TENFORCE elisa company × AI-PROFICIENT

Artificial intelligence for improved production efficiency, quality and maintenance

JUNE 8TH, 2023

# FUTURE

## THE FUTURE IS WOW 2023

BRINGING AI TECHNOLOGY TO THE PRODUCTION LINE

AI·PROFICIENT

Artificial intelligence
for improved production efficiency,
quality and maintenance

# Production Process Optimization through Quality Analysis Tools and Explainable AI

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Institute Mihajlo Pupin

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# Agenda

- Institute Mihajlo Pupin
- Use case description
- Workflow
- Proposed Solution
- Results

# Institute Mihajlo Pupin

# Institute Mihajlo Pupin

- One of leading Serbian R&D institution in information and communication technologies (ICT)
- One of the biggest and oldest (1946) R&D Institute in ICT area in whole Southeastern Europe
- 500+ employees, 350+ researchers & engineers
- 80+ % of turnover via Technology Transfer
- Affiliated to the University of Belgrade
- EU Commissionaire – “Pupin as the best practice example for bridging academia and industry”

# Our solutions

## MAIN PROGRAMS:

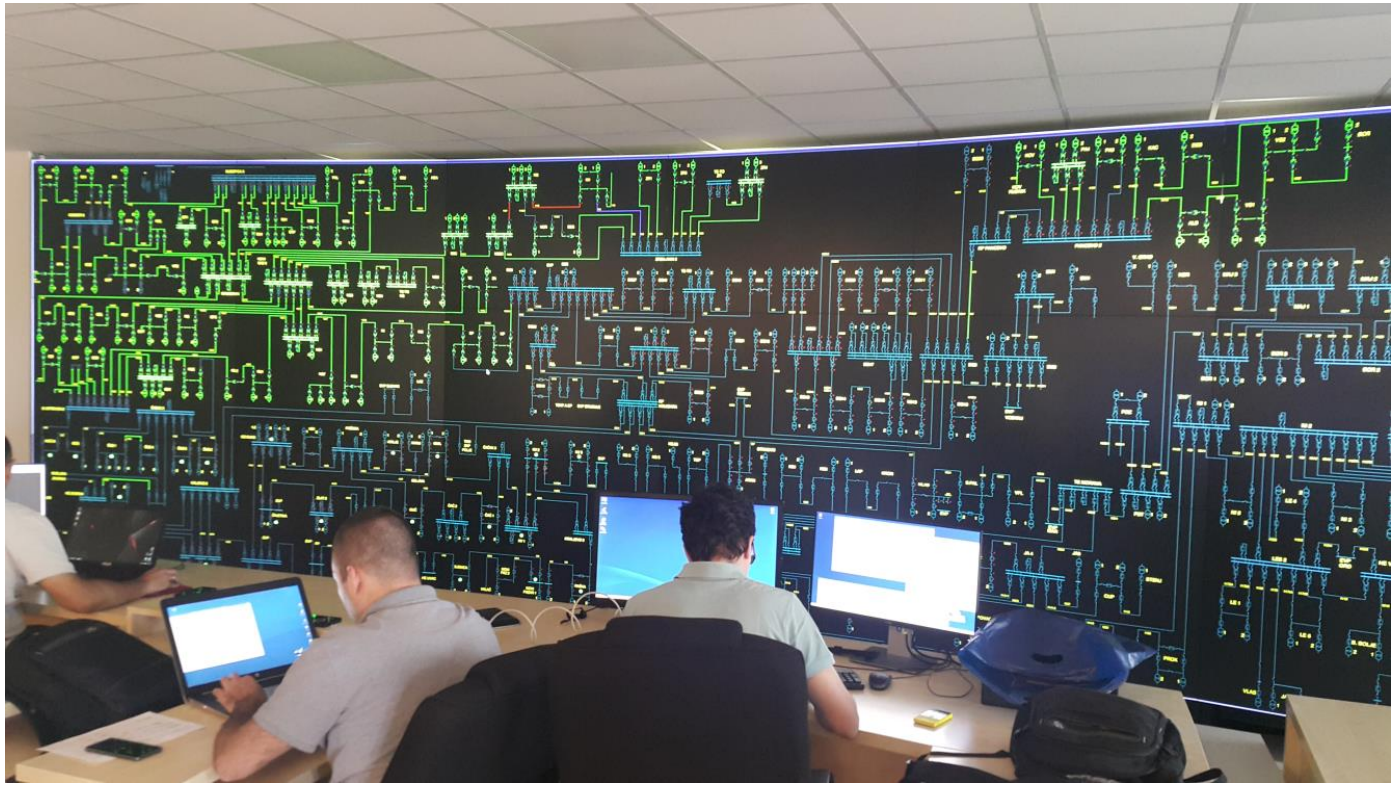
- **Information Systems:** E-government solutions, Document Management Systems, Decision Support Systems, AI based systems
- **Process Control Systems:** Power Production, Transmission and Dispatching Control and Supervision Systems, Water Supply and Management Systems
- **Traffic Management Systems:** Urban Traffic Control, Tunnel Management, Highway Pay-Toll Systems, Access control system
- **Railway Program:** Axle Counter, LED signals, HMI solutions
- **Defense Program:** Simulation and Training Systems, Air War Gaming Systems, Radar signal processing systems, Electronic Surveillance Systems, Ballistic Analyzer
- **Other Programs and Activities:** Robotics, Security, Embedded Systems, Surveillance, Alert & Warning Systems, etc.

