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BIM to BEM Interoperability Using Web Based Process Model

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Abstract

Building simulation is widely used for building performance prediction and assessment in the design process. For seamless connections between Building Information Model (BIM) and Building Energy Model (BEM), tremendous research efforts have been invested, especially with emphasis on data sharing and reuse out of BIM. However, what is lacking in the aforementioned approach is that enough attention has not been paid to the 'dynamic' design process strongly influenced by multiple building stakeholders with rapidly changing design context. This study presents a new approach, so called process driven energy simulation interface where a business process model is integrated with a dynamic building energy simulation tool (EnergyPlus) in WWW environment. Through the web interface, architects and simulation experts communicate and collaborate together for making an energy simulation model. Each participant of this project is called via email, SMS for data entering, simulation modeling, sharing design context and conflicts, etc. The simulation model is saved as XML format and then converted to EnergyPlus input file. In the paper, the real implementation of the aforementioned interface was discussed in detail. It was shown that a data driven model is not good enough for simulation and performance quantification.

Keywords: Interoperability, WWW, Process model, Building Information Model, Building simulation

1 Introduction

In the Architecture, Engineering, and Construction (A/E/C) industry, the information technology has continuously needed collaborations among multiple building stakeholders (owner, designers, engineers, and simulationists, etc.) to come up with an optimal solution over different design stages. Furthermore, a maturation of computer simulation tools in each domain has accelerated an environmental change (from a few experts having limited knowledge and information to distributed experts having professional knowledge and information) in the information technology. Under the circumstances, the importance of data sharing among different simulation models with their respective data formats is arising as one of the key issues in the field of building simulation [1]. In the light of this perspective, the previous studies [2-4] indicated that the process driven approach was more appropriate for adequate and robust decision than the data driven approach. However, the data sharing technology for interoperability is still focused on full or semi-automatic data exchanges (i.e. data driven approach) among different simulation models [5-9]. The automatic data exchange aims to pursue a seamless interoperability through the shared building information dominated by a certain rules. However, one may wonder how the data driven approach would yield meaningful and significant results for all building stakeholders if the simulation model was only approximated by the normative building information rules. Since, it is impossible to construct a certain shared model with free error while considering physical attributes and relations in respect of all building information. In other words, it would be inevitable for subjective judgments and assumptions of a few experts to be put in due to incomplete data sharing on the complex systems [2-4].

This study addresses barriers and limitations of the data driven approach and introduces the process driven energy simulation interface when it transfers Building Information Model (BIM) to Building Energy Model (BEM). The process driven energy simulation interface is integrated with a dynamic building energy simulation tool (EnergyPlus) in WWW environment. The building design space is bounded by two domain regions (design, energy simulation) for easy development of the interface program.

2 BIM to BEM interoperability

In the building design space, the number of computer simulation tools is continuously emerging for reliable quality assurances of the performance results. These simulation tools aim to provide the functions for an accurate and reliable decision-making tool through the collaborative design process. In terms of the design process, simulation information, which can be used for seamless data exchange, are composed of (1) boundary constraints, (2) components, and (3) relation required for specific domains. The boundary constraints provide a simulation space for approximating into mathematical forms and it can be divided into external or internal conditions. The external conditions include the shape and location of the target building, weather data, and modelling of neighboring buildings, etc. And the internal conditions can include modelling of thermal zones, HVAC systems, pumps, fans, and plants, etc. The

components are a set of attributes that mathematically represent the thermal properties within the boundary constraints. And the relation is to match between (1) components and components, (2) components and attributes, (3) attributes and attributes. In other words, the simulation model is completed by merging into simulation information having boundary constraints, components, and relation in each domain. However, simulation information works require management of complex data exchanges and it can incur problems such as deformation and missing data in the design space. In other words, the simulation model would be completed by unintended inputs and boundary constraints, which is feared to increase an epistemic uncertainty. To reduce the uncertainty, the interoperability is widely used in the building simulation [1]. The interoperability is to harmonize simulation information by using neutral or shared data model such as BIM formats (IFC and gbXML) and interface programs for extraction and elimination of simulation information. And it can reduce the epistemic uncertainty. But, it should be noted that the interface programs perform an important role for seamless data exchanges. It needs to consider data exchange scenarios including various mapping rules such as subschemas having the pre-defined logical data structures. In general, the interface programs can be divided into the (1) data driven and (2) process driven approach [2-4]. In terms of the interoperability, this study presents the barriers associated with the interoperability using the data driven approach. To solve the problems of the data driven approach, the author developed the process driven energy simulation interface in WWW and its merits are explained in detail.

