Centre for Applied Intelligent Systems Research

[project website]

XPM

eXplainable Predictive Maintenance XPM

Halmstad University & Inesc Tec &
Jagiellonian University & IMT Lille-Douai

Scientific Background

- Integrate explanations into AI solutions in Predictive Maintenance
- PM effectiveness depends less on the accuracy of alarms from AI…
  - than on the relevancy of actions operators perform based on these alarms
  - today, AI does not really support experts in making “smart” maintenance decisions based on the deviations that the black-box model detects
- Repair plan requires complex reasoning and planning processes
  - involving many actors and balancing different priorities
  - not realistic to be automated, with too much context to consider

Key Challenges

- Develop several different types of explanations, e.g.,
  - visual analytics, prototypical examples, deductive argumentative systems
  - in four domains: electric vehicles, metro trains, steel plants, wind farms
- Demonstrate benefits of explanations for AI decisions
  - identify component/part of the process where the problem has occurred
  - understand the severity and future consequences of detected deviations
  - choose optimal repair from several alternatives based on different priorities
  - understand the reasons why the problem has occurred in the first place, as a way to improve system design for the future

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Partners

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(coordinator)

- Halmstad University, Center for Applied Intelligent Systems Research
  - CAISR research focuses on weakly-supervised machine learning
  - “aware” intelligent systems & semi-automatic knowledge creation
- Inesc Tec, Laboratory of Artificial Intelligence and Decision Support
  - LIAAD works on modelling non-stationary data that evolve over time
  - require ability of handling regime shifts in the process generating data
- Jagiellonian University, Human-Centred AI Laboratory
  - researchers from engineering, law, psychology, games, physics
  - integration of human expert-based decision making with the AI operation
- IMT Lille-Douai
  - define a strategy for the design of predictive maintenance actions
  - optimize maintenance costs, logistic inventory and environmental conditions

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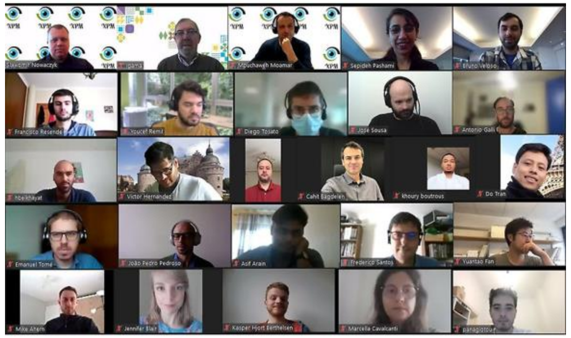
Organised Events