# Our clients

Public sector

Industrial sector

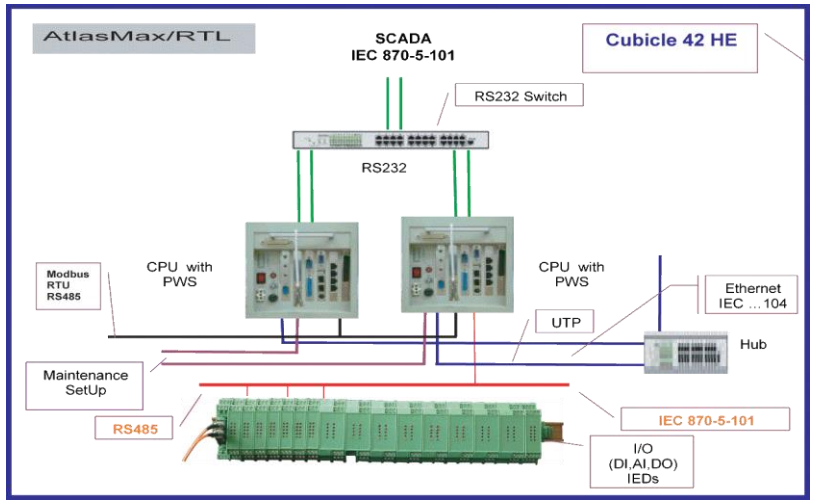
- Serbian Power Utility
- Road, railway and air traffic authorities
- Public administration (e-government)
- Ministry of Justice, Ministry of Interior
- Serbian Armed Forces
- Oil, gas and mining companies
- Process industries (food processing industry, tanneries, cement factories,  etc.)
- Water  Utility



# Process control systems

## TECHNOLOGY

- 40 years in Process Control Systems
- Supervisory Control and Data Acquisition Systems (SCADA) and Digital Control Systems (DCS)
- Process Optimization
- Decision Support Systems
- Proprietary SCADA  SW (VIEW®) and HW solutions (ATLAS®)
- Application of IMP’s proprietary HW and SW solutions in various industrial domains




# JOINING FORCES WITH EU-BASED R&D PARTNERS

## 108 International Research Projects, over 500 partners

- **7 HORIZON EUROPE** (LEGOFIT, ECHO, FEDECOM, R2D2, IntelliLung, POLICY ANSWERS, OMEGA-X)
- **21 H2020 (**NEON, AI-PROFICIENT, HESTIA, SINERGY, TRAPEZE, BorderUAS, PLATOON, TRINITY, IDEAS, REACT, LAMBDA, FeeelAgain, RESPOND, InBETWEEN, SlideWIKI, FLIRT, EEN INNO, FS4SMIH, EENSerbia, EENClientInnoJourney, EENInnoSJourney)
- **22 FP7 projects** (REFLECT, AgroSENSE, META-NET, WBC-INCO-NET, HydroWEEE, ICT-WEB-PROMS, HELENA, EMILI, ENERGY WARDEN, PROCEED, LOD2, CASCADE, H-WEEE-DEMO, EPIC-HUB, SPARTACUS, GenderTIME, ResearchersNight, GeoKNOW, Danube INCO.NET, NoSQL-NET, Trafoon)
- **7 CIP/EIP** (CESAR, EIIRC, GREEN, WEEEN, ICIP, IMAGEEN, Share PSI 2.0)
- **1 IPA Adriatic** (PACCINO)
- **1 ERASMUS+** (BEST)
- **4 SEE** (Intervalue, FORSEE, WBINNO, TV-Web)
- **3 TEMPUS (**CARE, HUTON, INCOMING)
- **8 COST Actions** (IC1004, IC1304, CA16116, CA15104, NexusLinguarum, Distributed Knowledge Graphs, VOICES, INTERACT)
- **1 RSEDP2** (EMC)
- **1 UNDP** (Smart Land)
- **3 FP6 projects** (SARIB, PROMETEA, Web4WeB)
- **3 Interreg DANUBE** (MOVECO, NewGenerationSkills, EDU-LAB)
- **2 EC Interreg/CADSES projects** (I2E, STRIM)
- **6 IPA** (EPS, Tax, Justice, Agro, POM, APML)
- **18 Bilateral projects** (2 Switz.,3 France, 5 Germany, 1 Cyprus,1 Greece, 1 Norway, 1 Portugal, 1 Slovenia, 3 China)

