Journée Des Doctorants 2023

Advanced Anomaly Detection Models based on Machine Learning for Industry 4.0

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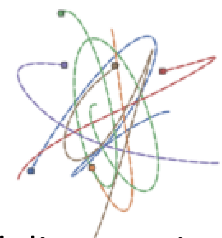
1. Introduction: Context / Motivation

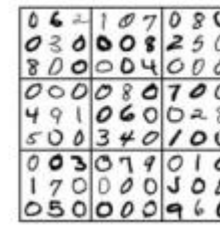
- Industry 4.0:
  - Complex monitoring systems generate a huge data
  - Reliability became more and more important
- Deep Learning: What do we do with deep learning?

Image classification

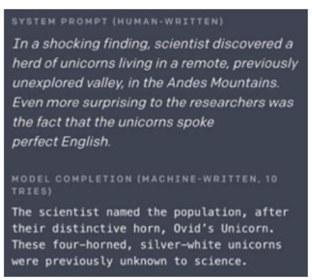
Semantic segmentation



Modeling continuous-time systems



Solving constrained optimization



Language modeling

Generative models

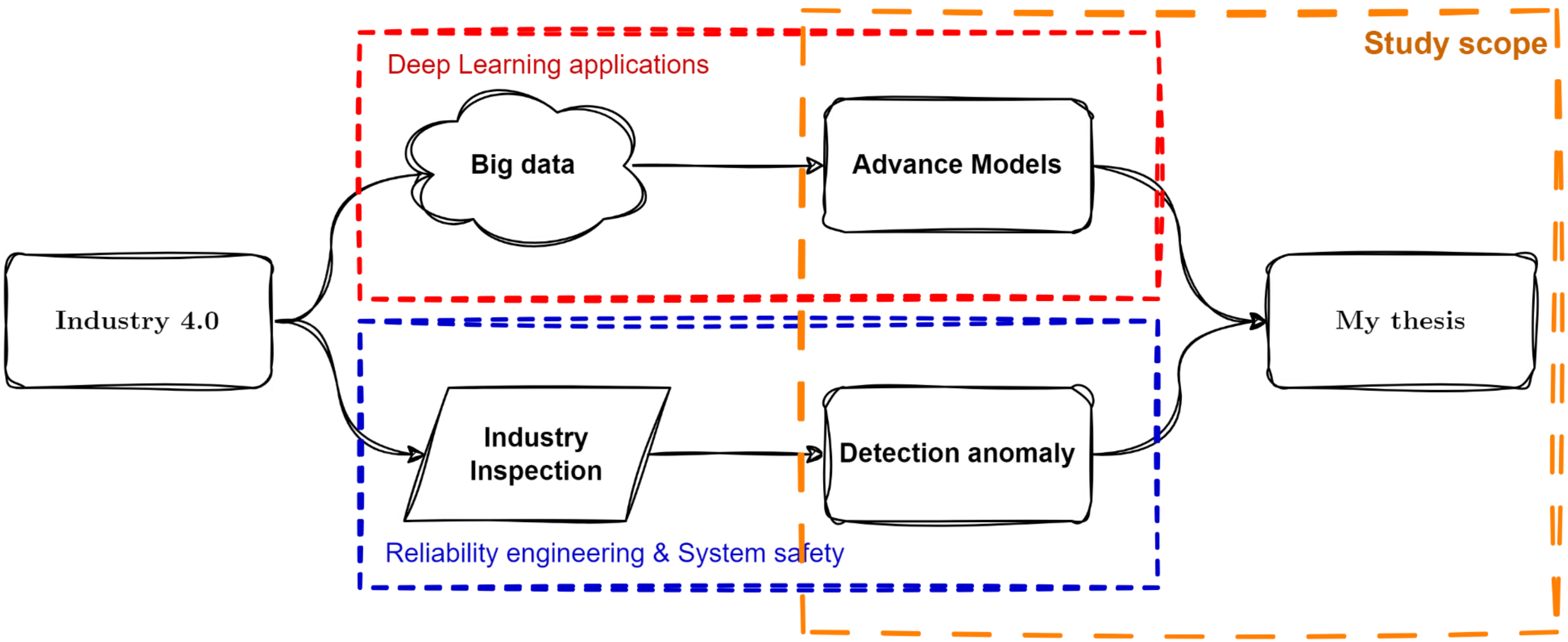
Smooth density estimation

"Traditional" deep learning domains

Emerging applications

Picture credits: [Krizhevsky et al., 2012; Bai et al., 2020; Grathwohl et al., 2018; Radford et al., 2019; Keras et al., 2018; Wang et al., 2019]

