MULTI-AGENT CONTROL OF FLUID SYSTEMS

COMPARISON OF APPROACHES

Kevin T. Logan, J. Marius Stürmer, Tim M. Müller, Tobias C. Meck, Peter F. Pelz
Chair of Fluid Systems, TU Darmstadt

TECHNISCHE UNIVERSITÄT DARMSTADT

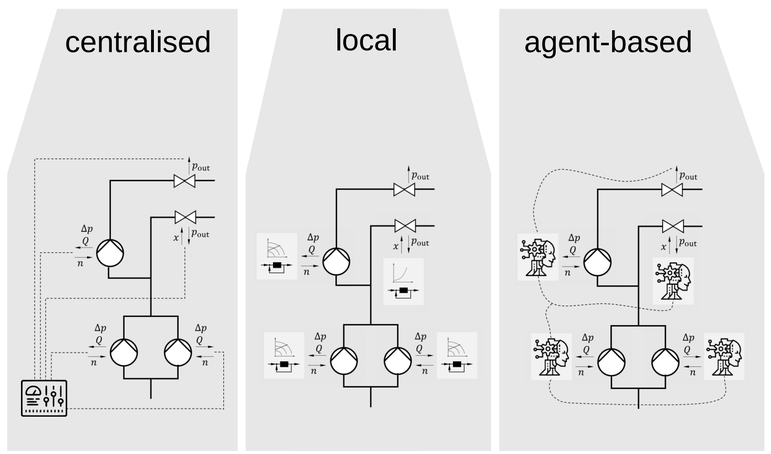
Multi-agent systems allow system-wide, energy efficient control of fluid systems, fulfilling volume flow demands even in the face of disruptions within the communication network.

MOTIVATION

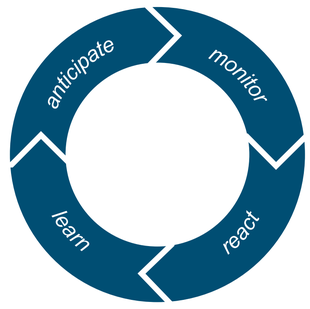
ensuring fluid systems fulfil their function while
(i) minimising effort
- set-up and start-up
- energy consumption

(ii) maximising acceptability
- transparency
- comprehensibility
- traceability

(iii) maximising availability in the face of disruptions

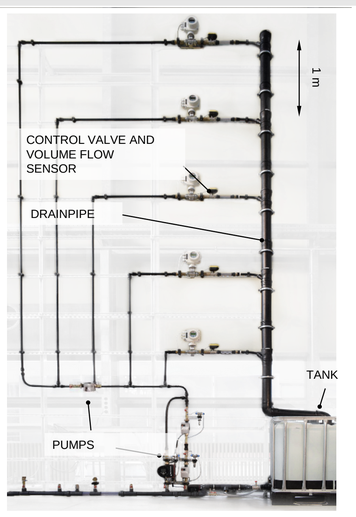


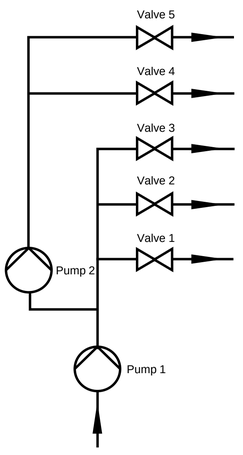
"Hollnagel outlines [...] four resilience functions [...]. All four functions (learning, responding, anticipating, monitoring) are seen as cross-sectional claims. This means that people are also required to learn, anticipate, monitor and respond in order to create a resilient socio-technical system."
Pelz et al., 2021. "Mastering Uncertainty in Mechanical Engineering." Springer, Cham

