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Fifth Annual Report of the Centre for Computational Geostatistics

SEPTEMBER 2003

- A Geostatistical and Flow Simulation Study on a Real Training Image, *W. Ren*

Mining Related

- Conditional Non-Bias of Geostatistical Simulation for Estimation of Recoverable Reserves *J.A. McLennan and C.V. Deutsch*
- A Practical Way to Summarize Uncertainty for Blockwise Resource Classification, *J.M. Ortiz and C.V. Deutsch*
- Application of Modern Geostatistics for Mine Planning, *O. Leuangthong*

Software Related

- VARFIT: A Program For Semi-Automatic Variogram Modelling, *P.F. Larrondo, C.T. Neufeld, and C.V. Deutsch*
- Selected Implementation Issues with Sequential Gaussian Simulation, *S. Zanon and O. Leuangthong*
- Uncertainty Upscaling, *J.M. Ortiz and C.V. Deutsch*
- Random number generation with acorni: a Warning note, *J.M. Ortiz and C.V. Deutsch*

Miscellaneous

- A Review of Some Fluvial Styles, *M.J. Pyrcz*
- Bank Retreat Meandering Fluvial Process-based Model, *M.J. Pyrcz*
- Short Note: Naïve Bayes Classifiers and Permanence of Ratios, *J.M. Ortiz*
- Short Note: Generating Regional Permeability Maps for Large-Scale Hydrogeological Studies, *D.K. Khan*

Abstracts Only

- Geostatistical Simulation of Optimum Mining Elevations for Nickel Laterite Deposits, *J.A. McLennan, J.M. Ortiz and C.V. Deutsch*
- Stepwise Conditional Transformation for Simulation of Multiple Variables, *O. Leuangthong and C.V. Deutsch*
- Multivariate Geostatistical Simulation at Red Dog Mine, Alaska, USA, *O. Leuangthong*
- Semi-Automatic Dig Limit Generation, *C.T. Neufeld, K.P. Norrena and C.V. Deutsch*
- Optimal Selection of Selective Mining Unit (SMU) Size, *O. Leuangthong, C.T. Neufeld, and C.V. Deutsch*
- Entropy in Random Functions and Consequences in Geostatistics, *P. Larrondo*
- Comparison of Bayesian Updating Methods for Integration of Multiple Secondary Data, *L. Zhang*
- SPE 78996: Automatic Determination of Well Placement Subject to Geostatistical and Economic Constraints, *K.P. Norrena and C.V. Deutsch*
- Uncertainty Quantification and Risk Analysis for Petroleum Exploration and Exploitation Projects, *S. Potlog*
- SPE 77332: Advances in the Prediction and Management of Elemental Sulfur Deposition, *N. Hands, B.Oz, B. Roberts, P. Davis and M. Minchau*
- A risk-qualified approach to calculate locally varying herbicide application rates, *T. Faechner, K. Norrena, A.G. Thomas, and C.V. Deutsch*

Introduction

There has been a fair amount of traffic in the CCG research group and member companies over the last year. Four students completed their PhDs (Ty, Zulfiquar, Oy, and Julián), two other students joined industry while trying to wrap up their theses (Bora and Karl), and three new students joined the CCG (Paula, Weishan, and Chad). Despite this turnover, this year's report continues the trend of increasing number of papers from last year's 28 papers and 481 pages to this year's 42 papers and 727 pages. Of course, we had eighteen months since the last report. The productivity as measured by number of papers and total pages is virtually the same as last year once we rescale the data to the same time support.

A hardcopy report is nice; it can be picked up and flipped through anywhere anytime for your reading enjoyment. We prepared special Mining and Petroleum versions of the hardcopy report this year. Only the abstracts of some clearly petroleum papers are included in the mining report and vice versa. Of course, the CD is essential in this digital age. The CD contains all papers in their original Word or LaTeX format with color figures, PowerPoint presentations, programs, and all of the non-proprietary datasets.

We are working to modernize our webpage for members and non-members alike (www.uofaweb.ualberta.ca/ccg). All member companies should have access to the software and reports section. All papers from all reports are available on line with a search engine; you can search for your favorite subject and all of the papers that reference the subject will come up. You can download the papers and so on. Newsletters and other information are on the web page. Limited information is available to non-members: hopefully just enough for them to seriously consider membership.

The Seventh International Geostatistics Congress will be held next year in Banff. The CCG is organizing the conference. Virtually everyone that would consider coming to the CCG meeting would want to be at the Congress. For that reason, the CCG meeting will be held the Thursday and Friday before the Congress (September 23rd and 24th, 2004). We will only change these dates under extreme duress.

CCG research is a pleasant mix of petroleum and mining applications. We have pioneered some novel applications into precision agriculture and natural attenuation, but our focus is developing solutions to longstanding problems of heterogeneity modeling and uncertainty management.

