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Author(s)	Nakamura, Futoshi; 中村, 太士
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The Method to Make Three Dimensional View of Land Configuration from Contour Map with Micro-computer*

By

Futoshi NAKAMURA**

地形図等高線データ入力による地形の立体化*

中村太士**

Contents

Introduction	525
I. Main flow for making the three dimensional view	526
II. Input process by digitizer	528
III. Calculation process	529
1. Selection of surrounding points	529
(1) Setting up the category	529
(2) Decision about the number of selected data	529
2. Interpolation of intersection heights	529
(1) Basic interpolation	530
a) Weighted average by the distance from the intersection points	530
b) Multiple regression analysis	530
(2) Applied interpolation	531
3. Rotation of points	531
IV. Output process	531
V. Working and operating time	533
Conclusion	535
References	535

Introduction

Three dimensional view (3 DV) is well developed and used in a lot of scientific fields to actualize the difficult configuration of objects. Especially in architecture and mechanics, the 3 DV is essential for designing¹⁾. And recently, in natural science such as environmental conservation and disaster prevention, the 3 DV is considered to be a good expression of landscape^{2,5,7)}. The planning to protect those areas from the occurrence of natural disasters and maintain the beauty of natural scenery are very important and, at the same time, very difficult with the extension of

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** Laboratory of Erosion Control Engineering, Faculty of Agriculture, Hokkaido University.

** 北海道大学農学部砂防工学講座

residential and product areas. Furthermore, the essential should be understood by the residents. Under these circumstances, the contour map is not considered to be a good expression of land configuration, because the skill to recognize the configuration is dependent on the experience of viewer. Even a viewer who has good experience to read the contour map sometimes lose the situation of the small area in the whole basin.

For above mentioned reasons the 3 DV is, recently, spotlighted with the development of computer technology. The merit to use the 3 DV with the computer is that :

① Once all data are fed into the computer, the 3 DV figures which can be viewed from any direction and dip angle are made easily.

② If the land configuration is not prominent enough, vertical emphasis is sometimes needed to make more clear the vague change of land configuration.

In the mountainous areas, designing and setting up the forest road route fitted to the land configuration, which does not damage the beauty of the area, are needed for the maintenance of the roads. Probably, the 3 DV will be a good material for setting up of those plans.

Deformation of mesh creates a clear 3 DV of the complex landscape. In the study titled "Studies on the Three Dimensional Graphics for Sabō Planning" (1985), the feeding process into the computer was done by reading the heights from contour lines with visual interpolation⁹. Making this process more automatic, new method was presented and that is divided into two processes: input process by digitizer and interpolation by computer calculations.

I. Main flow for making the three dimensional view

The 3 DV expressed as deformation of mesh is considered to be one of the best methods which can be applied to the topography of the natural landscape but not to the artificial objects. So the most important thing is the way of interpolation between the contour lines to estimate the intersection heights of mesh, when input process is carried out using the contour map.

One of the easy methods is that all interpolation between the contour lines are carried out by the visual interpolation with human eyes, and then these data are fed into the computer one after another. But this method has two problems. One is taking long time to read the intersection heights and another is difficulty for the people who are not accustomed to the contour map that cause many mis-readings.

To eliminate these problems, input process is carried out by the device named "digitizer" which make possible inputting of the horizontal data (x, y values). The 3 D data of the contour lines (basic data) are fed into the computer through the digitizer and intersection height (arranged data) are calculated from these basic data. It is important that the basic data are on the contour lines, because any figure will be generated by changing the factors on the category of needed unit and on the interval of mesh.

The flow of this program can be divided into several steps as follows (fig. 1). First step named "Input process" is mainly constructed as a routine of feeding the basic data by tracing the contour lines with digitizer. The effective number of the basic data will be discussed in the chapter II. Naturally following factors also should be inputted into the computer to make the 3 D figures :

