ROBOPROX

RA13: Complex systems for flexible production

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CIIRC, CTU in Prague

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MINISTRY OF EDUCATION, YOUTH AND SPORTS

Robotics and Advanced Industrial Production
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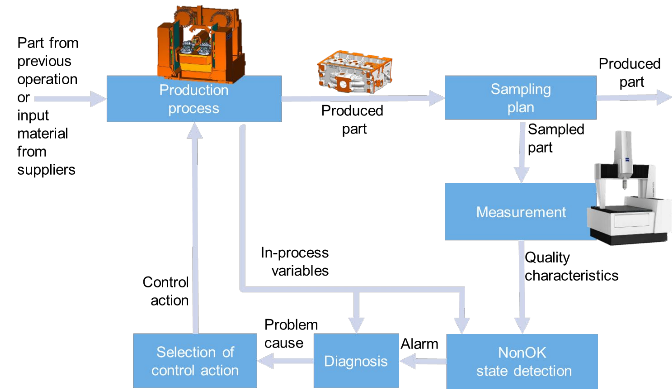
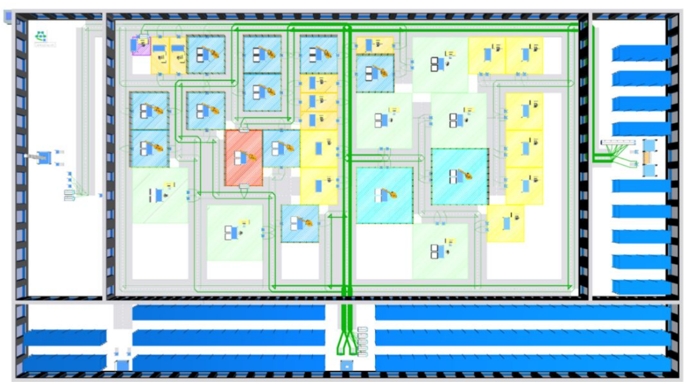
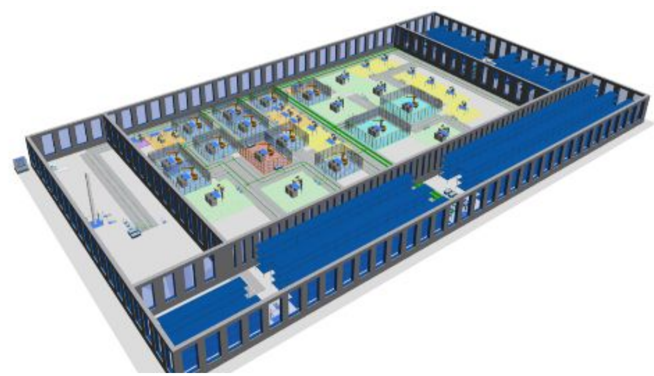
RA13: Complex systems for flexible production

- RO 13.1: Advanced Models of Complex Production Systems (Miroslav Svítek)
- RO 13.2 - Modularization of Production Systems (Petr Novák)
- RO 13.3 Quality Control in Flexible Manufacturing Systems (Martin Macaš)
- RO 13.4: Products, production systems, and devices (Václav Jirkovský)







RA13 people:

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Dr. Jiří Kubalík

Dr. Petr Novák

Dr. Martin Macaš

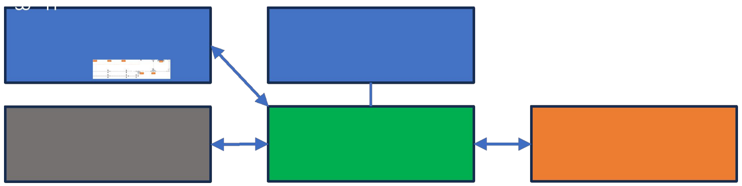
Sára Strakošová

Sergey Kozhevnikov

RO 13.1: Advanced Models of Complex Production Systems

- **Research group**:
  - Svítek Miroslav
  - Kozhevnikov Sergey
- **What we will aim for:**
  - Advanced models of complex systems to find an acceptable equilibrium that includes minimised use of natural resources, maximised sharing of existing infrastructure.
  - Modelling and simulation of complex production systems based on multi-agents negotiation between industry and smart urban systems (energy, logistics, environment, etc.)
  - Inclusion of holistic principles and future trends like ESG (environment, social and governance) indicators into design and assessment of production systéms
- **International collaboration:**
  - The University of Texas at El Paso (UTEP), USA
  - Technical University in Berlin (TUB)

