SERVICE-ORIENTED ARCHITECTURE FOR DATA EXCHANGE BETWEEN A BUILDING INFORMATION MODEL AND A BUILDING ENERGY MODEL

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ABSTRACT

Building energy simulation has become an important method for reducing energy use and carbon dioxide emissions in sustainable building design. In the last decade, we have witnessed the employment of building information model (BIM) and internet technologies to be harnessed for energy-efficient building design.

In this research the data exchange between a Building Information Model (BIM) and a Building Energy Model (BEM) is investigated. In previous research energy simulation engines are integrated into the BIM application for BIM users to evaluate the design directly at the conceptual design stage. After the conceptual design stage the energy analysis task is shifted to professional engineers. In a conventional process, engineers analyse the BEM, which has been previously exported manually from the BIM, and optimize the parameters in the BEM. These results are then used to manually update the BIM used in design. However, this process is cumbersome and error-prone as it is hard to keep the BEM up-to-date with the BIM, and the optimization of the parameters on the BEM cannot be easily synchronized back to the BIM model. The increasing uses of the internet for data exchange and new database technologies have the potential to change this. We employ service-oriented architecture (SOA) to connect the components of services in each side of BIM and BEM. Based on a critical study of data and schema in the BIM and the BEM model, we propose a SOA based BIM and BEM exchange framework that can be used to support the collaboration and information synchronization among the participants in a sustainable design project. This framework is exemplified using a case study.

Keywords: Data Exchange, Building Information Model, Building Energy Model, and SOA

1. INTRODUCTION

Building energy simulation has an increasingly important role in the design and optimization of buildings. Using simulation can help the design team to consider many different parameters and design options from an early stage to the construction [1]. As the architectural design is always changing, it is hard to keep the energy model up-to-date. By employing a Building Information Model (BIM), project teams can use the information contained in the models to perform visualization, construction simulation and energy analysis. There are two ways of acquiring Building Energy Models (BEM) from BIM applications: one is by exporting intermediate exchange files such as DXF, GBXML and IFC files; another one is through the application program interface (API) of the BIM modelling editor directly.

Each simulation program uses its own document format. The GBXML file format was developed to facilitate the transfer of building information stored in BIM. The GBXML file can be exported from BIM by the architect and then sent to the engineer by email or other document transfer methods. The engineers or professional users import the GBXML to their simulation program, then after the simulation is completed, the results and the opinions from the engineer to modify the design is sent to architect by meeting, email and telephone etc. (Figure 1). However, the aforementioned process is inefficient while the BIM is changing, and the architect need export an adequate GBXML in every coordination with engineer, moreover, the round-trip of the design optimization from the engineer side is manual and not fluent. The design coordination requires an efficient optimization process to realize a round-trip of data flow.

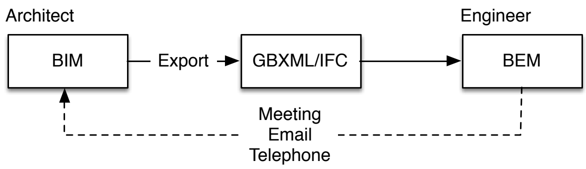

Figure 1 Conventional BIM and BEM communication

As the use of BIM is increasingly adopted in the AEC (architect, engineer and construction) domain and BIM application developers provide APIs for third-party programmers, some researches have built simulation plugins hosted in BIM software (Figure 2). As an example, an IFC based method for semi-automated building energy performance simulation is proposed to facilitate data exchange for BEM. A geometry simplification tool, a space boundary tool and Simergy were developed to realize the simulation in EnergyPlus [2]. However, the IFC file, which contains all information of the BIM, can only be exported manually from within the BIM applications. Generating and transferring IFC are time-consuming and cumbersome. Since 2009, the Design Performance Viewer (DPV) has been developed to calculate and visualize the energy performance of BIM [3].

