RawMat2021
International Conference on Raw Materials and Circular Economy
Athens | 05-09 September 2021

Machine Learning Based Systems Application to Mineral Resource Estimation and Compliance with Reporting Codes for Mineral Resources

Ioannis Kapageridis, Ioannis Sinatkas, Argyro Asvesta and Agni Patra

About this presentation

- International reporting codes for Mineral Resources and Reserves have been developed and adopted by the mining industry to raise the standards of produced reports, and increase confidence in mining investments.
- Reporting codes set minimum standards, recommendations, and guidelines for public reporting of Exploration Results, Mineral Resources, and Mineral Reserves.
- Machine learning (ML) algorithms have been used in various steps of Mineral Resource estimation in the last four decades, and have found their way in to commercially available software products.
- Due to the automated nature of these algorithms and the associated time saving, estimation practitioners tend to accept their results with little knowledge and control of how they work.
- In this presentation we will discuss compliance issues related to the application of ML based systems to Mineral Resource estimation.

Machine Learning Methods and Mineral Resource Estimation – the early days

- Machine learning (ML) methods have been gradually introduced to various tasks related to Mineral Resource estimation since the eighties.
- By the early nineties, a few ML methods have been developed and implemented in commercially available software, related to mostly simple tasks such as variogram model fitting and sample clustering.
- Early nineties were also a time when artificial intelligence (AI) techniques received a lot of attention from the scientific community, including people involved in geostatistics and Mineral Resource estimation.
- Expert systems, artificial neural networks (ANN) and genetic algorithms (GA) were used as the basis of quite a few research projects in the field, and it was a common belief that AI techniques could be combined with or eventually replace geostatistics.

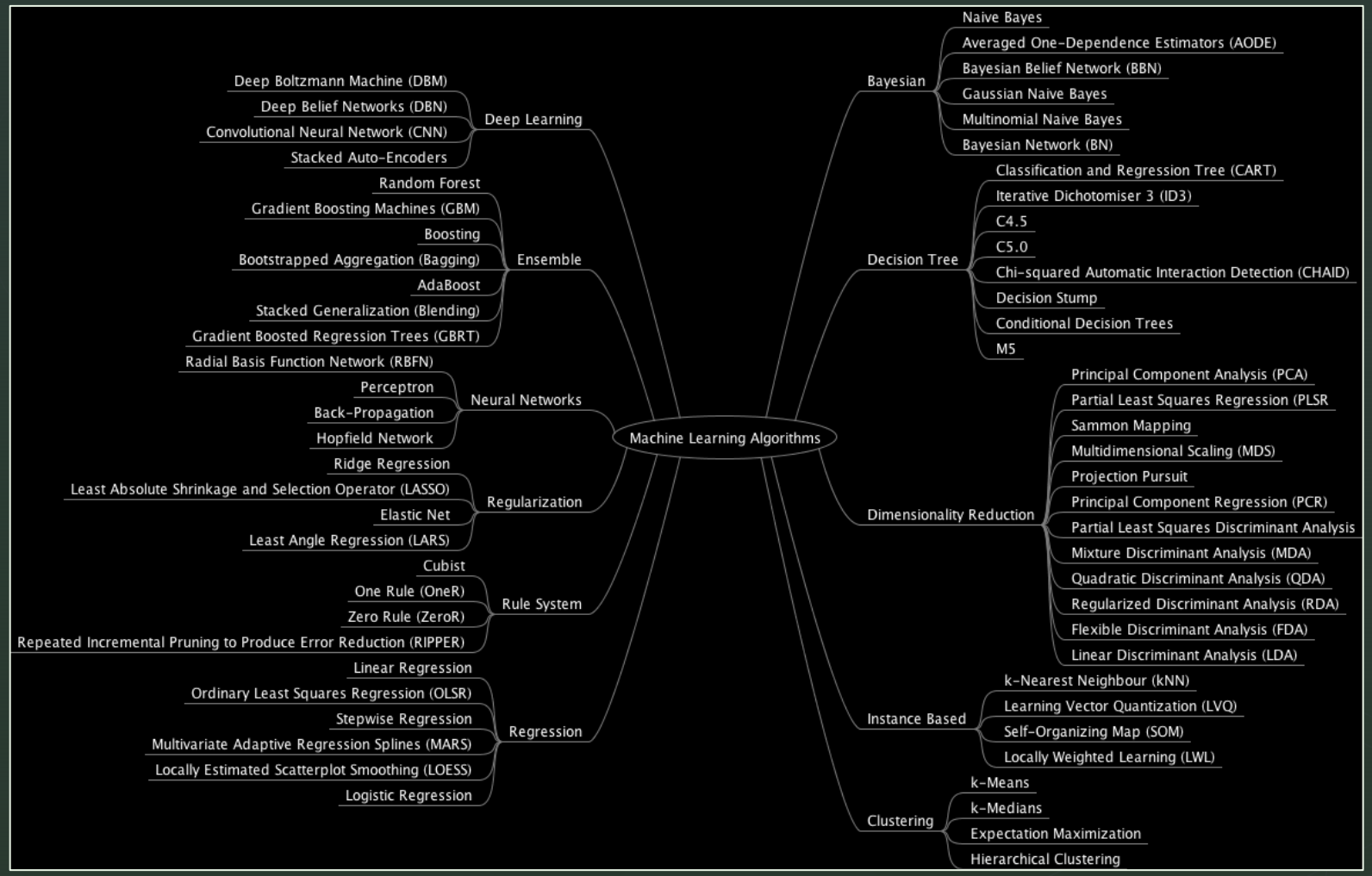
Machine Learning Methods and Mineral Resource Estimation – after the dust settled…

- Most of these techniques were (and still are) computationally intensive, and the hardware available at the time was not capable of producing results within acceptable time limits, leading to a lot of research remaining at a prototype level, never reaching the implementation stage as a tool available to the mining industry.
- The general conception that ML techniques are black box approaches, combined with the development of reporting standards for reporting of Mineral Resources and Mineral Reserves in the late eighties – early nineties also pushed estimation practitioners away from adopting ML techniques for critical tasks such as geological modelling or grade estimation.