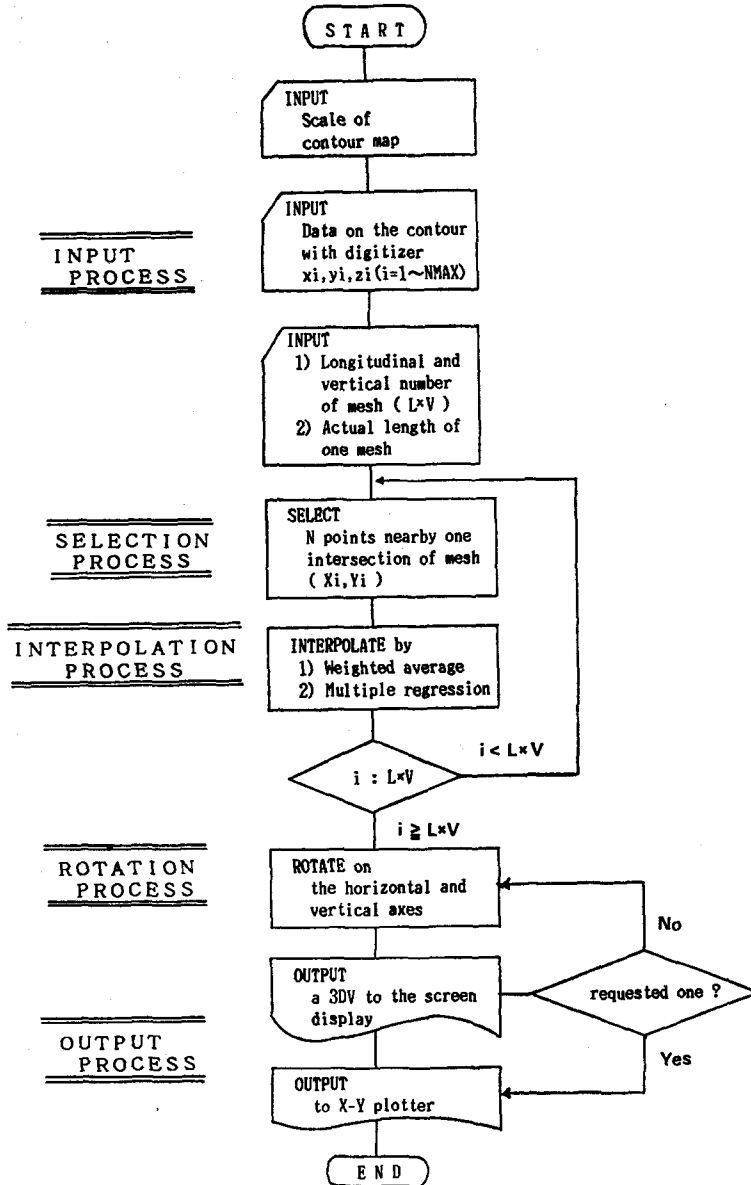


Fig. 1. The flow chart of the process to make three dimensional view.

図一1 3DV作成の流れ図

- ① Scale of the applied map
- ② Longitudinal and vertical number of mesh
- ③ Actual length of one mesh

Second step is named "Selecting process". The x and y values of each intersection points are automatically decided by inputting the above three factors. So the process on selecting n points of basic data (the data on the contour lines) is needed to estimate the height of each interpolation point. These n points should be collected from within the surrounding area of each intersection points.

After the selection process, the estimation of intersection height is carried out by using the statistical interpolation. Many statistical analyses exist for the interpolation from the contour lines. In this paper, however, the weighted average which is mean value of n points weighted by the distance from the intersection points and multiple regression analysis are applied. Those arranged data, formed as matrix through the interpolation process, are rotated on the horizontal axis (X or Y axis) and vertical axis (Z axis) to make the 3 DV. This process is named "Rotation process". Selection, interpolation and rotation processes can be coordinated into "Calculation process".

Last process is "Output process". The calculated 3 D data is outputted connecting each intersection to form the mesh, both to display screen and to X-Y plotter.

II. Input process by digitizer

The process is based on feeding x_i , y_i and z_i values of the contour lines into the computer, and is carried out by tracing with the digitizer. As it is shown in fig. 2, x_i , y_i and z_i values on the contour lines are inputted in adequate intervals tracing with digitizer. The digitizer is the device which make inputting of the horizontal data possible. Also before tracing each contour line the height of that line should be fed into the computer. It is better to display inputted points on the screen (fig. 2) for the adequate interval tracing. The area where the steep slope is continued has no problem to interpolate at the next stage because the contour lines are very dense and number of traced points are many. But in flat or nearly flat areas, where few contour lines exist, more tracing to fill these area are needed for good interpolation. At the end of input procedure, if the points in the screen are distributed uniformly, this is considered to be desirable.

