Development of an MVD for checking fire-safety and pedestrian simulation requirements

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The formal and automatic integration of building information among the different tools is crucial for delivering a seamless exchange of models. The Model View Definition (MVD) mechanism is a standard approach for IFC implementation. An MVD represents a subset of the IFC schema that specifies the requirements and specifications of the exchanged data between the involved software tools. Fire safety engineering and pedestrian simulations are highly connected domains evaluating the developed designs during the different events and scenarios. Hence, the early integration of those domains in the design process can support the decision-making process, reduce the project risks, and avoid a substantial amount of rework. In this paper, the Bavarian building law and the pedestrian simulation requirements are analyzed and mapped to the Industry Foundation Classes (IFC). Additionally, an MVD is developed to facilitate pedestrian simulators to parse and filter IFC building models and to automate checking the correctness and completeness of the exchanged IFC files.

Keywords: Building Information Modeling (BIM), Model View Definition (MVD), Fire safety, Building regulations, Pedestrian simulation

1 Introduction

Failures in fire protection cause enormous damages in the event of a fire and often endanger human lives. Recent examples are the Grenfell Tower fire in London in 2017 or the continuing delays in fire protection at Berlin Airport. If structural or technical fire protection measures are incorrectly implemented, they can also lead to additional damage, such as firefighting water damage or the contamination of ventilation systems with smoke gases. Consequently, it is essential to consider fire safety requirements as early as the planning stages.

In Germany, building permits are mandatory for construction projects. To receive a building permit, a fire safety certificate, or a fire safety concept developed by a fire safety engineer is necessary. Fire safety engineers manually create these certificates after, for example, evaluating the measures of escape routes to analyze possible dangers. The requirements given in building codes differ from country to country, rendering complexity and challenges in the automation of code checking and simulation. Code checking requires extensive expertise in the applicable law and a specialized analysis for each particular case; it is time-consuming and error-prone.

Developing a building project requires intensive collaboration between several domain experts. In this kind of collaboration, the information quality, such as compliance with regulations and analysis requirements, is essential for exchanging, coordinating, and integrating the partial designs at the different design stages. As the use-cases of building projects are highly specialized, a Building Information Modeling (BIM) model needs to include numerous additional information to satisfy the use-cases' requirements in proper representations (i.e. types, properties, and names). Hence, a robust mechanism for defining the requirements and automatic checking of the model's completeness and compliance to domain specification is vital for the practical use.

The Industry Foundation Classes (IFC) is a vendor-neutral format for exchanging building information among different BIM-authoring and simulation tools. IFC includes data specifications for the individual building elements and their relationships (Liebich et al. 2013; Borrmann et al. 2018). However, different researchers have identified the inflexibility of providing IFC data from the BIM-authoring tools to support the diverse use-cases during a construction project (Bazjanac 2002; Lee et al. 2013). As a solution for this inflexibility, the Information Delivery Manual (IDM) and the Model View Definition (MVD) approach was proposed by the buildingSMART to provide a common understanding of which information should be present in the export IFC model for a particular use-case (BLIS Consortium - Digital Alchemy 2019; buildingSMART 2019). Through the development of an IDM/MVD, the actual workflow and the required interaction between the different disciplines is explicitly defined.

Checking a building model for compliance with fire safety regulations involves verifying its geometric and semantic information as well as functional requirements, such as safe escape routes. Hence, providing seamless integration with pedestrian simulation tools and automatically checking their requirements is crucial.

In this paper, the building regulations in Bavaria are analyzed and mapped to IFC. At the same time, the requirements for integrating IFC building models into *crowd:it*[1] (a pedestrian simulation tool) are extracted. Finally, together the extracted regulations and simulator requirements are combined in an MVD, which is capable of ensuring the completeness and correctness of the exchanged building models. Figure 1 demonstrates the information flow from the BIM-authoring tool to the pedestrian simulator. First, an IFC file is exported and validated using an mvdXML file. Then the simulator uses the same mvdXML file to filter the IFC building model.