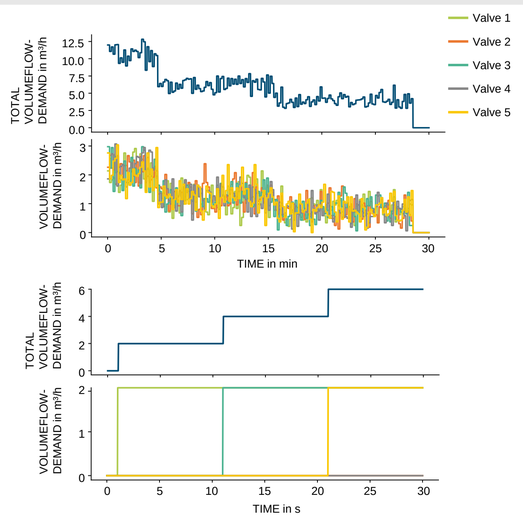


USE-CASE

- model of a high-rise building scaled to 5 m with central and decentral pumping station and five consumers on five floors
- representative load profile of 30 minutes duration with phases of high, medium, low and zero demand
- simplified load profile of 30 seconds duration for tracing and comprehending decisions made by the multi-agent system







METHODS

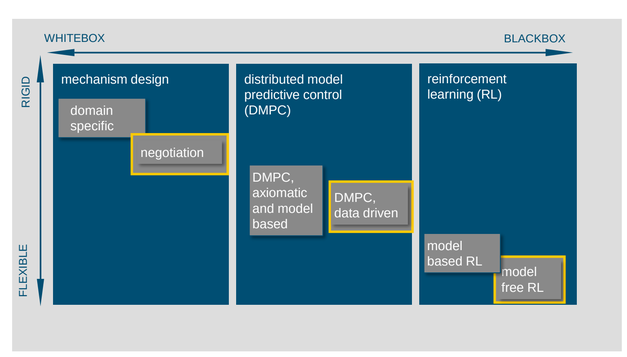
combining advantages of centralised system-wide control and local component control in distributed multi-agent system (MAS)

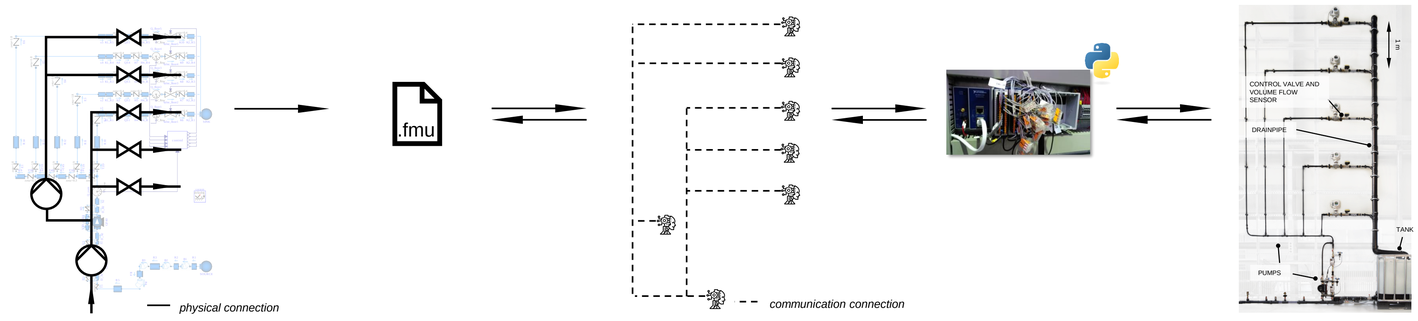
comparison of methods for designing the MAS:
(i) control technology
  (distributed) model-predictive control (D)MPC
(ii) machine learning
  multi-agent deep reinforcement learning (MADRL)
(iii) game theory
  market mechnism for trading gurantees of volume flow

- **What is my purpose?**
- **What can I monitor?**
- **What can I influence?**

Purpose: fulfill volume flow demand
Monitor: target and actual volume flow
Variable: valve opening
Costs: $c_{\mathrm{valve},i,t} = \lambda_i \left(Q_{i,t,\mathrm{demand}} - Q_{i,t,\mathrm{actual}}\right)^2,\ \forall t \in \mathcal{T},\ i \in \mathcal{V}$