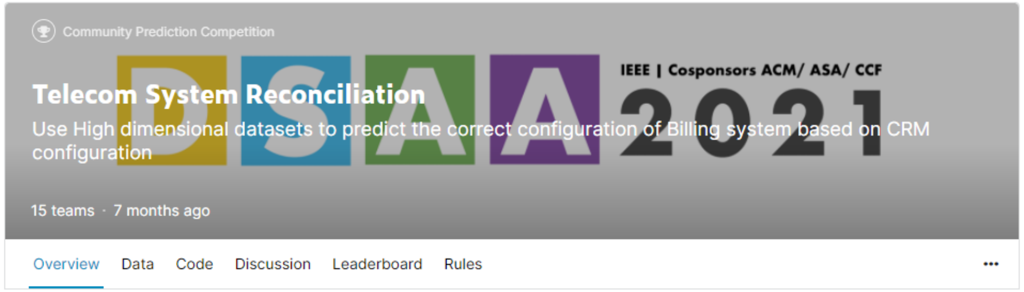
kaggle

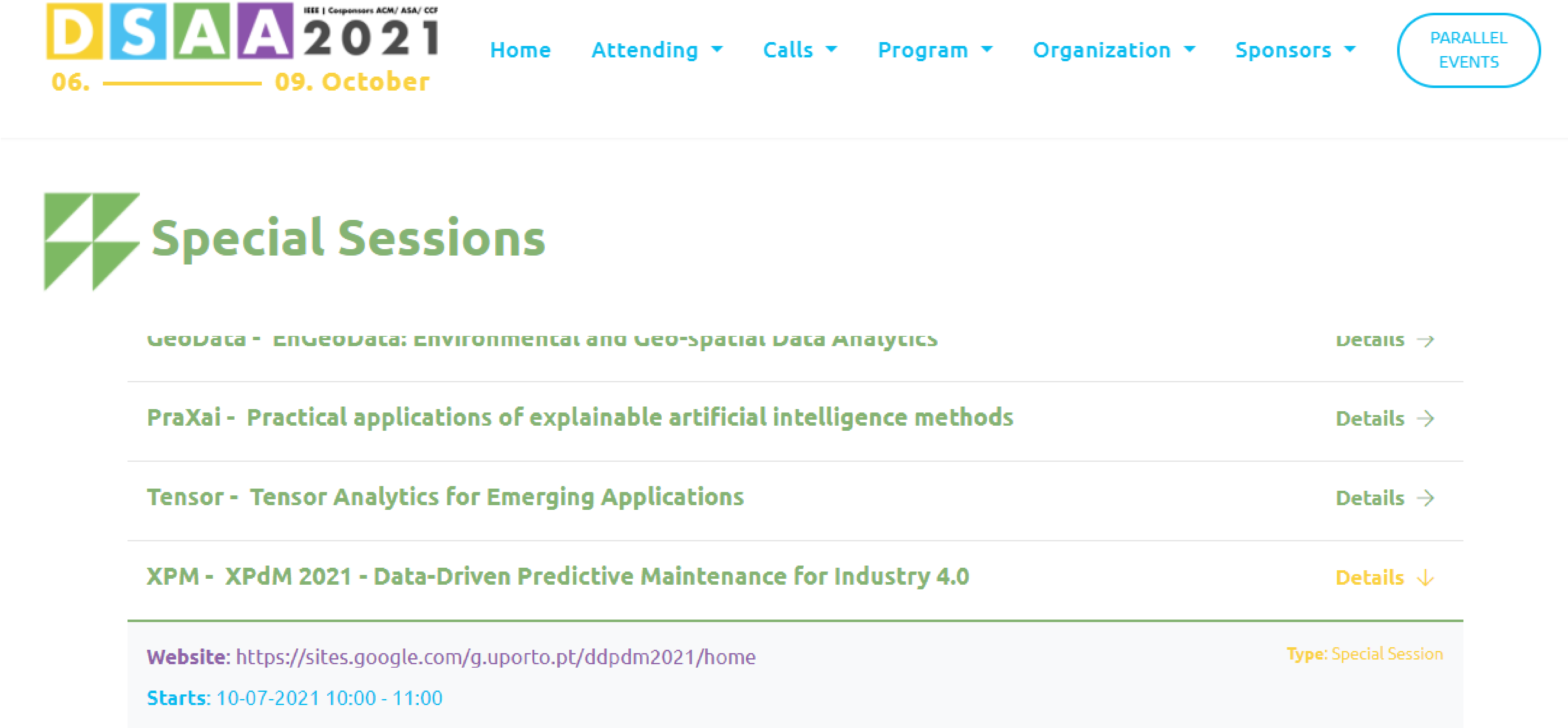
XPM

Summer School on Data-Driven Predictive Maintenance for Industry 4.0



70+ attendees





Introduction to Predictive Maintenance

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States of the equipment

- Normal/Healthy is acceptable/desired state, while Fault is an unpermitted deviation from the acceptable operating condition
- Failure is permanent inability of a system to perform its function; Failure Mode is cause of failure or one way a system can fail
- Component Degradation or Wear is change in condition over time, and Health Indicators are quantifiable characteristics of it
- Anomaly or Outlier is a deviation from the majority (or norm)

