Machine Learning Based Fault Detection and Diagnosis for Heat Pump Systems

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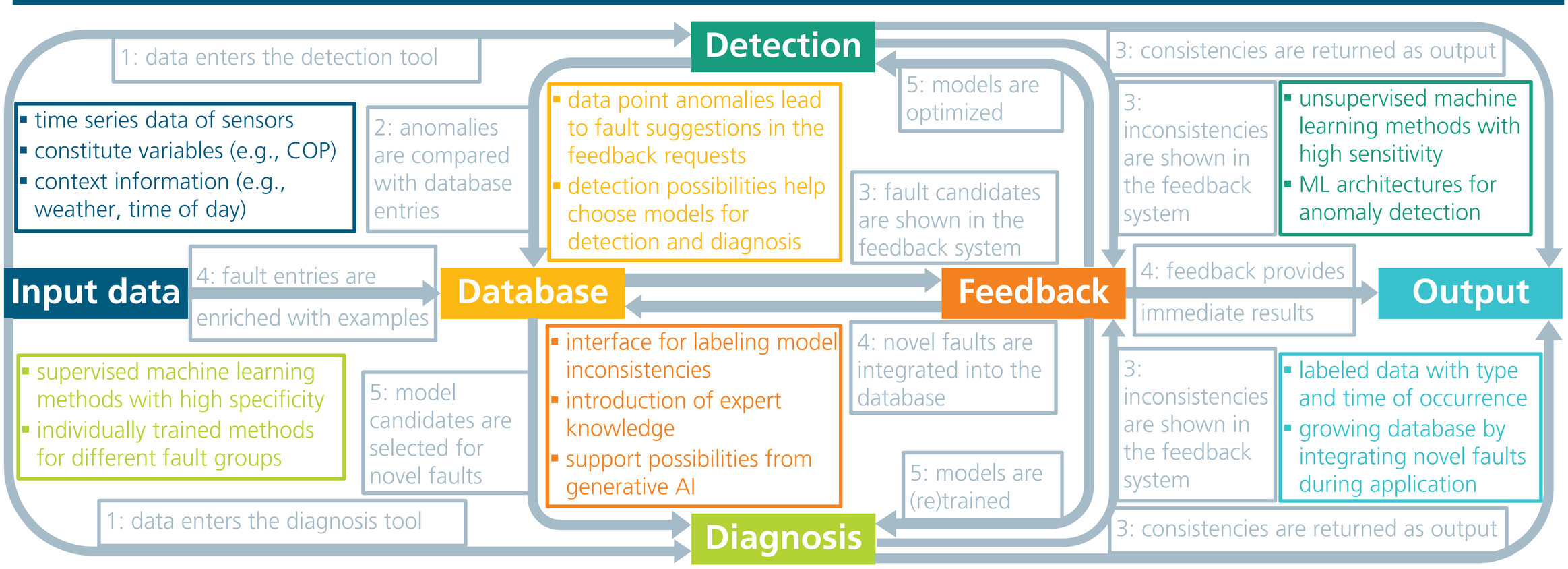
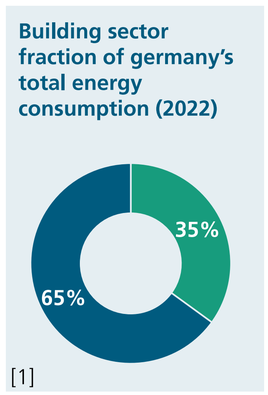
Structure of the Fault Detection and Diagnosis Tool



Motivation and Challenges



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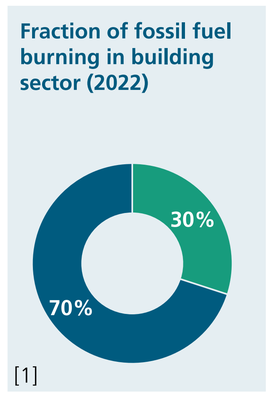
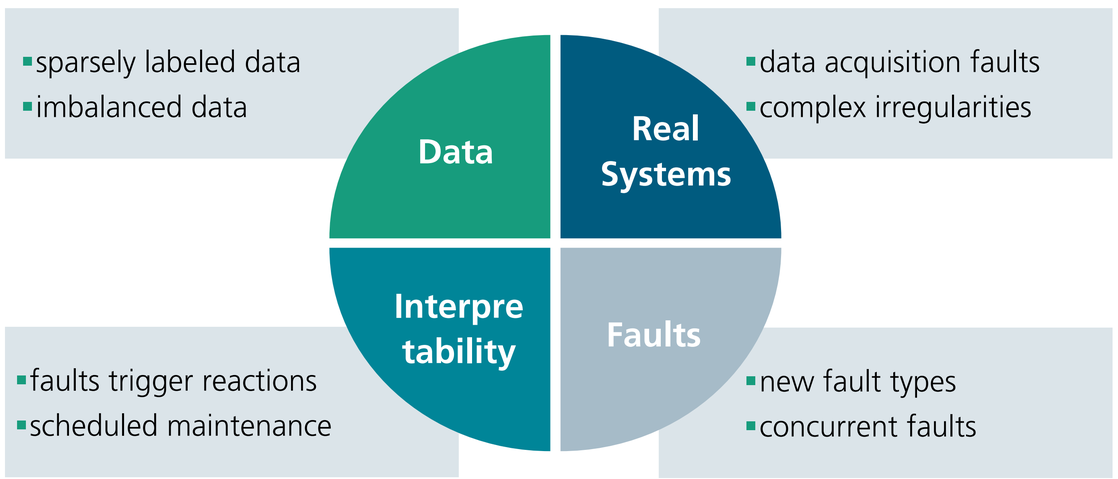


[1]