HORIZON EUROPE

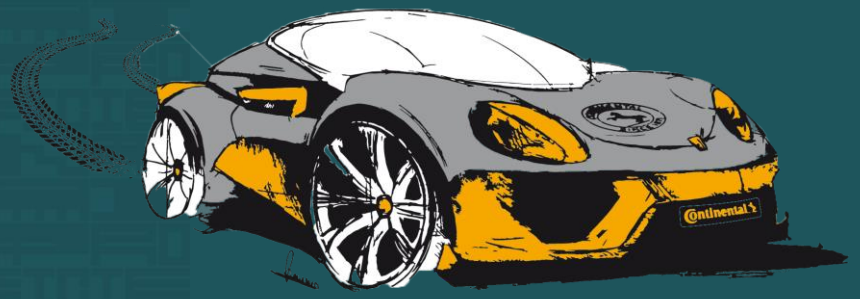
THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

SEVENTH FRAMEWORK PROGRAMME

SIXTH FRAMEWORK PROGRAMME

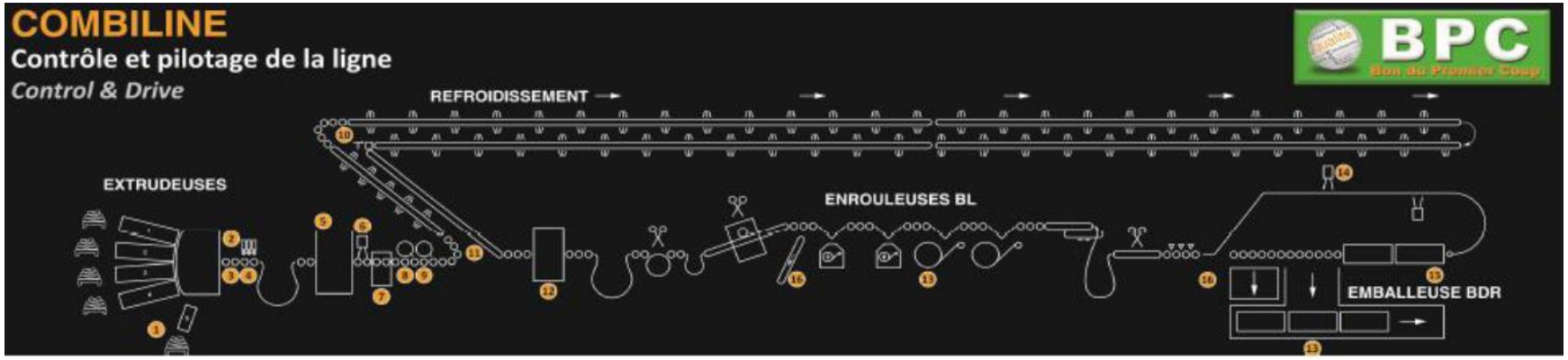
IPA INSTRUMENT FOR PRE-ACCESSION ASSISTANCE

# Introduction




# Use case description

- Focus on the line for thread production in the Continental factory
- During the production process, occasional product deviations out of the desired scope are inevitable, and, when it happens, the operator in charge of that product characteristic, takes actions
- The main goals of this use case were:
  - the development of a quality analysis tool for the improvement of final product quality characteristics
  - automation of the process of investigating the causes of quality deviations and providing proactive suggestions for preventing degradation