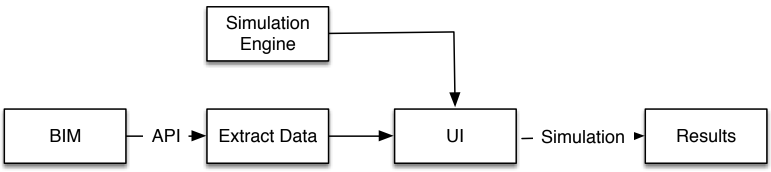

Figure 2 Integrated Building energy simulation Process

Some vendors also have built energy simulation services on BIM; the rising of cloud computation techniques are embedded in their services. Autodesk builds interfaces on their BIM application (Autodesk Revit) to connect to Green Building Studio, which is a cloud-based energy-analysis software that enables architects and designers to perform whole-building analysis and optimize energy consumption earlier in the design process (Autodesk, 2014). Sefaira integrates Autodesk Revit to extend the capabilities of the BIM users to make design decisions collectively using latest performance data. These above-mentioned researches aim to benefit the BIM users in the early concept design process. Algorithms are utilized to form a single-zone BEM model with the information extracted from BIM. However, in the further design development and construction design stages, the building energy performance strongly depends on the heating and cooling zone divisions and HVAC (heating, ventilating, and air conditioning) systems, so the models generated by algorithms are often inaccurate and over-simplified [4].

In this research, we introduce a method that allows considering the coordination of both BIM during design and BEM in a round-trip digital design process. This means the engineers can not only request the BEM from the BIM, but they can also update the BEM related parameters directly in the BIM. This simplifies the sustainable design process considerably and supports the integrated design processes. We present a SOA based framework to support the model exchange and we implement this framework in a BIM application and an energy simulation application. Finally, we perform a case study to demonstrate the applicability in the design process.

2. METHOD

2.1 FRAMEWORK

In this research, we develop a service-oriented architecture based BIM collaboration framework (SBCF) to handle the round-trip exchange between BIM and BEM (Figure 3). Our goal is to execute efficient data flow and management.

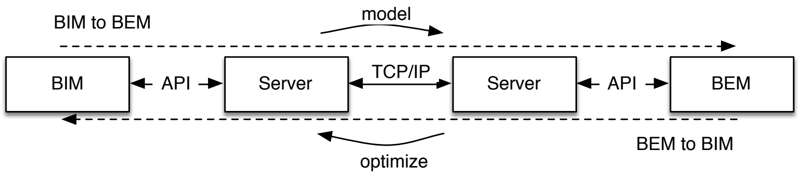

Figure 3 Round-trip between BIM and BEM

The users of the framework can share model information through application server on the internet. Each participant of the framework plays both server and client roles, so it provides flexible access services [5]. The aforementioned coordination process is achieved by integrating various modules to a server on each side of design participant's applications (Figure 4). The basic functions of the BIM application service are to extract models on request and apply modification requests to the BIM. And the basic functions of the BEM services are to send request to BIM and conduct simulation.

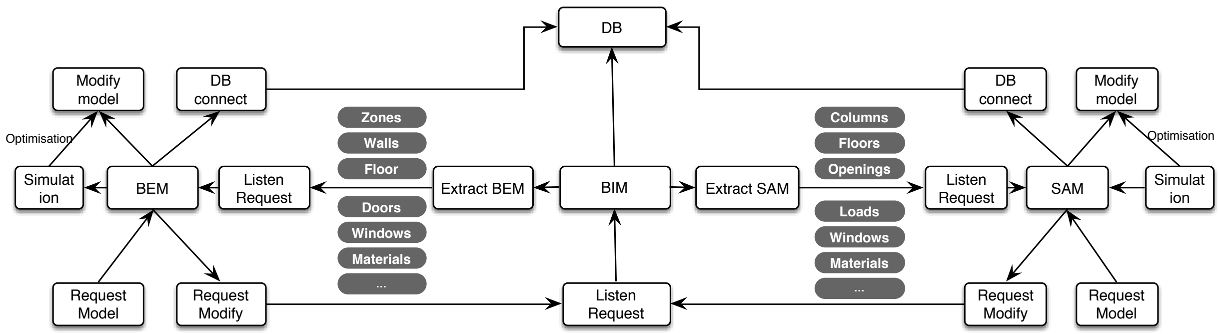

Figure 4 SBCF, coordination with BEM and Structural Analysis Model (SAM)

