Building system data integration using semantic

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Abstract. In recent decades the construction industry started a rapid digitalisation process resulting in the widely used BIM methodology. Despite developing multiple Industry Foundation Classes (IFC) schemas, the interoperability and data integration between models remains an issue. This study aims to fill this gap by providing a framework for data integration between various models, achieved by analysis of available ontologies, IFC schema limitations, and their relations. This methodology is tested based on a case study containing multiple BIM models. The study's findings are expected to enhance the connectivity between MEP components placed in different models and provide knowledge representation for developing the Digital Twin concept.

1. Introduction

1.1. Context

The origins of Building Information Modelling (BIM) can be traced back to the 1970s

The industry frequently employs the method described, which enables domain designers to work independently on their respective areas of expertise and later combine their knowledge by uploading their work to a Common Data Environment (CDE). However, this method is not without its limitations. One major drawback is the absence of all connections between the final asset. In particular, no relations are observed between two or more mechanical, electrical and plumbing (MEP) models. Mechanical equipment is being modelled in one domain while relying on resources from several others. Therefore, when exported from its native format to IFC, only relationships within one file are preserved, resulting in a lack of interdisciplinary connections between MEP systems and domains.

1.2. Research questions and overview

This research proposes a methodologic interdisciplinary framework linking MEP components in multiple domain BIM models. Therefore the following research questions have been formulated:

RQ1: What are the BIM model's undefined relations between MEP elements?

RQ2: How to complement missing knowledge between graph representation of BIM models?

Section 2 gives a background. Section 3 presents the methodology and applied rules. Section 4 discusses the results and limitations of the framework. Finally, the last two sections answer the research questions, draw a conclusion and give an overview of the further work.

2. Background

2.1. Ontologies

In recent years, various research initiatives focused on developing representation of the building MEP systems, significantly increasing the IFC models' potential. Nevertheless, Pauen et al. (Pauen *et al.*, 2021) noticed that the FSO ontology does not provide direct control and knowledge about the system's state and fluid mass proposing a Tubes System Ontology (TSO).

2.2. IFC schema limitations

Governments increasingly promote digital transformation to minimise costly planning errors and construction delays. In this context, the IFC format has emerged as a crucial tool for process stakeholders to exchange information without divulging proprietary knowledge or unique

Figure 1 The relation between mechanical equipment and a flow segment element in IFC 2x3 model

3. Methodology

3.1. Model representation

The first point of solving the interoperability issue and gaps in the connectivity between MEP systems was selecting a convenient, extensible and machine-readable structure. Therefore using the IFC-LBD tool proposed by Rasmussen (Rasmussen, 2023), IFC models are converted into RDF files using the FSO ontology requirements. The FSO ontology describes the relations between components more extensively than IFC does. It contains information about flow directions, heat transfer and electric flow (Kukkonen *et al.*, 2022). FSO relations between components in a tree structure form are shown in Figure 2. The diagram illustrate

The last step is the definition of the connection order. This definition is crucial in ensuring that the fluid flows in the correct direction. Such flow can be defined only in six variants based on the PortCharacteristic property, as presented in

Table 1. Provided comparison analysis cannot use more specific information like port geometrical properties or a domain because such knowledge is not available in the IFC 2x3 (Liebich, 2009).

Table 1 Flow direction predictability based on the ports features

PortCharacteristic	SOURCE	SINK	SOURCEANDSINK	NOTDEFINED
SOURCE	X			X
SINK		X		X
SOURCEANDSINK			X	X
NOTDEFINED	X	X	X	X

4. Results

4.1. Case study

The following section presents the implementation of the proposed methodology. Using Autodesk Revit 2021, three IFC models were generated to reflect the three domains: ventilation, sanitary, heating and cooling, as presented in Figure 3.

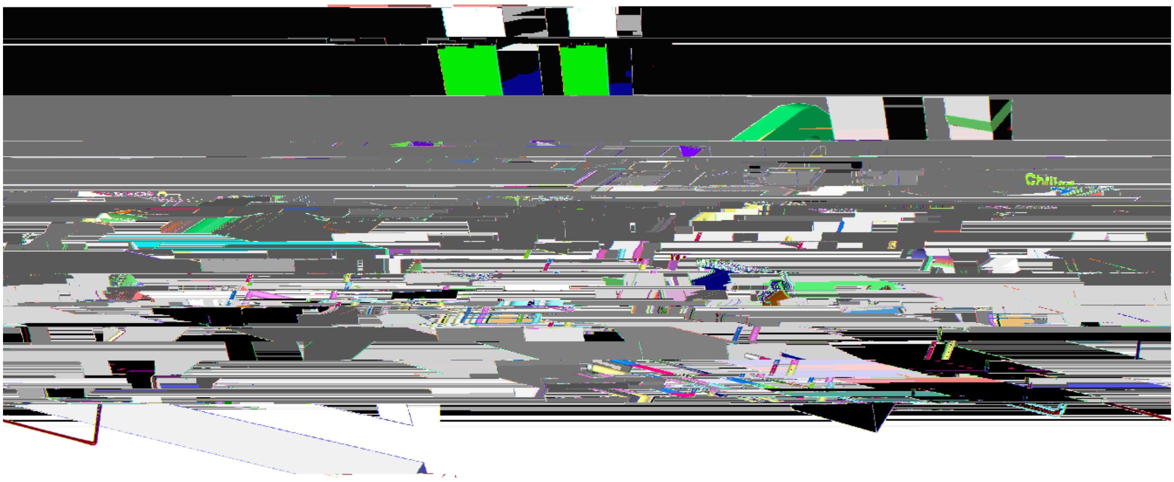

Figure 3 Federated model of three IFC models

All models are generated from Autodesk Revit to IFC separately using a standard IFC 2x3 Coordination View 2.0 skimmer, one of the standardised approaches of ISO 19650. IFC files contain elements and systems presented in Table 2.

various IFC models were presented. The first use case is a query returning all IfcEnergyConversion devices affecting the selected "startElement" component by supplying a fluid dependencies. Another benefit of concept application is the effortless knowledge extraction of data for a Building Management System (BMS) system. Based on relations and links between interdisciplinary elements, automation engineers might plan systems more efficiently and feasibly discover relations between multiple components, impacting a certain level, zone or space.

The presented framework solves the interoperability issue and lack of connectivity between elements in various IFC models. Based on the case study, different IFC models were connected, including the correct information about the flow direction. Nevertheless, the methodology has limitations caused by the constraints of the IFC schema. To make analysis more versatile and trustworthy, the IFC file could include additional characteristics of every connector. The first missing connector property is the geometrical characteristic of a shape and size. The lack of the property impedes the analysis and cannot ensure that two elements can be connected and maintain the same capacity and flow speed. Another useful feature would be the property of a port function, describing what type of system can be connected to a certain ifcPort. Additional features would add more value to the analysis, especially for complex elements, where belonging to only one system can not be determined. Therefore the current state of the proposed concept requires prudence and wells

References

Beetz, J., van Leeuwen, J. and de Vries, B. (2009) 'IfcOWL: A case of transforming EXPRESS schemas into ontologies',