1. Introduction: Context / Motivation

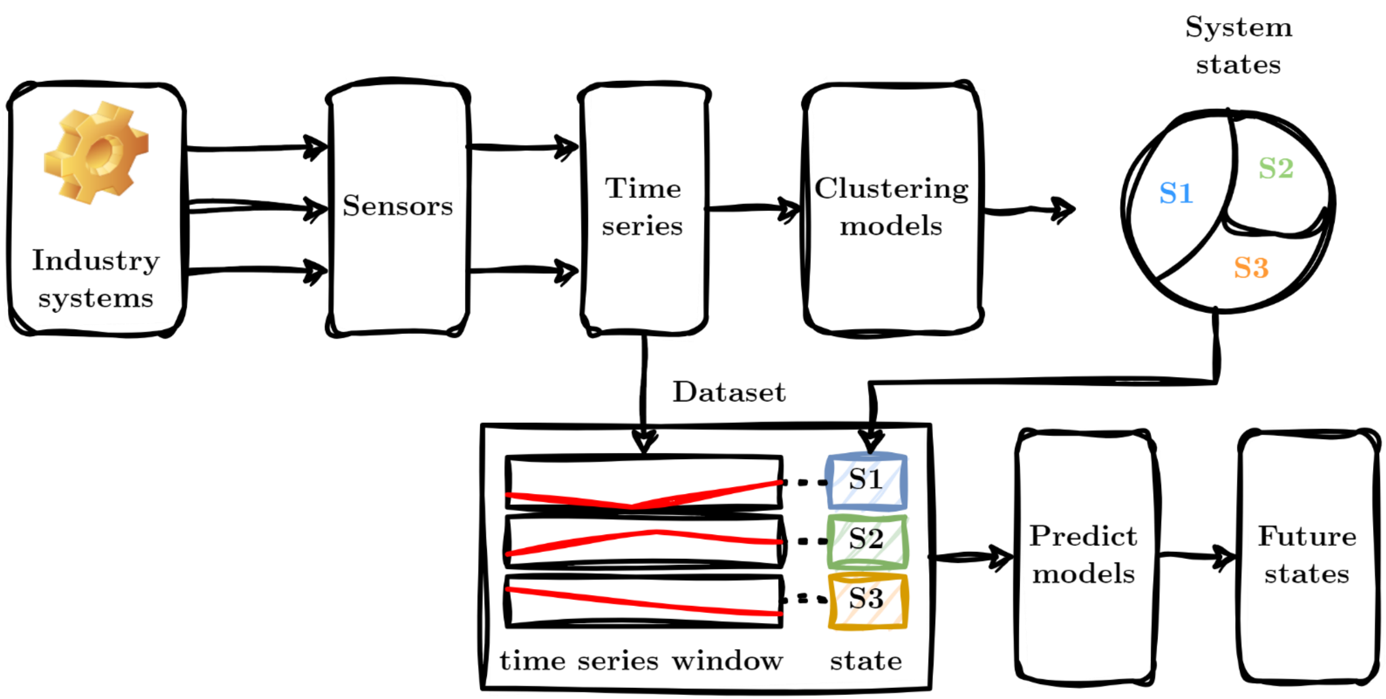


2. The challenges of this research direction

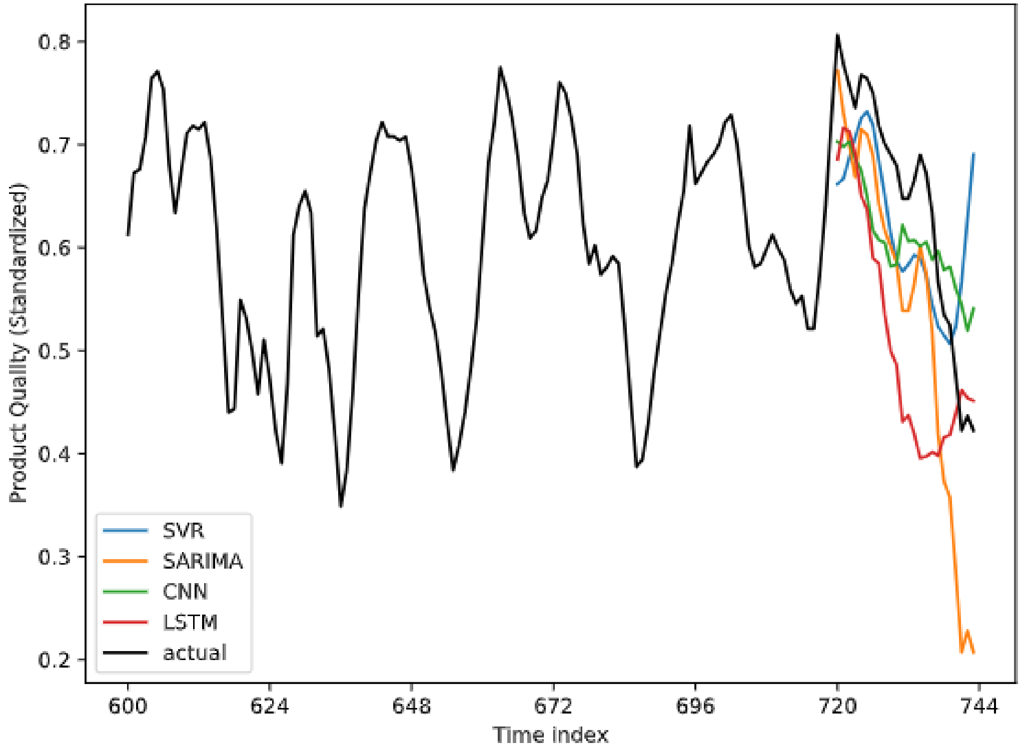
- **Incident Detection Capability**
  - **accurately** and **timely** detecting incidents.
- **Non-standardized Data**
  - **noise** or **missing information.**
- **Non-balance Data**
  - The anomalies **rarely exist** in historical data.

3. Result 1: Anomaly Prediction

Objective: Predicting System Failures Before they occur



3. Result 1: Anomaly Prediction



