A retro-review

Merks, J W, 2005

Practical Geostatistics

Clark, I, 1979

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On the jacket of *Practical Geostatistics* the author claims, "*Geostatistics is the popular name for the application of statistical methods to problems in mining and geology.*" In the *Preface*, she concedes that geostatistics is used in *"its European sense of the Theory of Regionalised Variables", developed by Matheron and his co-workers at the Centre du Morphologie Mathématique at Fontainebleau"*, and that Journel himself taught her everything she knows about it. So it is not at all surprising that *Practical Geostatistics* is a hodgepodge of good, bad and ugly statistics, copiously cluttered with confusing terms and strange symbols, much of which is traceable to Matheron's muddled teachings.

Even though the author does not discuss any of the differences between Matheronian geostatistics and mathematical statistics, she deserves praise for giving more numerical examples in 130 pages of *Practical Geostatistics* than Journel and Huijbregts do in 600 pages of *Mining Geostatistics.* The problem with numerical examples is that mistakes have a long shelf life. A case in point is *Chapter 4 Estimation*, in which the author points to *"...structure and continuity within the deposit"* but does not verify whether or not her set of hypothetical uranium concentrations display spatial dependence. Given that this set is randomly distributed within its sample space, it follows that the distance-weighted average concentration at Clark's coordinates is not an unbiased estimate.

It was H S Sichel who inspired the author's take on the properties of the lognormal distribution, which explains why she does not discuss any test to verify whether or not a set of independently measured values of a stochastic variable departs from the Gaussian or normal distribution. In fact, Sichel's t-estimator gives neither unbiased central values nor unbiased confidence limits for central values when sets of independently measured values depart from normality. ISO Technical Committee 69-*Applications of* s*tatistical methods* approved a number of tests to verify departure from the normal distribution but none of these tests is described in *Practical Geostatistics*.

In Chapter 1 *Introduction*, the author assumes that her readers have *"some previous knowledge"* of *"basic concepts of ordinary statistics such as mean, variance and standard deviation, confidence limits and probability distributions"* but her *Index* does not refer to basic concepts such as the *central limit theorem*, *degrees of freedom, independently measured values, functionally dependent values* and *spatial dependence*. The formula for the silly sill value on page 7 confirms that the variance of a randomly distributed or randomized set of $\boldsymbol{n}$ independently measured values has $\boldsymbol{df_r = n-1}$ degrees of freedom. However, degrees of freedom for ordered sets are nowhere to be found.

The author knows that the arithmetic mean is the central value of a set of independently measured values with equal weights, and that weighted averages (central values of sets of measured values with variable weights) converge on the arithmetic mean when all of the weighting factors converge on ***1/n***. As a matter of fact, Clark refers to the archaic *"standard error of the* [arithmetic] *mean"* on her jacket but the standard deviation of the distance-weighted average-*cum*-kriged estimate is missing as much in her *Practical Geostatistics* as it is in Journel and Huijbregts's *Mining Geostatistics* and David's *Geostatistical Ore Reserve Estimation*.

A simple statistical fact dodged Krige, the pioneering plotter of distance-weighted averages, Matheron himself, David, Journel and Huijbregts, Clark, and scores of similarly gifted geostatistical scholars. When Sir Ronald A Fisher was knighted in 1952, weighted averages did have variances but when geostatistics was hailed as a new science in the early 1960s, the distance-weighted average turned out to be the first and only weighted average that aborted its variance either during an honorific rebirth as the *kriged estimate*, or when it was born-again as the *kriged estimator* in Journel and Huijbregts's *Mining Statistics* and Clark's *Practical Geostatistics.*

Given that two or more independently measured values of a random variable, when determined in samples selected at different coordinates in a sample space, define an infinite set of distance-weighted averages, it follows that Krige, Matheron and scores of like-minded model makers made the infinite set of variances of distance-weighted averages-*cum*-kriged estimates vanish without a trace. Incredibly, pseudo variances and pseudo covariances of ***sets*** of kriged estimates became the cornerstones of geostatistics.

