Training Course on System Identification and Parameter Estimation

Professional Development Training Course Outline

Category	Engineering	**Duration**	10 Days
Base Fee	$3,000 USD	**Delivery Mode**	Online / On-site Hybrid

Course Introduction

Introduction

This specialized training course is designed to provide participants with a robust understanding and practical skills in System Identification and Parameter Estimation, crucial disciplines for modeling and analyzing dynamic systems across various engineering domains. Training Course on System Identification and Parameter Estimation focuses on extracting meaningful mathematical models from measured input-output data, a fundamental step for effective control system design, predictive analytics, and performance optimization. Attendees will delve into core concepts such as model structure selection, excitation signal design, least squares estimation, and model validation techniques, preparing them to accurately characterize industrial processes, economic systems, and biological models from empirical observations.

In an era driven by data-centric approaches and the pervasive influence of digital twins and predictive control, the ability to accurately identify system dynamics is more vital than ever. This course will cover trending topics such as subspace identification methods, recursive identification, nonlinear system identification, and leveraging machine learning for model discovery. Through hands-on exercises, real-world case studies, and the use of industry-standard software tools, participants will gain the expertise to build data-driven models, quantify uncertainties, and develop insights that enable proactive decision-making, fault detection, and the design of high-performance control strategies for complex and evolving systems.

Programme Curriculum

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Course Objectives

1. Understand the fundamental principles and workflow of system identification.
2. Select appropriate model structures (e.g., ARX, ARMAX, Box-Jenkins) for diverse dynamic systems.
3. Design effective excitation signals for rich data collection in identification experiments.
4. Apply various parameter estimation methods, including least squares and maximum likelihood.
5. Perform rigorous model validation to assess the accuracy and reliability of identified models.
6. Implement recursive identification techniques for online parameter tracking and adaptive control.
7. Utilize subspace identification methods for multivariable and state-space model estimation.
8. Address challenges related to noise, outliers, and disturbances in measured data.
9. Identify nonlinear system dynamics using both parametric and non-parametric approaches.
10. Apply system identification for fault detection and diagnostics in industrial processes.
11. Leverage identified models for predictive control design and process optimization.
12. Utilize specialized software tools for efficient system identification and analysis.
13. Contribute to data-driven decision-making and the development of digital twins.

Organizational Benefits

1. Improved Control System Performance: Designing controllers based on accurate models.
2. Enhanced Predictive Maintenance: Better forecasting of equipment behavior and faults.
3. Optimized Process Operation: Fine-tuning processes based on empirical models.
4. Reduced Development Time: Faster and more efficient model building.
5. Data-Driven Decision Making: Insights derived from robust system models.
6. Accurate Digital Twin Development: Creating realistic virtual representations of assets.
7. Proactive Fault Detection and Diagnosis: Early identification of system anomalies.
8. Better Understanding of System Dynamics: Deeper insights into complex processes.

9. Competitive Advantage: Leveraging advanced modeling for innovation.
10. Skilled Workforce: Empowered employees proficient in data-driven system analysis.

Target Participants

- Control Systems Engineers
- Process Engineers
- Automation Engineers
- Researchers in Academia and Industry
- Data Scientists working with dynamic systems
- Electrical Engineers
- Mechanical Engineers
- Chemical Engineers
- Robotics Engineers

Course Outline

Module 1: Introduction to System Identification

- **What is System Identification?** Definition, purpose, and relationship to control system design.
- **The System Identification Process:** Data collection, model structure selection, parameter estimation, model validation.
- **Mathematical Models in Control:** Transfer functions, state-space models, differential equations.
- **Parametric vs. Non-Parametric Models:** Overview of different modeling approaches.
- **Case Study:** Overview of identifying a simple DC motor model from input-output data.

Module 2: Data Acquisition and Experiment Design

- **Input Signal Design:** Step, impulse, PRBS (Pseudo-Random Binary Sequence), random signals, multi-sine.
- **Sampling Rate Selection:** Nyquist theorem, anti-aliasing filters.
- **Dealing with Noise and Disturbances:** Sources of noise, signal-to-noise ratio.
- **Data Pre-processing:** Detrending, filtering, outlier detection.
- **Case Study:** Designing an optimal PRBS input sequence for identifying a chemical reactor's dynamics.

Module 3: Non-Parametric Model Identification

- **Impulse Response and Step Response:** Direct estimation from input-output data.
- **Frequency Response Analysis (Bode, Nyquist Plots):** Obtaining empirical frequency responses.
- **Correlation Analysis:** Cross-correlation for impulse response estimation.
- **Spectral Analysis:** Power spectral density estimation for system characteristics.
- **Case Study:** Estimating the frequency response of a thermal process using sinusoidal input signals.

Module 4: Least Squares Estimation for Static Systems

- **Linear Regression Review:** Basic principles and geometric interpretation.

- **Least Squares Formula Derivation:** Minimizing sum of squared errors.
- **Properties of Least Squares Estimators:** Unbiasedness, consistency (under assumptions).
- **Ordinary Least Squares (OLS) Application:** Examples in curve fitting.
- **Case Study:** Estimating the static gain of a flow sensor using collected data.