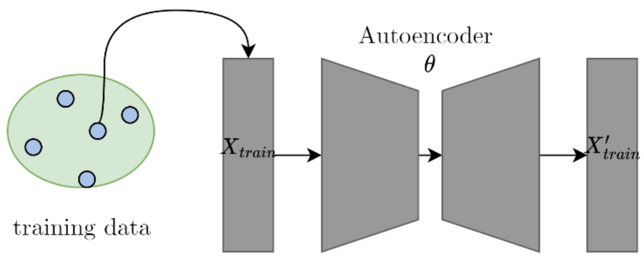
The prediction of the future states of systems based on product quality dataset

What if the anomaly event does not exist in historical states?
What if the historical data is non-standardized (e.g. having noise)?

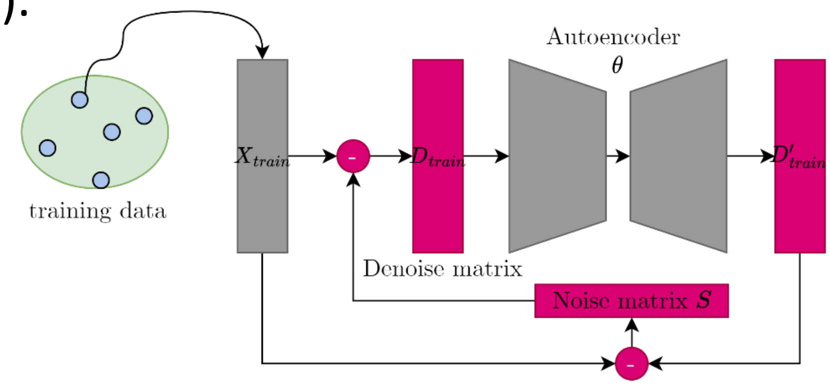
4. Result 2: Anomaly Detection

- We study anomaly detection based on **reconstruction models**
- We improve the **robustness** of our models by integrating the Robust Principle Component Analysis (RPCA).

