Geostatistical techniques are ideal for building valuable high-resolution models of acoustic and elastic properties derived from seismic volumes. These in turn are used for modeling lithology, porosity, permeability and other reservoir properties. The fundamental strength of geostatistics derives from its ability to integrate multiple related data types while simultaneously honoring their appropriate levels of contribution to the final reservoir model.

**Multi-Point Geostatistics**

While conventional geostatistical methods are still widely and successfully used in today’s oil and gas industry, the recent development of multi-point geostatistical tools is a great advancement, according to Chris Grant, senior applications developer, Transform Software and Services. Although these techniques have been around for many years, he said, they are only recently being applied commercially due to improved algorithms and increased compute power.

“Conventional variogram-based geostatistics model two-point statistics,” Grant told *Upstream Technology*. “In the simplest implementations of variogram-based geostatistics, it is difficult to model complex facies associations and non-linear spatial patterns, although there are tricks that can partially get around these limitations. Multi-point geostatistics techniques borrow from image analysis technology and are much better suited to model complex spatial patterns, such as meandering channel belts. The multi-point modeling approach is more demanding – yet probably more compelling for the geologist – than variogram-based modeling.”

With multi-point geostatistics, the geoscientist constructs a 3D model that mimics the geology of the reservoir, “kind of a 3D geological playground,” quipped Grant. This 3D model is known as a training image.

“Providing easy software tools to construct this 3D training image is a challenge,” Grant said. “The multi-point algorithm attempts to reconstruct the essence of the training image while simultaneously honoring available reservoir data such as well and seismic information. Multi-point methods are currently quite computationally demanding. Challenges include being able to interrogate the training image quickly with minimal memory requirements. A lot of research is being done in this area.”

For years, computationally intensive processes like geostatistics have relied on Moore’s law (doubling CPU efficiency every 24 months) in order to become practical and widely available to explorationists. Moore’s Law, however, is no longer the defining trend in computer hardware. The current dominant trend is increasing the number of CPUs on each machine in a parallel (multi-core) architecture.

“Challenges for the future are to design algorithms that maximize effective use of parallel processors,” Grant said. “While this can be challenging for sequential-based geostatistical algorithms, it can be done and is being done.”

www.transformsw.com

**Several Trends Underway**

Geostatistical modeling is a critical component of today’s reservoir modeling pipeline. A wrong geostatistical model can lead to wrong predictions, even though the history match is correct.

According to Guillaume Caumon, Director of
the Gocad Consortium, several directions are currently being taken in geostatistical modeling software. In addition to the development of multi-point geostatistics software mentioned previously, which techniques have been implemented internally at several oil companies and implementations in commercial software are forthcoming, he said, other developments include:

• Automatic history matching to generate realizations efficiently that fit the field history;
• Improvements in object-based modeling methods for fluvial systems so that well data are honored while local channel proportion constraints are respected;
• Extending geostatistics to represent not only petrophysical uncertainty but also structural uncertainty; and
• Scenario-based geostatistics to assess uncertainties about global parameters such as original hydrocarbon in place.

www.gocad.org

Geostatistical Inversion and Markov Chain Monte Carlo

At Fugro-Jason, a geostatistical inversion method is used in the StatMod MC software module. It combines classic geostatistics with innovative Jason Workbench seismic inversion methods in a program that is valuable in both exploration and reservoir development. StatMod MC uses geostatistics to identify models that are consistent with well log information and simultaneously inverts the data to find the subset of those models that are also consistent with the seismic data. This results in models that match all the input data in a single algorithm.

“The litho cube output developed in StatMod MC is a kind of automatic interpretation or body checking. Informational synergies allow substantially increased resolution, capturing details well beyond seismic bandwidth. By providing multiple, realistic scenarios, StatMod MC provides a tangible, intuitive handle on development risk,” said the StatMod website.

StatMod MC goes beyond traditional seismic inversion to solve problems like:

• Fine scale interpolation between closely spaced wells;
• Estimation of uncertainty to assess risk;
• Improvement of the resolution of standard seismic inversions;
• Generation of lithotype (e.g. sandstone, shale) volumes;
• Estimation of porosity from impedance;
• Integration of high-resolution well data with low-resolution seismic; and
• Creation of inputs for reservoir simulation.

In StatMod MC, a rigorous probability distribution is defined linking the property and lithofacies cubes with the seismic, well logs, histograms and variograms. The histograms and variograms are obtained from log analysis and geological insight, the former giving the likelihood of different values at any given point, the latter giving essentially the “characteristic scale” and texture of the geological features in lateral and vertical directions.

Subsequently, sophisticated Markov Chain Monte Carlo (MCMC) methods are used to get a statistically correct set of samples from the overall probability distribution function. This defines plausible alternative scenarios for what might be down there.

Realistic reconstructions yield more representative predictions when fed through a flow simulator. Since a truly simultaneous MCMC is performed on the lithofacies and property cubes, taking into account both the statistics and the seismic, it is possible to exploit “informational synergies” to retrieve details that deterministic seismic inversion techniques blur out or omit. While details beyond seismic bandwidth cannot, by definition, be resolved precisely and unambiguously, it is often possible to get a good idea of the existence, multiplicity, thickness and connectivity of sub-seismic sand formations.