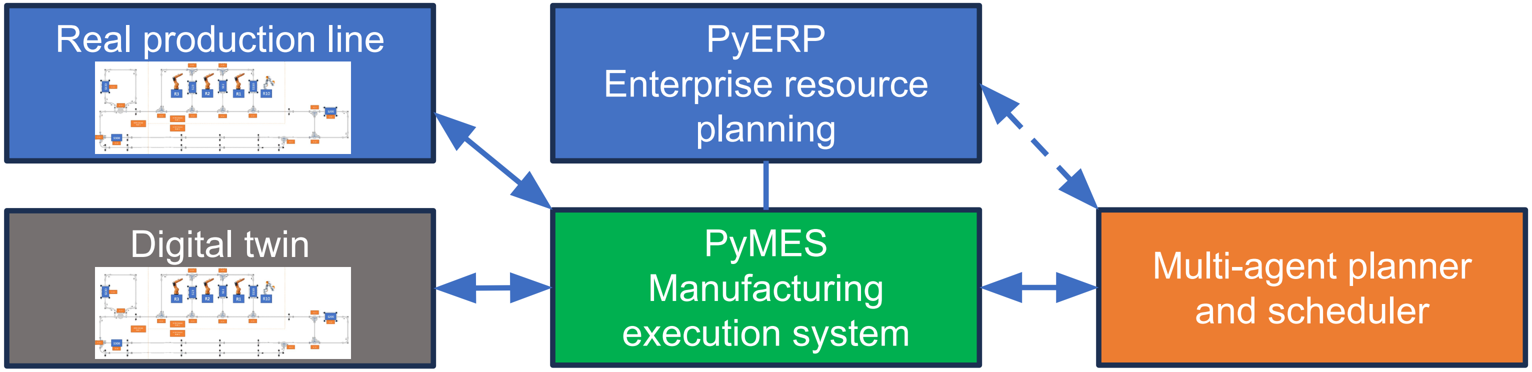
RO 13.2 - Modularization of Production Systems



- Flexible production systems
  - Integrating Industry 4.0 components
  - Communication with Industry 4.0 components via OPC UA
  - Systems modeling with AutomationML, ISA-95, PackML, and other relevant industrial standards
  - Multi-agent approach for supervision, control, and planning

- Multi-agent systems (MAS) in Manufacturing Execution Systems (MES)
  - How to integrate MAS in PyMES
  - How to represent and generate (machine-learn) plan templates
  - How to close the loop and enable real-time decentralized MAS control
  - How to enable (decentralized) intelligent monitoring and diagnostics

RO 13.2 - Modularization of Production Systems



- Long planning horizon and supply-chain logistics
  - Investigate the potential of extension to material planning and logistics integration on longer time horizon
  - Investigate the multi-line and multi-site scenarios
  - Integrate route planning and logistics/fleet optimization

- Generative AI and human-machine interaction for MES
  - Investigate the potential of human-agent interaction using generative AI (language models)

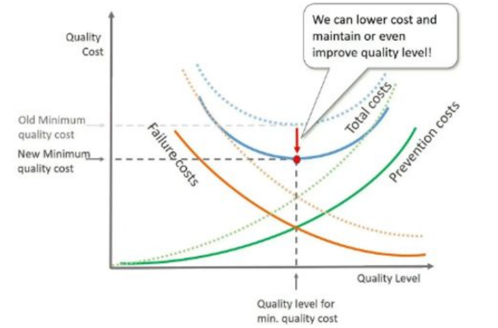
RO 13.3 Quality Control in Flexible Manufacturing Systems

