=76)N
DO 83 I=1,NLV
J=I
83 IF(LPP(I).GE.N)GO TO 84
CONTINUE

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84     IF(J.LT.2)GO TO 86
      TYPE 85,P(P1(LPP(J-1)),3)
85     FORMAT(' 2 FOR (LEVEL-1)=' ,E10.3)
86     TYPE 87,P(P1(N),3)
87     FORMAT(' 2 FOR (LEVEL)=' ,E10.3)
      IF(J.GE.NLV)GO TO 89
      TYPE 88,P(P1(LPP(J+1)),3)
88     FORMAT(' 2 FOR (LEVEL+1)=' ,E10.3)
89     TYPE 90
90     FORMAT(' ENTER 2 FOR VERTEX ' ,S)
      READ(5,*,END=76,ERR=76)ZV
      NJ=NJ+1
      P(NJ,1)=(EX(N,2)+EX(N,1))/2.
      P(NJ,2)=(EX(N,4)+EX(N,3))/2.
      P(NJ,3)=ZV
      IN=P1(N+1)-P1(N)-1
      RO=P1(N)-1
      DO 91 I=1,IN
      IP(1,NPT)=NJ
      IP(2,NPT)=RO+I
      IP(3,NPT)=RO+I+1
      IP(4,NPT)=0
      NPT=NPT+1
91     CONTINUE
      GO TO 76
92     TYPE 93
93     FORMAT(' START WITH WHICH LEVEL? ' ,S)
      READ(5,114,END=76,ERR=76)LIN
      IF(LIN.EQ.0)LIN=LIND
94     IND2=NLV-1
      IF(TRIC.EQ.'I')IND2=NLV
      IF(TRIC.NE.'A')GO TO 945
      TYPE 941
941    FORMAT(' POST-EDIT? ' ,S)
      ACCEPT 10,ANS
      PE=.FALSE.
      IF(ANS.EQ.'Y')PE=.TRUE.
945    DO 138 IL=LIN,IND2
      TO=LPP(IL+1)-1
      BO=LPP(IL)-1
      IF(TRIC.NE.'A')GO TO 98
C     EMPLOY CONNECTIVITY ALGORITHM
      DO 95 J=1,8
      FLAG(J)=.FALSE.
95     C(J,1)=0
      NL(1)=1
      NL(2)=1
      NLB=TO-BO
      NLT=LPP(IL+2)-LPP(IL+1)
      DO 97 J=1,NLB
      DO 97 K=1,NLT
      DO 96 L=1,3,2
      IF(EX(RO+J,L+1).LT.FX(TO+K,L))GO TO 97
96     IF(FX(RO+J,L).GT.EX(TO+K,L+1))GO TO 97
      C(J,1)=C(J,1)+1
      C(K+NLB,1)=C(K+NLB,1)+1
      C(J,C(J,1)+1)=K+NLB
      C(K+NLB,C(K+NLB,1)+1)=J
97     CONTINUE
      IF(TRIC.EQ.'A'.AND..NOT.PE)GO TO 121

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C PAINT & LABEL LOOPS
98   IF(.NOT. TEKT)GO TO 109
     DO 99 I=1,4
99   E(I)=EX(R0+1,I)
     DO 100 I=R0+2,LPP(IL+2)-1
     DO 100 J=1,3,2
     IF(F(J).GT.EX(I,J))E(J)=FX(I,J)
100  IF(E(J+1).LT.EX(I,J+1))E(J+1)=EX(I,J+1)
     DX=F(2)-E(1)
     DY=E(4)-E(3)
     XBAR=(E(2)+E(1))/2.
     YBAR=(E(4)+E(3))/2.
     SF=DX
     IF(DY.GT.SF)SF=DY
     SF=700./SF
     IND=2
     IF(TRIC.EQ.'A')GO TO 121
     CALL BOX
     IF(TRIC.EQ.'I')IND=1
101  DO 107 J=1,IND
     IND1=LPP(IL+J-1)
     IND2=LPP(IL+J)-1
     DO 107 I=IND1,IND2
     CALL MOVE(P1(I),0,0)
     DO 102 K=P1(I)+1,P1(I+1)-1
     KK=K
102  CALL DRAW(KK,0,0)
     II=I-IND1+1
     CALL MOVE(P1(I),-57,-10)
     CALL ALMODE
     IF(J.EQ.2)GO TO 105
     IF(TRIC.EQ.'I')TYPE 103,I
103  FORMAT(1H+,S,I3)
     IF(TRIC.NE.'I') TYPE 104,II
104  FORMAT(1H+,S,I3,'B')
     GO TO 107
105  TYPE 106,II
106  FORMAT(1H+,S,I3,'T')
107  CONTINUE
     CALL MVTC(0,767)
     CALL ALMODE
     TYPE 108,IL
108  FORMAT(' >> LEVEL ',I2)
     IF(TRIC.NE.'I')GO TO 109
     READ(5,114,END=76,ERR=76)ICONT
     GO TO 138
109  NL(1)=0
     NL(2)=0
C SELECT CONNECTIVITY MANUALLY
110  TYPE 111
111  FORMAT(' BOTTOM LOOP(S) (LOCAL):')
     GO TO 113
     TYPE 112
112  FORMAT(' BOTTOM LOOPS:(GLORAL)')
113  READ(5,114,END=76,ERR=76),N
114  FORMAT(I)
     IF(N.EQ.0)GO TO 115
     NL(1)=NL(1)+1
     LPSTK(1,NL(1))=N+R0
     IF(TRIC.EQ.'S')LPSTK(1,NL(1))=N