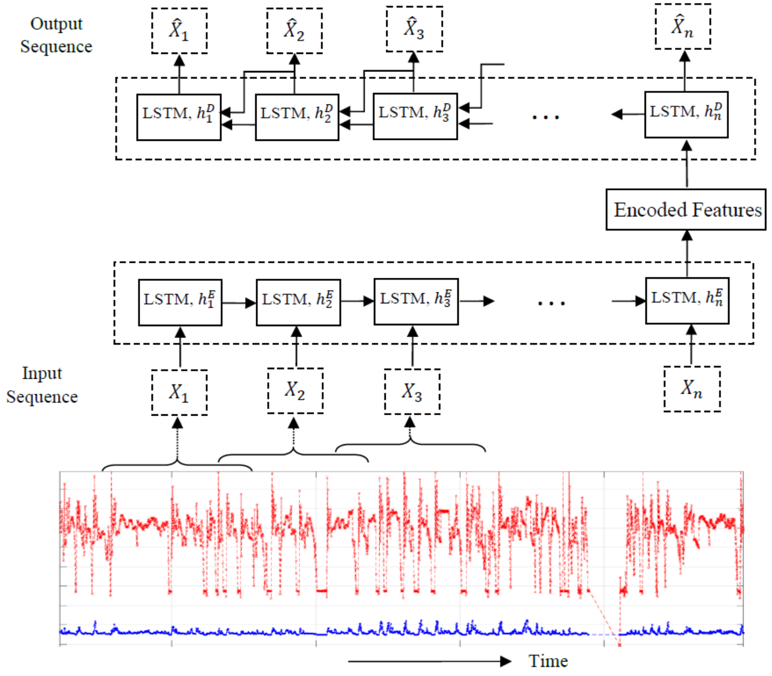
Analysis & Approach

- Fault Detection is determination of whether a fault is present in the system
- Fault Isolation is determination of the kind, location and time of fault occurrence (typically follows fault detection)
  - Root Cause Analysis is the process of discovering the underlying original causes of problems
- Fault Identification is determination of the size and time-variant behaviour of a fault (typically follows fault isolation)
- Fault Diagnosis is an overall terms combining fault isolation and fault identification
- Prognosis is determination of whether a fault (or failure) is imminent and forecasting future behaviour of the system
  - Failure Prediction is forecasting whether failure(s) will occur within a predefined future time frame
  - RUL Prediction is forecasting the time left until the equipment no longer functions correctly
  - Survival Analysis is estimating expected duration of time until an event occurs (reliability analysis, event history analysis)