3 Barriers of the data driven approach

The data driven approach conducts data exchanges by using the shared data models consisting of the previously defined logical data structures and input/output interfaces of the computer simulation tools. For transformation of files, the interface program using the data driven approach needs to structure numerous idealized mapping rules where roles extract an appropriate subschema for BEM from neutral or shared data model such as BIM formats. The goal of the approach is to minimize human interference and reduce the epistemic uncertainty during the design process [5]. If the BIM and mapping rules are structured perfectly for an import and export interface, it can provide some substantial contributions for information technology as well as building simulation. However, the data exchanges between the different files through the interface program using the data driven approach inevitably entail many missing data [2-4] due to the following barriers and limitations.

Firstly, the full or semi-automatic interface program needs to construct vast mapping rules and guidelines in accordance with peculiar entities defined in different computer simulation tools even if same BIM format was exported. In an example, ArchiCAD and Revit architecture can export the data schema based on IFC format for space boundary, but their IFC export rules have different x-y-z coordinates (internal line for ArchiCAD, center line for Revit architecture). And the automatic interface program must have data exchange scenarios regarding many entities such as thermal properties of opaque materials and windows, indoor load, and HVAC systems, etc.

But the aforementioned mapping rules and guidelines are not an easy task. In example, the HVAC system has not yet exist a significant data exchange scenario regarding various components (e.g. thermodynamic properties (flow rate, capacity, COP, and inlet/outlet temperature, etc.) of fan, pump, coil, boiler, chiller, etc.), but a simple 'namely' mapping rule such as 'Template' methods. Secondly, the data transfer schemas in BIM format are insufficient for an energy domain. The previous studies [9, 10] indicated that the data transfer schemas should be expanded in order to avoid data repetition and redundancy. In an example, PassiveBIM is an oriented program having extensible IFC files for liking between Revit architecture and PHPP [9]. However, it would further complicate the BIM data format because it is an inappropriate method, given that multiple simulation tools are being considered. Thirdly, non-structured data (emails, telephone calls, and fax messages) for the automatic interface program should be not reflected. Please be noted that it is important to help collaborations among multiple building stakeholders for energy simulation modelling during the real design process. Finally, the automatic interface programs have some limitations to acquire lessons or knowledge derived by the interoperability environment. The simulation works should provide valuable information to multiple building stakeholders and then the updated information can helpfully be used afterward. However, the interface programs only pursue an automated data exchange without meaningful communications for acquiring lessons or knowledge. In other words, it is unsuitable to perform data exchanges with acquiring lessons or knowledge throughout communications in the given target works.

With regard to what has been discussed above, the interoperability for transferring BIM to BEM inevitably requires the interventions of experts by reflecting communications among the decision-makers under the design context. To solve the problems, the author developed the process driven energy simulation interface throughout a business process model in WWW environment.

4 Process driven energy simulation interface

The web based process model is a process based management for data exchanges as well as communications among experts in various domains as shown in Figure 1. The modules of the process model are divided into main workflows having analysis scenarios and sub workflows having unit tasks. The analysis scenarios denote an overall flow for extracting subschemas in an energy domain under the design context and the unit tasks denote a management component for data exchanges and communications of experts. The experts (agents in Figure 1) can participate in the unit tasks of the each sub workflow (process in Figure 1) under the design context, and the unit tasks completed in the client computer are stored in the server computer's database (DB in Figure 1). In particular, the process driven energy simulation interface enables communications among the distributed experts by adopting the server-client system in the WWW environment. Each unit task of the sub-workflows under main workflows can be completed in parallel, and this led to reduce the bottleneck effect. And the XML schema was used for accurate and prompt data sharing and storage on the WWW environment. In other words, the completed XML

schemas were transferred into input files for generating the energy simulation tools. Figure 2 shows the coupling between the web based process model and EnergyPlus. The entire sub workflow is made up of five modules (geometry information, specified EnergyPlus information, schedule information, internal heat gain information, and HVAC system information).