2.2 IMPLEMENTATION

In this research, we implement SBCF with Autodesk Revit (BIM application) and EnergyPlus (BEM application). It should be noted that BIM and BEM model data have different data formats and hierarchical structure, so we have to build an intermediate representation for the information. On the BIM side, we extract geometrical and physical properties of zones, surfaces and openings using the Revit API [6]. On the BEM side, EnergyPlus uses the open-source format called IDF that contains the simulation model as geometries, systems, schedules etc. Apart from the model data, the intermediate representation transferred between two servers should carry additional information such as the data type, version, warning and error messages etc. In this research we utilize the JSON syntax to represent the data extracted from BIM based on the structure and relationship of BEM data. The ID information of each BIM element is contained in the JSON representation in order to be able to modify the BIM model.

The application services built on the BIM side (Figure 5) receives request and sends model. Once it received a JSON message from a remote participant, it reads the request and informs the BIM user to choose whether he approves the request. If the request is granted, the services will commit the request operations such as extract the model and modify the model.

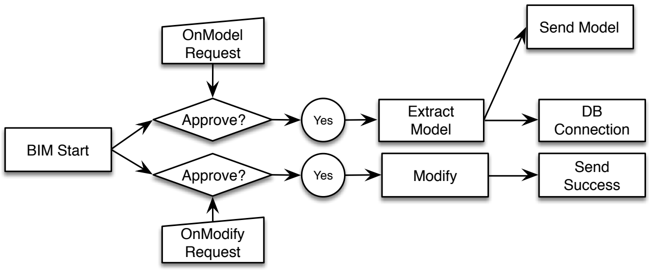

Figure 5 Workflow on the BIM side services

The BIM application chosen (Autodesk Revit) can store not only geometry related information, but also HVAC and MEP related model and information such as zones, systems, occupants etc., which enables the users to fetch more detail information about the project.