Module 5: Parametric Models for Dynamic Systems

- **ARX Models (AutoRegressive with eXogenous input):** Structure, advantages, and limitations.
- **ARMAX Models (AutoRegressive Moving Average with eXogenous input):** Handling colored noise.
- **Output-Error (OE) Models:** Direct modeling of the system transfer function.
- **Box-Jenkins (BJ) Models:** Most general form for process and noise dynamics.
- **Case Study:** Selecting the most appropriate parametric model structure for a batch distillation process.

Module 6: Parameter Estimation for Dynamic Models (Batch Methods)

- **Instrumental Variables (IV) Method:** Addressing correlation between noise and inputs.
- **Prediction Error Method (PEM):** General framework for consistent estimation.
- **Maximum Likelihood Estimation (MLE):** Probabilistic approach to parameter estimation.
- **Numerical Optimization Algorithms:** Iterative methods for solving non-linear estimation problems.
- **Case Study:** Estimating parameters of an ARMAX model for a drying process using PEM.

Module 7: Model Validation and Confidence

- **Residual Analysis:** Checking for white noise, uncorrelated residuals.
- **Goodness of Fit Metrics:** R-squared, fit percentage, RMSE.
- **Cross-Validation:** Testing model performance on unseen data.
- **Uncertainty Quantification:** Confidence intervals for parameter estimates.
- **Case Study:** Validating an identified furnace temperature model against new operating data.

Module 8: Recursive System Identification

- **Recursive Least Squares (RLS):** Online parameter estimation for time-varying systems.
- **RLS with Forgetting Factor:** Adapting to changing process dynamics.
- **Kalman Filter for Parameter Estimation:** State estimation combined with parameter tracking.
- **Applications in Adaptive Control:** Online tuning of controllers.
- **Case Study:** Implementing an RLS algorithm to track changing gain in a mixing process.

Module 9: State-Space System Identification (Subspace Methods)

- **Introduction to State-Space Models:** Advantages for multivariable systems.
- **Subspace Identification Algorithms (e.g., N4SID, MOESP):** Direct estimation of state-space matrices.
- **Output-Only Identification:** Identifying models from only output measurements.
- **Handling Multiple Inputs and Outputs (MIMO) Systems:** Extending techniques to complex systems.
- **Case Study:** Identifying a state-space model for a robotic arm from input-output data for control design.

Module 10: Closed-Loop System Identification

- **Challenges of Closed-Loop Identification:** Input and output correlation.
- **Indirect Identification Methods:** Using data from closed-loop operation to identify open-loop models.
- **Direct Identification Methods:** Specific techniques for closed-loop data.
- **Impact on Control Design:** Ensuring identified models are useful for controller synthesis.
- **Case Study:** Identifying the dynamics of a process operating under PID control.

Module 11: Nonlinear System Identification

- **Challenges of Nonlinear Identification:** Increased complexity, multiple equilibria.
- **Nonlinear ARX (NARX) Models:** Extending ARX to nonlinear functions.
- **Wiener and Hammerstein Models:** Block-oriented nonlinear models.
- **Neural Network Models:** Using NNs for black-box nonlinear system identification.
- **Case Study:** Identifying a nonlinear pH neutralization process using a NARX model.

Module 12: System Identification for Fault Detection and Diagnostics

- **Residual Generation:** Differences between actual and predicted outputs.
- **Statistical Analysis of Residuals:** Detecting deviations from normal operation.
- **Parameter Tracking for Fault Detection:** Monitoring changes in system parameters.
- **Model-Based Fault Diagnosis:** Identifying the root cause of failures.
- **Case Study:** Using parameter shifts in an identified model to detect fouling in a heat exchanger.

Module 13: System Identification in Digital Twin Development

- **Digital Twin Concepts:** Virtual representation of physical assets.
- **Role of System Identification in Digital Twins:** Building accurate physics-informed and data-driven models.
- **Real-time Model Updates:** Keeping the digital twin synchronized with the physical asset.
- **Benefits for Predictive Maintenance and Optimization:** Leveraging digital twins for advanced analytics.
- **Case Study:** Creating a digital twin of a pump system using identified models for predictive health monitoring.

Module 14: Software Tools for System Identification

- **MATLAB System Identification Toolbox:** Comprehensive features for identification and analysis.
- **Python Libraries (SciPy, Scikit-learn, PyTorch/TensorFlow):** Open-source options for modeling.
- **Commercial Software (e.g., SIMULINK, LabVIEW):** Integration with control design environments.
- **Data Visualization and Analysis Tools:** Effective presentation of

Upcoming Scheduled Sessions

Start Date	End Date	Location	Price

23 Nov 2026	04 Dec 2026	Online	$2,000
23 Nov 2026	04 Dec 2026	Physical	$3,000
23 Nov 2026	04 Dec 2026	Physical	$6,000
23 Nov 2026	04 Dec 2026	Physical	$6,000
23 Nov 2026	04 Dec 2026	Physical	$12,000
23 Nov 2026	04 Dec 2026	Physical	$9,000
23 Nov 2026	04 Dec 2026	Physical	$12,000
23 Nov 2026	04 Dec 2026	Physical	$12,000

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