Essential Topics and Open Challenges in System Identification

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Essential Topics (1/3)

Nonlinear and Complex Systems Identification

- Black-box modelling (e.g., neural networks, kernel methods, deep learning)
- Hybrid and piecewise-affine systems (e.g. Takagi-Sugeno prototypes)
- Stochastic nonlinear systems (Wiener, Hammerstein, Wiener-Hammerstein models)
- Data-Driven Techniques
 - Sparse Identification of Nonlinear Dynamical Systems (SINDy)
 - Dynamic Mode Decomposition (DMD) and variants
 - Reinforcement learning and dynamic learning methods

Essential Topics (2/3)

□ Machine Learning and Deep Learning Integration

- Deep neural networks for system identification
- Interpretable and explainable AI for dynamic systems
- Transfer learning across different system models
- Distributed and Networked Systems
 - Identification of complex dynamic networks and multi-agent systems
 - Decentralised and distributed identification methods

Essential Topics (3/3)

Cyber-Physical Systems (CPS) and Digital Twins

- Digital twins for monitoring and predictive maintenance
- Real-time integration of data with physical models

Optimal Experiment Design

- Strategies for optimal data collection and experiment planning
- Adaptive and real-time experimental designs

Open Challenges (1/2)

- Robustness and Reliability
 - Numerical stability and sensitivity to noisy data
 - Management of outliers, incomplete, or corrupted data
- □ Interpretability of Data-Driven Models
 - Balancing accuracy and interpretability of models
 - Developing transparent, interpretable modelling approaches
- Computational Scalability
 - Efficient methods for high-dimensional and large-scale systems
 - Techniques for model order reduction and parsimonious modelling

Open Challenges (2/2)

Integration with Adaptive and Predictive Control

- Online and adaptive identification for closed-loop systems
- Synergies between system identification and Model Predictive Control (MPC)
- Uncertainty Management
 - Identification under parametric and non-parametric uncertainty
 - Quantification and propagation of uncertainties in predictive models
- Automated Identification Processes
 - Automatic model structure selection
 - Automation of the complete identification-validation-update cycle

Frontier Research Directions

- Quantum System Identification
 - Identification methods applicable to quantum systems and quantum algorithms
- Explainable AI (XAI) for System Identification
 - Innovative approaches for enhancing model explainability in complex systems
- Data-driven Methods for Discrete Event Systems
 - Identification of hybrid models, Petri nets, and finite automata
- Causal Modelling in System Identification
 - Differentiating causality from correlation in dynamic modelling

Thanks for your attention