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GO TO 113
115 IF(NL(1).EQ.0)GO TO 119
    TYPE 116
116 FORMAT(' TOP LCOP(S)')
117 READ(5,114,END=76,ERR=76),N
    IF(N.EQ.0)GO TO 118
    NL(2)=NL(2)+1
    LPSTK(2,NL(2))=N+T0
    IF(TRIC.EQ.'S')LPSTK(2,NL(2))=N
    GO TO 117
118 IF(NL(2).EQ.0)GO TO 119
    CALL QUAD
    TRIC=TRIC1
    IF(TRIC.EQ.'A')GO TO 138
119 TYPE 120
120 FORMAT(' NEXT LEVEL?',5)
    ACCEPT 10,ANS
    IF(ANS.EQ.'Y')GO TO 138
    IF(.NOT.TEXT)GO TO 109
    CALL BOX
    GO TO 101
C AUTOMATIC BRANCHING ALGORITHM
121 NL(1)=1
    NL(2)=1
    IF(NCONC(IL).EQ.0)GO TO 128
    DO 127 J=1,NCONC(IL)
    K=SURR(J,IL)-B0
    FLAG(K)=.TRUE.
    IF(NCONC(IL+1).GT.0)GO TO 123
    IF(C(K,1).GT.1)TYPE 122,IL
122 FORMAT(' ?ILLEAGLE CONCENTRICITY IN LEVEL',I2)
    LPSTK(1,1)=K+B0
    LPSTK(2,1)=C(K,2)+T0
    CALL QUAD
    GO TO 127
123 DO 124 L=1,C(K,1)
    DO 124 N=1,NCONC(IL+1)
    IF(SURR(N,IL+1).EQ.C(K,L+1))GO TO 125
124 CONTINUE
    LPSTK(2,1)=C(K,2)+T0-
    GO TO 126
125 LPSTK(2,1)=SURR(N,IL+1)
    FLAG(SURR(N,IL+1)-T0)=.TRUE.
126 CALL QUAD
127 CONTINUE
128 IF(NCONC(IL+1).EQ.0)GO TO 130
    DO 129 J=1,NCONC(IL+1)
    K=SURR(J,IL)-B0
    FLAG(K)=.TRUE.
    IF(C(K,1).GT.1)TYPE 122,IL
    LPSTK(1,1)=K+B0
    LPSTK(2,1)=C(K,2)+B0
129 CALL QUAD
C PREPARE REMAINING LCOPS FOR QUAD
130 DO 131 J=1,NLB
    IF(FLAG(J))GO TO 138
    FLAG(J)=.TRUE.
    IF(C(J,1)-1)131,131,132
C SIMPLE 1 ON 1
131 IV=C(C(J,1)+NLB,1)

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IF(IV.GT.1)GO TO 132
FLAG(C(J,2))=.TRUE.
NL(1)=1
NL(2)=1
LPSTK(2,1)=C(J,2)+T0-NLB
LPSTK(1,1)=C(C(J,2),2)+B0
CALL QUAD
GO TO 138
C DETERMINE EXTENT OF BRANCHING
132 SP=1
NBR=1
BRANCH(1)=J
STACK(1)=J
133 DO 134 I=1,C(STACK(SP),1)
NODE=C(STACK(SP),I+1)
IF(FLAG(NODE))GO TO 134
FLAG(NODE)=.TRUE.
NBR=NBR+1
BRANCH(NBR)=NODE
IF(C(NODE,1).EQ.1)GO TO 134
SP=SP+1
STACK(SP)=NODE
GO TO 133
134 CONTINUE
IF(SP.EQ.1)GO TO 135
SP=SP-1
GO TO 133
135 NL(1)=0
NL(2)=0
DO 137 I=1,NBR
IF(BRANCH(I).LE.NLB)GO TO 136
NL(2)=NL(2)+1
LPSTK(2,NL(2))=BRANCH(I)+T0-NLB
GO TO 137
136 NL(1)=NL(1)+1
LPSTK(1,NL(1))=BRANCH(I)+B0
137 CONTINUE
CALL QUAD
138 CONTINUE
IF(TRIC.EQ.'I')GO TO 76
LIND=NLV+1
IF(DATAF)GO TO 6
C OUTPUT
139 TYPE 140
140 FORMAT(' DONE? ',S)
ACCEPT 10,ANS
IF(ANS.NE.'Y')GO TO 8
NPT=NPT-1
NP=NPMAX-1
TYPE 24,NJ,NPT
IPL(2,IPLI,N IPL(IPLI))=NPT
TYPE 141
141 FORMAT(' OUTPUT FILENAME? ',S)
ACCEPT 4,ONAME
OPEN(UNIT=22,FILE=ONAME)
DO 142 I=1,NP
NPIC(I)=0
DC 142 J=1,N IPL(I)
142 NPIC(I)=NPIC(I)+IPL(2,I,J)-IPL(1,I,J)+1
WRITE(22,146)NP,NJ,NPT

