Updated Program for Determining Data Spacing

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Data spacing is an appropriate measure for classifying resources and reserves. A program for calculating data spacing was documented previously. It can be dangerous to extrapolate data spacing beyond the limits of the data. New features have been added to the program to limit the extrapolation of data spacing.

Introduction

Geometric criteria such as data spacing have been promoted as a reasonable measure for classifying resources and reserves (Deutsch et al., 2006). A GSLIB-style (Deutsch and Journel, 1998) program for calculating data spacing and data density has been documented (Wilde and Deutsch, 2010). Moving windows scan the data determining local data density and spacing. It can be dangerous to extrapolate these measures beyond the limits of the data. Two features have been added to the program to prevent improper extrapolation. One feature limits extrapolation in the vertical direction using the mode of the elevation of the data in the local window; the other limits extrapolation horizontally by clipping to the convex hull of the data. The calculations presented in Wilde and Deutsch (2006) for calculating data spacing and data density are repeated below followed by explanation of the two new features.

Review of Data Spacing Calculations

Data spacing is the distance between adjacent data for a representative area. A densely sampled area will have a small spacing relative to an area that is sparsely sampled. Data spacing at a location, $s(\mathbf{u})$, is determined by considering the number of nearby samples, $n_v(\mathbf{u})$, within some volume, $V(\mathbf{u})$. If $V(\mathbf{u})$ is two-dimensional, the square root of $V(\mathbf{u})$ divided by $n_v(\mathbf{u})$ gives data spacing as shown in Equation 1. For the three dimensional case, the calculation of data spacing can be performed in two dimensions when the drillholes are all vertical. When the drillholes are not all vertical, as shown in Figure 1, the data spacing calculation must consider a three-dimensional volume. The along-hole spacing, c, is included in the calculation thus defining the equivalent square drillhole spacing (Equation 2).

$$s(\mathbf{u}) = \left(\frac{V(\mathbf{u})}{n_V(\mathbf{u})} \right)^{1/2} \qquad 1$$

$$s(\mathbf{u}) = \left(\frac{V(\mathbf{u})}{c \cdot n_V(\mathbf{u})} \right)^{1/2} \qquad 2$$

To calculate data spacing at a location, either $V(\mathbf{u})$ or $n_V(\mathbf{u})$ are normally fixed. If $n_V(\mathbf{u})$ is fixed i.e. $n_V(\mathbf{u}) = n_V, \forall \mathbf{u} \in A$, the volume $V(\mathbf{u})$ required to encompass the n_V data is calculated and spacing is determined as defined previously. If $V(\mathbf{u})$ is fixed i.e. $V(\mathrm{u}) = V, \forall \mathrm{u} \in A$, the number of observations $n_V(\mathbf{u})$ that fall within V is determined and spacing is determined as defined previously. The choice of n_V or V affects the results: too small of a volume or too few samples leads to noisy results; too large of a volume or too many samples leads to over smoothing. The units of spacing depend on the units of V. For example, if V is 1 mile x 1 mile (1 section) spacing has units of miles. If V is 100 cubic meters, Equation 2 is applied and spacing has units of meters.

Review of Data Density Calculations

Data density is the number of data observations per unit volume, commonly reported as number of data per section or hectare. Data density at a location, $d(\mathbf{u})$, is determined by considering the number of nearby samples, $n_v(\mathbf{u})$, within some volume, $V(\mathbf{u})$. Dividing the number of samples by their volume gives data density as shown in Equation 3. If the data are arranged such that many observations fall within a small volume, data density is high. If a large volume contains few observations, data density is low.

$$d(\mathbf{u}) = \frac{n_V(\mathbf{u})}{V(\mathbf{u})} \quad 3$$

Data density at a location, $d(\mathbf{u})$, is determined in the same manner as data spacing by fixing either V or n_V and calculating the other parameter. The units of density depend on the units of V; n_V is dimensionless making the units of d the negative reciprocal of the units of V. For example, if V has units of m^2, then density has units of m^{-2}. It may be desirable to convert the units of density to a more common measure such as $hectare^{-2}$ or $section^{-2}$. There are ten thousand square meters in a hectare and 2,589,988.11 square meters in a section. To convert density from data per square meter to more useful units, simply multiply density by the appropriate constant.

Review of V and n_V Calculations

Both data spacing and data density are calculated from V and n_V. One of these values is fixed allowing the other to be calculated from the nearby data. The program provides for V to be either circular or square, depending on the preference of the user.

If V is constant, n_V is location dependent. The size of V is specified by a for two dimensions and by a and h for three dimensions. This 'moving window' volume is translated over the domain, counting the number of data, $n_V(\mathbf{u})$, that fall within it to arrive at data spacing and data density at each location.