Train

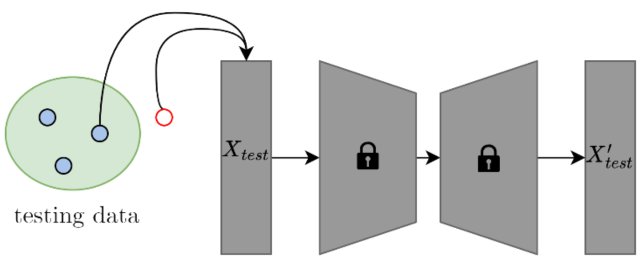


$\text{minimize}_{\theta}||X_{train} - X'_{train}||$

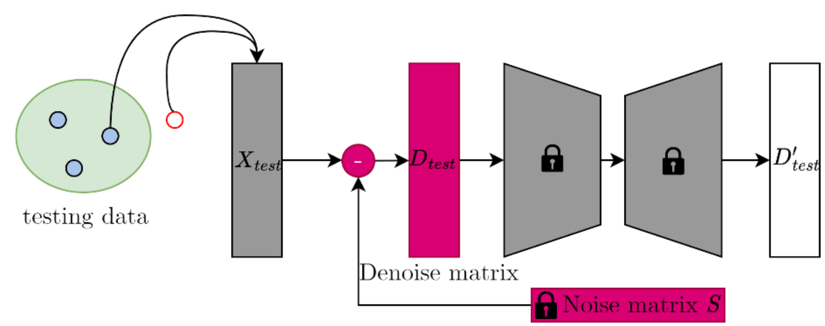


$\text{minimize}_{\theta,S}||D_{train} - D'_{train}||_2 + \lambda||S||_1$

Test



if $||X_{test} - X'_{test}|| \geqslant \gamma$, X_{test} is anomal
if $||X_{test} - X'_{test}|| < \gamma$, X_{test} is normal