Fixing the most effective number of traced points is a problem in this procedure. This number is considered to be related to the number of mesh matrix ($L \times V$), and dependent on the accuracy of the land configuration which is desired. One criterion is the same number as the mesh matrix but as the results of some trials have shown, traced number which is more than $2/3$ of mesh matrix was almost enough to express the land configuration. It is natural that feeding a lot of points makes a good figure (3 DV) but this may lead to waste of time.

For getting the good results of interpolation the highest point of the land surface should be fed at the area where the land configuration is convex, and in contrast with this, the lowest hight should be fed where the surface is concave.

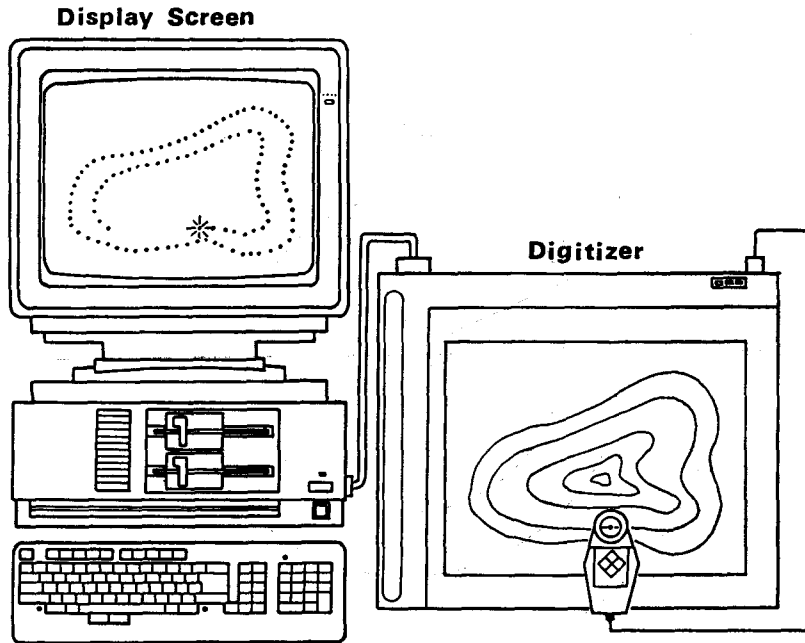


Fig. 2. The device for drawing three dimensional view.

図-2 デジタイザーによる等高線データ入力

III. Calculation process

1. Selection of surrounding points

To estimate the intersection height, the n points of contour data should be selected from the surrounding area of a given mesh (X_i, Y_i). In this process, there are problems on setting up the category of surrounding area and the decision about the number of selected data.

(1) Setting up the category

The circular category is found to be the best shape to select the surrounding points and, in this program, the radius is extended until the number of selected data reaches to constant n value. As the results of trials shows about 4 times of mesh length is considered to be proper as the initial value of radius. In order to make category area twice the extension rate of radius was decided to be $\sqrt{2}$ value in this program (fig. 3).

(2) Decision about the number of selected data

The number n should be decided in relation to the procedure of interpolation. The appropriate value is found to be from 5 to 10.

2. Interpolation of intersection heights

Interpolation method is divided into two kinds in this paper. Once is the method that all intersection points are estimated by same procedure (basic interpolation), and another is the method that interpolation is carried out several times