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N=0
DO 143 I=1,NP
J=N+1
N=J+NPIC(1)-1
NPLA(1,I)=J
143 NPLA(2,I)=N
WRITE(22,146)((NPLA(I,J),I=1,2),J=1,NP)
WRITE(22,147)((P(I,J),J=1,3),I=1,NJ)
WRITE(22,146)((((IP(I,J),I=1,4),J=IPL(1,N,M),IPL(2,N,M))
1,M=1,NIPL(N)),N=1,NP)
TYPE 144
144 FORMAT(' SPECIAL FUNCTION FILE?',S)
ACCEPT 10,ANS
IF(ANS.NE.'Y')GO TO 148
TYPE 145
145 FORMAT(' FILENAME OF S.F. FILE: ',S)
ACCEPT 4,SNAME
OPEN(UNIT=23,FILE=SNAME)
WRITE(23,147)(P(I,3),I=1,NJ)
146 FORMAT(20I4)
147 FORMAT(6E12.5)
148 STOP
END
SUBROUTINE QUAD
LOGICAL FLAG1,FLAG2,FLAG(5),CLOSE,IPF(10),DRAWF,MAP,BD,TEKT,PE,PEN
COMMON/O/NL(2),LPSTK(2,5),NPT,NJ,DZ,BD,TEKT,PE,
1 EX(100,4),P1(100),TRIC,IPL(2,5,10),NIPL(5),IPLI,NPMAX,IP(4,2000)
COMMON/XODE/P2(2,1100,3)
COMMON/TEK/XBAR,YBAR,SF,P(2000,3),IYD2
INTEGER TEMP(200),NV(2),NEW(2,5),V(2,200),FIRST,P1,PDUR(12)
REAL TRANS(2,4),THAP(2,2),S(2)
INTEGER ORDER(5,5),CP(5,5),O(5),FIRST1,FIRST2,CL,CT
REAL D(5,5),DT(5),E(4)
INTEGER NCP(2),CV(2,150),N1(2),N2(2)
DATA IVIEW,MAP,IND6/1,.,TRUE.,2/
NPT1=NPT
NPT2=NPT
NNEW=0
NTEMP=0
XHART=XBAR
YHART=YBAR
NTHAX=1
NBMAX=1
NLINE=767
PEN=.FALSE.
SFT=SF
DRAWF=.FALSE.
DO 48 M=1,2
O(1)=1
IF(NL(M).EQ.1)GO TO 29
IF(TRIC.NE.'A'.OR.PE)GC TO 12
C AUTOMATIC:
C FIND CLOSEST DISTANCE BETWEEN ALL LOOPS
DO 7 I=1,NL(M)-1
FIRST1=P1(LPSTK(M,I))
LAST1=P1(LPSTK(M,I)+1)-1
DO 7 J=I+1,NL(M)
FIRST2=P1(LPSTK(M,J))
LAST2=P1(LPSTK(M,J)+1)-1
CP(I,J)=FIRST1

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```

CP(J,I)=FIRST2
DIST=1E35
FLAG1=.FALSE.
1 FLAG2=.TRUE.
DO 3 K=FIRST1, LAST1
TDIST=(P(K,1)-P(CP(J,I),1))**2+(P(K,2)-P(CP(J,I),2))**2
IF(TDIST.GE.DIST)GO TO 3
DO 2 L=1,NL(M)
2 IF(K.EQ.CP(I,L))GO TO 3
DIST=TDIST
FLAG2=.FALSE.
CP(I,J)=K
3 CONTINUE
IF(FLAG2.AND.FLAG1)GO TO 6
FLAG1=.TRUE.
DO 5 K=FIRST2, LAST2
TDIST=(P(K,1)-P(CP(I,J),1))**2+(P(K,2)-P(CP(I,J),2))**2
IF(TDIST.GE.DIST)GO TO 5
DO 4 L=1,NL(M)
4 IF(K.EQ.CP(J,L))GO TO 5
DIST=TDIST
FLAG1=.FALSE.
CP(J,I)=K
5 CONTINUE
IF(FLAG1.AND.FLAG2)GO TO 6
GO TO 1
6 D(J,I)=DIST
7 D(I,J)=DIST
C PICK THE PROPER LOOP SEQUENCE
DO 9 I=1,NL(M)
J1=I
DT(I)=0.
DO 8 J=1,5
8 FLAG(J)=.FALSE.
DIST=0.
DO 9 J=1,NL(M)
FLAG(J1)=.TRUE.
DT(I)=DT(I)+DIST
ORDER(I,J)=J1
J2=J1
DIST=1E35
DO 9 K=1,NL(M)
IF(FLAG(K))GO TO 9
IF(DIST.LE.D(J2,K))GO TO 9
J1=K
DIST=D(J2,K)
9 CONTINUE
DIST=1E35
DO 10 I=1,NL(M)
IF(DIST.LE.DT(I))GO TO 10
DIST=DT(I)
IT=I
10 CONTINUE
DO 11 J=1,NL(M)
D(J)=ORDER(IT,J)
11 C DISPLAY LOOPS
12 IF(TRIC.EQ.'A'.AND..NOT.PE)GO TO 26
IF(.NOT.TEKT)GO TO 17
CALL BOX
DO 16 K=1,2

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```

DO 16 J=1,NL(K)
IND1=P1(LPSTK(K,J))
IND2=P1(LPSTK(K,J)+1)-1
CALL MOVE(IND1,0,0)
DO 13 L=IND1+1,IND2
LL=L
13 CALL DRAW(LL,0,0)
IF(M.NE,K)GO TO 16
CALL ALMODE
TYPE 14,J
14 FORMAT(1H+,S,'LOCP',I1)
DO 16 L=IND1+2,IND2,2
LL=L
CALL CROSS(LL,3)
CALL MOVE(LL,-57,-10)
CALL ALMODE
TYPE 15,L
15 FORMAT(1H+,S,I4)
16 CONTINUE
CALL MVTO(0,767)
CALL ALMODE
17 TYPE 18
18 FORMAT(' ENTER LOOP SEQUENCE')
N=0
DO 19 L=1,NL(M)
N=N+1
19 READ(S,*,END=137,ERR=137)O(L)
20 NL(M)=N
IF(N.EQ.1)GO TO 26
DO 23 L=1,NL(M)-1
TYPE 21,O(L)
21 FORMAT(' L',I1,' P?',S)
ACCEPT *,CP(O(L),O(L+1))
TYPE 22,O(L+1)
22 FORMAT(1H+,S,' TC L',I1,' P?',S)
23 ACCEPT *,CP(O(L+1),O(L))
TYPE 24
24 FORMAT(' CHANGES?',S)
ACCEPT 25,ANS
25 FORMAT(A1)
IF(ANS.EQ.'Y')GO TO 17
C INTERPOLATE NEW POINTS
26 IF(NL(M).EQ.1)GO TO 29
I=LPSTK(2,1)
261 J=LPSTK(1,1)
262 I1=P1(I)
263 J1=P1(J)
264 ZI=P(I1,3)
265 ZJ=P(J1,3)
266 Z=(ZI+ZJ)/2.
DO 28 I=1,NL(M)-1
NJ=NJ+1
NEW(M,I)=NJ
DO 27 J=1,2
K=J
270 I2=EP(O(I),O(I+1))
271 I3=CP(O(I+1),O(I))
272 TJ2=P(I2,J)
273 TJ3=P(I3,J)
274 TJ=(TJ2+TJ3)/2.