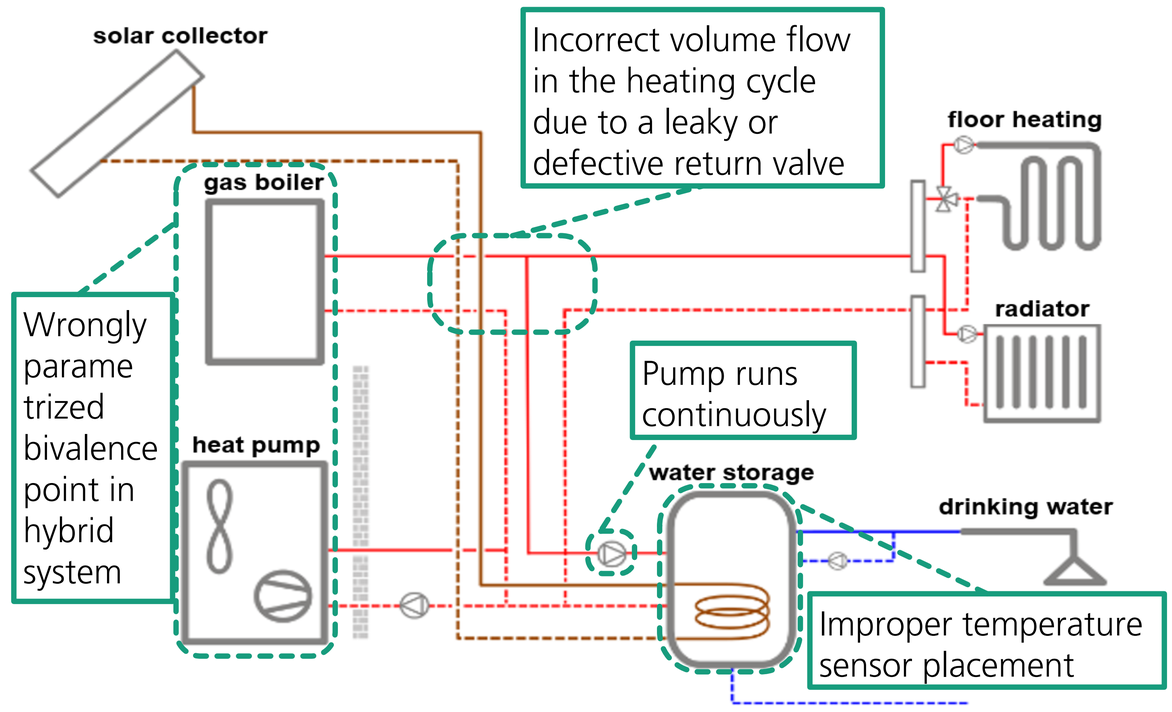
The most promising solution to reach Germany´s climate goals in the building sector is the heat pump technology. A heat pump does not depend on burning fossil fuels, but on electricity. In the first half of 2023, 52% of electricity consumption was covered by renewable energy sources [2].

The heat pump market is experiencing substantial growth. This trend underscores the importance of proper operation, as faults can lead to reduced efficiency, security issues, high maintenance costs, or even complete system breakdowns. To ensure optimal operation, Fault detection and diagnosis (FDD) are crucial. Fault detection involves identifying faults in a system and determining when they occur, while fault diagnosis involves assessing the impact, location, and progression of a fault based on its symptoms.

Although they are not the standard against simple rule-based systems, in recent years Machine Learning (ML) methods have gained more attention in the FDD sector in industrial systems. They show great potential in early fault detection and there are several examples where they far outperform conventional methods. However, there are challenges for ML in FDD.



Examples of Faulty Behaviour



Main Concepts of the FDD-Tool

Feedback System

Using expert feedback tackles two challenges of ML-based FDD. When a fault is detected, someone with an interest in the correct system operation needs to be informed. On the other hand, feedback can be used to label data on the fly for training supervised ML methods.

Expert Database

The feedback system can be enhanced by descriptions and classifications of already detected faults and operation modes. Furthermore, the databases can be transferred between heat pump systems, and novel faults can be integrated.

Complementary Methods

Because of simultaneous faults and to increase transferability, it is beneficial to train individual methods with high specificity. Because no fault should escape detection, some methods should specialize solely on sensitivity [3].

Sources
1. Bundesministerium für Wirtschaft und Klimaschutz. (2022). 65 Prozent erneuerbare Energien beim Einbau von neuen Heizungen ab 2024. Retrieved from: https://www.bmwk.de/Redaktion/DE/Downloads/Energie/65-prozent-erneuerbare-energien-beim-einbau-von-neuen-heizungen-ab-2024.pdf?__blob=publicationFile&v=6 (Accessed on: 14.03.2024)
2. Die Bundesregierung. (2023). Anteil der Erneuerbaren Energien steigt weiter. Retrieved from: https://www.bundesregierung.de/bregde/schwerpunkte/klimaschutz/faq-energiewende-2067498#:~:text=Die%20Stromerzeugung%20aus%20Erneuerbaren%20Energien,noch%20bei%2044%2C4%20Prozent. (Accessed on: 14.03.2024)
3. Benndorf, G. A., Wystrcil, D., & Réhault, N. (2018). A fault detection system based on two complementary methods and continuous updates. IFAC-PapersOnLine, 51(24), 353-358. doi:10.1016/j.ifacol.2018.09.601

Associated Projects
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- Joint project: Future-Hybrid - Complexity reduction for heat pump hybrid systems of the future; sub-project: Complexity reduction and autoparameterization. The research work is supported by funds from the Federal Ministry for Economic Affairs and Energy (BMWK.IIB5) under grant numbers 03EN4052B. Project management is undertaken by the Project Management Agency Jülich (PT-J.ESN4). The authors express their sincere gratitude for the funding, support, and collaboration