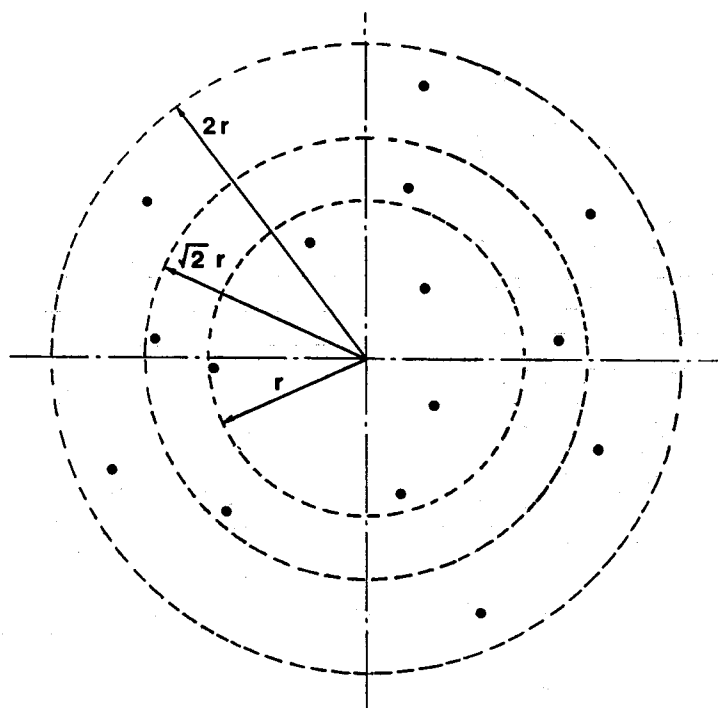


Fig. 3. Extension of the category to select the surrounding points.

図-3 円による選択領域の設定およびその拡張

in different ways (applied interpolation). The details are as follows.

(1) Basic interpolation

a) Weighted average by the distance from the intersection points

The height of intersection points are determined by the estimation of the weights which are added to each height of n points in inverse proportion to the power of the distance from the intersection points. According to this estimation, naturally, the height of the points which are situated far from the intersection is light-weighted and near ones are heavy-weighted. Examination on the value of power suggested that good estimation is gained by taking 2nd or 3rd power of the distance. This interpolation method is a kind of easy procedures but make relatively good results in a short time. All fig. 5, fig. 7 and fig. 8 were made by this interpolation method.

b) Multiple regression analysis¹⁾

This analysis is based on least-squares method that is the estimation by partial regression coefficient analyzed with the 3D data of n points. As the results of examinations of this method have revealed the analysis with contemporary micro-computer takes a long time and does not give the good interpolation. The reason for this was found to be that the number of inputted data was less than proper value for application of this analysis. But increasing the total number of inputted

data will lead to taking more time in the input and selection processes. Probably this interpolation would need the faculty of high-level large computer.

(2) Applied interpolation

As referred before calculation time is a big problem for the micro-computer, therefore, the second interpolation which is based on first interpolation data would be needed. One of the applied interpolation is as follows.

Showing in fig. 4 the intersection points plotted by circle are estimated at first by basic interpolation. And then other points like a-h points are estimated by taking average of surrounding nearest four points that are already interpolated. By this procedures, total operating time of system is reduced to about 2/3. Three figures shown in fig. 5 are made by visual, weighted average and applied interpolation, respectively. A is made by visual interpolation that is carried out by human eyes. B is made by basic interpolation of the weighted average in inverse proportion to the distance. And C is made by the applied interpolation explained in this section. Comparing these three figures, B and C which were made by computer-interpolation are a little smoothed by taking average, but as it can be seen from fig. 5 these methods presented here are not inferior to the visual interpolation.

3. Rotation of points

The requested 3 DV is given by the rotation process that is rotation on the horizontal axis and vertical axis according to the direction of view and dip angle. At first all the intersection points are rotated on the axes and then rotated points are projected on vertical face. At last all projected points are connected with each other to form mesh deformation⁹.

IV. Output process

After the rotation process the 3 DV should be drawn on the display screen to select the requested one. The rotation and output processes on the screen are repeatedly carried out until the desired 3 DV is gained. Once the best figure is chosen on the screen, there are two ways to output it: one is the copy of screen content to the device "printer" and another is drawing by the device "X-Y plotter". All 3 DVs in this paper were copied from the display screen.

Sometimes painting in the mesh will be needed to divide the whole basin into

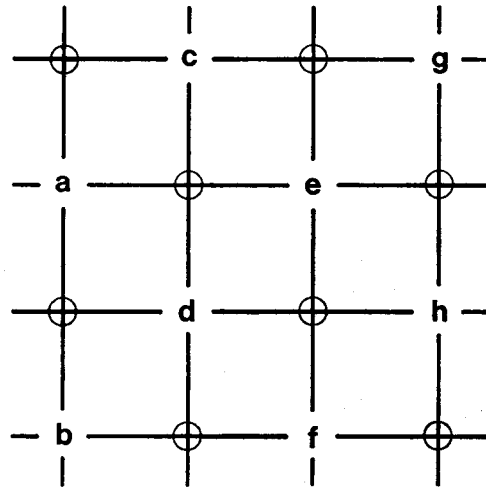


Fig. 4. Applied interpolation.