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27     P(NJ,J)=TJ
28     P(NJ,3)=Z
C     COMBINE LOOPS
29     FLAG1=.TRUE.
        FLAG2=.FALSE.
        NV(M)=0
        IND1=1
        IND2=NL(M)
        IND3=1
30     DO 43 I=IND1,IND2,IND3
31     FIRST=P1(LPSTK(M,0(I)))-1
        IF(NL(M).EQ.1)GO TO 39
        CL=CP(0(I),0(I+1))-FIRST
        IF(I.EQ.1.AND.IND3.EQ.-1)GO TO 38
        IF(I.EQ.1)GO TO 32
        CT=CP(0(I),0(I-1))-FIRST
        IF(I.EQ.IND2.AND.IND3.EQ.1)GO TO 35
        IF(.NOT.FLAG1)GO TO 33
32     FLAG1=.FALSE.
        FLAG2=.TRUE.
        N=CL
        IF(IND3)N=CT
        GO TO 40
33     IF(IND3)36,34
34     IF(CL.GT.CT)GO TO 37
        FLAG1=.TRUE.
35     FIRST=FIRST+CT-1
        N=P1(LPSTK(M,0(I))+1)-FIRST-2
        GO TO 40
36     IF(CL.GT.CT)GO TO 38
        FIRST=FIRST+CL-1
        N=CT-CL+1
        FLAG2=.TRUE.
        GO TO 40
37     FIRST=FIRST+CT-1
        FLAG2=.TRUE.
        N=CL-CT+1
        GO TO 40
38     FIRST=FIRST+CL-1
        FLAG1=.TRUE.
39     IDUM=LPSTK(M,0(I))+1
        N=P1(IDUM)-FIRST-2
C     ALL THAT WORK FOR THIS LITTLE LOOP!
40     IF(I.EQ.IND2)FLAG1=.FALSE.
        IF(N.EQ.0)N=1
        DO 41 J=1,N
41     NV(M)=NV(M)+1
        V(M,NV(M))=FIRST+J
        IF(.NOT.FLAG2)GO TO 42
        N=NEW(M,I)
        IF(IND3.EQ.-1)N=NEW(M,I-1)
        NV(M)=NV(M)+1
        V(M,NV(M))=N
        FLAG2=.FALSE.
42     IF(FLAG1)GO TO 31
43     CONTINUE
        IF(NL(M).EQ.1)GO TO 44
        IF(IND3.EQ.-1)GO TO 44
        FLAG1=.TRUE.
        IND3=-1

```

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```

IND1=NL(M)
IND2=1
GO TO 30
44 CONTINUE
C SEGMENT ENDPOINTS
NV(M)=NV(M)+1
GO TO 46
DO 45 I=1,2
45 IF(P(V(M,1),I).NE.P(V(M,NV(M)),I))GO TO 47
46 V(M,NV(M))=V(M,1)
GO TO 48
47 V(M,NV(M))=V(M,NV(M)-1)+1
48 CONTINUE
IF(TRIC.EQ.'A')TRI='A'
IF(TRIC.EQ.'A'.AND..NOT.PE)GO TO 111
C DETERMINE EXTREMES
DO 49 I=1,4
49 E(I)=EX(LPSTK(1,1),I)
DO 50 M=1,2
DO 50 J=1,NL(M)
DO 50 I=1,3,2
ET1=EX(LPSTK(M,J),I)
ET2=EX(LPSTK(M,J),I+1)
IF(ET1.LT.E(I))E(I)=ET1
50 IF(ET2.GT.E(I+1))E(I+1)=ET2
DX=E(2)-E(1)
DY=E(4)-E(3)
DYT=DY+DZ
SF2=DX
IF(DYT.GT.SF2)SF2=DYT
SF2=700./SF2
SF1=DX
IF(DY.GT.SF1)SF1=DY
SF1=700./SF1
XBAR=(E(1)+E(2))/2.
YBAR=(E(3)+E(4))/2.
51 IF(IVIEW.EQ.1)GO TO 52
SF=SF2
IYD2=390.*DZ/DYT
GO TO 53
52 SF=SF1
IYD2=0
53 IF(.NOT.TEXT)GO TO 63
CALL BOX
DO 54 M=1,2
CALL CROSS(V(M,1),5)
DO 54 J=2,NV(M)
54 CALL DRAW(V(M,J),0,0)
IF(IVIEW.EQ.1)GO TO 57
IY=10
DO 56 M=1,2
IX=SF*(P(V(M,1),1)-XBAR)+634
CALL MVTO(IX,IY)
DO 55 J=2,NV(M)
IX=SF*(P(V(M,J),1)-XBAR)+634
55 CALL VCTO(IX,IY)
56 IY=SF*DX+10
57 IF(NPT1.EQ.NPT)GO TO 60
IND=NPT1+1
DO 58 I=IND,NPT

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```

58 CALL MOVE(IP(1,I),0,0)
CALL DRAW(IP(2,I),0,0)
IF(IVIEW.EQ.1)GO TO 60
IYT=4+IYD2/39
IYB=35+IYD2/39
DO 59 I=IND,NPT
IX=SF*(P(IP(1,I),1)-XBAR)+634
CALL MVTO(IX,IYB)
IX=SF*(P(IP(2,I),1)-XBAR)+634
59 CALL VCTO(IX,IYT)
60 IF(TRIC.EQ.'A'.AND..NOT.PEN)GO TO 111
CALL MOVE(V(1,1),-10,-10)
CALL ALMODE
TYPE 600
600 FORMAT(1H+,S,'B')
CALL MOVE(V(2,1),-10,-10)
TYPE 601
601 FORMAT(1H+,S,'T')
DO 62 M=1,2
J=N*(M)-2
DO 62 I=M,J,IND6
CALL MOVE(V(M,1),-45,-10)
CALL ALMODE
TYPE 61,I
61 FORMAT(1H+,S,I3)
62 CONTINUE
CALL MVTO(0,767)
NLINE=767
CALL ALMODE
63 IF(DRAWF)GO TO 94
C ACCEPT COMMANDS
64 TYPE 65
NLINE=NLINE-20
65 FORMAT(' TRIANGULATE>',S)
ACCEPT 136,TRI
IF(TRI.EQ.'A')GO TO 111
IF(TRI.EQ.'V')GO TO 72
IF(TRI.EQ.'R')GO TO 90
IF(TRI.EQ.'C')GO TO 137
IF(TRI.EQ.'T')GO TO 73
IF(TRI.EQ.'I')GO TO 94
IF(TRI.EQ.'D')GO TO 69
IF(TRI.EQ.'P')GO TO 75
IF(TRI.EQ.'E')GO TO 71
IF(TRI.EQ.'O')GO TO 83
IF(TRI.EQ.'M')GO TO 67
IF(TRI.EQ.'U')GO TO 68
TYPE 66
NLINE=NLINE-80
66 FORMAT(' AUTO,INTERACTIVE,',/, ' RENUMBER,DENSITY,',/, ' CONT,
1 TOTALS',/, ' PART,ERASE,VIEW,MAP,UNMAP,ONE')
GO TO 64
C SET MAP FLAG
67 MAP=.TRUE.
GO TO 64
C RELEASE MAP FLAG
68 MAP=.FALSE.
GO TO 64
C SET NUMBER DENSITY
69 TYPE 70

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```

70     FORMAT(' IND3=',S)
      ACCEPT *,IND6
      GO TO 53
C ERASE
71     NPT=NPT1
      NTMAX=1
      NBMAX=1
      DRAWF=.FALSE.
      GO TO 53
C CHANGE NUMBER OF ORTHOGRAPHIC VIEWS
72     I=IVIEW
      IF(I.EQ.2)IVIEW=1
      IF(I.EQ.1)IVIEW=2
      GO TO 51
C TOTALS
73     TYPE 74,NJ,NPT
74     FORMAT(' ',I4,' NODES, ',I4,' ELEMENTS')
      GO TO 64
75     TYPE 76,IPLI
C CHANGE PART NUMBER
76     FORMAT(' CHANGE PART FROM ',I1,' TO ',S)
      ACCEPT *,N
      IF(N.LE.NPMAX.AND.NPT.GT.IPL(1,IPLI,NIPL(IPLI)))GO TO 80
      IF(N.GT.NPMAX)GO TO 78
      TYPE 77
77     FORMAT(' CANT CHANGE PART NUMBER YET')
      GO TO 64
78     TYPE 79,NPMAX
79     FORMAT(' MUST BE LESS THAN ',I2)
      GO TO 75
80     IF(IPLI.EQ.N)GO TO 64
      I=NPT-1
      IF(IPL(1,IPLI,NIPL(IPLI)).LT.I)GO TO 81
      NIPL(IPLI)=NIPL(IPLI)-1
      GO TO 82
81     IPL(2,IPLI,NIPL(IPLI))=I
82     NIPL(N)=NIPL(N)+1
      IPL(1,N,NIPL(N))=NPT
      IF(N.EQ.NPMAX)NPMAX=NPMAX+1
      IPLI=N
      GO TO 64
C ONE AT A TIME
83     DO 88 I=1,4
      NLINE=NLINE-20
      TYPE 84,I
84     FORMAT(' POINT ',I1,'. T/B,NO.',S)
      ACCEPT 85,T,N
85     FORMAT(A1,I)
      IF(T.EQ.'T')GO TO 86
      IF(T.EQ.'B')GO TO 87
      IF(I.NE.4)GO TO 64
      IP(4,NPT)=0
      GO TO 88
86     IP(I,NPT)=V(2,N)
      GO TO 88