Clark underscores the folly of geostatistics by bringing up in her *Introduction* the semi-variogram, berating those who *"sloppily call it the variogram"*, and belaboring in *Chapter 2* her strange interpretation of what is commonly called a *sampling variogram* in various ISO Standards. A sampling variogram is a graph in which $var_j(x)$, the variance terms of a temporally or *in situ* ordered set of independently measured values, are plotted against $var(x)$, the variance of the randomly distributed set, and the lower limits of its asymmetric 95% and 99% confidence ranges.

In mathematical statistics, an ordered set of ***n*** independently measured values gives $df_o=2(n-j)$ degrees of freedom for $var_j(x)$, the j^{th} variance term of an *in situ* ordered set. Fisher's F-test, when applied to verify the absence or presence of spatial dependence, is based on comparing $F=var(x)/var_1(x)$, the ratio between the variance of the randomly distributed set and the first variance term of the ordered set, with tabulated values of $F0.05;n-1;2(n-1)$ and $F0.01;n-1;2(n-1)$. Degrees of freedom for *in situ* ordered sets mystify Clark who messes with the factor ***2*** in front of her ***γ*** for *"mathematical convenience*". It is ironic to the extreme that ignoring ***1*** in ***n–1***, and placing the factor ***2*** in $df_o=2(n-1)$ in front of $var_1(x)$ to obtain $2 \cdot var_1(x)$, makes it impossible to apply Fisher's F-test and verify spatial dependence, and to chart sampling variograms that display where orderliness in sample spaces dissipates into randomness.

Given her penchant for semi-variograms, it is unsurprising that the author glorifies the spherical semi-variogram. It is rather peculiar, however, that she pontificates its *"ideal shape"* is "*to Geostatistics as the Normal distribution is to statistics"*. It is a statistical fact that a spherical semi-variogram is, and will always be, a pseudo variogram whereas a semi-variogram can always be transformed into a sampling variogram.

In Chapter 5 *Kriging*, the author describes a hypothetical uranium deposit to which she fits a spherical semi-variogram model with a sill value of 700 ppm^2, a nugget effect of 100 ppm^2, and a range of influence of 100 ft. In truth, the variance of the randomly distributed set is 4,480 ppm^2, and the hypothetical set of uranium concentrations cannot possibly provide an unbiased estimate for her nutty nugget effect (the sum of all of the extrinsic measurement variances). Fisher's F-test gives a calculated value of $F=var(x)/var_1(x)=4,480/2,186=2.05$, which is below the tabulated value of F0.05;4;8= 3.84 at 95% probability. Because the data set does not display spatial dependence at an average distance of 47 ft between hypothetical uranium concentrations, interpolation within this sample space is not permissible while extrapolation beyond it is a scientific fraud. Therefore, a distance-weighted average of 371 ppm at Clark's coordinates is not necessarily an unbiased estimate for the unknown true concentration at that position.

In the same chapter, the author summarizes the form of the "*new estimator"*, and states *"…the weightings sum to 1."* What eludes her is that the sum of the squared weightings is required to derive the degrees of freedom for the new estimator, and that degrees of freedom for variable weightings are positive irrationals. What is truly astounding is the statement on the first page of Chapter 5 where she concedes, *"The arithmetic mean is simply a special case where all of the weights are equal."* Clark earlier acknowledged that arithmetic means have variances. Does the author suggest that the convergence of a kriged estimator on the arithmetic mean makes the missing variance of a single kriged estimator re-emerge? Or could it possibly be overlooked in the early 1960s?

The author suggests the pronunciation of *"Krige"* is controversial and offers her own phonetic spelling, which begs the question why nobody asked Krige. Of course, the proper pronunciation of Krige's name cannot possibly be as controversial a topic as the irrefutable statistical fact that central values have variances, irrespective of whether they are arithmetic means or weighted averages. Krige may not have known much about one-to-one correspondence between variances and central values but he would certainly know how to pronounce his own name.

On the jacket of *Practical Geostatistics*, Clark claims, *"(G)eostatistics is the popular name for the application of statistical methods to problems in mining and geology"*. The question is then why scientifically sound applications of statistical methods do not abound between its covers. On a positive note, if ever a first generation geostatistician were to encounter a rare moment of perfect vision, it would be Dr Isobel Clark. And all it really takes is to grasp why each and every distance-weighted average-*cum*-kriged estimate not only has, but ought to have, its own variance. The rest are details.