Geologically realistic models have always been an issue in building stochastic simulation models. Advances in this area of research are numerous. Michael Pyrcz continues to explore the integration of architectural elements through hierarchical trend models and a library of training images for geostatistical model construction. A relatively new student, Paula Larrondo is beginning her research in geostatistical modeling accounting for uncertainty in geological boundaries and will present her results in next year's report. Paula presents her "warm up" project on semi-automatic variogram fitting.

Trends are an important consideration for any numerical geological model. Michael Pyrcz presents a methodology to construct hierarchical trend models that honour the depositional environment, and Oy Leuangthong presents an alternative transformation to handle simulation of detrended data.

Over the years, production data integration has been one of the prominent areas of CCG research. Zulfiquar Reza continues to pursue this research even after completing his PhD and presents some papers on his latest advances in variogram, fault and ϕ/K inversion. Linan Zhang presents her latest results in integrating well test pore volumes in reservoir modeling, and Stefan Zanon

presents a methodology to integrate multiple geological, geophysical and engineering variables to predict reservoir performance. Collaboration with Dr. Luciane Cunha continues to grow.

Multipoint statistics is gaining popularity. The idea of accounting for higher order statistics, beyond the second-order statistics of the variogram, has been a major area of research for the CCG. Julian Ortiz wraps up his PhD in this area with some interesting and innovative ideas about a data-driven multipoint statistical approach to simulation, while Michael Pyrcz showcases a library of training images for fluvial and deepwater reservoirs from which these higher order statistics can be inferred. Weishan Ren begins his PhD program with a flow simulation exercise with a training image.

The theme of uncertainty formulation and assessment was introduced last year. This year, Julian Ortiz presents novel results in uncertainty upscaling using p-field simulation and Oy Leuangthong explores the use of experimental design for optimal sensitivity analysis. Stefan Zanon will focus his PhD research in this area and will present some research results at next year's meeting.

Documentation of mining case studies and software implementation guidelines all contribute to improve mining geostatistical practice. Jason McLennan presents a case study of a nickel laterite deposit and also contributes to a joint effort to document the minimum acceptance criteria for geostatistical realizations. Karl Norrena, who is nearing the end of his PhD program, presents results on semi-automatic dig limit determination. Chad Neufeld, who on the other hand begins his Ph.D. studies this month, is off to a running start with several contributions including automatic variogram fitting and optimal SMU size selection.

CCG membership has continued to increase over the last year and a half. Last year, we had eight members and the next page shows that this number has grown to thirteen members. We are happy to see strong representation from the mining industry and welcome AMEC, Barrick Gold, Maptek, Placer Dome and Teck Cominco to the CCG research team. We must be careful to balance research objectives and productivity with courting current and new members. With Clayton on sabbatical this year and Oy joining the CCG as a research associate, we anticipate that both research directions and industry relations will advance to strengthen the CCG as a center of excellence in geostatistics.

Oy Leuangthong

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CCG Staff / Researchers / Students

Following are people at the University of Alberta who are affiliated with the Centre for Computational Geostatistics. There are numerous contacts in member companies who contributed in significant ways to the results presented in this report. They are prominently acknowledged in the author lists of each paper.

- **Clayton V. Deutsch**: Professor of Civil & Environmental Engineering and Director of CCG
- **Ty Faechner**: Ph.D. graduate working on application of geostatistics and risk-qualified decision making to agricultural problems; now an instructor at Assiniboine College.
- **Paula Larrondo**: new M.Sc. student working on the rock type modeling and accounting for uncertainty in geologic boundaries.
- **Oy Leuangthong**: Ph.D. graduate working on multivariate geostatistical methods; now a research associate with the CCG.
- **Jason McLennan**: summer intern who worked on SAGD reservoir characterization, beta-testing of Pangeos software, and various case studies for both mining and petroleum.
- **Chad T. Neufeld**: new Ph.D. student working on dig limits and mine planning.
- **Karl P. Norrena**: Ph.D. student working on decision making in the presence of uncertainty and application of optimization techniques for geostatistical modeling; now working with Nexen Canada Ltd.
- **Julian Ortiz C.**: Ph.D. graduate working on multiple point statistics for geologically-realistic models; now a postdoctoral fellow jointly with Stanford and the CCG. Soon to resume a professorship at the University of Santiago, Chile.
- **Bora Oz**: Ph.D. student working on scaling relationships in presence of complex geologic structures; now working with Shell International in Calgary.
- **Michael J. Pyrcz**: Ph.D. student working on integration of geological elements for stochastic simulation.
- **Weishan Ren**: new Ph.D. student working on integration of multiple point statistics for petroleum reservoir characterization.
- **Zulfiquar A. Reza**: Ph.D. graduate working on the integration of historical production data in reservoir models; now a professor at the Bangladesh University (BUET).
- **Stefan Zanon**: M.Sc./Ph.D. student working on the integration of secondary data and improved Gaussian simulation techniques.
- **Linan Zhang**: Ph.D. student working on the integration of production data in geostatistical reservoir models.