URAI 2024

# Artificial Intelligence for Quality Assurance and Troubleshooting in Industry

Rudolf Hoffmann[1], Slimane Arbaoui[2], Léa Charbonnier[3], Amel Hidouri[2], Ali Ayadi[2], Franco Giustozzi[2], Thomas Heitz[4], Julien Saunier[3], Frédéric Pelascini[4], Christoph Reich[1], Ahmed Samet[2], Cecilia Zanni-Merk[3]

1 Institute for Data Science, Cloud Computing and IT Security; Furtwangen University; 78120 Furtwangen
2 ICube, CNRS (UMR 7357) INSA Strasbourg, University of Strasbourg, 67000 Strasbourg
3 INSA Rouen Normandie, Normandie Univ, LITIS UR 4108, F-76000 Rouen
4 CETIM – Centre Technique des Industries Mécaniques, 67402, Illkirch-Graffenstaden

Project Website: www.x-quality.de

Funded by: Deutsche Forschungsgemeinschaft (DFG), agence nationale de la recherche (anr)

# Agenda

- Introduction
- X-Quality Conceptional Framework
- Combining AI and FTA
- Discussion
- Conclusion

# Introduction

## Problem Description

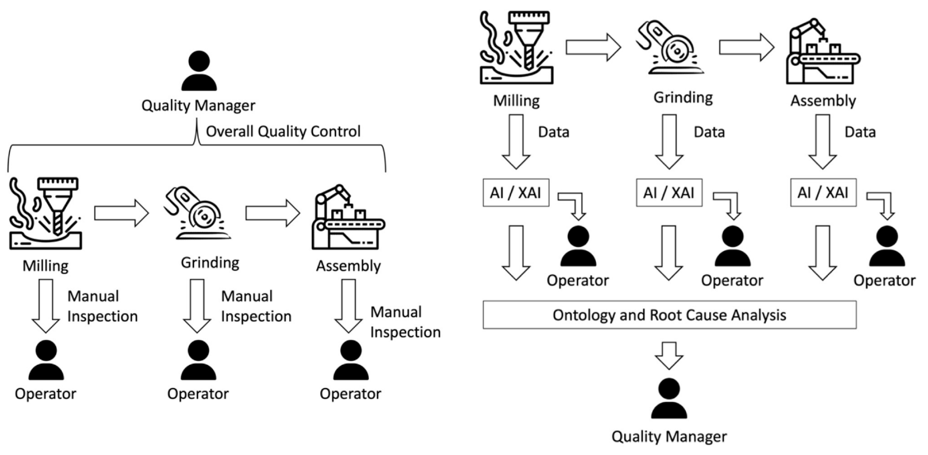
- Monitoring manufacturing processes is essential to prevent failures and maintain product quality.
- Using AI to automate quality assurance and improve accuracy and consistency in defect detection.
- Results produced by AI must be explainable to enable troubleshooting and acceptance by experts and regulators.

## Objective

- Improve quality assurance and troubleshooting processes using AI/XAI

# X-Quality Conceptional Framework

- In multi-stage manufacturing processes failures at one process can propagate, affecting subsequent processes
- Each operator does manual quality control at machine and quality manager supervises overall process




a) Manual Quality Control

b) Quality Control with AI, XAI and Stream Reasoning

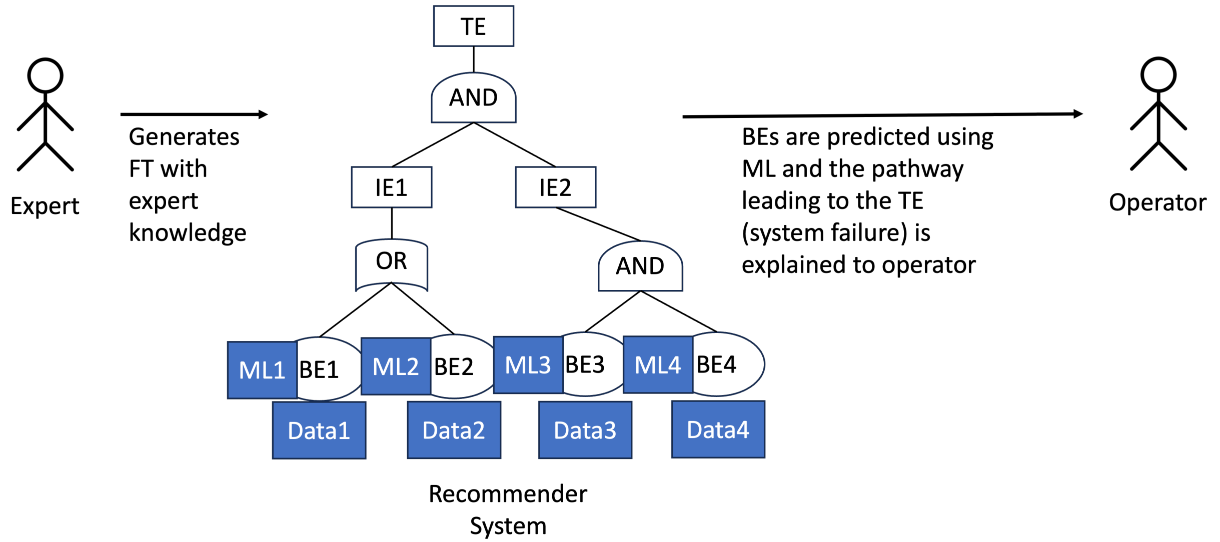
- From each machine data is collected and AI/XAI techniques are applied
- Data streams, predictions, and explanations are used to enrich ontology
- Quality manager used ontology to trace root cause

