Book Review


This volume is the sixth in the series published under the auspices of the IAMG but other than the multilingual glossary edited by Ricardo Olea, it is the first on geostatistics. It is organized into thirteen chapters and a preface. The reader need not be very familiar with geostatistics in the sense that it has existed in the literature for the last 30–35 years since the author claims the following:

"It is widely recognized that the techniques of classical geostatistics, which have been used for several decades, have reached their limit and the time has come for some alternative approaches to be given a chance" (page ix). That statement sets the tone for the rest of the book.

Preface

This is largely devoted to the author’s motivation and philosophical stance with respect to “modern spatiotemporal geostatistics.” These are laid to be down in a series of “postulates” purportedly analogous to the development of Euclid’s geometry. It is claimed that “modern spatiotemporal geostatistics” incorporates or integrates more information than just the data.

Chapter 1: Spatiotemporal Mapping in Natural Sciences

The simplest way to describe the content of this chapter is to quote some of the “postulates.” Postulate 1.1 In the natural sciences, a map is not merely a data loaded artifact, but rather a visual representation of a scientific theory regarding the spatiotemporal distribution of a natural variable.

Page 6 “Mapping techniques provide the means for estimating unsurveyed areas using a limited number of sample points in space/time.”

Page 10 “Formally, a mapping approach consists of three main components:

1. The physical knowledge $K$ available, including data sets, physical models, scientific theories, empirical functions, uncertain observations, justified beliefs, and expertise with the specified natural phenomenon.
2. The estimator $X^\ast$ which denotes the mathematical formulation used to approximate the actual (but unknown) natural variable $X$.
3. The estimates $\hat{X}$ of the actual values $X$ generated from the estimator $X^\ast$, usually on a regular grid in space/time. These grid values constitute a spatiotemporal map.”

Postulate 1.2 Modern spatiotemporal geostatistics is concerned with stochastic analysis that functions at both the ontological (i.e., building models for natural systems) and the epistemic level (i.e., using what is known about the systems and how knowledge is integrated from a variety of scientific disciplines), rather than with pure inductive procedures based on linear relationships between data and hypotheses using physical theory free techniques.

Definition 1.1: Modern spatiotemporal geostatistics is a scientific discipline that arises from the advancement of the ontological and epistemic status of stochastic analysis, as described in Postulate 1.2 above.

Postulate 1.4: Modern spatiotemporal geostatistics recognizes that spatiotemporal geometry is not a purely mathematical affair and relies on physical knowledge in order to decide which mathematical geometry best describes reality.

The author seems to be unaware of or chooses to ignore the use of the term “map” as it is used in the mathematical literature or even in the geography literature. There is little in this chapter that is needed when reading the subsequent chapters.

Chapter 2: Spatiotemporal Geometry

The author begins by listing the supposed three fallacies of classical geostatistics: “1. Spatiotemporal structure is a purely geometrical affair, 2. The data always speak for themselves, 3. Estimation is an exercise of mathematical optimization.” Then there are additional “postulates”

Postulate 2.1 Space/time $E$ is viewed as a set of points that are associated with a continuous spatial arrangement of events combined with their temporal order.
Postulate 2.2: Since events are associated with points of the spacetime continuum $E$, relationships between events are essentially relationships between the points of $E$.

"Generally four essential characteristics of spatiotemporal geometry may be identified: (i) Geometric objects (individual points, lines, planes, vectors, and tensors), (ii) Measurable properties of objects and spaces (angles, ratios, curvature, and distance or metric) that give geometry its quantitative features, (iii) Modes of comparison (equal, less than, greater than) that give geometry its comparative features, (iv) Spatiotemporal relationships (inside, outside, between, before, after) that give geometry its relative features".

Postulate 2.3: Since a set of physical relationships between events is associated with a set of geometrical relationships between points in $E$, a spatiotemporal structure is imposed on $E$ by means of these physical relationships.

Postulate 2.4: The choice of an appropriate geometry to describe space/time continuum $E$ depends on whether one adopts an intrinsic or an extrinsic visualization of $E$.

Definition 2.1: The general curvilinear coordinate system $\{s_i\}, i = 1 \ldots n$ associated with a point $P$ is the set of oriented $n$ coordinate curves that are the intersections of the $n$ coordinate spaces ($s_i$ is a constant) through the point $P$.

Definition 2.10: AnS/TRF $X(p)$ is a collection of complementary field realizations $\chi$ associated with the values of a natural variable at points $p = (s, t)$ of a spatiotemporal continuum $S \times T$. Mathematically the S/TRF is the mapping $X(p) : S \times T \rightarrow L_q(\Omega, F, P)$ where $\Omega$ is the sample space that includes all possible field realizations, $F$ is a family of realizations, $P(\cdot) \in [0, 1]$ is a probability associated with each realization and $L_q(\Omega, F, P)$, $q \geq 1$ denotes the norm on the probability space $(\Omega, F, P)$.

Although the new content of this chapter is not very extensive, there are a great many new terms and symbols introduced that will be used in subsequent chapters.

Chapter 3: Physical Knowledge

The general knowledge base is assumed to consist of information obtained from physical laws and theories, summary statistics, logical principles, etc., whereas the specificatory includes information about the specific case or problem. The specificatory knowledge base may include both "hard" and "soft" data. The combination of the two is the physical knowledge base. The purported intent of this chapter is to describe this physical knowledge base in mathematical terms. In "classical" geostatistics, general knowledge might consist of simply the covariance or variogram, specificatory knowledge would simply be the data.

Chapter 4: The Epistemic Paradigm

This chapter is again largely philosophical and is intended to motivate the introduction of BME (Bayesian Maximum Entropy).

Chapter 5: Mathematical Formulation of the BME Method

This chapter introduces BME, based on the various papers published previously by the author. Hidden in this chapter is the assumption that there is always a transformation to a gaussian distribution, the posterior distribution must then be back-transformed. Little attention is paid to the problems of generating or finding this transformation.

Chapter 6: Analytical Expressions of the Posterior Operator

In keeping with the term "Bayesian" in BME, the interpolation problem is described in terms of a posterior function conditioned on the physical knowledge base.

Chapter 7: The Choice of a Spatiotemporal Estimate

The BME approach results in a posterior distribution and hence one may select between several functionals on this distribution such as the mean or mode. An example is given (West Lyons Porosity Field) where the posterior distribution is conditioned with respect to skewness.

Chapter 8: Uncertainty Assessment

Although it is well-known that the kriging variance is not a data dependent measure of variability, it is often used as a relative measure of reliability. However one must be careful about attempting to use it to construct confidence intervals. The problem of constructing confidence intervals using the posterior distribution is considered in this chapter, discussed in the two cases where the pdf is symmetric and where it is not symmetric. There is a serious mis-statement about confidence intervals in Comment 8.1 however which taints all of the discussion. This pertains to the distinction between probability and confidence level.