The paper is organized as follows: Section 2 discusses the background and related work of our research. Section 3 provides an overview of the steps follow to extract rules and develop and MVD from the Bavarian law and the used simulator. Finally, Section 4 summarizes our progress hitherto and presents some of the limitations that we have encountered during this research.

[1] https://www.accu-rate.de/

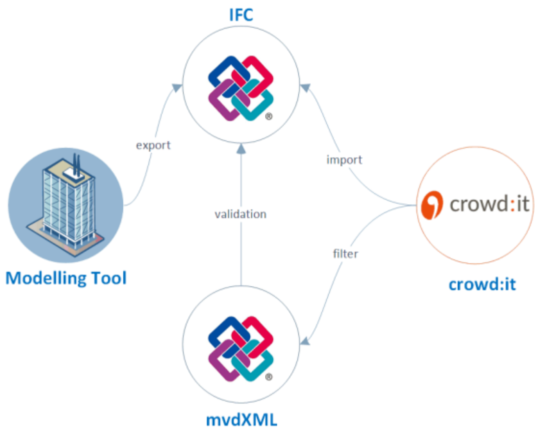

Figure 1: Flow of information from BIM-authoring tools to the pedestrian simulator, demonstrating the usage of the generated mvdXML file for validating and filtering IFC building models.

2 Background & Related work

2.1 Fire-safety Engineering

Typically, fire safety engineers require a minimum set of information from the architect when exchanging construction plans to perform their analysis. Accordingly, when exchanging a BIM model, a set of information needs to present in the model. Fire safety engineers analyze the model comprehensively; if necessary, they require altering the model to incorporate certain fire safety measures to comply with the building codes. These required changes can be concerned with missing information or changes to the developed design. This process is recursive, depending on the size of the project and the integrity of the exchange data.

Various requirements of different building codes place complex demands. In practice, escape routes are manually checked and evaluated as part of fire safety by specialized engineers. This traditional building plan checking and verification process are inefficient and time-consuming. Automated checking offers various benefits; flaws can be allocated within seconds instead of hours, and inconsistencies can be avoided. This could speed up the design process and reduce costs.

In contrast to the compliance check, evacuation models simulate the movement of pedestrians through the building model in the event of an evacuation. This kind of simulations can help architects and engineers to detect flaws in the designs. Mainly, it assists in managing crowd movements and avoids fire-exit flaws.

2.2 Bavarian Building Regulations

Building regulations ensure the quality as well as safety of building projects and differ from country to country. Regulations represent the minimum requirements in which a building must comply within. Model Checking denotes the automated, rule-based verification of the model for building code requirements. Typically, building codes include fire safety, structural safety, accessibility, technical requirements, and other aspects. A major challenge of compliance checking is the translation of rules into a computer-readable format.

This paper deals with the applicable law in Bavaria, Germany - Bayerische Bauordnung (BayBO) (Bavarian Building Regulations). The BayBO includes the minimum requirements that must be complied with during the whole construction project in 84 Articles. One of the essential parts of the BayBO is the building classes' classification (so-called Gebäudeklassen). The classification consists of five classes where the requirements regarding fire protection differ for each class. The determination of the classes relies on the building's usage, type, height, number of storeys, and the gross floor area. The higher the Building Class, the stricter the BayBO's regulations.

2.3 Pedestrian Simulation

The evacuation of pedestrians securely and in a timely manner is very crucial during unexpected disaster events (Yu et al. 2018). Pedestrian dynamics in emergencies has become increasingly important and got the attention of both researchers and practitioners (Yu et al. 2018). Various attempts have been made to model the behavior of crowds in emergencies for the validation of buildings and public environments in general. In the last decade, a lot of effort was taken to enhance models and simulators.