# X-Quality Conceptional Framework

- 3 approaches integrated into the X-Quality conceptional framework
- 1) LSTM-CNN combination to predict quality issues in time series data and SHAP for explanation
- 2) Combination of AI and FTA for transparent TE occurrence
- 3) Stream reasoning to process continuous real-time data streams from multiple sources and enrich ontology. Using ontology to trace quality issues back to root causes

# Combining AI and FTA

- Combining AI and FTA to enhance prediction and understanding of system failures.
- Expert generates FT
- ML models are built to predict the BEs
- FTA to determine TE occurrence



# Combining AI and FTA

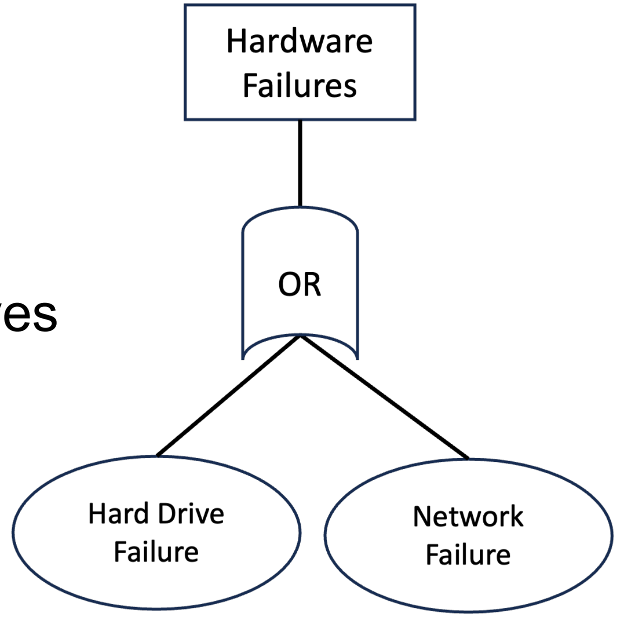
- Proof of Concept
- Using a simple FT focusing on Hardware failures
- Using **2 datasets** to predict the BEs:
  - ❖ **SOFI** (**S**ympt**o**m-**F**ault relationship for **I**P-Network):

    Information about extensive enterprise network‘s performance

    34 features (e.g. Bits received, speed, ...)
    https://data.mendeley.com/datasets/tc6ysmh5j8/2
  - ❖ **SMART**: S.M.A.R.T attributes from hard drives

    56 features

    https://www.kaggle.com/datasets/sskanyal/harddrive-cleaned-smart-dataset



# Combining AI and FTA

**Predicting the TE**

- Merging both datasets to predict the TE
- Using features of both datasets for TE prediction
- Using DL model

**Predicting the BEs**

- Using both datasets
- Using two DL models (one model each dataset)
- FTA to determine TE occurrence

# Combining AI and FTA

## Results

- K-fold cross validation with 10 splits

| Metric | TE Prediction | BEs Prediction |
|---|---|---|
| Accuracy | 99.1 % | 99.4 % |
| Precision | 99.7 % | 99.8 % |
| Recall | 98.6 % | 99.1 % |
| F1-Score | 99.2 % | 99.5 % |
| AUC-ROC | 99.9 % | 99.6 % |

- Approach „BEs prediction“ slightly better
- Additional benefit:
  - Identification of root causes
  - Interpretability of results
- However, BE prediction might be opaque

# Discussion

**Strengths of the X-Quality Conceptional Framework**

- Enhanced defect detection and troubleshootingby integrating AI, XAI, and expert knowledge
- Provides actionable explanations and contextual insights

**Challenges of the X-Quality Conceptional Framework**

- High computational resources for large-scale deployment
- Ontology and fault tree updates require expert input

# Discussion

**Future Work**

- Improving scalability by automating ontology updates
- Improving interpretability and comprehensability of explanation
- Developing methods to process high-frequency data for real-world deployment

# Conclusion

- The X-Quality Conceptional Framework combines AI, XAI, and expert knowledge
- Offering explanations to enable troubleshooting
- Downtime reduction, efficiency improvement, and cost reduction

# Appendix

## DL architecture:

| Layer | Units | Activation Function |
|---|---|---|
| Dense1 | 128 | ReLu |
| Dense2 | 64 | ReLu |
| Dense3 | 32 | ReLu |
| Dense4 | 1 | Sigmoid |

## Hyperparameters

- Optimizer: Adam (lr=0.001)
- Loss: Binary Crossentropy
- Epochs: 30
- Batch Size: 32