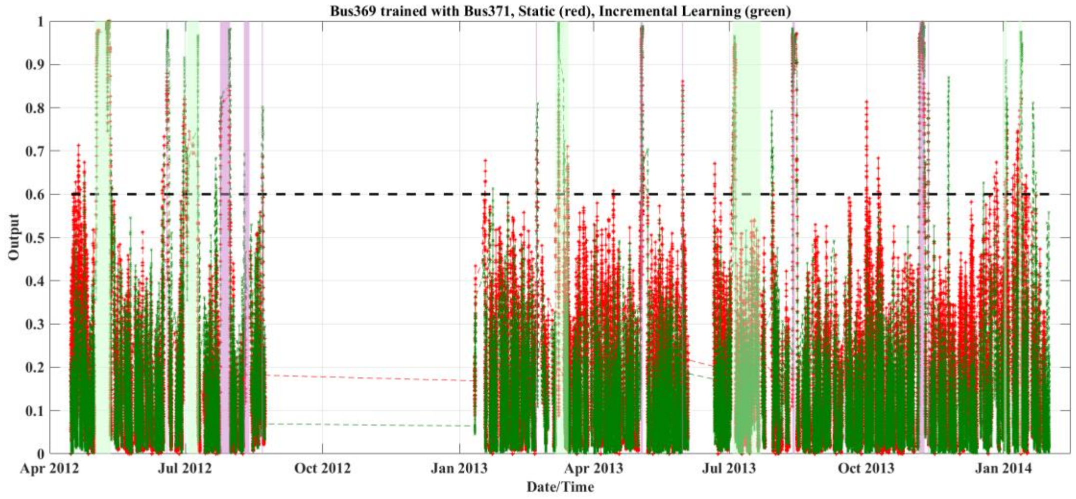
Maintenance Paradigm

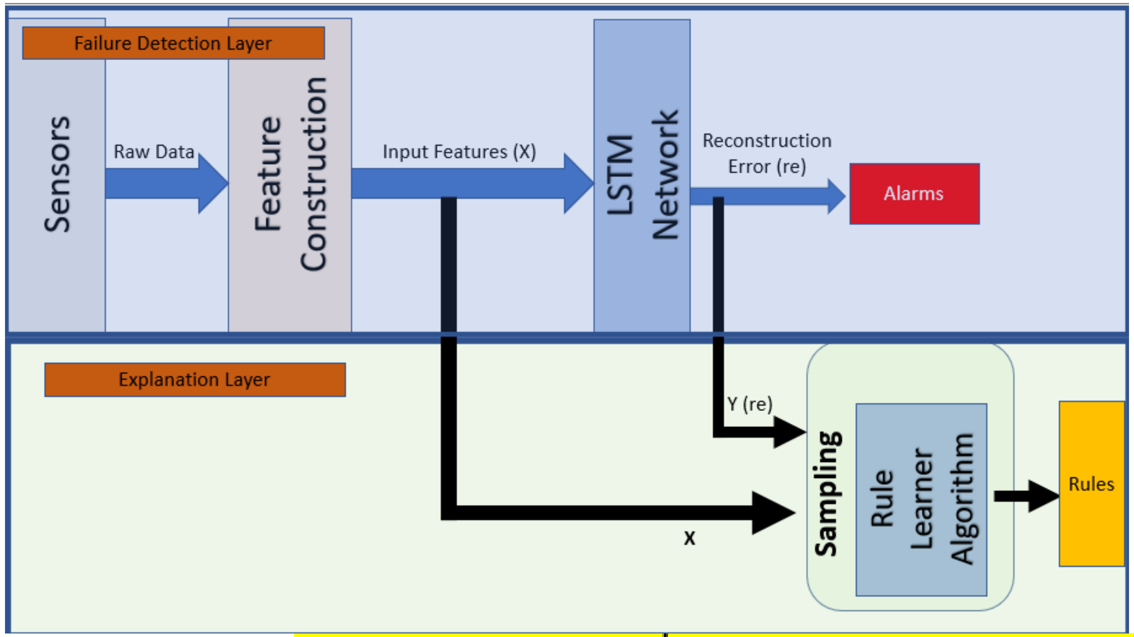
- Reactive Maintenance is performing maintenance after the equipment breakdown happens
- Preventive Maintenance are maintenance actions performed based on predetermined time intervals or age of the equipment
- Predictive Maintenance is maintenance being adaptively scheduled based on continuously monitored condition
- Prescriptive Maintenance aims to predict required maintenance measures, or a course of actions based on current condition