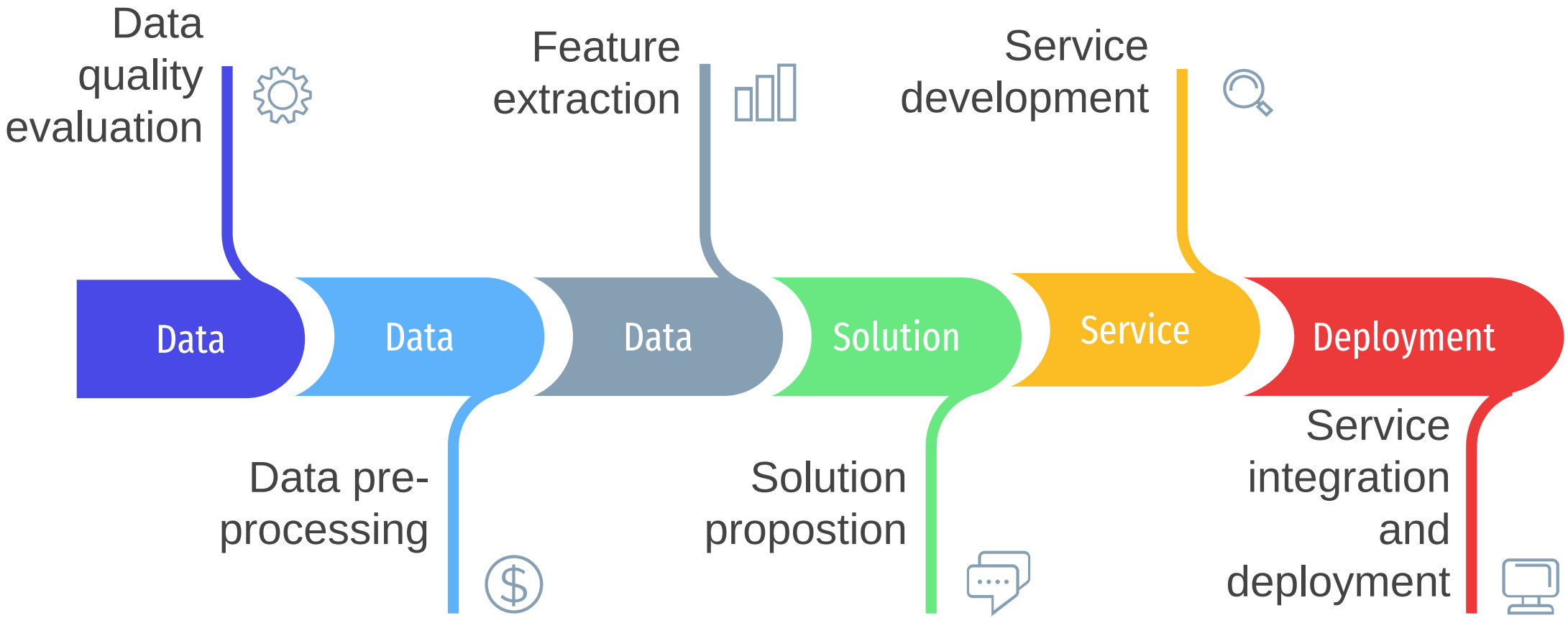
# Use case description

- Different quality metrics (length, weight, profile thickness, wings deformation level, etc.) are affected by different process variables, machine settings, breakdowns, and certain operators' decisions
- The idea was to provide a recommendation system that would maintain these characteristics within the predefined bounds, so that quality is assured