87     IP(I,NPT)=V(1,N)
88     CONTINUE
      CALL MOVE(IP(1,NPT),0,0)
      CALL DRAW(IP(2,NPT),0,0)
      CALL DRAW(IP(3,NPT),0,0)

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      JF(IP(4,NPT).EQ.0)CALL DRAW(IP(4,NPT),0,0)
89   NPT=NPT+1
      CALL MVTO(0,NLINE)
      CALL ALMODE
      GO TO 64
C   RENUMBER
90   TYPE 91
91   FORMAT(' NEW #1 NODE',/, '(TOP CONTOUR)',S)
      NLINE=NLINE-40
      DRAW=.FALSE.
      ACCEPT *,N5
      IF(N5.LT.1)GO TO 90
      GO TO 113
94   NTMT=NTMAX
      NBMT=NBMAX
      TYPE 95,NTMAX,NV(2)
      NLINE=NLINE-80
95   FORMAT(' TOP:',I3,'-',I3)
      READ(5,96,END=64,ERR=64),N1(2),N2(2)
96   FORMAT(2I)
      IF(N1(2).EQ.0)GO TO 137
      TYPE 97,NBMAX,NV(1)
97   FORMAT(' BOTTOM:',I3,'-',I3)
      READ(5,96,END=64,ERR=64),N1(1),N2(1)
      NPT2=NPT
98   IF(TRI.AE.'A')GO TO 99
      N1(1)=1
      N1(2)=1
      N2(1)=NV(1)
      N2(2)=NV(2)
99   NTDEL=1
      IF(N1(2).GT.N2(2))NTDEL=-1
      NBDEL=1
      IF(N1(1).GT.N2(1))NBDEL=-1
      IF(.NOT.MAP)GO TO 108
      DO 100 I=1,2
100  IF(N1(I).EQ.N2(I))GO TO 110
      DO 102 I=1,2
      IND1=N1(I)
      IND2=N2(I)
      IF(IND1.LT.IND2)GO TO 101
      IND1=IND2
      IND2=N1(I)
101  TRANS(I,1)=P(V(I,IND1),1)
      TRANS(I,2)=TPANS(I,1)
      TRANS(I,3)=P(V(I,IND1),2)
      TRANS(I,4)=TRANS(I,3)
      DO 102 J=IND1+1,IND2
      PX=P(V(I,J),1)
      IF(PX.LT.TRANS(I,1))TRANS(I,1)=PX
      IF(PX.GT.TRANS(I,2))TRANS(I,2)=PX
      PY=P(V(I,J),2)
      IF(PY.LT.TRANS(I,3))TRANS(I,3)=PY
      IF(PY.GT.TRANS(I,4))TRANS(I,4)=PY
102  DO 104 I=1,2
103  TMAP(1,I)=(TRANS(I,2)+TRANS(I,1))/2.
104  TMAP(2,I)=(TRANS(I,3)+TRANS(I,4))/2.
      DO 105 I=1,2
      IF(TRANS(I,2).EQ.TRANS(I,1))GO TO 108
105  IF(TRANS(I,3).EQ.TRANS(I,4))GO TO 108

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```

C MAP
DO 107 I=1,2
S(1)=100./(TRANS(I,2)-TRANS(I,1))
S(2)=100./(TRANS(I,4)-TRANS(I,3))
IN=NBDEL
IF(I.EQ.2)IN=NTDEL
DO 107 J=N1(I),N2(I),IN
DO 106 K=1,2
106 P2(I,J,K)=S(K)+(P(V(I,J),K)-TMAP(K,I))
107 P2(I,J,3)=P(V(I,J),3)
GO TO 110
C DON'T MAP
108 DO 109 I=1,2
IN=NBDEL
IF(I.EQ.2)IN=NTDEL
DO 109 J=N1(I),N2(I),IN
DO 109 K=1,3
109 P2(I,J,K)=P(V(I,J),K)
110 NT=N1(2)
NB=N1(1)
NTMAX=N2(2)
NEMAX=N2(1)
GO TO 117
111 D1=1E35
X1=P(V(1,1),1)
Y1=P(V(1,1),2)
DO 112 I=1,NV(2)
D2=(P(V(2,I),1)-X1)**2+(P(V(2,I),2)-Y1)**2
IF(D2.GE.D1)GO TO 112
D1=D2
N5=1
112 CONTINUE
C RE-ORDER
113 IF(N5.EQ.1)GO TO 116
DO 114 J=1,NV(2)
114 TEMP(J)=V(2,J)
DO 115 J=1,NV(2)
JR=J+N5-1
IF(JP.GT.NV(2))JR=JR-NV(2)+1
115 V(2,J)=TEMP(JR)
116 IF(TRI.EQ.'R')GO TO 53
GO TO 98
C TRIANGULATE BETWEEN LIMITS
117 IFLAG=0
118 IP(1,NPT)=V(2,NT)
IP(2,NPT)=V(1,NB)
IP(4,NPT)=0
PX=P2(2,NT,1)-P2(1,NB,1)
PY=P2(2,NT,2)-P2(1,NB,2)
PZ=P2(2,NT,3)-P2(1,NB,3)
IF(NT.EQ.NTMAX)GO TO 125
IF(NB.EQ.NBMAX)GO TO 120
D1=0.
D2=0.
DO 119 I=1,3
119 D1=D1+(P2(2,NT,I)-P2(1,NB+NRDEL,I))**2
D2=D2+(P2(2,NT+NTDEL,I)-P2(1,NB,I))**2
C SELECT SHORTEST DIAGONAL
IF(D1.LT.D2)GO TO 125
C TOP NODE IS CLOSEST

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```

120  NT=NT+NTDEL
      JP(3,NPT)=V(2,NT)
121  NPT=NPT+1
      SX=P2(2,NT,1)-P2(1,NB,1)
      SY=P2(2,NT,2)-P2(1,NB,2)
      SZ=P2(2,NT,3)-P2(1,NB,3)
      X1=RY*SZ-RZ*SY
      Y1=RZ*SX-RX*SZ
      Z1=RX*SY-RY*SX
      AREA1=(X1*X1+Y1*Y1+Z1*Z1)
      IF(AFEA1.NE.0)GO TO 122
      NPT=NPT-1
      GO TO 118
122  IF(IFLAG.EQ.2)GO TO 124
123  IFLAG=1
      GO TO 118
124  ANGT=(X1*X2+Y1*Y2+Z1*Z2)/SQRT(AREA1*AREA2)
      IF(ANGT.LT.WANG)GO TO 123
      IFLAG=0
      IP(4,NPT-2)=V(2,NT)
      NPT=NPT-1
      GO TO 118
C  BOTTOM NOCE IS CLOSEST
125  IF(NB.EC.NBMAX)GO TO 130
      NR=NB+NBDEL
      IP(3,NPT)=V(1,NB)
126  NPT=NPT+1
      SX=P2(1,NB,1)-P2(1,NB-NBDEL,1)
      SY=P2(1,NB,2)-P2(1,NB-NBDEL,2)
      SZ=P2(1,NB,3)-P2(1,NB-NBDEL,3)
      X2=RY*SZ-RZ*SY
      Y2=RZ*SX-RX*SZ
      Z2=RX*SY-RY*SX
      AREA2=(X2*X2+Y2*Y2+Z2*Z2)
      IF(AFEA2.NE.0.)GO TO 127
      NPT=NPT-1
      GO TO 118
127  IF(IFLAG.EQ.1)GO TO 129
128  IFLAG=2
      GO TO 118
129  ANGT=(X1*X2+Y1*Y2+Z1*Z2)/SQRT(AREA1*AREA2)
      IF(ANGT.LT.WANG)GO TO 128
      IP(4,NPT-2)=IP(1,NPT-1)
      IP(3,NPT-2)=IP(3,NPT-1)
      NPT=NPT-1
      IFLAG=0
      GO TO 118
130  IF(TPIC.EQ.'A'.AND..NOT.PE)GO TO 137
C  PAINT NEW DIAGONALS
      IF(.NOT.TEXT)GO TO 134
131  DO 132 I=NPT2,NPT
      CALL MOVE(IP(1,I),0,0)
132  CALL DRAW(IP(2,I),0,0)
      IF(IVIEW.EQ.1)GO TO 134
      IYT=4*IYT2/39
      IYP=35*IYT2/39
      DO 133 I=NPT2,NPT
      IX=SF*(P(IP(1,I),1)-XBAR)+634
      CALL MVTO(IX,IYB)
      IX=SF*(P(IP(2,I),1)-XBAR)+634

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```

133 CALL VCTO(IX,IYT)
134 NLINE=NLINE-100
    CALL MVTO(0,NLINE)
    CALL ALMODE
    TYPE 135
135 FORMAT(' CHANGES?',S)
    ACCEPT 136,ANS
    DRAWF=.TRUE.
    IF(NLINE,LT,200)GO TO 53
136 FORMAT(A1)
    IF(ANS,EG,'Y')GO TO 138
    IF(TRI,EG,'A')GO TO 137
    IF(NTHAX,EG,NV(2),AND,NBMAX,EG,NV(1))GO TO 137
    GO TO 94
138 NTHAX=NTHM
    NBMAX=NBMT
    NPT=NPT2
    IF(TRI,EG,'A')DRAWF=.FALSE.
    IF(TRIC,NE,'A')GO TO 53
    PEN=.TRUE.
    TYPE 139
139 FORMAT(' CHANGE CONNECTIVITY? ',S)
    ACCEPT 136,ANS
    IF(ANS,NE,'Y')GO TO 53
    TRIC='M'
C RESTORE PARAMETERS BEFORE RETURNING
137 YBAR=YBART
    XBAR=XBART
    IYD2=0
    SF=SFT
    RETURN
    END

