EC055: Geostatistics for the Energy Industry

Format and Duration

Self-Paced - 10 Hours

Summary

This course will introduce the practical principles and workflows that are used when building subsurface models for the energy industry. This course will start by considering the wide application of geostatistics within the energy sector. Gathering, cleaning and analysing the data to be used alongside managing missing data and how to deal with sparse data situations will be discussed. The learner will be introduced to the variogram and instructed on creation of both the horizontal and vertical variogram for use in geostatistical modelling.

Kriging and conditional simulation are the modelling and simulation methods used in geostatistics to estimate and predict values at unsampled locations. These techniques produce maps along lines, areas and volumes with a high degree of statistical rigour that emphasises the assessment of uncertainty. Both methods will be discussed in detail with reference to the variogram. Finally the learner will gain an appreciation of how to summarise a geostatistical model at the post processing stage for use in economic assessment and to prepare for a dynamic simulation.

Learning Outcomes

Participants will learn to:

1. Appreciate the broad application of geostatistics to the energy industry.
2. Develop an understanding of regionalised variables and the difference between classic statistics and geostatistics.
3. Understand how to manage missing and sparse data when building inputs for a geostatistical model.
4. Use classic statistical and graphical display techniques to summarise data.
5. Learn about the definition, function and construction of a variogram and how these are used in geostatistics.
6. Learn about kriging and conditional simulation and appreciate how the variogram applies to these techniques.
7. Understand how to summarise geostatistical models and prepare a model for dynamic simulation.

Training Method

This is a self-paced e-learning course, approximately 10 hours learning time, consisting of 10 modules. Within each module the learning materials are structured into short sections, each including interactive text and image content, animations, video, and audio. Each module has a scored quiz at the end to provide the learner with their learning progress.

Who Should Attend

This course is aimed at anyone in the energy industry who wants to understand and model subsurface data for the process of dynamic simulation and economic assessment.

Course Content

Exploratory Data Analytics

This module looks at the origins of geostatistics, tracing its development and foundational principles. It explores the diverse applications of geostatistics across different industries, highlighting how it plays a crucial role in fields such as mining, environmental science, and energy. The module introduces Geostatistical Modelling, emphasising the distinctions between Deterministic and Stochastic solutions, which are key to accurate spatial predictions and risk assessments. Additionally, the learner will consider the different data formats and the difference between Categorical and Continuous variables, helping learners appreciate how these data types influence Geostatistical analysis and decision-making.

Univariate and Bivariate Statistics

This module covers key statistical methods used in data analysis, starting with univariate statistics, which focus on analysing single-variable data using typical statistical measures like mean, median, variance, and standard deviation. It then explores bivariate statistics, which examine relationships between two variables through tools like covariance and the correlation coefficient, helping to understand how variables interact. The discussion extends to regression analysis and geostatistical methods such as co-kriging, where an example is considered developing porosity maps by integrating seismic acoustic data and porosity well logs. Finally, multivariate statistics are introduced, emphasising predictive and imputation methodologies that handle complex data with multiple variables, enhancing data analysis and decision-making processes.

Data Analytics

This module considers techniques for managing missing and sparse data when preparing inputs for geostatistical models, which is crucial for ensuring the accuracy and reliability of the models. Pattern recognition is highlighted as a valuable tool in these scenarios, helping to identify trends and make informed estimates where data is lacking. The importance of graphical displays, such as histograms, bar charts, and box plots, is also emphasised as they provide visual insights into data distribution, variability, and outliers, making complex data easier to interpret. Additionally, the module covers the Gaussian distribution and the Normal Score Transform, key statistical concepts that help in normalising data and improving the quality of geostatistical analyses by transforming skewed data into a normal distribution.

