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Application of Kriging with Omni Directional Variogram to Finding the Direction of Anisotropy Axes

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Abstract: Detecting anisotropy direction is one of the basic steps at variography and estimation by Kriging. A display that quickly reveals directional anisotropies is a contour map of the sample variogram surface. Contour maps of the variogram surface from primary data are not commonly used in practice. For very erratic data set, the variogram values within the various rectangular lags may be too erratic to produce a useful contour map. So the conventional approach is to compare experimental variograms computed in several directions. The approach presented here is a method to calculating variogram surface more effectively so that it is very clear to detect the direction of the anisotropy. Fist the omni directional variogram is calculated and best model is fitted to the experimental values. Then by ordinary Kriging, the region is estimated by fitted variogram model. The variogram surface is calculated with estimated values. Because of Kriging smoothing effect, a regular variogram map that the anisotropy axes can be detected very clearly, is created.

Key words: Omni directional variogram, anisotropy direction, kriging

INTRODUCTION

Geostatistics is a tool for analyzing of regionalized variables with spatial and temporal data from natural phenomena. In this analysis the fundamental tool is the variogram that characterizes the spatial continuity or roughness of a data set. The variogram shows the degree of spatial dependence between samples for a specific support. Variogram analysis consists of the experimental variogram calculated from the data and the variogram model fitted to the data. The experimental variogram is calculated by averaging one half the differences squared of the z-values over all pairs of observations with the specified separation distance and direction. It is plotted as a two-dimensional graph:

$$\gamma(h)=\frac{1}{2*N_h}\sum_{i=1}^{N_h}\left[Z(x_i+h)-Z(x_i)\right]$$

Where h = lag distance, N_h = number of pairs

The variogram model is chosen from a set of mathematical functions that describe spatial relationships. The appropriate model is chosen by matching the shape of the curve of the experimental variogram to the shape of the curve of the mathematical function. This step involves the knowledge and researcher's experience concerning the phenomenon and the study area and also some criteria such as least square and weighted least square. A good adjustment is necessary for achieving a good result (Iwashita *et al*., 2005).

VARIOGRAM MAP

In many data sets the values along certain direction are more continuous than others. So a variogram can be different when calculated along at different directions. This occurs with anisotropic phenomena. To account for geometric anisotropy (variable spatial continuity in different directions), separate experimental and model variograms can be calculated for different directions in the data set.

A display that quickly reveals directional anisotropies is a contour map of the sample variogram surface. A variogram map is a plot of experimental semivariogram values in the system of coordinates (h_x, h_y). The center of the map corresponds to the origin of the semivariogram: $\gamma(0) = 0$. Any cross section appears as a traditional one-dimensional semivariogram. Semivariogram values are small near the origin and increase with the distance form the origin (Goovaerts, 1998).

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Despite their effectiveness, contour maps of the variogram surface from primary data are not commonly used in practice. For very erratic data set, the variogram values within the various rectangular lags may be too erratic to produce a useful contour map. So the conventional approach for detecting anisotropy is to compare experimental variograms computed in several directions (Isaaks and Srivastava, 1989).

One of the reasons for beginning with omni directional calculations is that they can serve as an early warning for erratic directional variogram. The omni directional variogram contains more sample pairs than any directional variogram and therefore is more likely to show a clearly interpretable structure.

In this article first the omni directional variogram has been calculated then the semivariogram model fitted and by using this model the region has been estimated by Kriging estimator, and finally the variogram map has been calculated from estimated values, because of smoothing effect of Kriging, the variogram map of estimated data is clearly shows the direction of maximum and minimum continuity.

CASE STUDY

The data used at this study were collected by the Swiss Federal Institute of technology at Lausanne; Cobalt data from 256 locations has been considered (Goovaerts, 1998). GSLIB software (Deutsch and Jurnel, 1998) is used to calculate variogram map (varmap.exe), experimental variogram (gamv.exe), theoretical variogram (vmodel.exe) and Kriging estimation (k3d.exe). Figure 1 shows the Experimental omni directional semivariogram plot of data (Dash line) and variogram model (Solid Line) that fitted with Winvam software (Kushavand *et al*., 2005) by least square criteria. The variogram model is calculated as:

$$\gamma(h) = 1.58 + 12.78 * Sph(\frac{h}{1.31})$$

Figure 2A shows the variogram map of these data that is calculated by varmap and Fig. 2B shows the variogram surface by isolines. It is very hard to understand the anisotropy axes from these maps.

Figure 3 shows the variogram map and variogram surface (isoline) which is calculated with presented omni directional variogram by GSLIB Kriging estimation program (k3d). The solid line at right graph indicates anisotropy axes which is very clear at this graph. The parameter file of k3d program is shown at Fig. 4.