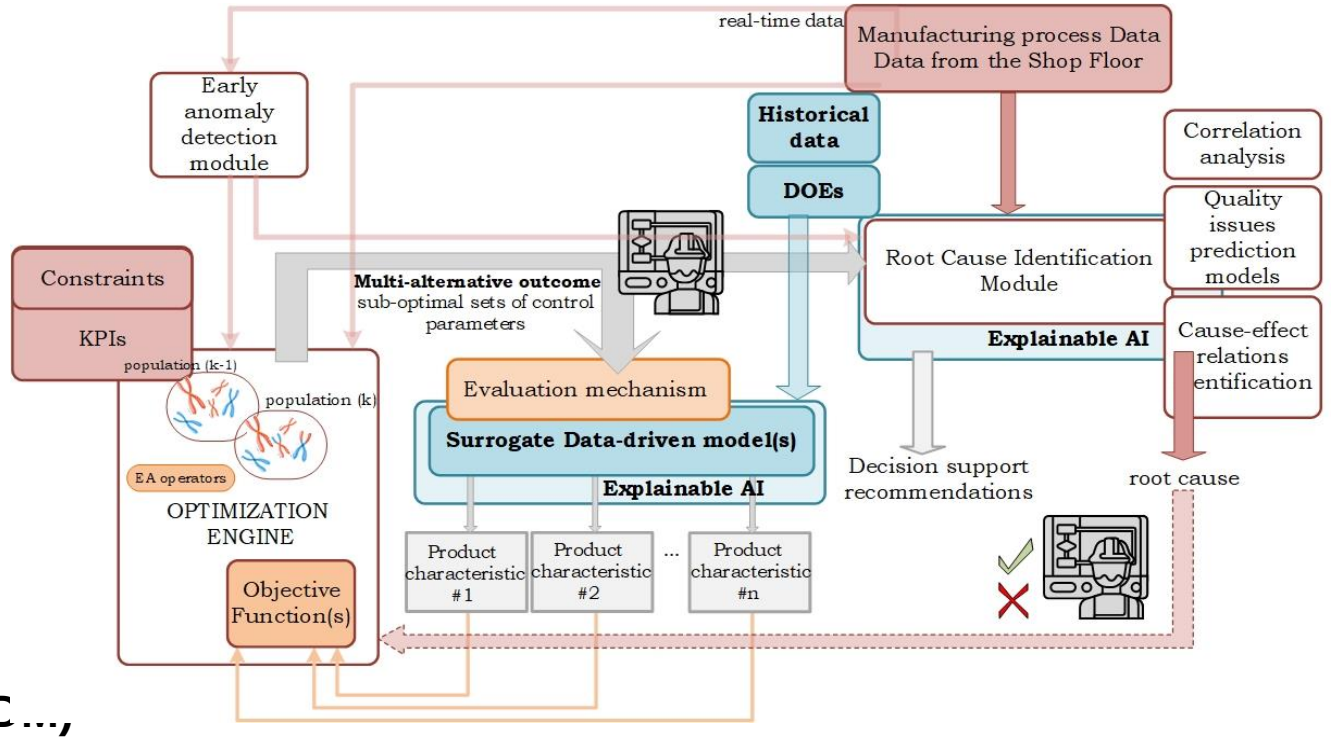
| Product characteristic | Influent factor 1 | Influent factor 2 | Influent factor 3 | Influent factor 4 | Influent factor 5 | Influent factor 6 | Influent factor 7 | I |
|---|---|---|---|---|---|---|---|---|
| **Weight** | **Machine speed** | **Screw speed** | **Base mix storage time** | **Final Mix storage time** | **% of remill in mix** | **Mix viscosity** | **Screw pressure** | T |
| Detection Zone | Supervision pilot | Supervision pilot | Mixing room | Mixing room | EWM | QDV | Supervision pilot | C |
| **Cold width** | **Conveyor speed** | **Screw speed** | **Mix viscosity** | **Tool wear** | **Tool conformity** | **Mix temperature** | **Tool position** | % |
| Detection Zone | Supervision pilot | Supervision pilot | QDV | Visuel opérateur | Check info CGRS | Supervision pilot | Operator visual check | |
| **Profile thikness** | **Machine speed** | **Screw speed** | **Conveyor speed** | **Base mix storage time** | **Final Mix storage time** | **% of remill in mix** | **Mix viscosity** | S |
| Detection Zone | Supervision pilot | Supervision pilot | Supervision pilot | Mixing room | Mixing room | EWM | QDV | Su |
| **deformation of wings** | **Screw speed** | **Mix viscosity** | **Base mix storage time** | **Final Mix storage time** | **Raw material dealer** | **Mix temperature** | **Tool position** | % |
| Detection Zone | Supervision pilot | QDV | Mixing room | Mixing room | Mixing room | Supervision pilot | Visuel opérateur | |
| **Length** | **Conveyor speed** | **Cut length** | **Machine speed** | **% of remill in mix** | **Mix viscosity** | **Cooling unit temperature** | | |
| Detection Zone | Supervision pilot | Operator visual check | Supervision pilot | EWM | QDV | Supervision pilot | | |
| **Base thickness** | **Pression mélange** | **Base screw speed** | **Base mix storage time** | **Final Mix storage time** | **% of remill in mix** | **Mix viscosity** | **Tool wear** | M |
| Detection Zone | Supervision pilot | Supervision pilot | Mixing room | Mixing room | EWM | QDV | Check info CGRS | Su |
| **blocked CCB** | **Screw pressure** | **Tool cleaning** | **Tool conformity** | **Mix temperature** | | | | |

# Workflow and the proposed solution

# Workflow


Data quality evaluation
Feature extraction
Service development
Data
Data
Data
Solution
Service
Deployment
Data pre-processing
Solution propostion
Service integration and deployment

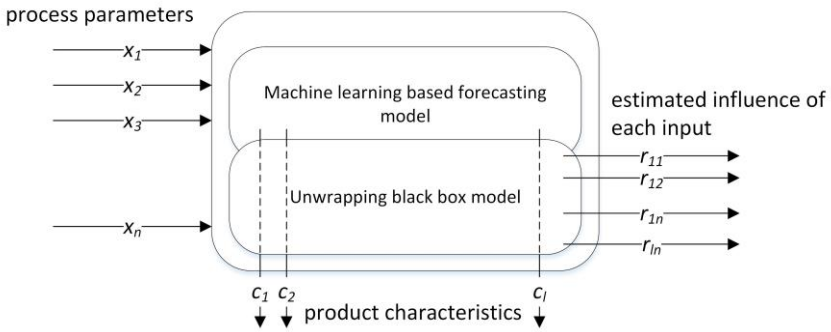
# Proposed solution (1)

