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A Simplified Conversion Method of Contour Line Surface Model to Mesh Surface Model

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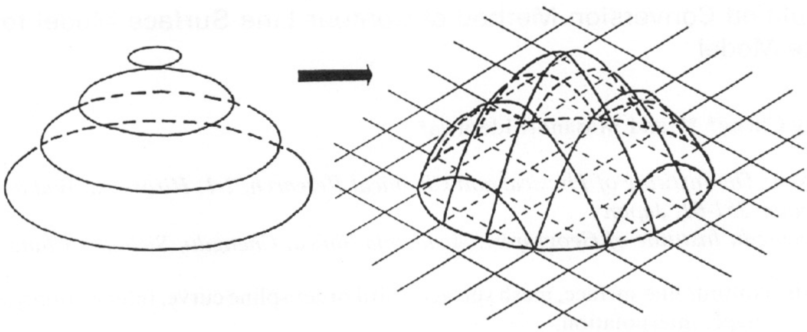
A contour line surface model can be used to represent three dimensional information very accurately. However, it is not suitable for computer processing and the data conversion to a mesh surface model is often required. One of the interesting subjects in this data conversion is how to decide mesh data along a mesh line which has fewer intersections with contour lines with minimum loss of the fringe pattern information. In this paper, the authors describe a new and simplified conversion method with considering some factors. At first, lines which constitute meshes are set on the contour lines and the intersections of the lines with contours are calculated. Secondly, a mesh line with maximum number of intersections and highest priority is selected and a sectional shape corresponding to it is decided, by which mesh point data along the mesh line can be fixed. Fixed mesh points are regarded as equivalent to the intersections and then the second process is kept on repeating till all mesh data are decided.

INTRODUCTION

Of late years, handling of the features of three dimensional object, including the reconstruction of the surface and the calculation of the mass properties, has become very important and has occupied a considerable position in the fields of CAD / CAM, civil engineering, medical science, geosciences, entertainment and the like. It is obvious that one of the most important subjects referring to the applications to the above fields is to find a suitable method to represent three dimensional (3 - D) information in a computer so that we can use them to make some meaningful calculations. As we all know, CSG (Constructive Solid Geometry), B-rep. (Boundary representation) are widely used for representing a solid object in the applications to CAD / CAM(Ota et al: 1985).

Contour line type surface model is traditionally used to represent a three dimensional surface and it is very useful for a human being to understand the structure of an object surface. It is still an important and popular method favoured by the people because some informations could be directly perceived through the senses.

With the help of some approaches such as interferometric technique, the moire photography technique (Takahashi: 1970, Idesawa et al: 1977) and so forth, we can obtain fringe patterns corresponding to the contour lines which show three dimensional properties of the object. However, the results and discussions of the last years suggest that a direct interpretation of these patterns, for instance, moire pattern, is less promising(Hierholzer et al: 1983). This problem refers to many factors, one of which is that the irregular data form of the contour lines (or in a broad sense, all analo-



(a) contour line surface (b) mesh surface

Figure 1. A conceptual figure showing the data form conversion from contour line model to mesh surface model.

gous fringe patterns) is not suitable for the automatic measuring and processing in a computer. Therefore, it is often required to convert the data into an appropriate form by using some approximation methods. Usually, a conversion to the mesh type data is very desirable. Figure 1 is a conceptual figure showing the conversion. There are many strategies proposed to perform the conversion on the basis of digitizing the contour topography and the like(Windischbauer: 1981, Hierholzer et al: 1983).

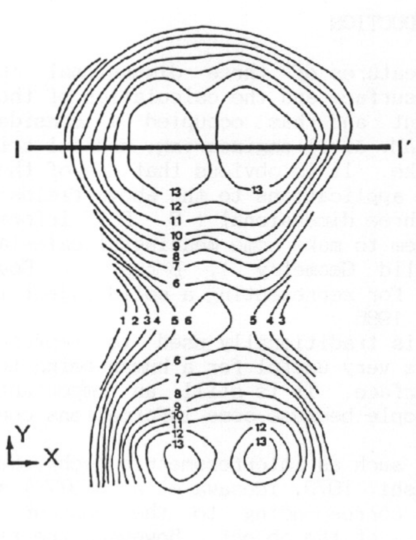


Figure 2. Contour line surface and mesh line : numbers on the contour lines = orders of contour lines.