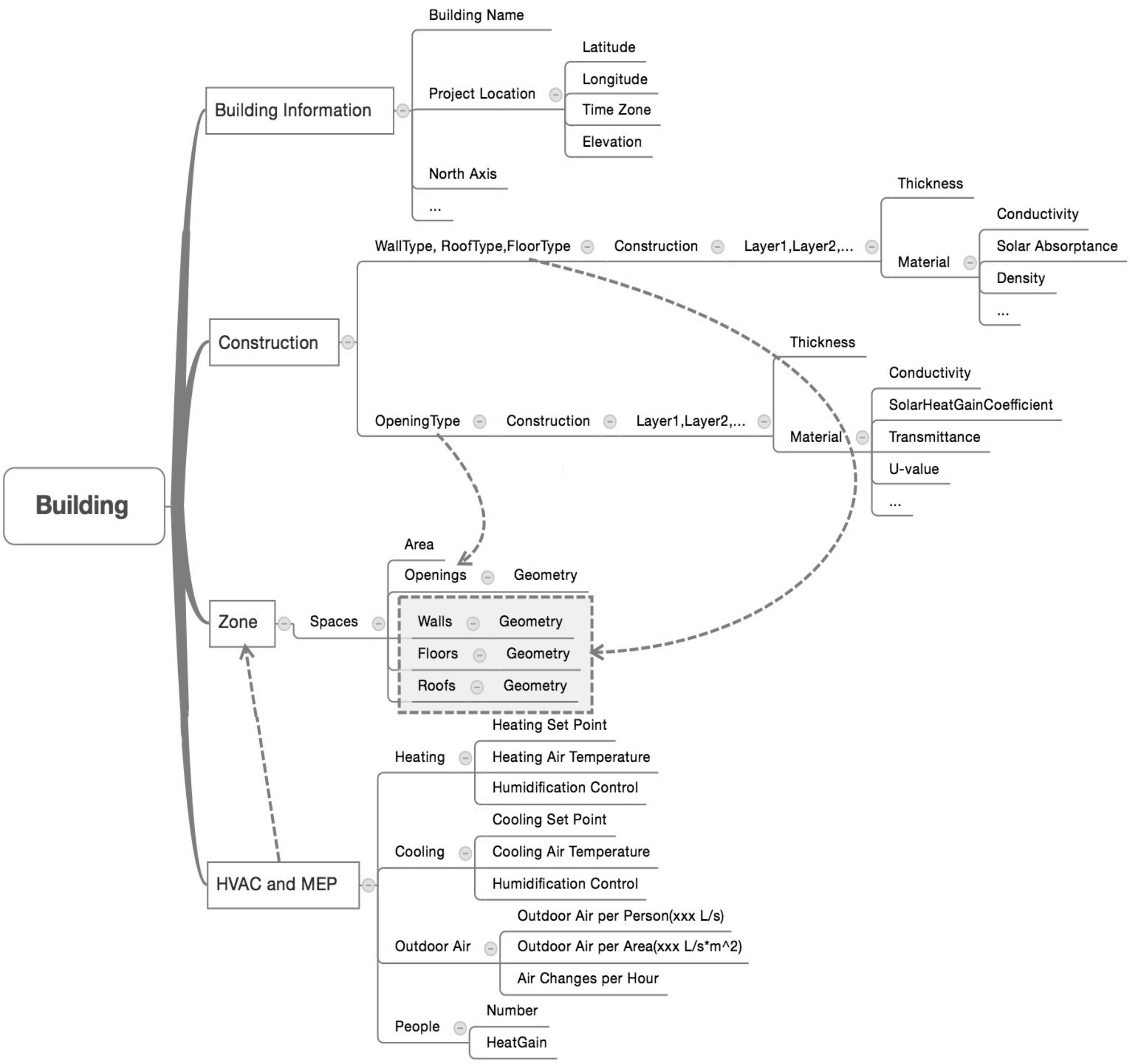

Figure 6 Multi-zones based model extraction structure from BIM model

Different from other methods that use algorithms to form a single-zone BEM from BIM in the concept design stage, in this research, the zones are manually defined in the BIM model and then we extract the geometrical and physical properties around the predefined zones using the API. A multi-zones BEM model with a typical IDF data structure (Figure 6) is generated after the extraction. The model is stored in JSON model and ready to be exchanged over the internet.

On the BEM side, the application services convert the JSON model to IDF, and run the simulation. Model modification request could be sent to the services on BIM side if some model parameters are changed.

3. CASE STUDY

To demonstrate the aforementioned framework (SBCF), we apply it to a case study building design. The object is a two-story office building (Figure 7) with 6 thermal zones. By implementing the SBCF, we realize a design process for determining the window size of the building. We separate the thermal zones in the BIM (Autodesk Revit). On the BEM side, we receive the BEM in JSON syntax after we request. Then, the service converts the JSON file to an IDF file (Figure 8, visualized in Open Studio/ SketchUp). In this process, the HVAC system and lighting controls are defined.

