

# Application of Contour Map Creating Technique in Magnetic Exploration

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**Abstract**—The contour map is an important expression method for magnetic data. In this paper we studied in depth the 3-D interpolation technique and the way of creating contour lines. We also studied the algorithm of area filling based on contour line classification. We designed a program to generate contour map and realized the visualization of magnetic data. We did an experiment to test the validity of our program. Then at the end of this paper, we applied our program to magnetic exploration. We generated a contour map and filled it. The result shows the perfect effect of our program.

**Keywords**- contour map; magnetic exploration; visualization

## 1. Introduction

The contour map is a useful tool to show the distribution of magnetic anomaly visually. It is a plan map of continuous 3-D physical variant  $f(x, y, z)$  in 2-D field. The isoline in a contour map is variation tendency of the variant  $z$  in  $(x, y)$  plane. In magnetic exploration, the magnetic anomaly  $\Delta T$  is such a variant that can be expressed in a contour map.

To generate a contour map we need to interpolate discrete data, to draw isoline and to fill in the isoline area. In this paper, we studied the three techniques above in detail and applied it to visualization in magnetic exploration.

## 2. Discrete points interpolating technique

To generate a contour map we need regular distributed data, however, the field observation data are always irregular distributed for all kinds of reasons. For example, we have to avert obstacles in some circumstances. Moreover we sometimes have to miss some survey points in hard conditions and so on. So we have to take some measures to deal with our data so as to meet the demand of generating a contour map. Discrete data gridded method is a common way to do this work.

The task of discrete data gridded method is to find a fitting function according to the characteristic values of a set of discrete data and their coordinates. This function should sufficiently reflect the mathematical relation between the characteristic values of the given points and their positions in space. Thus we can deduce

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characteristic values of other points in space. The nature of gridding is to build an approximating function to fit the distribution of a variant in space.

At present there are many gridding methods including linear interpolation, inverse distance to a power, multiquadric, minimum curvature, radial basis function and kriging, etc. Every method has its advantage as well as its disadvantage. For example, the result of linear interpolation is not smooth very much and its accuracy is limit. The multiquadric method is based on global calculation, which requires solving a large system of linear equations. So it can only be used to medium and small scaled data. When we use minimum curvature method, we always find that concussion is easy to occur at those places where control points are rare. H.Y. Zhu summed up in detail in his paper the interpolation technique (H.Y. Zhu, 2004). He pointed out that the most commonly used and most superior method is kriging method. In this paper, we designed a program based on Kriging.

### 3. Theory of Kriging

Kriging algorithm is an optimum interpolation method named by a South African mining engineer called D.G. Krige. This method is based on an assumption that the alternation of a certain property is neither completely arbitrary nor completely confirmative. By applying random function theory and evaluation theory, the Kriging method firstly corresponds to a variable in space with a random function  $Z(x)$  and makes them have the same domain. Secondly the Kriging method regards the observed values of the variable  $z(x_1), z(x_2), \dots, z(x_n)$  at  $x_1, x_2, \dots, x_n$  as actual values of the random variable. Using evaluation theory, we estimate the value of  $Z(x)$  at  $x_0$  according to  $Z(x_1), Z(x_2), \dots, Z(x_n)$ . The result is remarked as  $Z^*(x_0) = f[Z(x_1), Z(x_2), \dots, Z(x_n)]$ . We displace  $Z(x_1), Z(x_2), \dots, Z(x_n)$  in  $f$  with the observed values  $z(x_1), z(x_2), \dots, z(x_n)$ , and then we will get the Kriging estimate values  $Z^*(x_0)$ . Suppose there are no deflections, the kriging method places stress on the spatial correlation. The semi-variance of the selected given points' dependent level is calculated as follows:

$$r(h) = \frac{1}{2n} \sum_{i=1}^n (z(x_i) - z(x_i + h))^2 \quad (1)$$

In the equation above,  $h$  is the distance between two points, which is always used to be hysteresis coefficient.  $n$  is the number of the paired sample points divided by  $h$ .  $Z$  is an attribute value. The semivariance will increase when  $h$  increase. The common equation to calculate  $z$  using Kriging method is shown as follows:

$$z_0 = \sum_{i=1}^s z_x W_x \quad (2)$$

Where  $z_0$  the estimated value and  $z_x$  is the measured value of a given point.  $W_x$  is the associative weight of between the current point and each given point.  $s$  is the number of the given points which are used to estimate.  $W_x$  can be obtained by solving simultaneous equations. For example, the following simultaneous equations are necessary to estimate an unknown point from 3 given points.

$$\begin{bmatrix} r(h_{11}) & r(h_{12}) & r(h_{13}) & 1 \\ r(h_{21}) & r(h_{22}) & r(h_{23}) & 1 \\ r(h_{31}) & r(h_{32}) & r(h_{33}) & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix} \bullet \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ 1 \end{bmatrix} = \begin{bmatrix} r(h_{10}) \\ r(h_{20}) \\ r(h_{30}) \\ 1 \end{bmatrix} \quad (3)$$

After solving the equations above, we can get the weight coefficients:

$$\begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ 1 \end{bmatrix} = \begin{bmatrix} r(h_{10}) \\ r(h_{20}) \\ r(h_{30}) \\ 1 \end{bmatrix} \bullet \begin{bmatrix} r(h_{11}) & r(h_{12}) & r(h_{13}) & 1 \\ r(h_{21}) & r(h_{22}) & r(h_{23}) & 1 \\ r(h_{31}) & r(h_{32}) & r(h_{33}) & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}^{-1} \quad (4)$$

Then we can estimate  $Z_0$  using the following equation:

$$Z_0 = Z_1W_1 + Z_2W_2 + Z_3W_3 \quad (5)$$

## 4. Steps to map contour diagram of magnetic anomaly $\Delta T$ based on Kriging method

### 4.1. Interpolate to generate regular grids

Regular grids model is an important manifestation of DEM. Generating regular grids from discrete irregular point set in fact is to calculate the elevation value of the undetermined grid node according to the adjacent sample points. In math this is a interpolation.