図-4 二次補間の方法

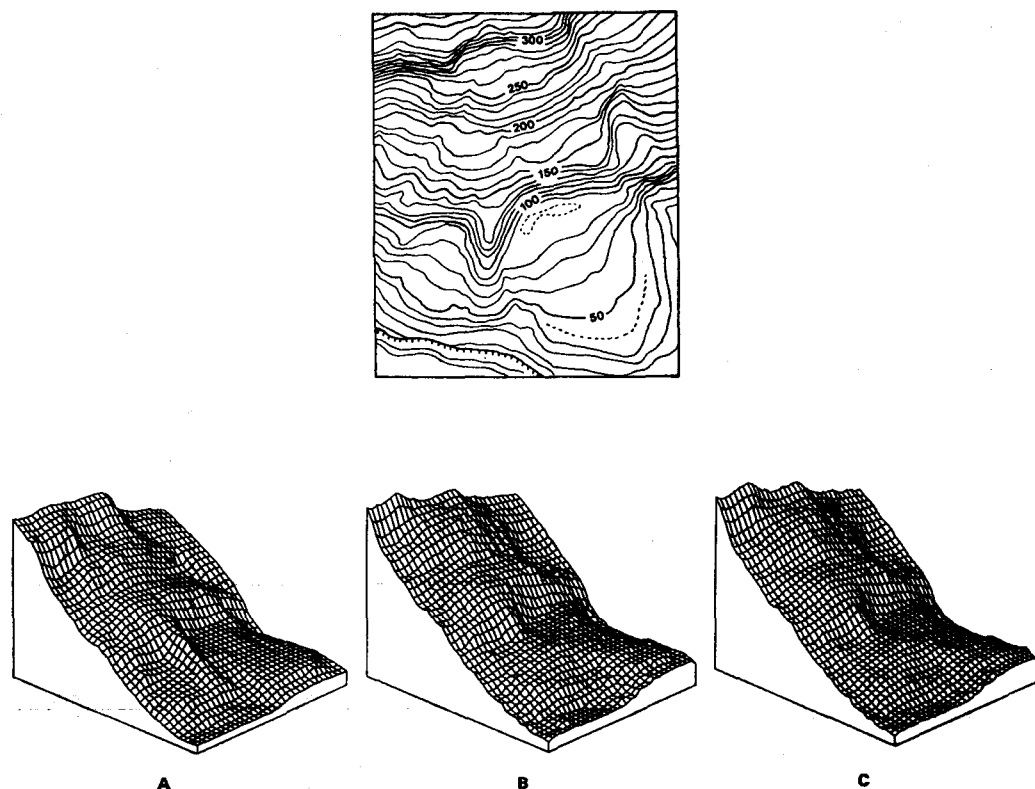


Fig. 5. The comparison of three kinds of interpolation.

(A: Visual, B: Basic, C: Applied)

図-5 補間法の違いによる3DVの比較

(A: 視覚による補間, B: 1次補間, C: 2次補間)

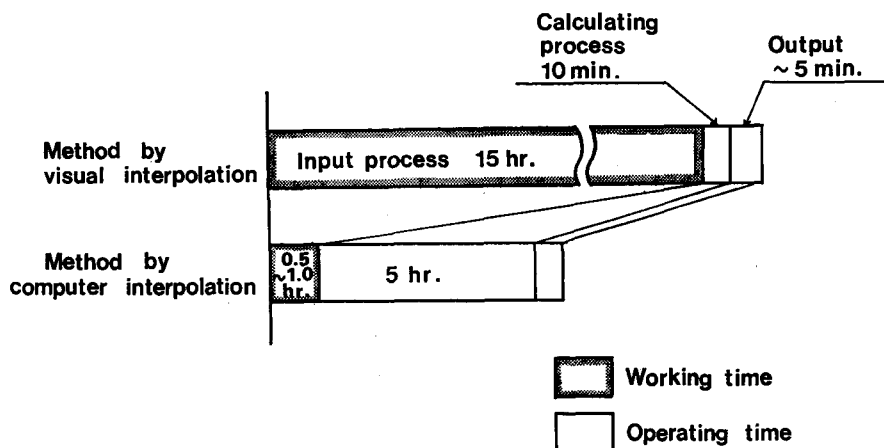


Fig. 6. Working and operating time on different methods.