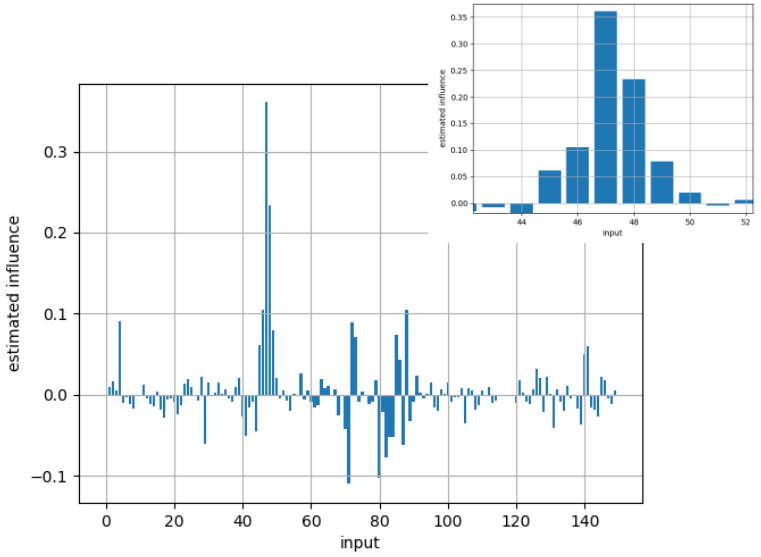



- (Early) anomaly detection module
  - for estimating expected degradation or detecting the existing one in (close to) real-time environment:
    - **Short-term post-hoc anomaly analysis (SPAA)**
    - **Surrogate data-driven module (SDD ...,**
- **Generative holistic optimization (GHO)** - (close to) real-time optimization of current process set up with the aim of preventing degradation or restoring product quality
- **Post-hoc explainable anomaly analysis (PEAA)** for process manager and thorough offline data analysis
- Feedback system included

# Proposed solution (2)

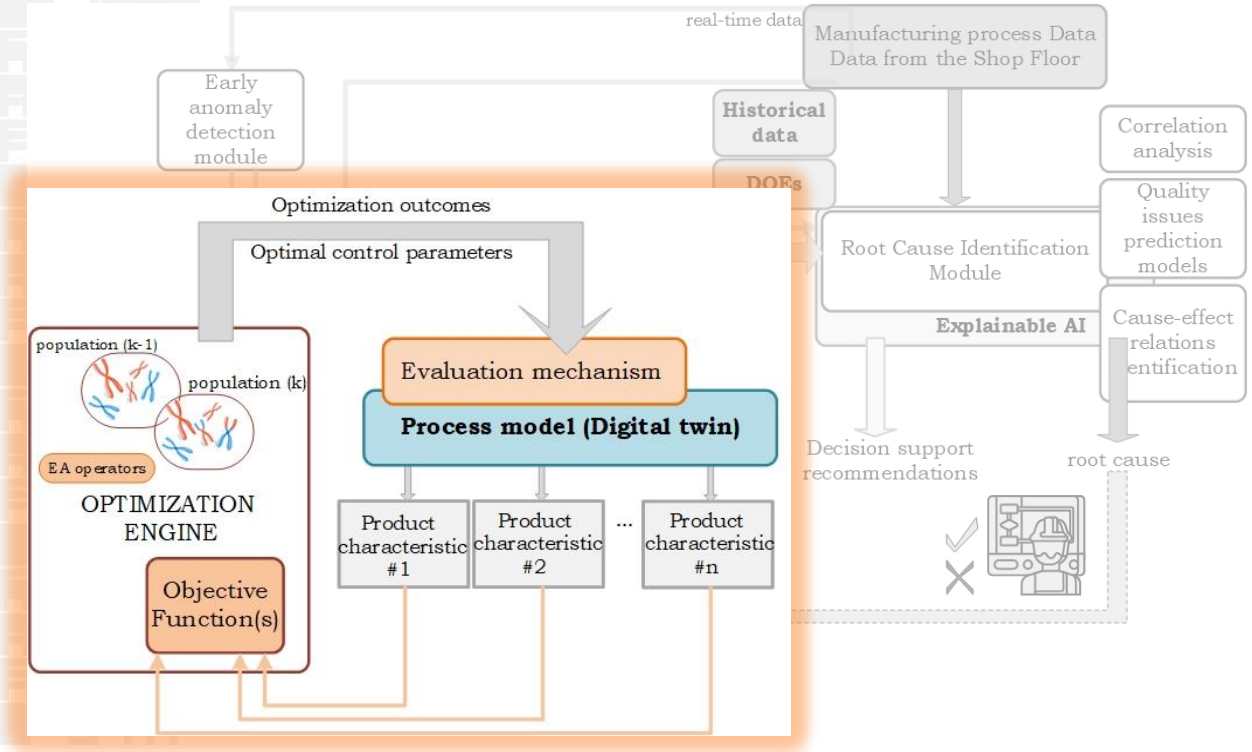
- **Surrogate data-driven module (SDDM)** - continuously monitoring process variables for detecting potential degradation in various product characteristics
  - when degradation expected, optimization is run for adapting process parameters
  - apart from the degradation forecast, its most probable cause is determined via explainable AI (XAI) techniques
  - combination of various performable ML techniques and XAI approaches – LIME, DeepLIFT, etc.
- **Short-term post-hoc anomaly analysis (SPAA)** – analyzing current product characteristics and process variables