Purpose: minimise power consumption
Monitor: power consumption, volume flow
Variable: on/off, rotational velocity
Costs: $c_{\mathrm{pump}\,i,t} = \lambda_i \left(\frac{P_{i,t} - P_{i,\min}}{P_{i,\max}}\right)^2,\ \forall t \in \mathcal{T},\ i \in \mathcal{P}$



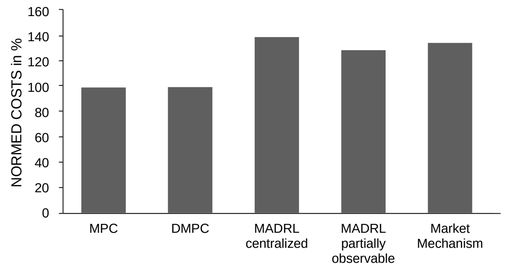


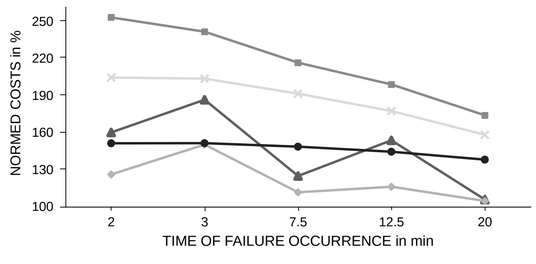
Model (OpenModelica) → *Functional Mock-Up Unit* ⇄ *Multi-Agent System (Python environment)* ⇄ *NI-DAQmx API (Python)* ⇄ *Test Rig*

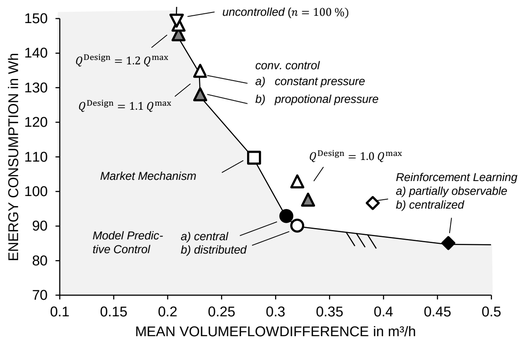
Co-Simulation of FMUs with Integrated Research Data Management (SOFIRpy)

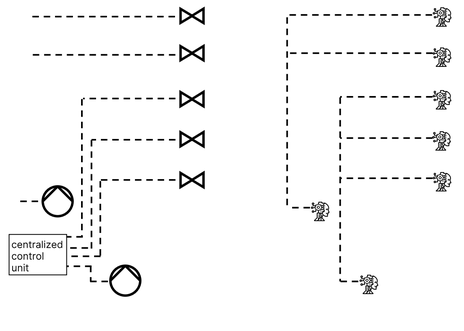
RESULTS

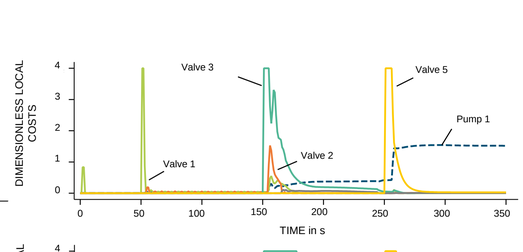
(i) DMPC performance close to optimum of centralised system-wide control
(ii) costs of MADRL and markget mechanism 30-40% higher
(iii) costs of the different approaches pareto-optimal with regard to conflicting optimisation goals energy efficiency and control accuracy
(iv) DMPC and one MADRL approach more robust with regard to a disruption within the communication network compared to centralised control

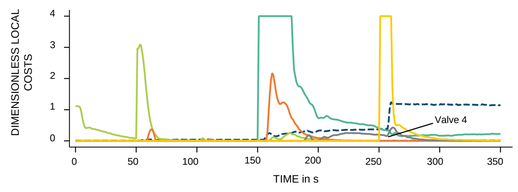












- The costs of the physical system exceed those of the simulation by ≈51%.
- The simulated model does not consider system dynamics.

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Prof. Dr.-Ing. Peter F. Pelz

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