図-6 本方法による作業時間の短縮

several units by colors on 3 DV. This painting is a good way to understand the relation between the land configuration and colored factors. It will be actualized easily because most of the contemporary micro-computer have the function for painting.

V. Working and operating time

It is very obvious that the working time depends on the ability of the worker and operating time depends on the efficiency of the operating system. In this chapter, the generalized working and operating time are introduced. The time to finish the input process actually changes according to whether the worker is ac-

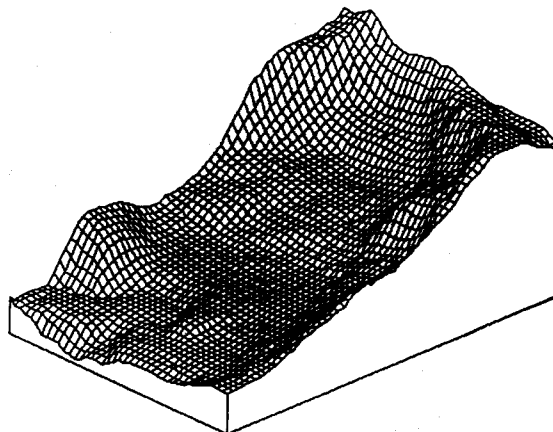
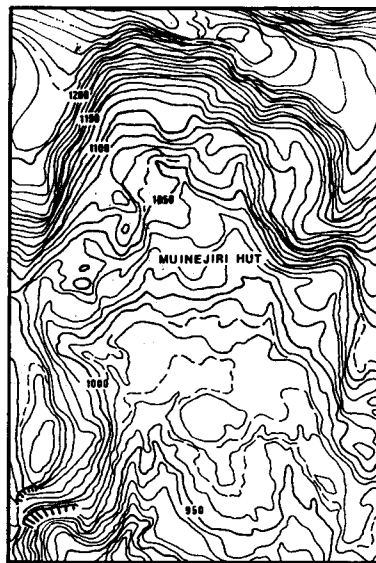


Fig. 7. The 3 DV of landslide occurred at the branch of Ususbetsu river.

図-7 薄別川支流小川流域における地すべり地形

customed to this work or not. But roughly it can be estimated to be from 0.5 to 1 hour as fig. 6 shows. Selection and interpolation process cannot be separated in this program, but as it is estimated the time for interpolation only is not so long. Selection process takes the longest time of all the processes. The calculation time is naturally reduced by using the high-level operating system.

It the program is built "BASIC" and the micro-computer is 16 bit-machine, and if mesh matrix is 60×60 (L \times V) calculation time to select 10 points corresponding each intersection takes from 4 to 6 hours. But this operating time can be