Machine Learning Methods and Mineral Resource Estimation – lately…

- The speed of current computing systems, personal or cloud based, has allowed for complex models to be built using machine learning algorithms within minutes, leading to a few commercial implementations becoming available to Mineral Resource estimation practitioners and gaining their acceptance as reliable systems.
- The successful application of machine learning systems in other areas related to mining has also paved the way for the acceptance of machine learning for Mineral Resource Estimation tasks.
- In the last decade, several Mineral Resource estimation reports, part of various levels of study from preliminary economic assessments to feasibility studies, were based to some extent on the results of machine learning algorithms application.
- Estimation practitioners are under pressure to produce results quickly and keep costs down to take advantage of commodity demand and price cycles, sometimes at the expense of maintaining a good standard in conducting technical and economic assessments.

Overview of Machine Learning Methods



(Brij Rokad, Machine Learning Approaches and Its Applications, Data Driven Investor, 2019)

Machine Learning Applications in Mineral Resource Estimation

- **Experimental variography and variogram model fitting** (clustering and regression methods)
- **Samples clustering** (clustering methods)
- **Sample dimensionality reduction** (PCA and other reducers)
- **Samples classification** (SVM, neural networks, clustering)
- **Geological / resource estimation domain modelling** (neural networks)
- **Spatial interpolation / grade estimation** (mostly neural networks, combinations with kriging)
- **Grade estimation parameters optimisation** (genetic algorithms)

Overview of Reporting Codes

- Reporting Codes have been adopted by and included in the listing rules of the relevant securities exchanges, and impose specific requirements on exploration and mining companies reporting to these exchanges.
- Furthermore, the Codes have been adopted by the relevant professional bodies, associations, and councils and are binding on members of those organizations.

Code	Region	Publisher
JORC Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves	Australasia	Joint Ore Reserves Committee of the Australasian Institute of Mining & Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia
PERC Pan-European Code for Reporting Exploration Results, Mineral Resources and Reserves	Europe	The Pan-European Reserves and Resources Reporting Committee (PERC)
SAMCODES South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves	South Africa	Working Group of the SAMREC/SAMVAL Committee
SME Guide for Reporting Exploration Results, Mineral Resources, and Mineral Reserves	United States	The Resources and Reserves Committee of the Society for Mining, Metallurgy, and Exploration, Inc (SME)
National Instrument 43-101	Canada	Canadian Securities Administrators

Reporting Code Considerations

- The main principles governing the operation and application of most Reporting Codes are:
  - **transparency:** adequate information is presented clearly and unambiguously,
  - **materiality:** considers all relevant information available at the date of reporting and,
  - **competence:** work is prepared by suitably qualified and experienced **Competent Persons**
- All codes make reference to a Competent (or Qualified) Person – CP, defined more or less in the same way as to qualifications, experience and certification.

Transparency

- It is important to provide transparent and consistent reporting of Mineral Resources, Mineral Reserves, and study outcomes, and to provide a discussion on the expected accuracy, precision, and confidence levels of the estimates.
- If the assumptions related to the reported estimates are not made transparent by the CP, then one CP may report very different Mineral Resource quantities to another, even using the same basic data.
- So the question then is, how can CPs responsible for the report, and the practitioners involved in producing the estimates, make these assumptions transparent when they don’t and/or can’t understand the system they have used to produce them?

Competence

- Even though **competence** mostly refers to the experience in the style of mineralisation or type of deposit under consideration, the issue lies not with the definition of the Competent Person but with the related duties of CPs responsible for producing the estimates.
- When it comes to machine learning methods, there are very few CPs with related knowledge.
- The available knowledge of how commercially available machine learning based systems work is very limited, as software vendors are commonly protective of their intellectual property.
- The automated nature of these systems also leaves CPs with little control of how results are produced.
- All these factors place the CP in a difficult position, not being able to effectively report the assumptions and associated risks.

Conclusions - Recommendations

Software Vendors

- Provide information on how their systems work that will allow the estimation practitioner to be **Competent** in using them and for the produced report to satisfy reporting code requirements for **Transparency**.
- Provide more **Controls** to the practitioner as to the way the ML based system produces results.
- Integrate measures of **Confidence** of the results produced by the ML based system – these should be clearly explained as to how they are calculated and how they should be interpreted.

Practitioners

- Maintain competency by learning the principles of ML based systems through personal development.
- Adhere to the principles of reporting codes and good practice in general and not sacrifice them for time and effort saving.

Academia

- Incorporate ML and AI in undergraduate and postgraduate study programmes for engineers and geologists.
- Incorporate subjects related to reporting codes, risk management, and investment analysis.

Thank you for your attention!