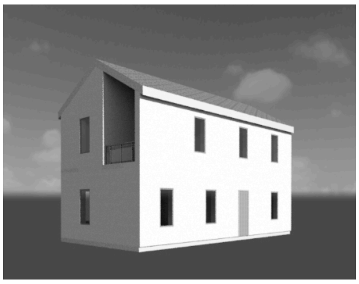

Figure 7 BIM with initial window size

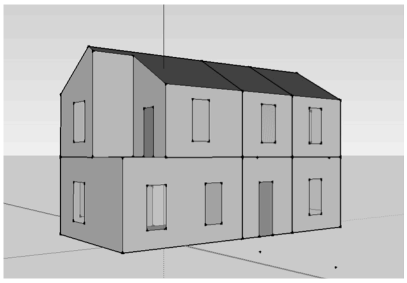

Figure 8 BEM visualized in application

The initial size of the windows is 1.8 by 0.6m and the construction is single-glazed. We change the width of the north, east and west-facing window in BIM from 0.6 to 2.7m in steps of 0.3m, simulate BEM and collect the corresponding results to the result pool. In order to prevent the model from conflicts, the BIM service declines the request of changing the width to above 2.8m. Figure 9 shows the performed round-trip design process.

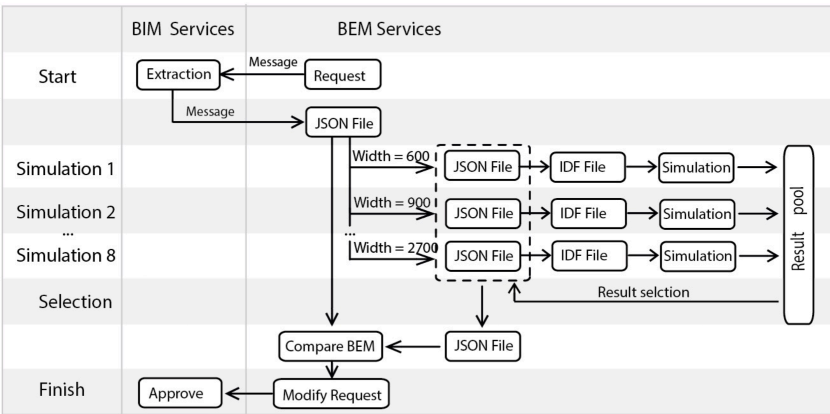

Figure 9 Round-trip design process of determining windows size

As the increasing width of window decreases the lighting energy demand and improves energy demand for heating, we measure the lighting energy uses and heating uses in the results to determine an adequate size.

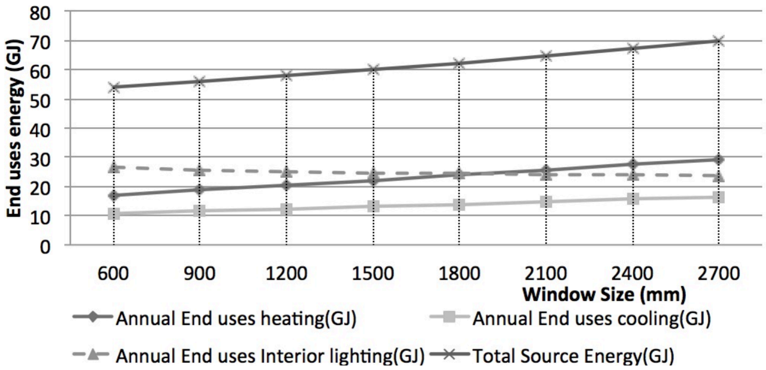

Figure 10 End uses energy performance

In Figure 10, we plot the simulation results from the result pool. In the practical BIM-BEM collaboration, engineers can have a clear understanding of the building energy performance with different window sizes, and then they can select a certain size for the windows based on their goal, which can be sent back to BIM. We compare the selected BEM with the initial BEM, and then the modification of windows are found, at last we send the IDs with their modified parameters to the BIM services.

4. CONCLUSION

This paper illustrates a SOA based method that simplifies the data exchange between a BIM and a BEM. With a case study we test a building with 6 thermal zones using the framework developed. We execute multi-zone model extractions and remote operations on application services. We present BIM-to-BEM and BEM-to-BIM data exchange in a design process, and we have seen benefits of this efficient and accurate model exchange method. This research simplifies the process of BIM-BEM data exchange, enables engineers to be efficient up-to-date with BIM and benefit architects to receive the feedback from engineers. We are currently working on improving the applicability and user interaction on the BEM side as well as extending the data types for exchange.

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