```

```

SUBROUTINE BOX
CALL CLMOA
CALL MVTO(244,779)
CALL VCTO(1023,779)
CALL VCTO(1023,0)
CALL VCTO(244,0)
CALL VCTO(244,779)
RETURN
END
SUBROUTINE CROSS(I,ISIZE)
COMMON/TEK/XBAR,YBAR,SF,P(2000,3),IYD2
CALL MOVE(I,-ISIZE,0)
CALL DRAW(I,ISIZE,0)
CALL MOVE(I,0,ISIZE)
CALL DRAW(I,0,-ISIZE)
CALL MOVE(I,0,0)
RETURN
END
SUBROUTINE MOVE(I,IXD,IYD)
COMMON/TEK/XBAR,YBAR,SF,P(2000,3),IYD2
IX=SF+(P(1,1)-XBAR)+634+IXD
IY=SF*(P(1,2)-YBAR)+390+IYD+IYD2
CALL MVTO(IX,IY)
RETURN
END
SUBROUTINE DRAW(I,IXD,IYD)
COMMON/TEK/XBAR,YBAR,SF,P(2000,3),IYD2

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```
IX=SF*(P(1,1)-YBAR)+634+IXD  
IY=SF*(P(1,2)-YBAR)+390+IYD+IYD2  
CALL VCTO(IX,IY)  
RETURN  
END
```

