

From Data to Dynamics

Advanced Process Modelling for Chemical Engineering

Dates:	February 16–20, 2026
Duration:	4 hours/day
Venue:	Dept. of Chemical Engineering, NIT Calicut
Instructor:	Ranjeet Utikar
Affiliation:	Curtin University

Process modelling is central to chemical engineering, from conceptual design to the ongoing optimization of brownfield assets. It provides the rigorous framework necessary to predict equipment performance, ensure process safety, and maximize economic returns in an increasingly competitive landscape.

Modern engineering systems present multidimensional challenges and simple analytical solutions do not always provide a complete picture. For example, process data is often noisy and highly correlated; reaction kinetics are non-linear; and multiphase flows exhibit complex spatiotemporal behavior. Addressing these issues requires a convergence of techniques. Process engineers must now be well versed in both data-driven strategies, to extract value from operational historians, and mechanistic approaches, such as Computational Fluid Dynamics (CFD), to resolve physical phenomena at the unit operation scale.

The purpose of this short course is to provide the essentials of advanced process modelling to participants in a compact format. The course starts with an introduction to data-driven foundations (handling noise and multivariate correlations), and covers latent variable methods such as principal component analysis, partial least squares; nonlinear modelling like decision trees and neural networks; and the fundamentals of CFD.

The course employs lectures, practical sessions, and case studies. Practical work involves the exploratory analysis of engineering datasets and model training, while case studies examine systems such as industrial separators. The course is designed for beginners and experienced students alike. It provides beginners with a sound basis in modelling literacy and allows experienced students to refresh their knowledge of modern computational tools.

Course Program

Part 1: Data-Driven Foundations

Day 1: Data-Driven Modelling

- Modelling Landscape: First principles vs. Empirical models. Simulation vs. Prediction.
- Data Reality: Handling noise, drift, bias, and missing values. Design of experiments.
- Multivariate Analysis: Moving beyond single-variable plots. Correlation and scaling.
- Hands-on: Exploratory analysis of real engineering datasets.

Day 2: Latent Variable Methods

- Principal Component Analysis (PCA): Geometric interpretation, fault detection, and data compression.
- Partial Least Squares (PLS): Regression under collinearity. Interpretation of latent variables.
- Hands-on: Building PCA/PLS models for process monitoring.

Day 3: Nonlinear & ML Models

- Tree-Based Models: Random Forests, Decision Trees, and preventing overfitting.
- Model Interpretation: Variable importance and “Black Box” transparency.
- Neural Networks: From Perceptrons to Deep Learning basics.
- Hands-on: Benchmarking ML against classical latent variable methods.

Part 2: Computational Fluid Dynamics

Day 4: CFD Fundamentals

- Governing Equations: Conservation laws and transport phenomena.
- Numerical Core: Finite Volume Method, stability, and convergence.
- Meshing Mastery: Grid independence and avoiding common pitfalls.
- Hands-on: Simulation of single-phase flow systems.

Day 5: Advanced Multiphase Flows

- Multiphase Approaches: Eulerian-Eulerian, VOF, and Particle Tracking.
- Closure Models: Drag, turbulence, and scale dependence.
- The Frontier: DEM, DNS, and hybrid Physics + Data models.
- Hands-on: Eulerian simulation of gas-solid flow.

Target Audience and Learning Outcomes

The course is designed for final year undergraduate and postgraduate chemical engineering students who need to understand the fundamentals of process modelling. It is suitable for those seeking elective coursework or professional upskilling.

Participants will learn to map theoretical concepts to real-world industrial problems and critically assess the validity, assumptions, and limitations of process models. By the end of the course, students will be able to bridge the gap between empirical data science and physical engineering.

Participants should have a foundation in chemical engineering, calculus, linear algebra, and basic programming skills. Familiarity with basic statistics and machine learning concepts is recommended but not required.

About the Instructor

Ranjeet Utikar is an Associate Professor in Chemical Engineering at Curtin University, leading the Sustainable Manufacturing and Intelligent Process Engineering (SMILE) lab. A/Prof Utikar's research focuses on process modelling, scale-up, and process intensification, bridging the gap between fundamental research and industrial application. Extensive experience in technology development across the chemical, energy, and resource sectors has led to collaborations with numerous multinational partners on the troubleshooting and optimization of complex unit operations. Also an active entrepreneur, A/Prof Utikar co-founded Tridiagonal Solutions in 2006 and Vivira Process Technologies (Vorta) in 2015, working to realize untapped applications for process waste streams.