Special Issue on Computational Methods for the Earth, Energy and Environment—IAMG 2009

Jef Caers

Received: 31 May 2010 / Accepted: 1 June 2010 / Published online: 15 June 2010
© International Association for Mathematical Geosciences 2010

On August 23–28, 2009, despite difficult economic conditions, more than 200 enthusiastic IAMG participants and sympathizers gathered for the annual meeting at Stanford University. At the heart of the San Francisco Bay area, delegates were able to sample an excellent technical program, as well as explore this important pacific gateway at the confluence of Latin, Asian, and European cultures.

Computational aspects of geological modeling have always been at the heart of the IAMG. With the advent of new paradigms in hardware and software, IAMG 2009 sought to be both novel and forward-looking. With the advent of cluster computing, it has now become clear that modern mathematical and quantitative methods in the Earth and Environmental Sciences and Engineering require an increasingly strong computational component and are rich in computational research and applications. The increased computational complexity of our problems has prompted computer scientists, both hardware and software, to come together with the Earth and Environmental Sciences and Engineering communities to tackle new computational challenges. Ideally, this will foster an integration with Computer Science, each driving development of the other in the areas of their interfacing. The computational capacity and the availability of large volumes of data from a variety of data sources offer new challenges in modeling various components of the Earth, whether this concerns the modeling of an aquifer or the process-simulation of a large sedimentary basin, as well as the human activities that interact with these Earth processes.

A few key papers were selected from the many excellent contributions and rich technical program. The selected papers show a slight bias toward geostatistics, understandable given Stanford's research programs in this area; however, they also reflect the keywords of this conference: computation, Earth, energy, and environment.

J. Caers (✉)

Department of Energy Resources Engineering, Stanford University, Stanford, CA, USA
e-mail: jcaers@stanford.edu

Two papers on multiple-point geostatistics (MPS) demonstrate the increasingly computational (algorithm-driven models) aspect of geostatistics over the more traditional parsimonious approaches of spatial model building. In MPS, a full 3-dimensional training image is used to express explicitly the desired “patterns of variability” for a site under investigation. The idea is simply to extract these patterns from the training image, then anchor them to any data (hard, soft, dynamic), thereby creating geologically (or in any other field of application) realistic 3-dimensional models (realizations). Various approaches exist in extracting these patterns.

In the paper by Roussos Dimitrakopoulos (keynote speaker at IAMG 2009) et al., patterns are captured in a statistical sense, namely through the definition of spatial cumulants. They show how spatial cumulants of orders three to five are able to capture directional multiple-point periodicity, connectivity (such as connectivity of extreme values), and spatial architecture of an image. The paper presents a new framework for stochastically simulating realizations sequentially on the basis of such high-order cumulants by using Legendre polynomials to approximate the conditional probability distributions. Examples show that the proposed method is much less sensitive to the training images than the existing MPS methods, due to the data-driven nature of the method. On the other hand, Mehrdad Honarkhah, as winner of the student paper contest at IAMG 2009 (a primer competition for IAMG), presents an entirely different approach to MPS by directly simulating patterns instead of pixels. Patterns can be extracted directly from the training image through a template, then his algorithm uses various clustering and dimensionality reduction tricks to basically piece a puzzle of patterns together, thereby creating an image that looks like the 3-dimensional training image and, in addition, is constrained to the available data. His method is lightening fast (about 10 times faster than state-of-the-art MPS algorithms), yields excellent pattern reproduction and requires few user parameters.

A non-statistical approach to creating models that are geologically realistic is to use process-based models. Since the advent of “SedSim,” developed by John Harbaugh and co-workers at Stanford University, many modeling approaches to the computer-based simulation of sedimentation have been developed. Ana Carmona et al. present a methodology coupling the sedimentation process with the deformation process into one single effective model.

An issue that often occurs is that of modeling with data that records the variable of interest at different scales. The challenge lies in creating models that incorporate such multi-scale data. While many applications of this are found in mining and petroleum geostatistics (the problem of support), Pierre Goovaerts (keynote speaker at IAMG 2009) provides a novel method (a general formulation to kriging with multi-scale data), and novel application on heavy metal concentration and incidence rates of late-stage breast cancer.

Guillaume Caumon, the 2009 Vistelius Award winner and keynote speaker at IAMG 2009, presents an overview of some of his recent research in 3-dimensional geological modeling. As head of the gOcad research group in Nancy, France, he tackles many challenges in modeling 3-dimensional structures and properties, using a wide range of mathematical and Computer Science techniques. His aim is to better achieve this through the inclusion of both stochastic (uncertainty) and time-varying geomodeling (such as the unfolding of structures back in geological time).

Aggregation is a keyword in the final two papers of this special issue, one on mineral resources and one on hydrocarbon resources, both still important topics to the IAMG research community and to the world. Vladimir Lisitsin presents an approach for a quantitative probabilistic assessment of undiscovered mineral resources, in his case in Victoria, Australia. The characterization of grade-tonnage models is often hampered by lack of data, and assessment of undiscovered deposits is at best controversial without appropriate guidelines. His paper suggests approaches that address these two critical issues. The paper by John Schuenemeyer and Donald Gautier presents a method to aggregate results from a USGS assessment over 48 geologically defined regions (units) of undiscovered conventional oil and gas resources of the Arctic. The main objective is to construct a geologically-based probabilistic assessment of the potential for new discoveries north of the Arctic Circle. Critical to such aggregation method is to obtain a representative pairwise correlation between geological parameters characterizing each unit.

I hope you will enjoy the papers and appreciate efforts of the authors in this special issue.