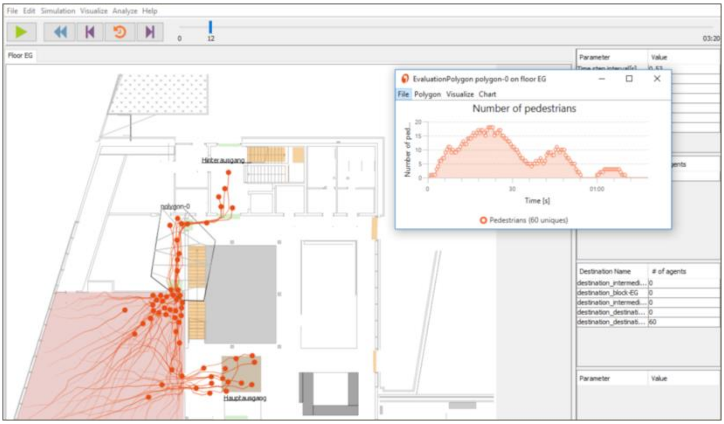

Figure 2: Screenshot of crowd:it[2], a pedestrian simulation tool.

Figure 2 shows a screenshot of the pedestrian simulator used in this paper, crowd:it. The simulator is capable of analyzing the pedestrian flow and movement patterns, evaluating the building against safety concepts as well as its performance during a particular event or worst-case scenarios. Pedestrian simulators are mainly interested in boundaries, spaces, transport elements, and exits. Besides the elements' geometry, additional information is required, including, the escape routes, spaces' maximum number of occupants, the demographics of the occupants, the stairs number of treads, or riser height…etc. (more details are provided in Section 3).

[2] https://www.accu-rate.de/en/software-crowd-it-en/

3 Requirements analysis and Developing an MVD

The process of developing an MVD involves multiple steps: (1) analyze the Bavarian law and extract rules from the provided regulations, (2) investigate which building information is required by the simulator to generate the scene and perform the analysis, and (3) map the extracted requirements to IFC and generate an mvdXML file.

Figure 3 presents part of the extracted rules from the BayBO regulations for all building classes. The building requirements are mapped to the common property sets defined in IFC. The provided flowchart describes logical checks to identify the requirements a building element needs to fulfill based on its building class. At the same time, it assigns each check with a set of IFC requirements.