If n_V is constant, V is location dependent. In two dimensions, $V(\mathbf{u})$ is calculated by finding $a(\mathbf{u})$. $a(\mathbf{u})$ is twice the average distance to the n_V and n_V +1 samples as shown in Equation 4 where r_i is the distance to the i^{th} sample from $\mathbf{u}$. $V(\mathbf{u})$ for a square volume in two dimensions is calculated as shown in Equation 5 and for a circle volume in Equation 6.

$$a(\mathbf{u}) = r_{n_V} + r_{n_V+1} \quad 4$$

$$V(\mathbf{u}) = a^2(\mathbf{u}) \quad 5$$

$$V(\mathbf{u}) = \frac{\pi a^2(\mathbf{u})}{4} \quad 6$$

In three dimensions, $V(\mathbf{u})$ is also calculated by finding $a(\mathbf{u})$, but considering only those data that fall within $\pm h/2$ from $\mathbf{u}$ in the vertical direction. The volume is determined by applying Equation 5 or 6 as appropriate and multiplying by h.

Calculating Depth-Limited Data Spacing

A concern in ore reserves is extrapolating at depth and having those values carry pit limits that are larger than warranted. Estimators are extremely careful these days, but there is a need to make sure the data spacing calculation is adjusted, particularly when data spacing is used to clip the model (grid cell locations far away from the data are set to unestimated) and classify the cells into measured, indicated and inferred. Figure 2 shows an area estimated at depth (the yellow shaded area) that could potentially expand the pit in an unreasonable manner (see gray shaded area).

To limit extrapolation at depth, the program has been modified to read in a base-of-data surface. This is a 2D surface with the predetermined base-of-data elevation indicated for each column of the 3D data spacing model. If a cell elevation falls below the base-of-data elevation, the data spacing for that cell is set arbitrarily high. Cells above this surface have data spacing calculated in the usual manner.

The base of data surface would likely be constructed by considering the sample from each drillhole which has the minimum elevation. These samples are indicated by the black circles in Figure 3 and are hereafter referred to as the toe samples. The coordinates of these samples would comprise a dataset to be used to interpolate the base-of-data surface (red line). It is recommended that global simple kriging be used for the interpolation as this creates a smooth artifact-free surface. The simple kriging mean should be set to a value greater than the maximum elevation found in the new dataset. This will ensure that the surface will approach the ground surface away from data. The simple kriging mean to use could be determined by taking the difference between the maximum and minimum toe sample elevations and adding half of this difference to the maximum toe sample elevation. This is illustrated in Figure 3.

Calculating Aerially-Limited Data Spacing

In addition to considering depth limits in the data spacing calculation, it can also be appropriate to consider aerial limits. One suggestion is to consider only locations which fall within the convex hull of the data. The convex hull is illustrated in Figure 4. It is the set of vectors which completely encloses all the data when projected onto a 2D horizontal plane. The option is available in the data spacing program to clip the locations outside the convex hull.

Conclusions

Geometric criteria such as data spacing have been recommended for resource/reserve classification. Calculating data spacing naively without considering possible extrapolation can be dangerous. Doing so may lead to extreme over-estimation of resources/reserves. It is reasonable to consider clipping of the data spacing grid based on the data. Clipping should be considered both depth-wise and aerially. The data spacing program has been updated to perform these additional clipping operations. A base-of-data surface is used to clip depth-wise while the convex hull of the data is used to clip aerially.

References

Deutsch, C.V. and Journel, A.G., 1998, *GSLIB: Geostatistical Software Library and User's Guide*, Oxford University Press, New York, 2nd Ed., 369 pp.

Deutsch, C.V., Leuangthong, O., and Ortiz, J.C., 2006. A case for geometric criteria in resources and reserves classification. Centre for Computational Geostatistics Annual Report Eight. University of Alberta. 22p.

Wilde, B.J., and Deutsch, C.V., 2010, Programs for data spacing, uncertainty, and classification. Centre for Computational Geostatistics Annual Report 12. University of Alberta. 6p.

Figures

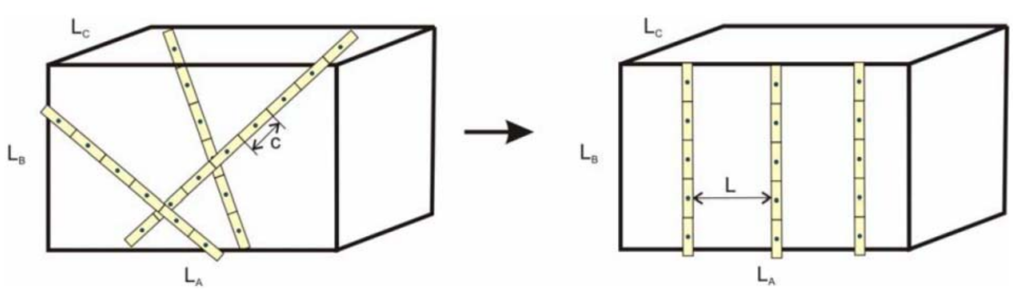

Figure 1: Illustration of a 3D volume containing *n* samples with along-hole spacing of *c*.

