Predictive Geometallurgy and Geostatistics Lab
Queen's University

Annual report 2021

This report summarizes the ongoing research of the Predictive Geometallurgy and Geostatistics Laboratory at Queen's University in Kingston, Ontario, Canada. 2021 was a challenging year, with continuous restrictions to meetings and limited group interactions. Despite these difficulties, the lab completed important and novel work. The delay in the release of this report is just another sign of the strain of the last couple of years, however, results are encouraging and the lab is doing important contributions to research and industry.

This year, two students graduated, one Master of Applied Science and one Doctor of Philosophy, two new students joined the group. The following two theses were completed in this period:

- Mehmet Altinpinar, M.A.Sc. (Sep. 2021), "***Synthetic high resolution block model for benchmarking mining technologies***"
- Sebastian Avalos, Ph.D. (Sep. 2021), "***Advanced predictive methods applied to geometallurgical modelling***"

The work in this annual report includes that of the six graduate students active in 2021. The research group is composed of:

- Mehmet Altinpinar, M.A.Sc. student
- Sebastian Avalos, Ph.D. student (continues as a Post-Doc)
- David Casson, Ph.D. student
- Kasimcan Koruk, M.A.Sc. student
- Paula Larronfo, Ph.D. student
- Alvaro Riquelme, Ph.D. student

Two new M.A.Sc. students started their programs in 2021

- Noble Potakey, M.A.Sc. student
- Alvaro Mariño, M.A.Sc. student

We continued collaboration with other faculty members and researchers, including:

- Willy Kracht, Adjunct Professor – The Robert M. Buchan Department of Mining (Queen's University) and Associate Professor – Department of Mining Engineering (U. de Chile). Dr. Kracht and Dr. Ortiz co-supervise Carlos Moraga in his Ph.D. in Mining Engineering at Universidad de Chile.

- Asli Sari, Assistant Professor – The Robert M. Buchan Department of Mining (Queen's University). Dr. Ortiz and Dr. Sari co-supervised Mehmet Altinpinar in his M.A.Sc.
- Raimon Tolosana-Delgado, Senior Scientist (Helmholtz-Zentrum Dresden-Rossendorf). Dr. Tolosana-Delgado hosted a research internship of Sebastian Avalos.
- Brian Frank, Professor – Electrical and Computer Engineering (Queen's University). Dr. Frank and Dr. Ortiz co-supervise Paula Larrondo in her Ph.D.

Eight contributions are available this year, totaling 92 pages, with very innovative topics, including causal inference, reinforcement learning, and topology of random fields, in addition to documentation of machine learning methods, planning and geostatistical methods. Industrial collaboration continues with SRK Consulting Canada, Natural Research Council (NRC) and ArcelorMittal Mining Canada G.P.

As always, we welcome industrial and academic collaboration. This provides opportunities to fund new graduate students and novel research, and directly benefits industrial partners. If interested, please send a note to julian.ortiz@queensu.ca.

Julian M. Ortiz
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Journal and Conference Publications and Presentations

Publications in book chapters, peer-reviewed journals and international conferences are listed below for 2021. These are not included in this report, since the copyright belongs to the corresponding publishers, but can be requested for personal use or research purposes directly to julian.ortiz@queensu.ca.

Book chapters

1. Sadeghi B, Ortiz JM (2021) ***Simulation***, in Encyclopedia of Mathematical Geosciences, Daya Sagar B, Cheng Q, McKinley J, Agterberg F (Eds.), Encyclopedia of Earth Sciences Series, Springer, Cham, 6 p. https://doi.org/10.1007/978-3-030-26050-7_292-1

2. Caers J, Mariethoz G, Ortiz JM (2021) ***Multiple Point Statistics***, in Encyclopedia of Mathematical Geosciences, Daya Sagar B, Cheng Q, McKinley J, Agterberg F (Eds.), Encyclopedia of Earth Sciences Series, Springer, Cham, 11 p. https://doi.org/10.1007/978-3-030-26050-7_24-1

Journal papers

1. Cevik IS, Leuangthong O, Cate A, Ortiz JM (2021) ***On the use of machine learning for mineral resource classification***, Mining, Metallurgy & Exploration, 38:2055-2073. https://doi.org/10.1007/s42461-021-00478-9

2. Faraj F, Ortiz JM (2021) ***A simple unsupervised classification workflow for defining geological domains using multivariate data***, Mining, Metallurgy & Exploration, 38: 1609-1623. https://doi.org/10.1007/s42461-021-00428-5

3. Riquelme AI, Ortiz JM (2021) ***Uncertainty assessment over any volume without simulation: revisiting multi-Gaussian kriging***, Mathematical Geosciences, 53:1375-1405. https://doi.org/10.1007/s11004-020-09907-9 (Correction: https://doi.org/10.1007/s11004-021-09927-z)

4. Cevik IS, Ortiz JM, Olivo GR (2021) ***A combined multivariate approach analyzing geochemical data for knowledge discovery: the Vazante-Paracatu Zinc district, Minas Gerais, Brazil***, Journal of Geochemical Exploration, Vol. 221, 106696. https://doi.org/10.1016/j.gexplo.2020.106696

Conference papers and presentations

1. Riquelme AI, Ortiz JM (2021) ***A non-stationary linear model of coregionalization***, in 11th International Geostatistical Congress, Toronto 2021, July 12-16, 2021.

2. Avalos A, Ortiz JM (2021) ***Geometallurgical modeling and deep Q-Learning to optimize mining decisions***, in 11th International Geostatistical Congress, Toronto 2021, July 12-16, 2021.

3. Cevik IS, Leuangthong O, Cate A, Machuca-Mory D, Ortiz JM (2021) ***Mineral resource classification using machine learning***, in 11th International Geostatistical Congress, Toronto 2021, July 12-16, 2021.

4. Larrondo P, Frank B, Ortiz JM (2021) ***State of the art in providing automated feedback to open-ended student work***, CEEA/ACEG 2021, Annual Conference of the Canadian Engineering Education Association, Charlottetown, PEI, June 20-23, 2021.

5. Riquelme AI, Ortiz JM (2021) ***An approach to characterize complex geological models based on higher-dimensional surfaces***, Geomin-Mineplanning 2021, 7th International Conference on Geology and Mine Planning, June 9-11, 2021.

6. Avalos S, Ortiz JM (2021) ***Open pit mine scheduling via deep Q-Learning***, Geomin Mineplanning 2021, 7th International Conference on Geology and Mine Planning, June 9-11, 2021.

7. Avalos S, Ortiz JM (2021) ***Heuristic risk-based policy to outline final pit in open mines***, CIM VTL 2021, Virtual Convention + Expo, May 3-6, 2021.

8. Riquelme AI, Ortiz JM (2021) ***A geostatistical approach to characterize complex geology***, CIM VTL 2021, Virtual Convention + Expo, May 3-6, 2021.

9. Ortiz JM (2021) ***Geometallurgical modeling to manage uncertainty in a mining system***, invited talk, 10 Years of Helmholtz Institute Freiberg for Resource Technology, September 9, 2021, Germany.

10. Ortiz JM (2021) ***Machine learning in mining***, invited webinar, Colegio de Ingenieros de Peru – Consejo Departamental de La Libertad, Apr 23, 2021. https://fb.watch/575-W1q_nB/

11. Ortiz JM (2021) ***Predictive models in geometallurgy***, invited seminar, Geoblast Chile, Dec 16, 2020.

12. Ortiz JM (2021) ***Multiple point geostatistics to model rock textures***, invited talk, NRC (National Research Council), Nov 5, 2020.

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