Incremental Learning and Anomaly Explanation



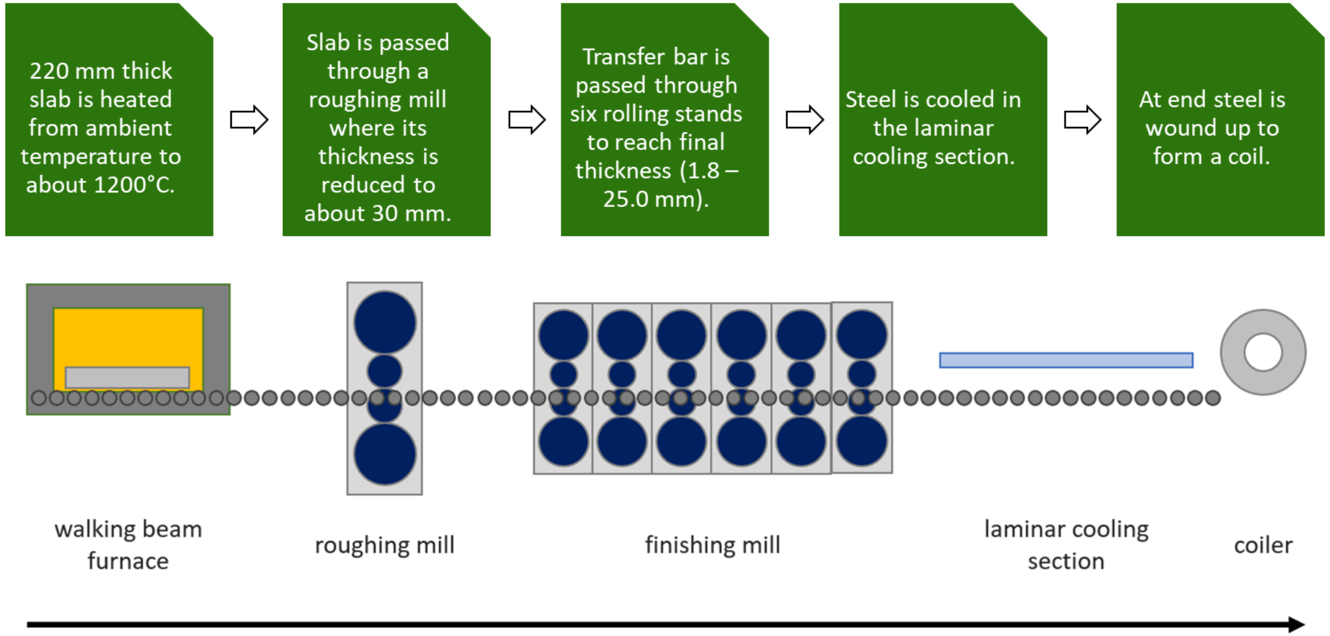
Bus 369	Mode	#FP	#TP	#FN	Precision (%)	Recall (%)	F1 score (%)
Trained with Bus 369	**Static**	3	16	1	84	94	89
	Incremental Learning	1	16	1	94	94	94
Trained with Bus 370	**Static**	5	13	4	72	76	74
	Incremental Learning	3	15	2	83	88	85
Trained with Bus 371	**Static**	4	12	5	75	70	72
	Incremental Learning	3	14	3	82	82	82