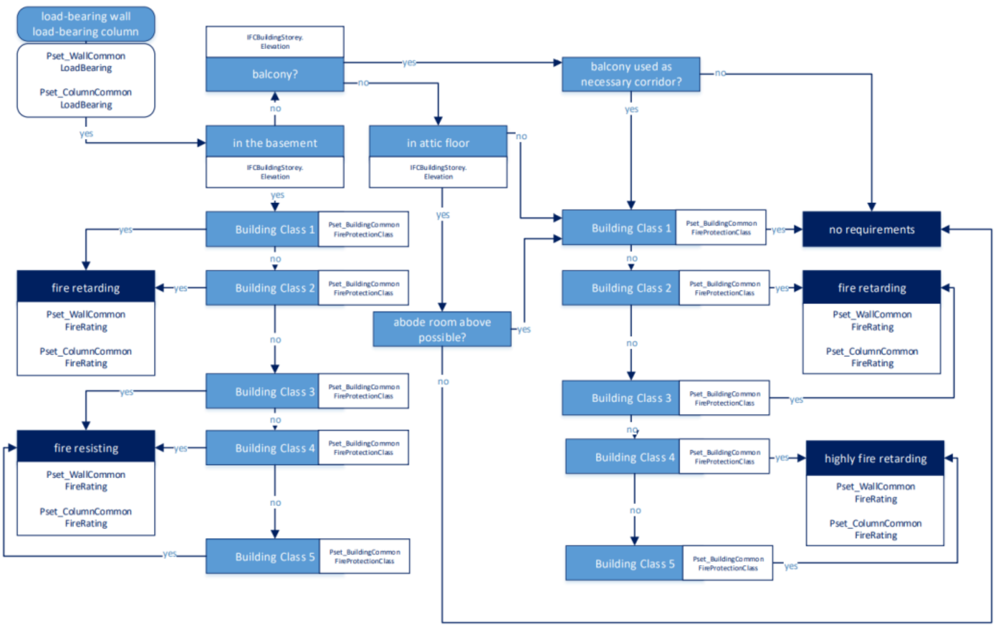

Figure 3: Flowchart mapping the requirements of one example from the BayBO to IFC. This figure shows the requirements of a load-bearing wall or column, depending on the building class. For instance, if a building model belongs to building class 1 and has a load-bearing wall in the basement, this wall needs to be fire retarding. If the same model has a load-bearing wall in any other storey but not in the attic floor with an abode room, a wall has no requirements.

Besides the resultant flowchart, the complete analysis is available online on GitHub[3], the repository includes a table comparing the requirements of each building class as well as a list identifying which of the requirements can be checked by an mvdXML or require a manual check by a specialist. Afterwards, in collaboration with *accu:rate*[4], the required building information for the simulator to parse and import the building IFC model were investigated.

[3] https://github.com/SinaPf/BIM-based_Fire_Code_Compliance_Checking

[4] http://www.accu-rate.de/

Figure 4 provides an overview of the main classes that were investigated and their mappings to the IFC schema.

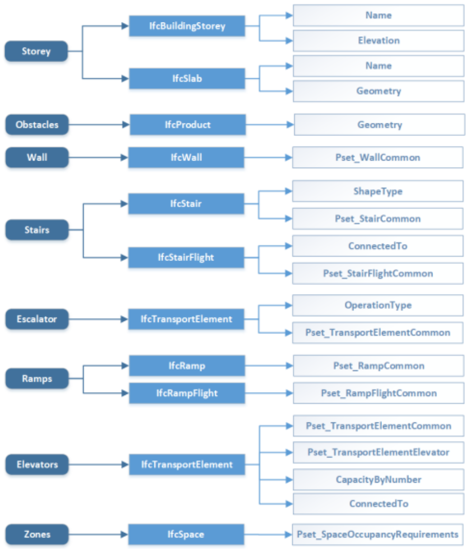

Figure 4: Extracted information required for pedestrian simulation

To support developing MVDs, the buildingSMART provided a free tool called ifcDoc. Using this tool, it is possible to build over the commonly available MVDs[5], including coordination, reference, and design transfer views. Additionally, the ifcDoc is capable of exporting mvdXML, the open standard for developing an MVD (Chipman et al. 2012). The mvdXML can be used to structure the exchange requirements with specific IFC types, entities, and attributes (See et al. 2012). Based on the extracted requirements from the Bavarian law and the pedestrian simulator, an mvdXML file is generated. Figure 5 demonstrates the ifcDoc user interface used to input the extracted requirements from Figure 3 and 4. Each of the required IFC classes is defined and assigned to the required properties.

After the mvdXML file is exported from the ifcDoc, two parties can use it: (1) the software vendors, to filter and understand the exchanged IFC files, (2) the architect or engineer, who is interested in evaluating the performance of the developed designs, to verify the exchanged model's compliance to requirements before handing it to the simulation specialist. The software vendors need to implement a generic algorithm that would understand the links and the relationships between the mvdXML templates and views. In this regard, the buildingSMART has provided a sample implementation that is integrated with their tool, XbimXplorer, and

[5] http://www.buildingsmart-tech.org/specifications/specification-tools/ifcdoc-tool/ifcdoc-baselines

available online[6]. Figure 6 illustrates using the XbimXplorer for validating the developed mvdXML.

