A Short Note on the Generation of Geologically Realistic Stochastic Models

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This short note outlines some of the areas that will be addressed in the coming year. The research will be focused on developing geostatistical tools and methods for the further integration of geologic information in stochastic models.

Introduction

Most research in geostatistics is algorithm focused. Issues such as one and two points statistic reproduction, models of uncertainty, computational efficiency and decision-making after the application of a transfer function are primary motives. A common compliant of those from the geologist perspective of earth modeling is that while the resulting models may be statistically correct they lack geologic realism. While statistics based on the insitu population are applied, the physics behind this population is generally ignored.

Depositional environments conform to well known physical laws. Base level and sediment supply vary over a hierarchy of scales and generate characteristic depositional patterns. The results are assemblages of deposition with complex trends and bounding surfaces. In each unique depositional setting there is a story to be unraveled and told.

Traditional stochastic methods with stationary one and two point statistics applied to build regular facies and property block models do not utilize the wealth of information available from geologic knowledge based on physical understanding and analogue sites. In general, current geostatistical tools and methods are blunt instruments that lack the ability to integrate this valuable information.

This work outlines general areas of research that has been conducted and will be explored by the author. The focus will be on potential methodologies and algorithms for further integrating geologic information into the stochastic framework. Since there is great variability between different types of geologic settings and models need to be fit for purpose, it is not anticipated that one final solution will be found in the form of a new simulation algorithm. Instead it is anticipated the many new or modified algorithms will be developed as additions to the orthodox tools such as those found in GSLIB (Deutsch and Journel, 1998). These tools may be tailored to integrate geologic information to specific sites, tempered by the modeling needs.

While generating models with geologically realistic appearances is beneficial since they will improve model credibility, there is a quantifiable advantage. Geologic information interpreted as numerical constraints will reduce the resulting model uncertainty. This translates directly into reduced uncertainty in the distribution of response variables after the application of a transfer function. This will improve the quality and confidence of decisions made in the presence of geologic uncertainty.

Irregular Grids

Simulation directly to irregular grids has been held up by the limitations inherent to the Gaussian transformation. The nonlinear nature of the Gaussian transform precludes linear averaging, and thus it is not possible to calculate mean covariance values in Gaussian space for the general kriging equations. This prevents the use of conditioning data and model nodes of different support sizes, and thus prevents simulation to irregular blocks and with multiple data scales. We must work in direct space with the actual data values in order to work directly with irregular grids.

There has been substantial progress in the application of simulation in direct space within the Centre for Computational Geostatistics within the last year. Many individuals have been involved in the development of an operating direct sequential simulation (DSS) algorithm. X. lie et al. (2001) developed techniques for working in direct space. Deutsch et al. (2001) demonstrated a method to calculated feasible local distributions of uncertainty in direct space which result in the global distribution being honored. The authors (Pyrcz and Deutsch, 2002) developed well documented subroutines for the calculation of these distributions and for the rapid calculation of mean covariance values.

These developments have allowed for the construction of a tartan simulation algorithm (TARTANSIM), with a radial grid module which allow for the direct simulation to tartan grids and the post insertion of radial grids. This algorithm is described within the CCG report, *Direct Sequential Tartan Grid Simulation (TARTANSIM),* (Pyrcz and Deutsch, 2001). An important advantage of this algorithm is its computational efficiency when compared to sequential Gaussian simulation (SGSIM) on a fine grid and block averaging to a tartan grid. The use of a nonstationary mean covariance lookup table and fast mean covariance calculations by random sampling are novel techniques that have drastically improved computational efficiency.

In the near future work will progress into methods for simulation directly to the more general case of irregular grids, corner point grids. The development of these tools greatly improves the ability of stochastic models to conform to geologic architecture and allow for the direct integration of a wide variety of quantitative geologic information.

Multiple Point Statistics

The concept is based on the use of a training image to build a database of multiple point statistics (Strebelle and Journel, 2000). Then these statistics are applied to local conditioning. This procedure may be applied to reproduce nonlinear futures and complex geometries. There is issues with respect to the generation of training images and the over constraint of the resulting space of uncertainty. Investigation will be conducted into these techniques.

Sequence Stratigraphic Surface Modeling

Surface modeling has previously been address by the Centre for Computational Geostatistics. Xie et. Al. (1999) addressed methods for stochastically generating surfaces that honor the available data and rules based on volume filling and the type of stratal termination. These methods have been shown to generate surfaces, which mimic the appearance of actual geologic bounding surfaces. Further investigation will be conducted into these methods, and the integration of these surfaces into numeric models.

Facies Relationships and Ordering

The problem of reproducing facies relationships and ordering in rock type/facies simulations has been frequently identified. It has been seen as a strength of truncated Gaussian simulation (GTSIM) that ordering relationships may be reproduced. Sequential indicator simulation (SISIM) is able to reproduce specific correlation structures through the application of indicator variograms. The addition of prior proportion models may inject nonstationary facies trends, but there is no constraint on ordering. Facies ordering is common in assemblages of process related facies. For example in a prograding regressive coastal system tract a natural transition from marine to non-marine facies. Stranded facies would not be possible but would occur in a model in which ordering is not constrained.

A method of modeling facies tract distributions in shoreface reservoirs has been presented by MacDonald and Aasen (1992). Their proposed model not only reproduced facies ordering but also integrated the effect of change of based level change on bivariate distribution of aggradation and progradation angles. Their preliminary work has demonstrated the potential in integrating a variety of sequence stratigraphy concepts.

Sequenced Models

Sequenced models are models in which objects are seeded and grown over a series of modeling steps. This method has been applied to fracture modeling. This technique may have applicability in the areas of surface and object modeling. A major advantage may be the potential ability to condition the model without the use of an inefficient acceptance rejection method.

Object Models

Object models are very efficient at reproducing self-similar repetitive geologic signatures, such as filled fluvial channels and deltaic lobes (Deutsch and Tran, 1999). In general, simulated annealing has been applied to place and perturb objects in a manner to minimize an objective function that accounts for facies proportions, continuity and honoring of the available data.

Conclusions

The research will explore a wide variety of methods and algorithms for the integration of geologic information into stochastic models. The previously mentioned areas are only a sample of the possible avenues which be explored. The final deliverable will be a new set of tools that may be tailored to unique depositional settings.

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