Firstly we grid the region of interest, then we calculate the central coordinate  $(x, y)$  of each grid and finally we interpolate its magnetic anomaly  $z$  using Kriging method.

### 4.2. Mapping a contour line

The key algorithm to map a contour line is to trace it. In computer graphics, a contour line should satisfy the following quests:

- a) A contour line should not intersect with another.
- b) A contour line is always a continuous curve.
- c) Given a value, there are more than 1 contour line at corresponding field.
- d) A contour line is closed or continuous with outer field

Now there are two main tracing methods. One is to get an equivalent point by linear interpolation and trace total discrete points of a contour line according to a certain rule. Then complete a contour line by smooth it using curve smoothing algorithm. The other method is to fit a smooth surface using the given mesh data. The surface has a unified mathematical expression and all known mesh node are on the surface. According the expression, we can trace the contour line of every given value and thus we can finally get the contour lines.

### 4.3. Filling in a contour map

There are two ways to fill in a contour map, scanning filling method and area filling method. In this paper, we adopted area filling method based on contour line classification (D.W. Liu, 2009). In this method the contour lines are classified into 11 kinds according to their position relative to the boundary as is shown in Fig.1.

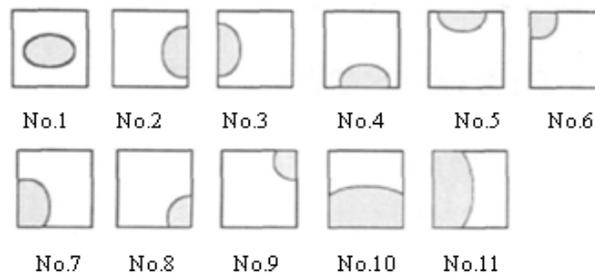


Fig.1. Classification of contour lines.

From Figure 1 we can see that a contour line is either self-closed or enclosed together with the boundary. We sort the contour lines according their classification sequence numbers. If two contour lines have the same sequence number, we put the inner contour line backward. When doing this, we do not involve those open contour lines, so we add a rectangular area made up of the boundaries. We fill in the closed areas which contain boundary first, then fill in those self-closing areas successively. Thus we will fill in every area finally.

## 5. Applications

We did an experiment to test the effect of our program. We designed a  $100m \times 20m$  grid data to generate a contour map. The grid has 11 lines with 80 points on each line. Figure 2 shows the effect of our program. There are no intersection points in the map. The result satisfied the request of a contour map. It proves that our program is valid.

Then we applied it to display magnetic data of a field work. Figure 3 shows a magnetic work in a place north of China. In the field work, we completed 45 profiles. At each profile, we collected data of 234 survey points. There are one river and 3 villages in our work area so we could not get the data of some of the survey points. The initial data were interpolated using Kriging method after all kinds of corrections.

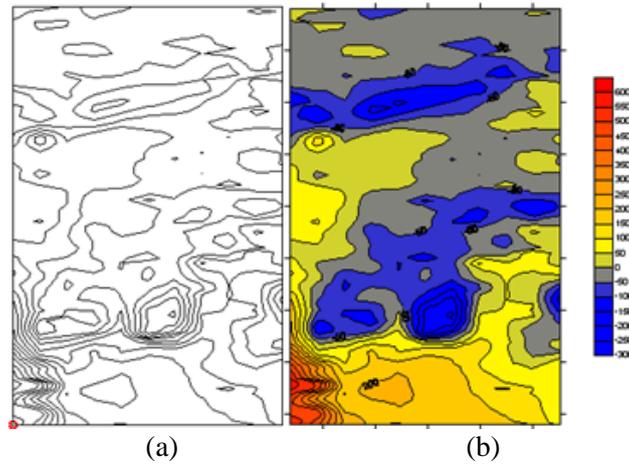


Fig.2. Result of an example (a: before filled; b: after filled).

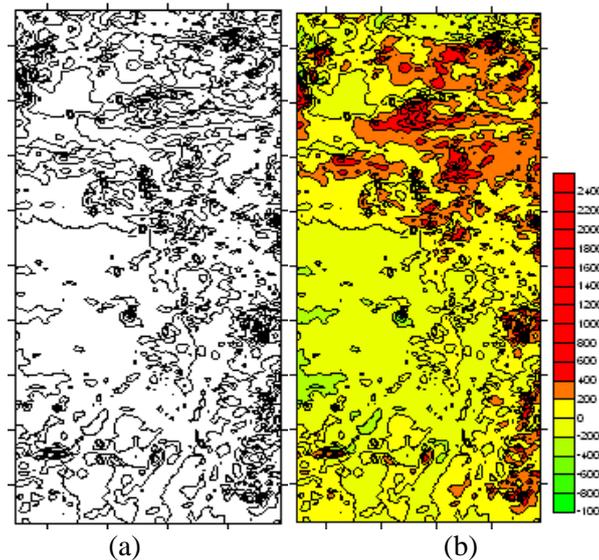


Fig.3. Contour map of  $\Delta T$  in a place north of China (a: before filled; b: after filled).

From Figure 3 we can see clearly the magnetic anomaly's distribution of the work area. And we can also see the magnetic anomaly at those positions where there were no data at all. This brought great facility for further data processing.

## 6. Conclusions

In this paper we applied Kriging method in visualization of magnetic data. The contour lines in our example are smooth enough and show visually the distribution of the magnetic field. We adopted interpolation technique to solve the absent of data in some rough area.

## 7. References

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