# Proposed solution (3)

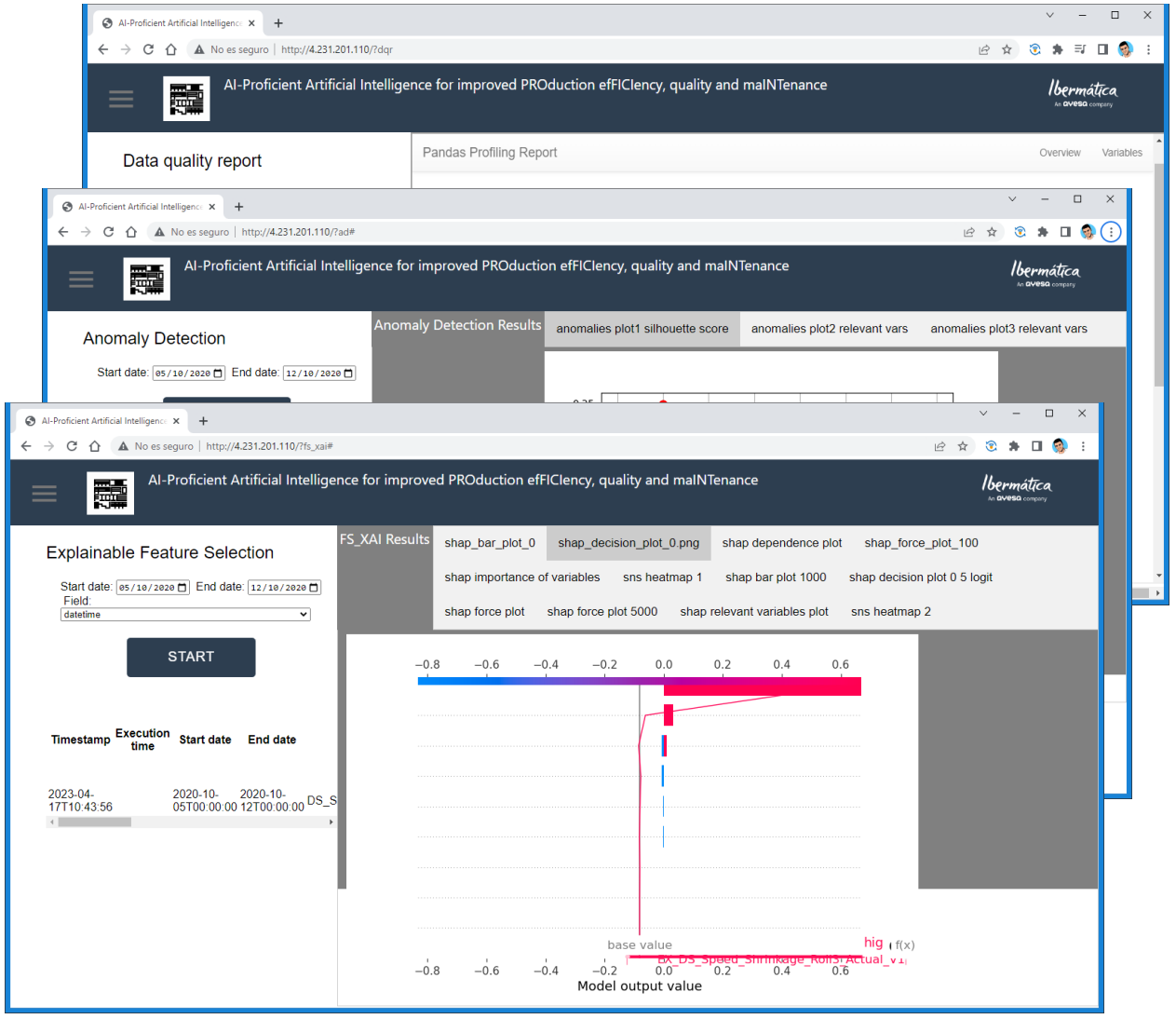
- **Generative holistic optimization (GHO)** – envisioned to be the core of the recommendation system which provides suggested parameters updates