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APPENDIX B  
USER DOCUMENTATION

Throughout this documentation, cues typed by the computer are underlined. The program commences by asking:

BRAIN DATA?

User replies "yes", or "no" (brain data is handled slightly differently than user generated data). Next, the program requests

FILE NAME OF INPUT DATA?

Whereupon the user types the file name. The brain data files are called Bn.DAT where n is an integer from 1 to 22. Now the program requests a command by giving the prompt:

READ>

This prompt is so named because it is here that parameters are set preparatory to reading the data files. READ> responds to the following commands, of which only the first letter is required.

- PARAMETERS - Change node elimination parameters  $S_{min}$ ,  $S_{max}$ , and  $\theta_{min}$ .
- TOTALS - Causes the current number of nodes and panels to be output on the terminal.
- SCALE - Enables change of scale factor. Default is .0001 for brain data and 1 for non-brain data.
- CLOSE - Computer responds, CLOSE ALL LOOPS? If yes, every contour line will be treated as a closed loop. Otherwise, only contour lines whose first and last nodes agree will be considered closed. Default is "yes".
- DEVICE - Computer responds: TEKTRONIX SCOPE? "Yes" enables graphical output. "No" prohibits it. Default is "yes".
- CLOCKWISE - Computer responds: CLOCKWISE ORDERING? "Yes" forces all loops to run clockwise. "No" forces counterclockwise ordering. Default is "yes". Clockwise loops result in counterclockwise

definition of visible panels. This understanding is useful in using the Poor Man's hidden surface elimination in MOVIE.BYU.

- EXIT - Exits from the program.
- LEVEL - Since there are no convenient default values for the parameters set by the LEVEL command, this is the command which actually initiates the reading of the disk file - after the following two questions are answered:  
Z SPACING= . User responds with an integer "n" which indicates that every "nth" contour level is to be read in from disk. The computer then asks: LEVEL RANGE:. The user enters two integers, j and k. Thereupon, the algorithm proceeds to read every nth contour level from j to k inclusive, imposing the node elimination parameters. When array P has been loaded, ready for triangulation, the program issues the BRANCH> prompt.
- BRANCH - Proceeds to the BRANCH> prompt without reading from disk.
- MANUAL - Same as LEVEL, except loops from the brain data can be constructed interactively from their constituent segments. This command is never needed except in cases where closed and non-closed contour lines coincide on the same level.

The commands of PARAMETERS, TOTALS, SCALE, KLOCKWISE, CLOSE, and DEVICE return to the READ> prompt: LEVEL, BRANCH and MANUAL proceed to the next prompt:

BRANCH>

BRANCH> responds to the following commands.

- TOTALS - Same as above.
- EXIT - Same as above.
- AUTOMATIC - Computer responds  
START WITH WHICH LEVEL?  
 User responds with an integer, n.  
 The computer asks,  
POST-EDIT?  
 User responds "yes" or "no", the consequence of which will be explained momentarily. The

branching algorithm is now invoked which determines connectivity on the basis of window overlap. Branching and triangulation are also handled automatically. If POST-EDITING was refused, the entire data file is thus triangulated - with no guarantees. If POST-EDITING was requested, each triangulated contour pair is displayed for approval as the computer asks,

CHANGES?