RO focused on whole quality control loop

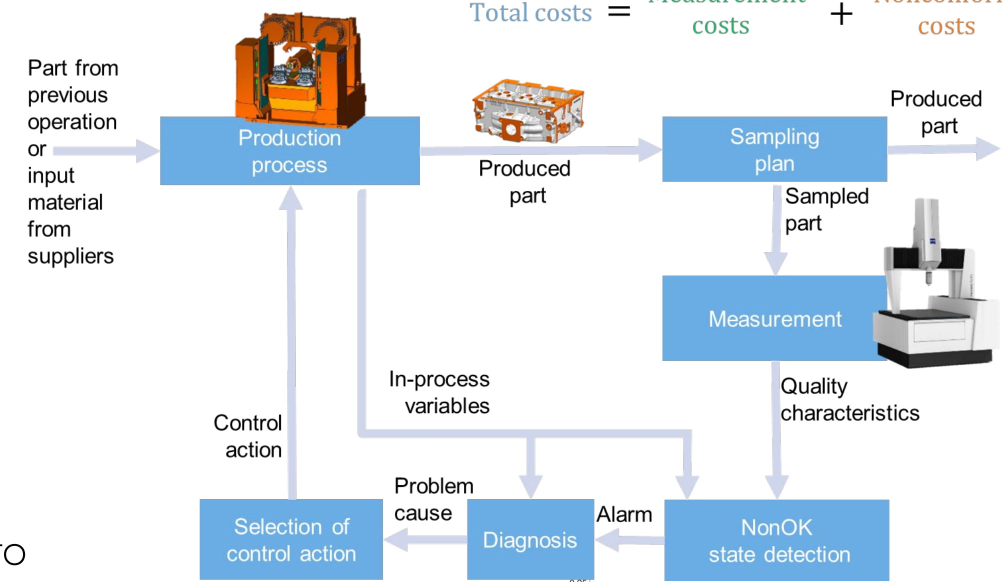
- Optimization of parts sampling (ontologies representing process structure knowledge, definition of total quality cost, optimization)
- Detection of nonOK state from post-process data or from in-process data (anomaly detection, regression, classification, forecasting)
- Semi-automated diagnosis (interpretation, explanation and root cause analysis)

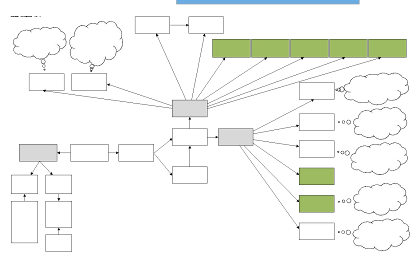
Issues to be solved

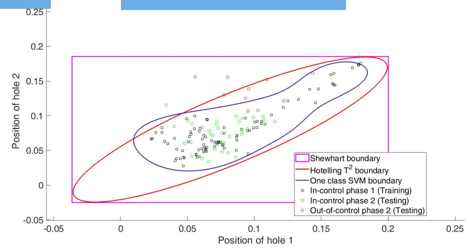
- Lack of data for predictive models due to flexibility of manufacturing (active learning, transfer learning and federated learning)
- Acceptability problems due to low explainability and interpretability (methods like LIME, ANN)



Total costs = Measurement costs + Nonconformity costs







RO 13.3 Quality Control in Flexible Manufacturing Systems

Solutions to issues of FMS quality control:

Acquire data needed for training more quickly, create adaptive and optimal sampling plans monitor process directly and online, transfer learning for quality models, utilize semantic knowledge representation and adequate reasoning

Industrial collaboration

- RO 13.4 – Products, production systems, and devices (G13, V. Jirkovský)
  - Ontology of quality inspection process, which will help to define cost functions for optimization of quality control