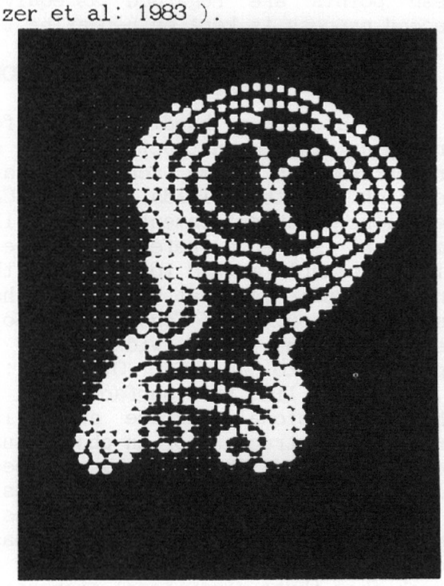


Figure 3. Mesh lines and intersections of mesh lines with contour lines

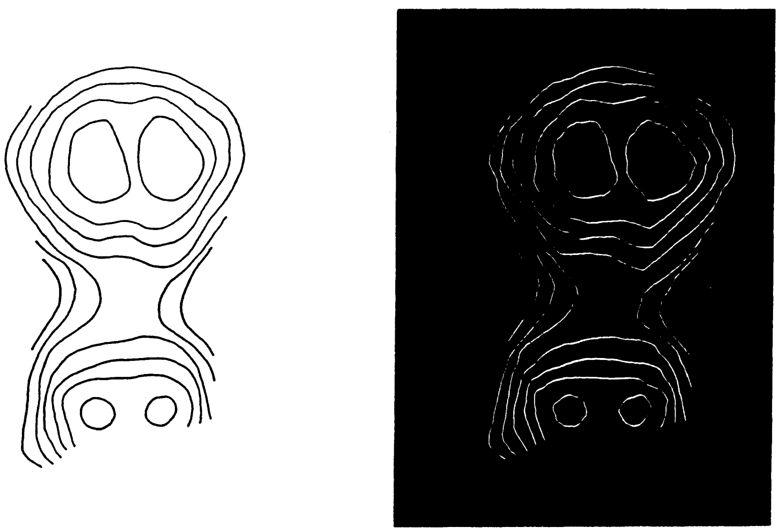
In this paper, the authors present a simplified method of the data form conversion from contour line surface model to mesh surface model. The focus on the method can be thought of as how to determine the mesh data with minimun errors in the region where the distribution of the contour lines are quite rare. In the remainder of the paper, we will describe the method in detail.

A METHOD OF THE DATA FORM CONVERSION

The conversion procedure described herein is essentially a two-step process. The contour line surface description is obtained in the first step. The second one performs the final calculation of the conversion.

1. Input of the Original Contour Lines

Figure 2 is a conceptual diagram of the contour lines, which shows a human back. These contour lines can be input into computer memory in a man-machine interactive method semi-automatically. The initial data of these ridge lines stored in computer are some point strings without ordering. Usually we begin the job with calling the original data from a record which stores a model. The model connected by the point strings could be smoothed by spline curves and they could also be ordered by the corresponding fuctions in RIFRAN II (Idesawa & Yatagai: 1982). The procedure proposed herein has been combined with RIFRAN II . Figure 4 is an example showing the original contour lines (a) and smoothed contour lines, looped or unlooped, which are connected by point strings (b). The result of each step can be displayed on the screen simultaneously.



(a) (b)

Figure 4. Original contour lines and smoothed contour lines.