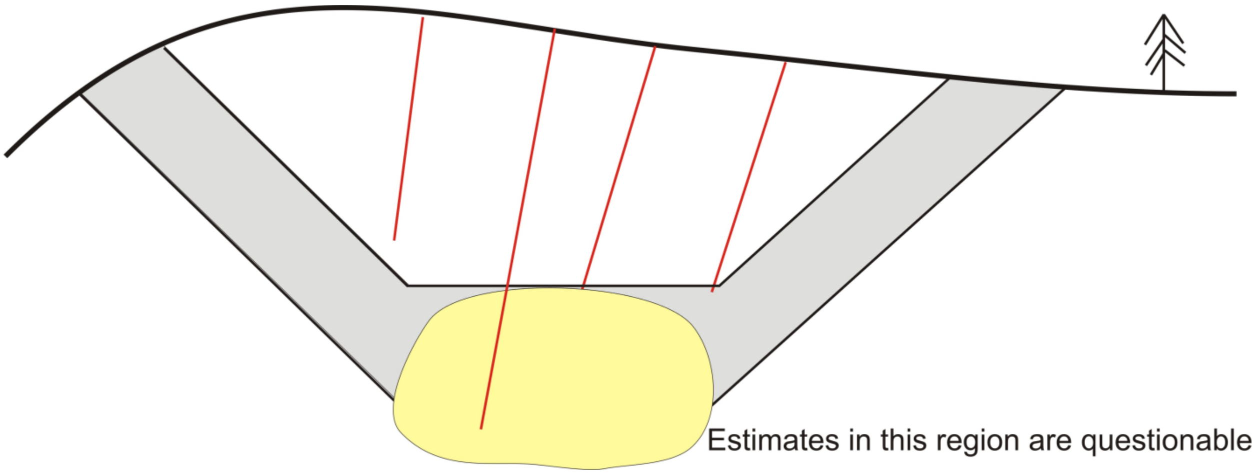

Figure 2: Schematic showing region with improper classification potentially expanding pit in unreasonable manner.

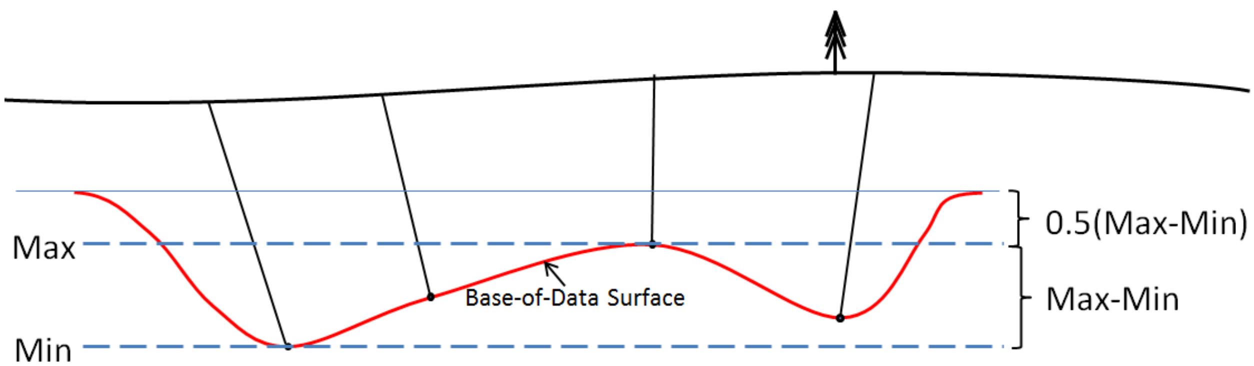

Figure 3: Schematic showing suggestion for creation of base-of-data surface.

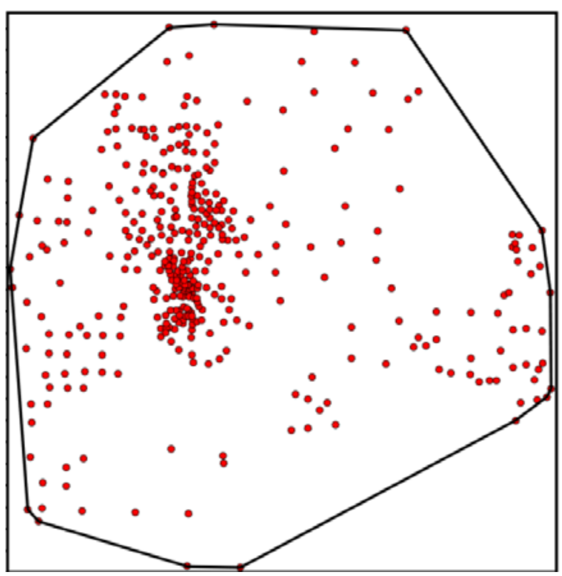

Figure 4: Illustration of the convex hull of a dataset.