Two things may be in error - the triangulation itself, or the choice of loops involved in branching. If either of these errors necessitate change, answer "yes". The computer then asks,

CHANGE CONNECTIVITY?

If the branching was at fault, answer "yes". This has the effect of changing from AUTOMATIC to MANUAL mode, and the user is free to manually control the branching. If only the triangulation was bad, answer "no". This moves the program counter to the TRIANGULATE> prompt, so the user can guide triangulation manually.

If no changes at all are needed, a carriage return pronounces acceptance and the algorithm proceeds to the next contour pair.

- WARP - Computer responds  
MAX. WARP ANGLE:  
Here the user sets the Maximum Warp Angle described in chapter 5. Default is 45 degrees.
- INSPECT - Computer responds  
START WITH WHICH LEVEL?  
After which the user responds with an integer, n. The tektronix scope then displays the contour line(s) of level n, labelled with global loop numbers. A carriage return will cause level n+1 to be displayed; a "control-Z" (end of data) returns control to BRANCH>.
- MANUAL - Again, the computer asks,  
START WITH WHICH LEVEL?  
The user responds with an integer, n. This initiates branching and triangulation. Each pair of neighboring contour levels is considered respectively ranging from n to the last level read in. All contours from the two relevant levels are displayed, and identified by a number followed by T(top) or B(bottom). The user selects from these loops the ones

which belong together for triangulation. (This need only be used for complex cases of branching. Normally, the AUTOMATIC command handles branching adequately.) The computer asks:

BOTTOM LOOP(S) (LOCAL):

Here, the user enters the loop numbers of all the loops that are to participate in triangulation. The loop numbers are delimited by carriage returns. The series is terminated by a double carriage return, after which the computer asks:

TOP LOOP(S) (LOCAL):

The same procedure is again followed in inputting the top loops. This sequence of loop numbers is loaded into an array called Loopstack, which is passed to SUBROUTINE QUAD for triangulation. If there are more than one loop on either top or bottom (i.e. branching) QUAD displays all the loops and inquires of the user how to assemble them into one loop by asking

ENTER LOOP SEQUENCE:

The user now enters the sequence in which the loops are to be re-constructed (as explained in chapter 3). If not all loops are intended to be included, the sequence may be terminated with a control-Z. Next, the computer asks how to interconnect the loops by typing: (where the loop sequence is i,j,k)

LIP?

Enter the node on loop i to be joined to loop j.

LJP?

Enter the node on loop j to be joined to loop i. etc.

When this series of questions is answered, the routine re-arranges the branching loops into one loop (as explained in chapter 3), and proceeds to the final command prompt of TRIANGULATE>. Commands for that prompt are discussed later.

SINGLE -

This command performs a function similar to that of MANUAL. The difference is that global loop numbers are used instead of local. This enables any loop(s) to be defined as top or bottom. The SINGLE command is used only in irregular situations involving concentric loops. Execution proceeds as in MANUAL.

CAP -

CAP invokes an algorithm to form a pyramidal cap on a specified loop. The computer asks:

GLOBAL LOOP NUMBER:

To find out what the global loop number is (in case the user doesn't know) use the INSPECT command. This should be done prior to invoking the CAP command.

WARP, CAP, INSPECT, and TOTALS return to the BRANCH> prompt. AUTOMATIC returns to the READ> prompt after triangulating all available contours.

The final prompt, TRIANGULATE>, is only encountered during the BRANCH command, or possibly during the AUTOMATIC/POST-EDIT command (if triangulation is faulty).

TRIANGULATE> responds to these commands:

- AUTOMATIC - Same as the AUTOMATIC command in the BRANCH> menu.
- DENSITY - As default, the program labels every other node for identification. If this labelling is too dense to decipher (or too sparse), the DENSITY command provides help. The computer asks, IND3= , where IND3 is the 3rd DO LOOP parameter in the labelling loop.
- TOTALS - Same as before.
- PART - The MOVIE.BYU graphics package enables panels to be grouped together as parts. Each part can then be addressed separately with its own set of display parameters. Here, the PART command funnels all succeeding panels into a specified part number. The computer asks: CHANGE PART FROM n TO : where n is the currently assigned part number. Initial part use must proceed in numeric order. That is, part 2 must be used before part 3, etc. However, once used, there is no restriction on future use, i.e. the part number could be changed from 5 to 2, for example. The algorithm safeguards these rules, and notifies the user of violations.
- UNMAP - Sets a flag that causes the mapping algorithm to be bypassed, so contours are considered in their initial orientation for triangulation.



- MAP - Opposite of UNMAP. Default is MAP.
- ONE - Permits the user to manually define a single panel from any 3 (or 4) nodes from the contour pair.
- INTERACTIVE - Permits interactive guidance of the triangulation by requesting limits for both loops between which to triangulate. The computer types  
TOP: n-m  
where n is the last node to be triangulated and m is the number of nodes on the top contour. (n and m are merely stated for clarity). The user responds with two integers delimited by a comma. The first delimiter is generally n, and the second is always  $\leq m$ . Delimiters are also requested for the bottom loop. Triangulation occurs within the prescribed limits and is displayed for approval. If approval is denied, only the newest panels are erased, and the user is invited to try again. A control-Z returns control to TRIANGULATE>.
- ERASE - Erases all panels from the present pair of contours.
- RENUMBER - Triangulation is facilitated if node 1 on the top loop neighbors node 1 on the bottom loop. RENUMBER enables this by asking  
NEW #1 NODE  
(TOP CONTOUR)  
The renumbered contours are then displayed. This renumbering must occur before any triangulation. AUTOMATIC automatically renumbers before triangulating.
- CONTINUE - Returns control to the main program.

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