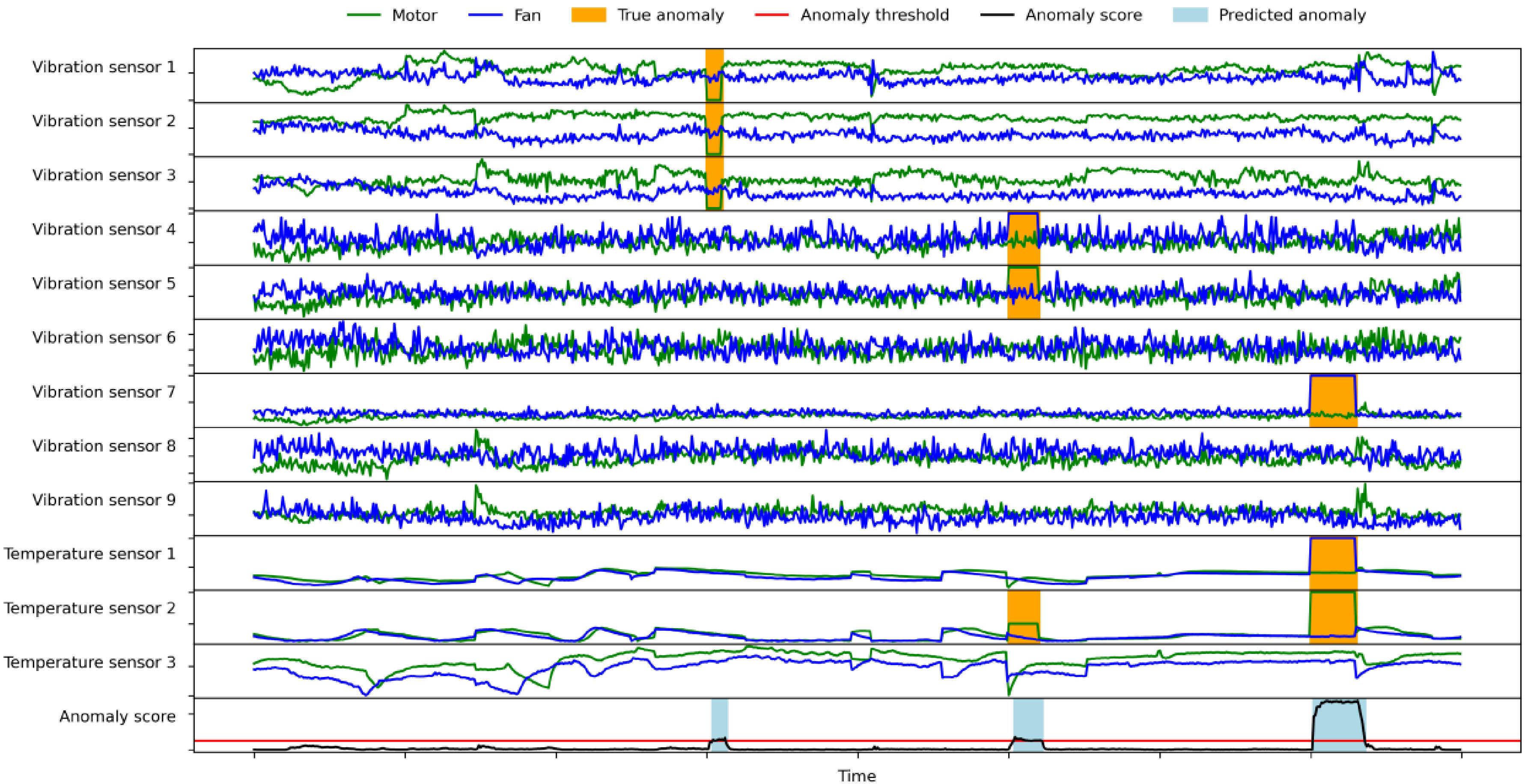


if $||X_{test} - S - D'_{test}|| \geqslant \gamma$, X_{test} is anomal
if $||X_{test} - S - D'_{test}|| < \gamma$, X_{test} is normal

Reconstruction models

Our models
(we add red-block)

4. Result 2: Anomaly Detection



Predicted and Ground Truth labels for the KappaX dataset provided by Sensoteq, Ireland

4. Result 2: Anomaly Detection

We also compare the performance of our models to that of the others.

$$\text{Pre} = \frac{TP}{TP + FP}$$

$$\text{Rec} = \frac{TP}{TP + FN}$$

$$\text{F}_1 = 2 \times \frac{\text{Pre} \times \text{Rec}}{\text{Pre} + \text{Rec}}$$

Where:

- TP: true positive
- FP: false positive
- TN: true negative
- FN: false negative

Models	KappaX		
	Pre	Rec	F1
OC-SVM-Linear	0.32	0.95	0.48
OC-SVM-RBF	0.24	1.00	0.39
HBSO	0.44	0.06	0.11
GMM	0.48	0.83	0.61
DeepLog	0.47	1.00	0.64
DGMM	0.33	0.20	0.25
LSTM-NDT	1.00	0.56	0.72
LSTM-ED	1.00	0.61	0.76
MSCRED	1.00	0.70	0.82
RCLED	**0.83**	**0.87**	**0.85**
Gain (%)	-	19.5	3.5

Our model

Publications

“**A deep learning approach for Control Chart Patterns (CCPs) prediction**”. The 32nd European Safety and Reliability Conference (ESREL), Dublin, Ireland, 2022.

“**Forecasting product quality using peephole long short-term memory**”. The CIGI-QUALITA-MOSIM International Conference (Conference on Modeling, Optimisation, and Simulation), Trois-Rivières, Canada, 2023.

“Explainable Artificial Intelligence (XAI) for non-conforming product detection: an application to fuel tank manufacturing”. The 12th IMA International Conference on Modelling in Industrial Maintenance and Reliability (MIMAR), Nottingham, UK, 2023.

“**Unsupervised detecting anomalies in multivariate time series by Robust Convolutional LSTM Encoder – Devoder (RCLED)**”, summitted in **Neurocomputing Journal**, 2023.

6. Conclusions and Perspectives

Conclusions:

- In this study**, we focused on developing anomaly detection models** based on machine learning.
- The research **results have demonstrated the effectiveness** of these models in addressing challenges such as imbalanced data and noise.
- This approach holds **great promise and is noteworthy in the field** of anomaly detection.

Perspectives:

- While our research has provided deeper insights into this issue, there are still **numerous opportunities for further exploration**.
- Moving forward, we propose continuing research on models detecting incidents based on **extracting common features across various types of data (images, 3D, time series),** promising robust and comprehensive solutions for the industry.
- Additionally, **considering the integration of other advanced methods** to optimize the stability and anomaly-detection capability of the models is crucial.

Thank you for your listening