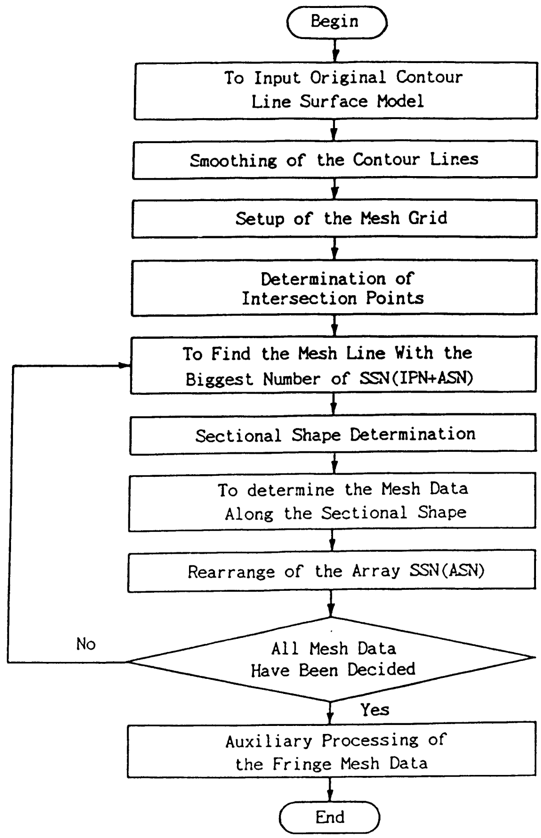


Figure 5. A general flow diagram of the conversion procedure: **IPN** = number of intersection points on a mesh line, **ASN** = number of determined mesh points on the line, **SSN** = **IPN** + **ASN**.

2. Main Procedure of the Method

Depending upon the need of the application, we can design some horizontal and vertical lines in an interactive manner at the very beginning of the procedure. These lines are parallel to the X axis and Y axis, respectively with a given interval and constitute meshes (small square grids) which are superimposed to the input contour plane surface. We regard the surface as equivalent to a three dimensional pattern because of the ordering of the contour lines, therefore each designed line could be thought of as corresponing to a plane which is perpendicaular to the X-Y plane. All these planes intersect with a curved surface represented by the smoothed and ordered contour lines (hereafter referred to as contour lines, even though they are slightly different from the original ones) and their intersections comprise the mesh points at which mesh data will be determined. We call such a line as a mesh line in our paper.

As shown in Figure 3, we can see that all mesh lines intersect contour lines at several points, some of them have more intersections, and some of them have less intersections. The number of intersections of each mesh line is very important and it should be counted and stored in a special array. In our procedure, the X and Y coordinates of each intersection along a mesh line are determined with the help of some calculating routines in a computer automatically, rather than being digitized on a tablet. Its Z coordinate can be obtained by converting the order of the contour which the mesh line intersects into an absolute value.

The above processes are only implemented once during the job as we can

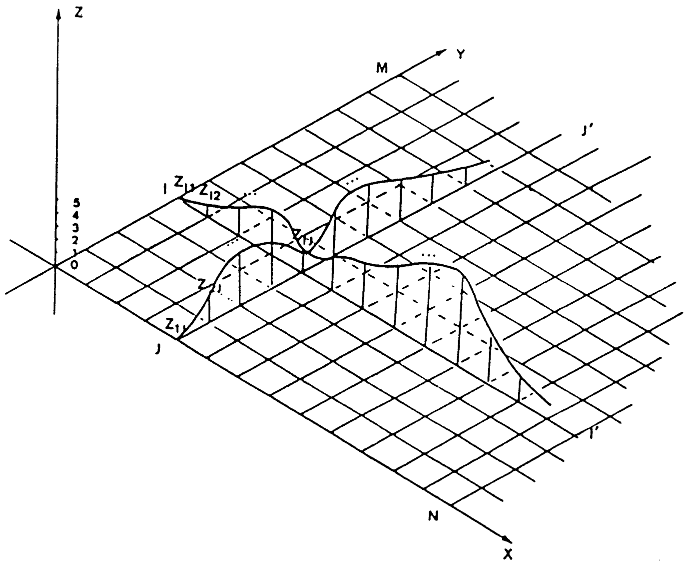


Figure 6. Sectional shapes of mesh line II',JJ' and mesh points along them: Z_{ij}, i = 1, ···, m; j = 1, ···, n.

see in Figure 5. The results derived from these processes, including the number of intersections of each mesh line with contour lines and the coordinates of these intersections, will be stored for the further calculations.

Next a suitable mesh line should be selected on the basis of the number of intersections and of the other conditions. In concrete term, we do this on a principle that a mesh line with maximum number of intersections and highest priority (described in detail in section 3) will be chosen first. By using the intersections of the chosen mesh line, the sectional shape corresponding to it could be decided by third order spline curve with some parameters(see Figure 6).