MCMC is a technique for obtaining a statistically correct random sample from a complex probability distribution, via incremental adjustments similar to those made by an optimization algorithm (such as conjugate gradients). It is much better suited for seismic inversion problems than sequential simulation-type algorithms, because it can take both the seismic and the geostatistics into account – rigorously – all the way through the process. Geostatistical inversion using sequential simulation is not and cannot be statistically correct because the approximations on which sequential simulation is based break down once the grid has been filled in. Moreover, MCMC is a good basis for more sophisticated algorithms with favorable convergence properties, which is why StatMod MC can extract geologically plausible litho cubes from the seismic automatically.

www.fugro-jason.com

Stanford’s GSLIB Morphs into SGeMS

The folks at Stanford University are putting the finishing touches on the next generation of their geostatistical modeling software.

“SGeMS is replacing the older GSLIB programs,” Alex Boucher told Upstream Technology. “We felt that we needed a more modern platform to better pursue and distribute the research done at the SCRF (Stanford Center for Reservoir Forecasting) research group. SGeMS is written in C++, has 3D visualization capabilities and includes most of the classical geostatistical algorithms as well as new developments such as multi-point geostatistics. It was originally written by Nicolas Remy during his PhD (he is currently working at Yahoo). Since then, Jianbing Wu, Ting Li and I have joined him by adding new algorithms and maintaining it.”

The algorithms can be extended with plug-ins, Boucher said. For example a researcher can write his own algorithm and insert it seamlessly into the software, thus
exploiting its full capabilities. Writing a plug-in does not require any user interface programming; only the core algorithm has to be implemented. Because this is open-source software, all the geostatistical libraries that Stanford developed are also available, facilitating the generation of new algorithms. The advanced geostatistical solutions of SGeMS can also be called from external integrated software such as Petrel. In addition, SGeMS allows the use of the Python scripting language to automate complex and/or repetitive tasks.

“GeMS has been downloaded 4,860 times in the last year, with visitors from more than 71 countries or regions,” Boucher said. “We are currently writing a complete user manual for the software, which we expect will be available by early 2008.”

The software and more information about it can be downloaded from the following website:

http://sgems.sourceforge.net/

Garbage In, Garbage Out

Stochastic simulation is being applied routinely today in the construction of reservoir models – it’s an unavoidable step of any subsurface study. The emphasis needs to be on rigorous methodologies and clear explanations of the applicability of the various techniques available. Most importantly one should focus on the accuracy of the input data and the choice of the algorithm parameters, according to Emmanuel Gringarten, reservoir product line manager, Paradigm.

“At Paradigm, our current development efforts in this area focus on workflows in which we systematically guide the users through rigorous data analysis for the purpose of getting the right data and input parameters for reservoir property modeling. Any modeling is only as good as the reservoir grid that supports it. In structurally complex settings, many assumptions made to be able to construct the grid not only violate the geology but many of the assumptions underlying the geostatistical algorithms. At Paradigm we have developed a way to remove the dependency between the property modeling and the grid construction, thus allowing modeling that honors any structural constraints. Watch this space....”

www.paradigmgeo.com
www.earthdecision.com

Commercial Software Packages:

• Datamine
• Geostokos Toolkit & ECOSSE
• Geovariances’ ISATIS
• Geostat Systems Int. Inc.
• GS+ from GammaDesign
• Surfer from Golden Software
• SAGE2001
• Lynx Geosystems
• GeostatsOffice
• SurGe

Free Software for Analyzing Geostatistical Data

List from www.ai.geostats.org

- Agromet [Unix / Windows/ C++] (V-K-C-2D)
- Cosim [Windows / Fortran] (S-2D)
- E{Z} -Kriging [Windows] (V-K-2D)
- GCOSIM3D [Windows / C] (S-3D)
- Geo-EAS [Windows] (V-K-2D)
- GeoPack [Windows] (V-K-C-2D)
- GeoDa [Windows] (O-2D)
- Geostatistical Toolbox [DOS] (V-K-C-3D)
- GMT [Unix / C] (O-2D)
- GRNN [Windows] (O-2D)
- GSLIB [Fortran 77] (V-K-C-3D-S)
- Gstat [Linux, Windows / C/ R] (V-K-C-3D-S)
- ISIM3D [Windows / C] (S-3D)
- Kriging [Unix / C] (K-2D)
- SADA [Windows] (V-K-O-3D-G)
- SAGA GIS [Windows] (V-K-O-2D-G)
- SGS [Linux, C] (K-S-2D)
- S-GeMS [Windows, Linux, C++] (V-K-C-3D-S)
- Spheredikit [Unix, C] (K-O-2D)
- Surface III [Mac] (K-O-2D)
- Surfit [Windows, C++] (O)
- UNCERT [Unix / C] (V-K-O-C-2D-G)
- Variowin [Windows] (V-2D)
- Vesper [Windows] (V-K-2D)

Key:

V = Variography
K = Kriging
C = Co-Kriging
S = Simulations
G = GIS functions
O = Other Estimators (NN, IDW, splines)
2D/3D = maximum dimensions