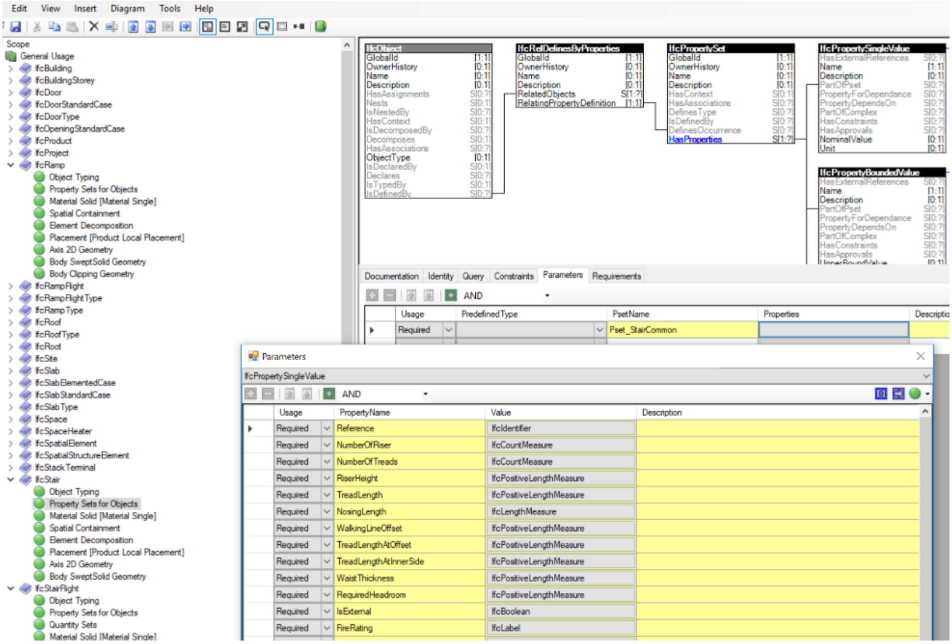

Figure 5: Using the ifcDoc to develop an MVD

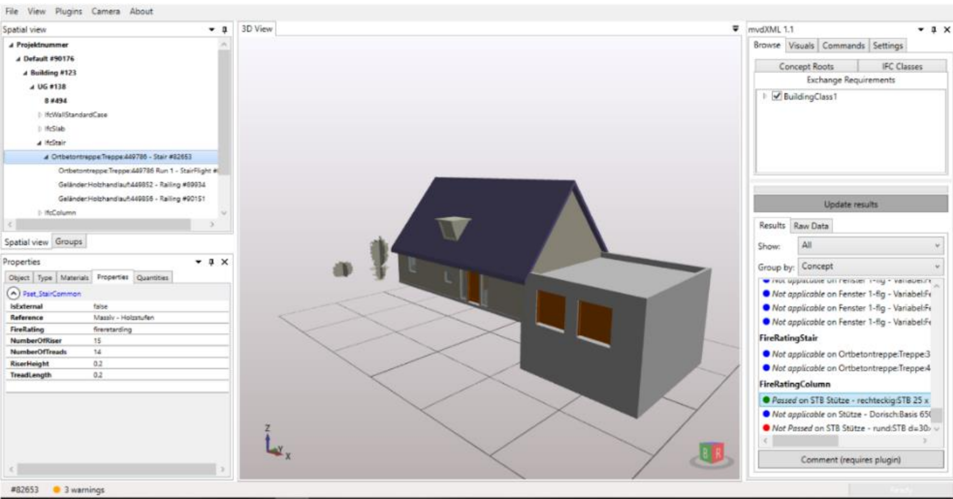

Figure 6: Using the XbimXplorer to validate an IFC against the developed mvdXML

6 https://github.com/xBimTeam/XbimMvdXML

4 Conclusions

In this paper, the Bavarian law and the requirements for importing an IFC file to a pedestrian simulator were analyzed and mapped to the IFC schema. Based on the results, an MVD is developed to facilitate the pedestrian simulator to parse and filter IFC building models and to automate checking the correctness and completeness of the exchanged IFC files. Translating the BayBO's regulations completely to an MVD is a complex task; many parts of the BayBO are vague (include many exceptions and allow multiple interpretations). Additionally, the common property sets defined in IFC are not capable of covering all of the use-cases included in the BayBO or required by the pedestrian simulator (a comprehensive list of the missing properties is available on the authors GitHub).

5 Acknowledgments

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