Since a sectional shape is represented by spline curve with some parametric values, this is tantamount to saying that we can fix the Z value of any mesh point by a spatial interpolation method between two adjacent intersections so long as we know the X and Y coordinates of the point, which can be obtained by knowing the sequences of the corresponding X and Y mesh lines that intersect each other at the point. The determination of the mesh points can be summarized as how to decide an intersected point of a straight line with a third order spline curve. The details of the mathematical basis for this routine can be found in Cheng & Idesawa (1985). The number of determined mesh point(s) along this line and the number of mesh point(s) that have been obtained at the same time along those mesh lines which are perpendicular to this chosen line will be stored in another array and they will be used for selecting the other mesh lines later.

Each mesh line can only be used once, so the program will then select the second suitable mesh line, the third one and so forth and repeat the above steps as shown in the general flow diagram till all mesh data have been decided. What we want to bring up here is that from second mesh line, we should select them in accordance with the both number of intersections and the number of mesh points which have been decided in the previous processing. And the sectional shapes corresponding to these lines should also be determined by using both kind of points. This is why we can determine the coordinates of the points that distribute in the peripheral region where the contour fringe are rare, although the both kind of points we use have different weights.

The points which distribute outside the original contour line surface would not be determined by the method of interpolation along the selected mesh lines because actually they are not between the two end intersections of the corresponding mesh line or sectional shape. This kind of points are fewer for each line, but they are necessary for the sake of complete discription of the surface. However, the problem can be tackled by extrapolation method. For instance, the gradient of the point can be thought of as the same as that of the adjacent intersection, so the position of the point can then be fixed on the basis of this gradient. In our procedure, we developed an auxiliary routine to perform this calculation.

The data structure related to the procedure is shown in Figure 7.

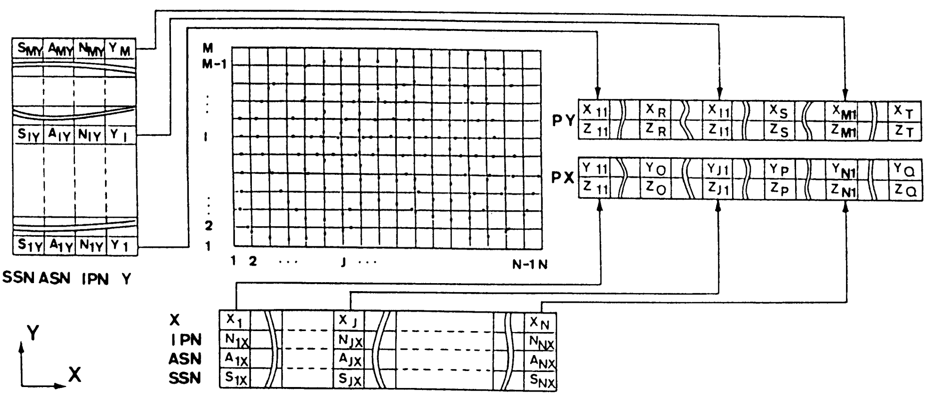


Figure 7. Data structure related to the procedure.

3. Consideration of the Problem of Priority

The result will be very different if we select different mesh line to start our calculation, so There are some cases we have to consider in programming. We merge them into the problem of priority. A line with highest priority among those on which there are same number of intersections means it will be selected first. As shown in Figure 8(a), the first case is that there are more than two continuous intersections with the same order on a mesh line. It is very difficult to use such a kind of intersections to decide sectional shape well because we can not judge the situations of concave and convex in the region. So if there is a line with the same number of intersections but without more than two continuous points which have the same order, the former line will have a lower priority. Figure 8(b) gives another case that indicates some lines on which there are same number of intersections. On L_1 the distance between P_{11} and P_{12} is much larger than the distance between P_{12} and P_{13} and that between P_{13} and P_{14}, but on L_2 we can not find so large differences between every two adjacent points. We can describe this difference by calculating the deviations against the sub-distance between every two adjacent points on L_1 and L_2, respectively. In case of Figure 8(b), the deviation D_1 (of L_1) is larger than D_2. A line with smaller deviation against sub-distance between every two adjacent intersections on it has a higher priority. It is necessary for us to consider the problem of priority to improve the accuracy of the calculation. In our latest program, some routines have been extended to execute the consideration of the problem.