Rule Nr.1 Instances seen:125	Decil12 > 0.0 **Output:** 14.646700016

Explainable Anomaly Detection for Asset Degradation



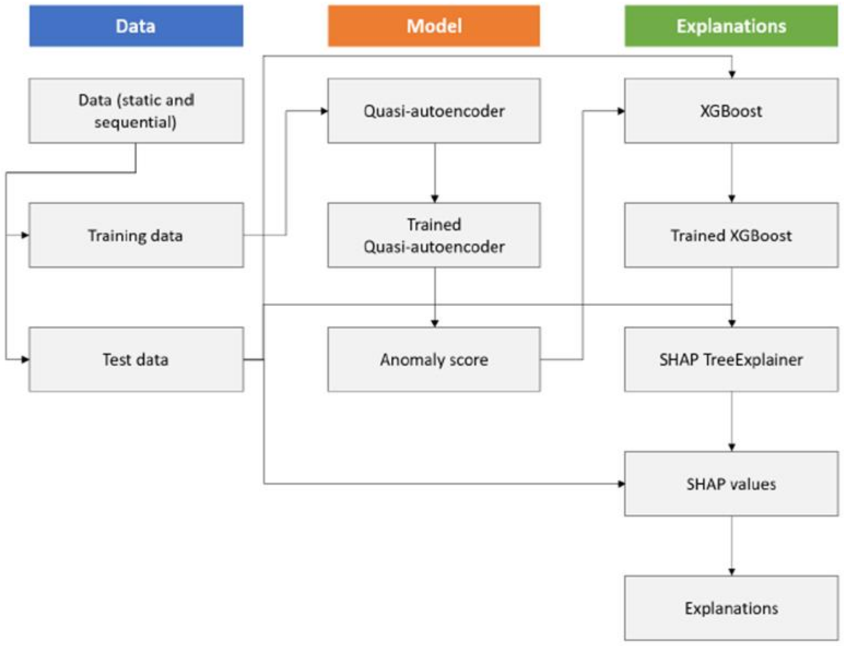
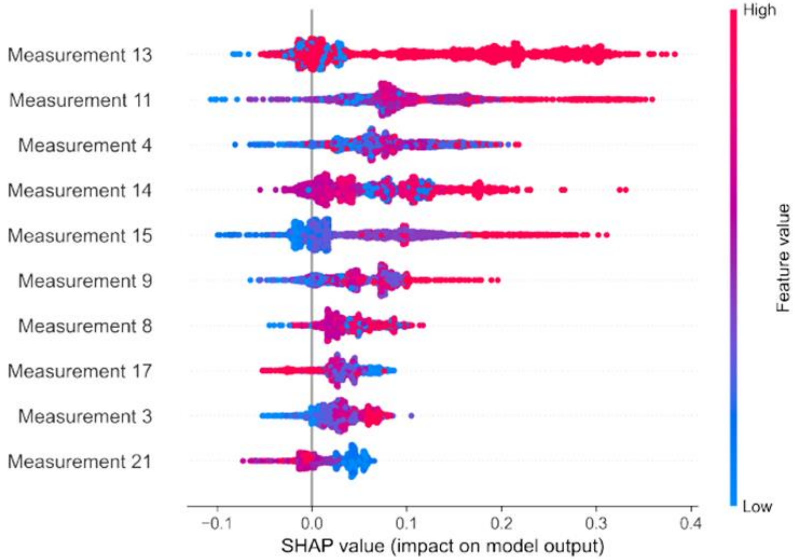


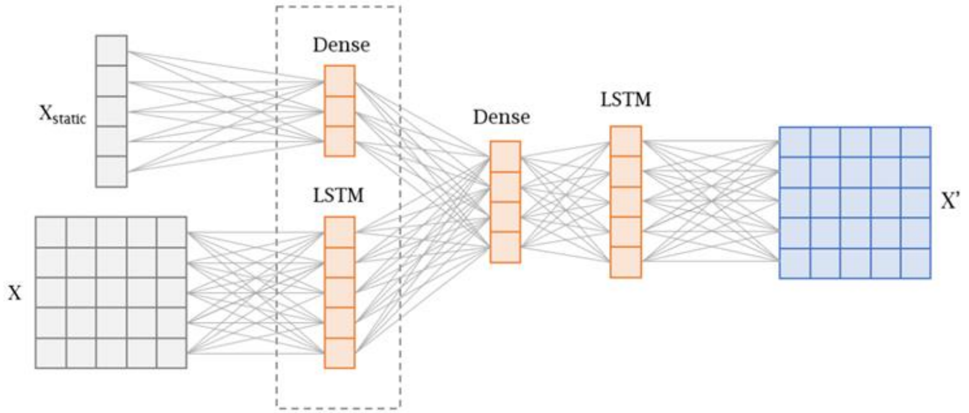
Table 5. The obtained hyperparameters form HRM data set.

Hyperparameter	AE	VAE
Layers	3	4
Latent size	7	10
Activation	relu	relu
Dropout	0.102	0.115
Batch size	32	32
Epochs	45	34
Quantile threshold	0.930	0.916
Beta max		0.0081
Epochs Beta		8

Table 6. Confusion matriices for HRM data set.

		AE		VAE	
		Predicted			
		Normal	Anomaly	Normal	Anomaly
Actual	Normal	435	6	431	10
	Anomaly	45	41	40	45





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