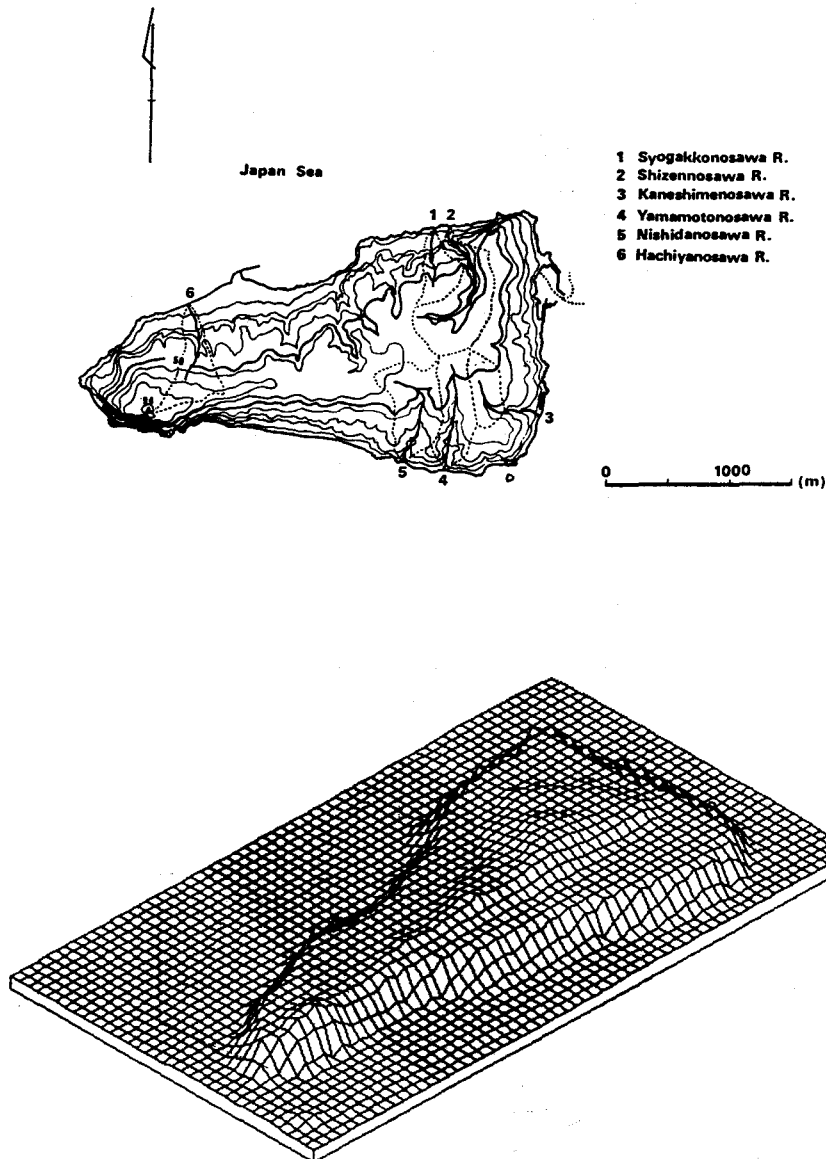


Fig. 8. The 3DV of Yagishiri island.

図-8 焼尻島の3DV

reduced by applied interpolation as referred before. It doesn't take long time to rotate all the intersection points, so under the same condition, the rotation process takes about 5 minutes. Output to the display screen takes the shortest time of all the processes, but output to X-Y plotter is particularly dependent on the efficiency of the device.

Fig. 7 is the 3 DV of landslide occurred at the branch of Usubetsu river, and fig. 8 is the island named Yagishiri. As an example, fig. 7 took about 5 hours to be completed and fig. 8 took 6 hours.

Conclusion

As the results of repeated examinations showed, this method was regarded as appropriate to make 3 DV. The problem of calculating time will be solved by using more high-level operating system. The merit to use this kind of system is that the 3 DV of any area can be drawn with any size of mesh, once the data of the contour lines are fed into the computer.

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摘 要

近年、コンピューターの普及にともなって、三次元グラフィックスの発達はめざましく、技術・科学の分野を問わず、多分野において利用されている。しかし、データ入力、処理過程等がやや複雑で、一般に手軽に利用できる表現法とはなっていないのが現状である。ここに提示した方法は、地形図等高線をデジタイザーでたどることにより、容易に立体地形が得られるものである (fig. 1)。以下、その特徴を述べる。

1) 本方法による三次元グラフィックスは、メッシュのゆがみによって立体感を表現するもので、凹凸が激しく起伏に富む地形表現法として適している。

2) データ入力は、等高線をデジタイザーでトレースすることにより行なうもので、データ数は表現するメッシュ交点数の3分の2から同程度が適当である (fig. 2)。

3) 計算過程は、メッシュ交点の近傍から n 点を順次選択する過程 (選択過程) とこの n 点によりメッシュ交点の標高を推定する過程 (補間過程), そして推定した点を水平軸, 垂直軸の回りで方向角・俯角に順じて回転させる過程 (回転過程) の三過程に区分することができる。

4) 選択過程での範囲決定は、中心をメッシュ交点として円を徐々に拡大する方法によって行った。選択する個数 n は、5~10 が適当であると考えられる (fig. 3)。

5) 補間方法は統計的に多々あると考えられるが、今回は ① 距離の α (2~3 適当) 乗に反比例する重みを課し、標高を平均化する方法と ② 重相関による方法を検討した。重相関による方法は入力するデータ数を増やし、大型コンピューターを使用して行なう方が、精度的にも時間的にも適していると考えられた。また、重みつき平均は計算過程の容易なわりには、比較的良好な結果が得られた。

6) 選択・補間過程は本方法のなかにおいて一連の流れであり、区別して時間を計測することはできないが、特に選択過程で非常に多くの時間を要していることが理解された。そこで約半数をまず 5) で述べた方法で補間し、後の半数をこの補間データをもとにさらに補間を行う 2 次補間の方法が検討された。その結果は良好であった (fig. 4, 5)。