Spatial Analysis Principles

This module explores how geostatistics, which specifically addresses spatial data, plays a crucial role in the petroleum industry by modelling subsurface variability, aiding in resource estimation and decision-making. Three fundamental geostatistical tools are introduced: variograms, kriging, and conditional simulation. Variograms are essential for understanding spatial correlation, defining how similarity between data points changes with distance. They are constructed by analysing data pairs at varying distances to quantify spatial continuity, influencing the weighting process in kriging, which uses these spatial relationships to predict values at unsampled locations. Conditional simulation further extends these techniques by generating multiple possible scenarios, providing a comprehensive understanding of uncertainty. Together, these tools enhance the accuracy of subsurface modelling.

Variograms

In this module, you will learn how to construct different types of variograms, essential tools in geostatistics for analysing spatial relationships. You will explore the construction of horizontal, vertical and directional variograms, that capture spatial dependencies in specific directions, revealing anisotropies in the data. The module will also cover the key parameters of a variogram. Finally, you will learn how to construct a 3D horizontal variogram, which extends variography concepts into three dimensions, providing a comprehensive view of spatial patterns and aiding in more accurate modelling of complex geological structures.

Spatial Modelling

In this module, you will gain a comprehensive understanding of the nugget effect, a phenomenon that reflects either measurement errors or very small-scale variability in spatial data, and learn how to avoid inducing a false nugget effect when constructing variograms. The module will also cover the integration of horizontal and vertical variograms to capture comprehensive spatial relationships. Additionally, the module details common model types and the importance of directions of continuity. Finally, you will learn about variogram polar plots, which provide a visual representation of spatial continuity and directionality, aiding in the assessment of anisotropic behaviours in subsurface models.

Geostatistical Estimation Methods

In this module you will learn how kriging, a geostatistical interpolation method, works by using spatial correlation to provide predictions at unsampled locations, setting it apart from other interpolation techniques that do not account for spatial relationships. The importance of neighbourhood design in kriging is emphasised, as it determines which data points are considered for estimation, influencing the accuracy and reliability of predictions. Kriging is known as B.L.U.E (Best Linear Unbiased Estimate) because it provides the most accurate and unbiased predictions by minimizing error variance using the variogram—a key tool that models spatial continuity and impacts the kriging weights. The module also covers multivariate kriging, which extends kriging principles to multiple variables, allowing for the integration of correlated datasets, enhancing predictions and providing a more comprehensive approach to spatial modelling.

Conditional Simulation Principles

Understanding the importance of variance is crucial when building Earth models, as it helps to quantify the uncertainty in predictions and assessments of geological structures and properties. Variance plays a key role in enhancing the accuracy and reliability of these models by accounting for natural variability in Earth processes. Conditional simulation methods, such as Monte Carlo Simulation, Conditional Simulation, and Unconditional Simulation, are essential techniques used to address this uncertainty. Monte Carlo Simulation, for example, generates multiple possible scenarios based on random sampling, while Conditional and Unconditional Simulations offer different ways to incorporate known data or operate independently of specific constraints. These approaches collectively help to produce more robust and realistic Earth models.

Post Processing

This module compares kriging and conditional simulation, two of the geostatistical techniques used for spatial prediction and modelling that have been discussed through this course. The module also covers post-processing options, including uncertainty mapping, which visualizes the degree of confidence in different areas of the model, and ranking, which helps prioritize the most likely scenarios. Additionally, you will learn about cumulative probability distributions, which are used to quantify the probability of outcomes across multiple realizations, offering a statistical overview that helps assess risks and make data-driven choices in spatial modelling.

Common Simulation Methods

This module introduces common simulation methods used in geostatistical modelling, focusing on both pixel-based and object-based approaches. The module also explores the multivariate form of conditional simulation, which extends traditional simulation techniques by incorporating multiple correlated variables simultaneously. This approach allows for a more realistic representation of complex geological settings, as it accounts for the interrelationships between different properties, such as porosity and permeability, enhancing the accuracy of subsurface models and providing a comprehensive view of spatial uncertainty.