Research Talk

Part 2

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Discussion Topics

1. Investigation general issues

2. Further research directions

3. Comments and Suggestions

Explainable and Interpretable Machine Learning

- **Goal**:
  - Develop Machine Learning (ML) models that clearly explain diagnostic decisions
- **Approaches**:
  - Black-box models
  - Integration of fuzzy logic and ML

Transfer Learning & Domain Adaptation

- Goal:
  - Adapt ML models trained on one system for application to similar systems
- Approaches:
  - Supervised/unsupervised transfer learning
  - Neural networks for domain adaptation
  - Shared feature extraction across different domains

Online & Incremental Fault Diagnosis

- **Goal**:
  - Real-time updating of ML models with streaming sensor data.
- **Approaches**:
  - Incremental ML methods (e.g., Online Support Vector Machines (SVM), Incremental Random Forest (IRF))
  - Adaptive feature extraction
  - Real-time model updating

Robustness against Data Corruption & Adversarial Attacks

- **Goal**:
  - Enhance model robustness to noisy, corrupted, or adversarial data
- **Approaches**:
  - Robust neural networks (Adversarial Training)
  - Robust statistical data preprocessing
  - Ensemble-based robust detection methods

Unsupervised & Semi-Supervised Fault Diagnosis

- **Goal**:
  - Develop fault diagnosis methods with limited labelled data
- **Approaches**:
  - Autoencoder-based anomaly detection
  - Density-Based Spatial Clustering of Applications with Noise (DBSCAN), Isolation Forest
  - Semi-supervised ML techniques (e.g., Co-Training algorithms)

Hybrid Approaches: Data-driven & Model-based Integration

- **Goal**:
  - Combine advantages of physical (model-based) and ML-based (data-driven) approaches.
- **Approaches**:
  - Kalman filters integrated with ML classifiers
  - Model-based feature extraction integrated into ML
  - Physical residual generation combined with ML-based decision logic

Fault Prognosis & Remaining Useful Life (RUL) Prediction

- **Goal**:
  - Extend fault diagnosis to fault prognosis and Remaining Useful Life (RUL) prediction of systems/components.
- **Approaches**:
  - Recurrent Neural Networks (RNN) such as Long Short-Term Memory (LSTM) and Gated Recurrent Units (GRU)
  - Autoregressive Integrated Moving Average (ARIMA) models
  - Deep learning-based predictive maintenance
- ***Health Aware Control (new, since 2023)***
  - Replaces FTC, sustainable control, …

Now: From Your Side…

- **Goal**:
  - New targets.
- **Approaches**:
  - Methodologies and solutions of interest for your course of studies
- **Applications**
  - Novel plants, processes and systems
  - Simulated, real or realistic
  - Hardware In the Loop (HIL)

Concluding Remarks on Future Directions

- Increasing demand for robust, adaptive, and interpretable ML methods
- Potential impact on predictive maintenance and operational efficiency
- Encouragement to pursue interdisciplinary approaches (control theory, data science, engineering)

Thanks for Listening!

From you all:
Comments and Suggestions

Please feel free to contact me via email (silvio.simani@unife.it) or phone (+393203044076) if you need help or have suggestions and recommendations regarding your thoughts and work