7) 回転および出力過程は、方向角・俯角を調節して求める立体図が得られるまで繰り返して行い、必要な図を画面コピー、もしくは X-Y プロッターにより出力する (fig. 7, 8)。

8) 本方法により、コンピューターの計算処理時間は増大するが、データ入力に要する作業時間は、人間の視覚による作業とくらべて大幅に短縮することができ (fig. 6)、標高の読み取りミスもなくすることができる。

9) 本方法は、いったん等高線データが入力されれば、求められた範囲に任意の大きさのメッシュをかけることが可能である。



Photo 1. The first stage of input process.
(The 3D data of the contour lines traced by the digitizer.)



Photo 2. The last stage of input process.
(All points are almost uniformly distributed.)

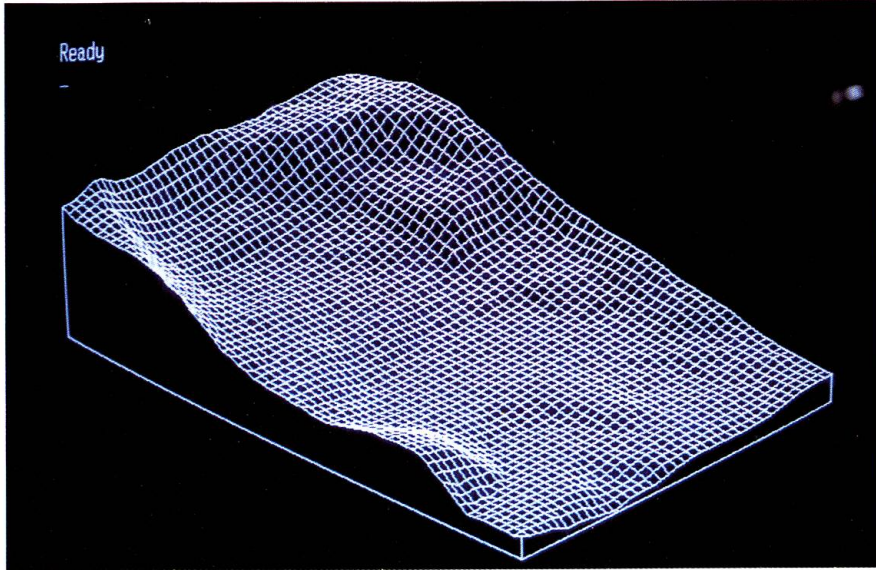


Photo 3. The 3DV of landslide on the display screen.

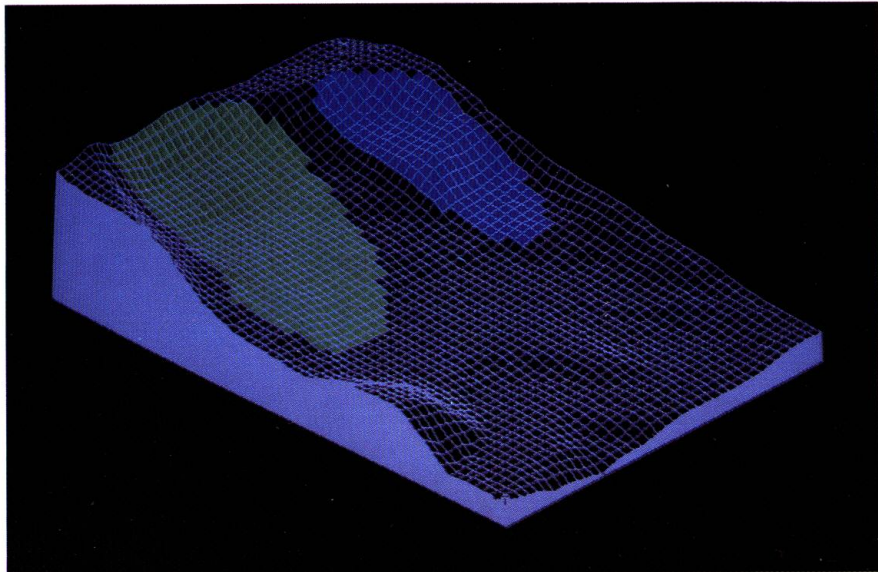


Photo 4. The painting which divide the whole basin into several units by colors.