Potential international collaboration

- Partners from AI REDGIO 5.0 project and its more than 10 use cases related to quality control , e.g.
  - Brainport Innovation Campus, Eindhoven, Netherland (production monitoring)
  - Jozef Stefan Institute (JSI), Ljubljana, Slovenia, (monitoring of assembly lines)
  - Politecnico di Milano, Italy
  - I4.0 Lab, Fondazione Bruno Kessler, Trentino, Italy (predictive maintenance and quality control)
- Partners from AIQUAMA (AI-based Quality Management for Smart Factories)
  - DFKI, Saarbrücken, Germany

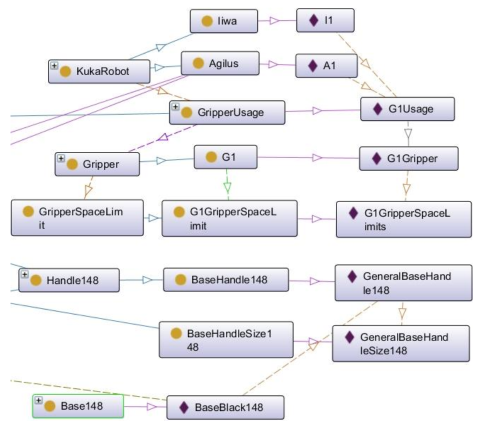
RO 13.4: Products, production systems, and devices

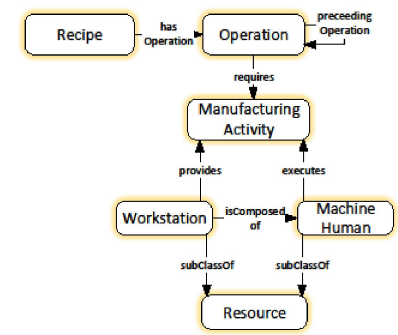
Explicit specification of industrial system components using ontologies

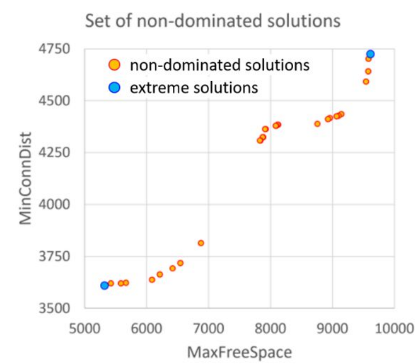
- Knowledge base specification covering production resources and recipes
- Production feasibility – Q: is the given product manufacturable using given hardware?

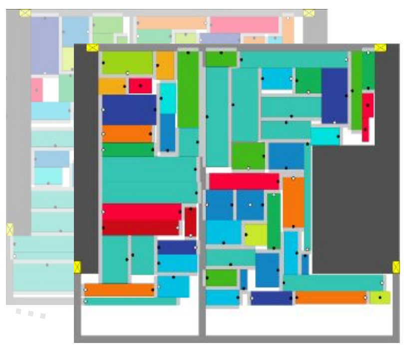
Multi-objective evolutionary optimization for hard industrial optimization problems:

- Nonlinear objectives
- Nonlinear constraints
- Simulations involved in solution evaluation
- Diverse set of high-quality solutions is required









Kubalík, J., Kurilla, L., and Kadera, P. *Facility layout problem with alternative facility variants. Appl. Sci.* 2023, 13, 5032

RO 13.4: Products, production systems, and devices

- **What we will aim for:**
  - Ontological description of production resources (products, product decomposition, and available HW) and recipes
  - Exploitation of semantic matchmaking for production feasibility
  - Tight integration of industrial system ontological description and evolutionary algorithms
  - Design MOEA for various aspects of production process optimization:
    - Facility layout optimization, industrial system generation
  - Investigate utilization of digital-twin simulations and LP/CP solvers within the MOEA.
- **International collaboration:**
  - Airbus research center ; Rockwell Automation research center
- **Cooperation with other RAs:**
  - R. Babuška, RA7 and Z. Hanzálek, RA11

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Thank you for your attention!

CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE

BRNO UNIVERSITY OF TECHNOLOGY

RA13: **Complex systems for flexible production**

VSB TECHNICAL UNIVERSITY OF OSTRAVA

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