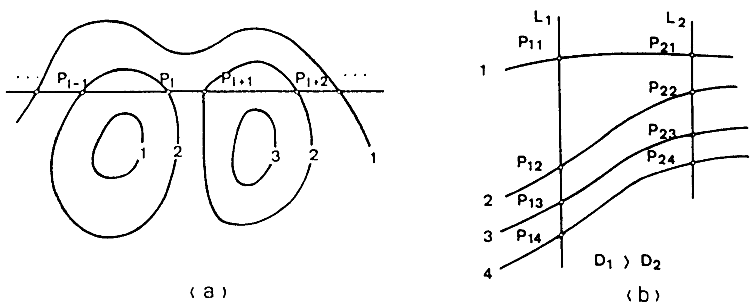


Figure 8. A figure showing the problem of priority.

RESULTS AND DISCUSSION

At current stage, we have obtained mesh data of some models which are originally represented by contour lines. The whole job could be finished in a few seconds with real-time display of the result of each execution step. Figure 9 and Figure 10 show examples of the application of the obtained data. These figures are constructed by sectional shapes of both X and Y directions, which have been rotated around X and Z axes, respectively. We considered the problem of priority in Figure 10. As we can see, the result seems to be more satisfactory than that shown in Figure 9.

The accuracy of the obtained mesh data depends upon the number of intersection points on which a sectional shape can be described and is seems to be independent of the size of mesh grid. Of course, for the applications to some fields, the denser the mesh grid is, the better the pattern can be described. But it needs more memory in computer and becomes more time-consuming. We should consider these two respects when we decide what size should be taken. One of the methods to check the accuracy of the calculation result is to reconstruct the contour lines on the basis of the obtained mesh data. Now the procedure for executing this is under way.

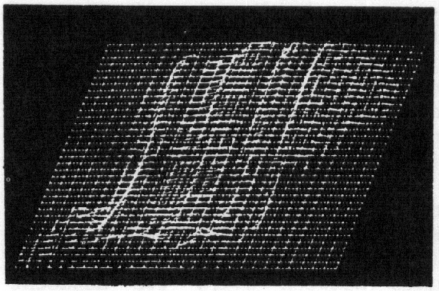


Figure 9. An example of application of the obtained mesh data without considering the problems of priority. Original contour lines corresponding to it is shown in Figure 4.

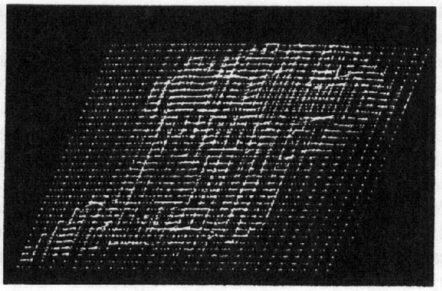


Figure 10. An example of application of the obtained mesh data with considering the problems of priority.

CONCLUSION

A new and simplified method of data form conversion with considering the problem of priority has been described. The original contour line data are input into computer memory more precisely. By using the intersections of the designed mesh lines, we can determine the corresponding sectional shapes by third order spline curve. And futhermore, we can obtain all the mesh data by the spatial interpolation method on these sectional shapes.

REFERENCES

Cheng,K. and Idesawa,M. (1985): A simplified interpolation and conversion method of contour line surface model to mesh surface model, 6th Riken Symp. on Non-touch Measurement & Image Processing, pp.1-6, Wako, Japan.

Hierholzer,E. et al.(1983): Computerized data acquisition and evalution of moire topograms and rasterstereographs, Moire Fringe Topography and Spinal Deformity, pp.233-240, Gustav Fisher Verlag, Stuttgart; New York.

Idesawa,M.,Yatagai,T. and Soma,T.(1977): Scanning moire method and automatic measurement of 3-D shapes, Applied Optics, Vol. 16, No. 8, pp. 2152-2161.

Idesawa,M.and Yatagai,T. (1982): RIFRAN : Interactive fringe pattern analysis and processing system, Proc. ISMIII'82, pp. 554-559, Berlin, F.R. Germany.

Ota,Y. et al.(1985): An automated finite polygon division method for 3-D object, IEEE Computer Graphics and Applications, April 1985, P61.

Takahashi,H.(1970): Moire topography, Applied Optics,Vol. 9, No. 6, pp. 1467-1472.

Windischbauer,G. (1981): Moire contourography - recommendations for standardization criteria based on computer aided modelling, Moire Fringe Topography and Spinal Deformity, (ed. M.S.Moreland et al.), pp. 244 - 248, Pergamon Press, New York.