- GHO obtains current line setup, estimated or realized degradation, the most probable cause of it and provides updated process parameter set up
- Close to **real-time**
- The main characteristics of the proposed optimization approach:
  - **multi-objective optimization** method based on **evolutionary algorithms**
  - assisted by **time-series clustering** for improved recommendations
  - recommendations are be based on the **process digital twin** (SDDM)
  - for performance improvement over time and service adjustment in accordance with the process change, **human feedback** is included

# Proposed solution (4)

- Post-hoc Explainable Anomaly Analysis (PEAA):
  - envisioned for process manager thorough post-hoc data analysis
  - provides data quality report, anomaly detection and feature selection options – different ML techniques
  - works on the historical data
  - includes explainable artificial intelligence techniques (LIME, ELI, SHAP)



# Results

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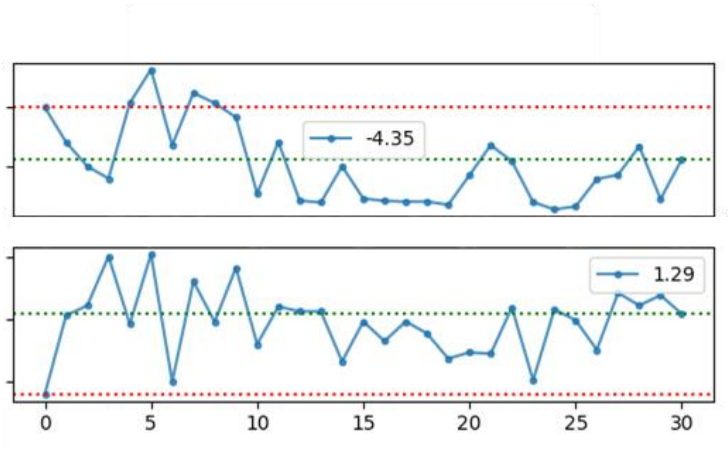
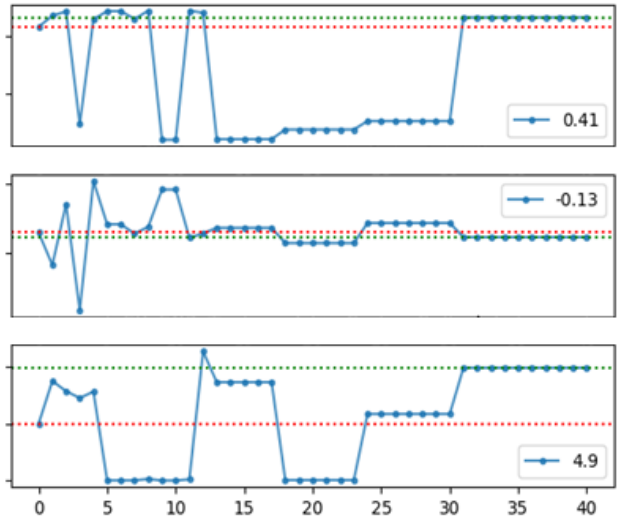
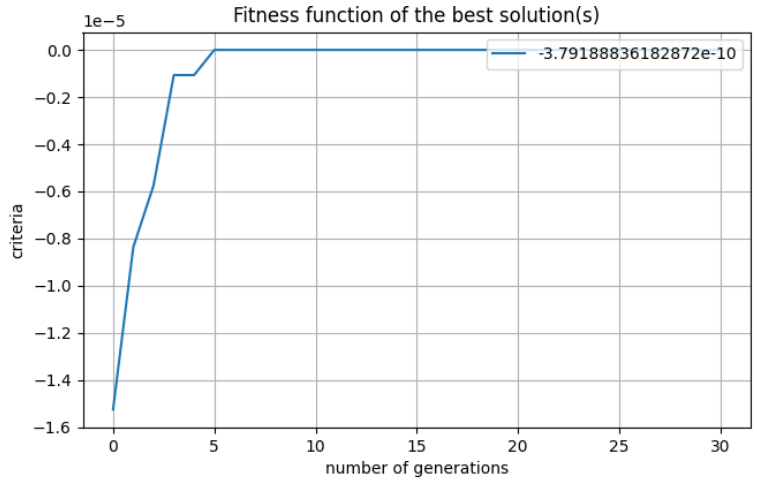



- **Example** of the optimization outputs run for optimizing **thickness** and **width**
- **Number** of the **adjusted** process **parameters** could **vary – balance** with **number** of changed parameters and **time** of **convergence**
- In the presented case, convergence was reached after **30 generations** with **two** adjusted **parameters** and **40 generations** with **three parameters**
- Optimization could **offer couple** of **recommendations** for operator to choose the right set



# Thank you for you attention!

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