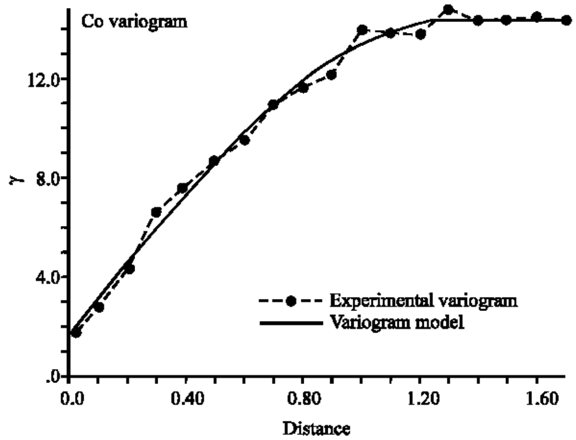
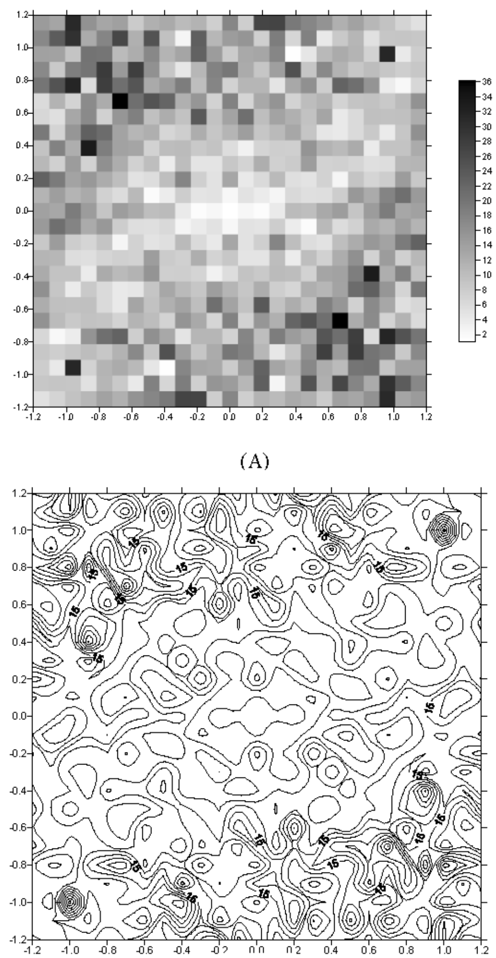


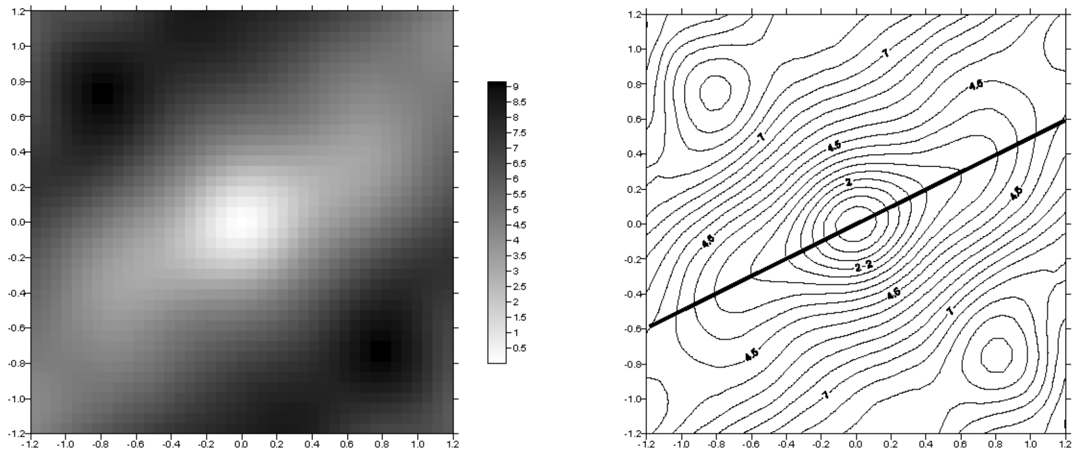
Fig. 1: Experimental variogram and variogram model fitted to it



(A)

(B)

Fig. 2: Primary data variogram map (A graph) and variogram surface with isolines (B graph)



(A) (B)

Fig. 3 Kriging estimated variogram map (A graph) and variogram surface (B graph) with isolines and the anisotropy axes (solid line)

Parameters for KT3D
****

```
Start of parameters:
C:\krig\predict.dat
0 1 2 0 6 0                      -Columns for Dh, X, Y, Z, var, sec var
-100 1E+21                       -Trimming limits
0                                -Option: 0 = grid, 1= cross, 2 = jackknife
C:\krig\xvk.dat
1 2 0 3 0                        -Columns for X, Y, Z, vr and sec var
0                                -Debug level (0-3)
C:\krig\K3_Co.dbg
C:\krig\K3_Co.out
100 0 0.06                       -nx, xmin, xsize
100 0 0.06                       -ny, ymin, ysize
1 0 1                            -nz, zmin, zsize
1 1 1                            -x, y and z block discretization
4 16                             -Min and max data for kriging
1                                -Max per octant (0-> not used)
1 1 1                            -Maximum search radii
0 0 0                            -Angles for search ellipsoid
1 0                              -o = SK, 1= OK, 2 = non-st SK, 3=exdrift
0 0 0 0 0 0 0 0 0                -drift: x, y, z, xx, yy, zz, xy, xz, zy
0                                -Variable; 1, estimate; trend
C:\krig\extdrift.dat             -Gridded file with drift/mean
4                                -  Column number in gridded file
1 1.58126                        -nst, nugget
1 12.78339 0 0 0                 -It, cc, ang1, ang2, ang3
1.30526 1.30526 1.30526          -a_hmax, a_hmin, a_vert
```

Fig. 4: Parameter file for k3d.exe

CONCLUSIONS

At this study a very simple and applicable method has been presented for detecting the anisotropy of a region.

Since Kriging estimator by omni directional variogram dose not change the direction of anisotropy axes, but the range of raw data would be different with range of estimated values. Thus after determining the anisotropy axes by presented method, it is necessary to calculate the directions of minimum and maximum continuity and fit variogram model for given directions.

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