Popular science summary of the PhD thesis - Ali Kücükavci

Title of the PhD thesis: A Data-Centric Framework for HVAC Information Management - To Facilitate HVAC Rightsizing and Compliance Checking.

The Architecture, Engineering, Construction, and Operation (AECO) industry's impact on global warming and energy consumption is undeniable, with buildings responsible for 36% of worldwide CO2 emissions and 40% of global energy use. Heating, Ventilation, and Air Conditioning (HVAC) systems play a critical role, accounting for 39% of this energy consumption. These staggering statistics underscore the urgent need to revolutionize HVAC design to enhance efficiency and sustainability.

Despite its pivotal role, the AECO industry faces significant challenges, including productivity stagnation, limited digitalization, and inefficient information management. The reliance on document-centric approaches in the HVAC design process leads to inefficiencies and inaccuracies, resulting in oversized and inefficient systems. Existing Building Information Modelling (BIM) and Common Data Environment (CDE) solutions struggle with system and data interoperability and fail to fully support a data-centric information management framework within the HVAC design process.

This PhD thesis addresses these challenges through three primary research questions aimed at developing and integrating semantic data and rule models within CDEs to enhance HVAC workflows and productivity. The Design Science Research (DSR) methodology underpins this study, guiding the iterative development and validation of the proposed solutions.

The primary approach of this thesis includes several key solutions. The Flow Systems Ontology (FSO) and Flow Properties Ontology (FPO) provide a detailed, semantically rich representation of HVAC systems, including their distribution components and capacity- and size-related properties. These ontologies, integrated with existing ontologies, offer a modular approach to represent static and dynamic HVAC properties. Additionally, the Declarative HVAC Rule Model, developed using the SHACL rule language, ensures the accuracy and reliability of HVAC data in BIM models, facilitating efficient compliance checking and reducing errors and inconsistencies in data models. The Semantic HVAC Tool, integrating these ontologies and rule models within a CDE, provides a robust architecture for data storage, management, and user interaction, enabling HVAC rightsizing, compliance checking, and performance evaluation.

Empirical validation through case studies demonstrates this data-centric approach's practical viability and substantial benefits. The results show that FSO and FPO effectively represent detailed HVAC information, including distribution components and their capacity- and size-related properties. The Declarative HVAC Rule Model can constrain and validate HVAC data, ensuring accuracy and reliability in BIM models. Integrating FSO, FPO, and the Declarative Rule Model within the Semantic HVAC Tool enhances system and data interoperability, supports detailed HVAC information representation, enables automated compliance checking, and ultimately facilitates rightsizing.

This research significantly advances the representation, management, and compliance checking of detailed HVAC information, providing practical solutions to improve efficiency, accuracy, and interoperability in HVAC design. The findings contribute to academia by providing a format-agnostic data model to represent detailed HVAC information and a declarative rule-set to constrain detailed HVAC information. Moreover, the findings contribute to academia by enabling automated reasoning and inference, enriching knowledge representation in the HVAC domain. For industry practice, the Semantic HVAC Tool offers seamless information exchange and automated compliance checking. Additionally, the solutions are scalable and adaptable, promoting broader adoption and significantly contributing to the ongoing digital transformation of the AECO industry.

To ensure the continued advancement and practical application of the research findings, this study recommends future research to focus on both short-term and long-term directions. In the short term, it is crucial to explore automatic classification techniques for FSO to categorize generic HVAC components and validate FSO's applicability to electrical systems. In the long term, extending the Semantic HVAC Tool to facilitate seamless data exchange between HVAC designers and manufacturers using ontology-based data repositories accessible via APIs is essential. Additionally, investigating the use of Federated SPARQL for decentralized data management and exploring collaborative models and industry partnerships to develop advanced integrated platforms are recommended.