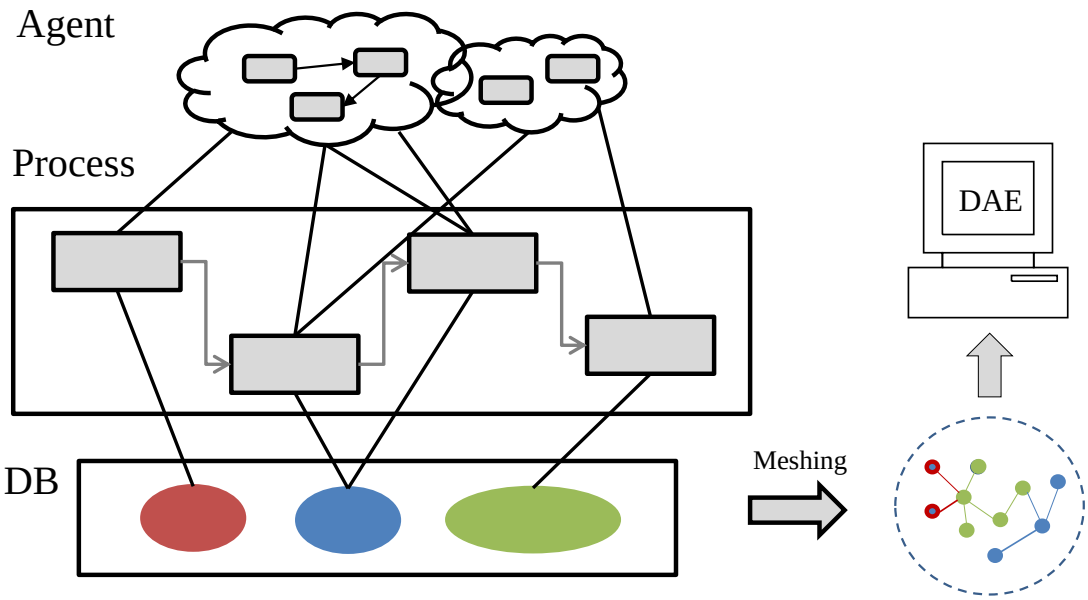

Fig 1. Web-based process driven BIM to BEM

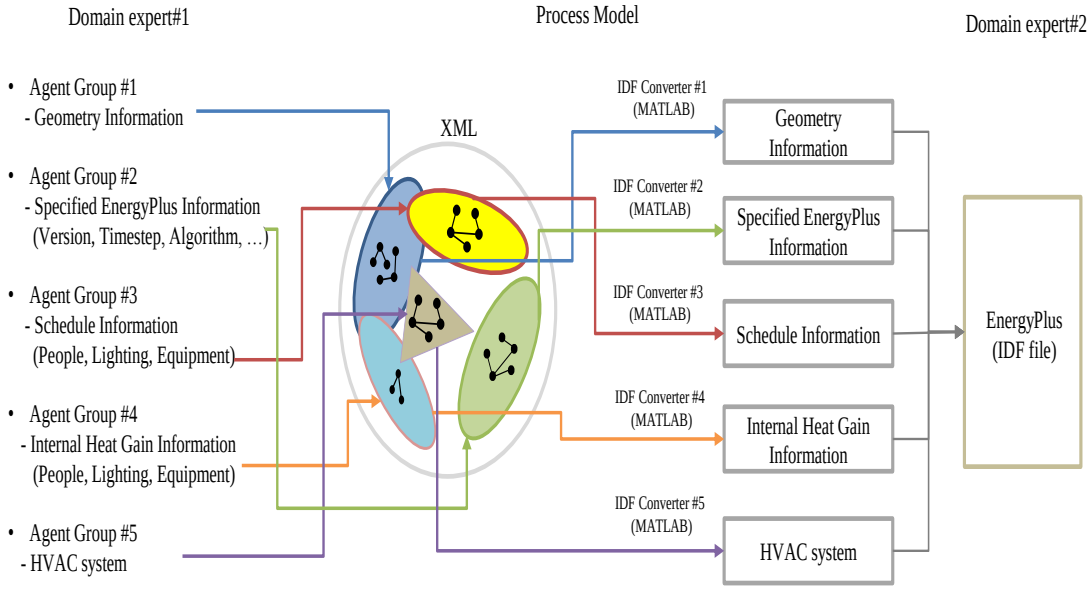

Fig 2. WWW + Process + Energy model

The five modules were structured by data transfer of unit tasks embedded in sub workflows throughout client applications. In particular, the interoperability deals with data information for BEM according to mutual communications and collaborations of various experts on WWW environment. And the experts in the client applications have been delegated to participate in their respective unit tasks and it was assigned by the top process manager. They deal with data transfers for the construction of the energy simulation program via their individual client computer, and the dataset are reviewed and modified by other experts throughout email, SMS, telephone calls, and fax messages, etc. And then the completed dataset having XML schemas were stored in the sever computer, and transform the XML schemas into a IDF file for EnergyPlus through a EXE file embedded in the process driven energy simulation interface.

5 Case study using the process driven energy simulation interface

For the energy performance assessment using the process driven energy simulation interface, a five-story office in the concept design stage was chosen. The interface was implemented by five experts (one top process manager, one designer, one HVAC engineer, and two simulationists). The experts participated in their respective unit tasks predetermined by the top process manager, and multiple experts could exchange data or communications on a unit task. In the interface, the top process manager was allowed to check the progress of each task and whole process. Figures 3 only shows a web browser displayed in a client computer implemented by a sub workflow for geometry information out of the five modules. The geometry information is implemented by automatically transmitting the initial inputs (owner name, schedule time, occupation, email, telephone, and requirements) to the designers through email or SMS. Afterwards, the gbXML format having the XML schemas (i.e. BIM format) was exported by the completed a BIM authoring tool according to the initial inputs. The XML schemas were automatically transformed into an IDF file for Geometry information of the EnergyPlus, and the IDF file is stored in the server computer if there is nothing wrong through the communications among the experts with authority for geometry information. In other words, the experts can acquire lessons and knowledge for the seamless data exchanges in given target building due to communications in the WWW environment. Figure 4 shows the completed EnergyPlus model.

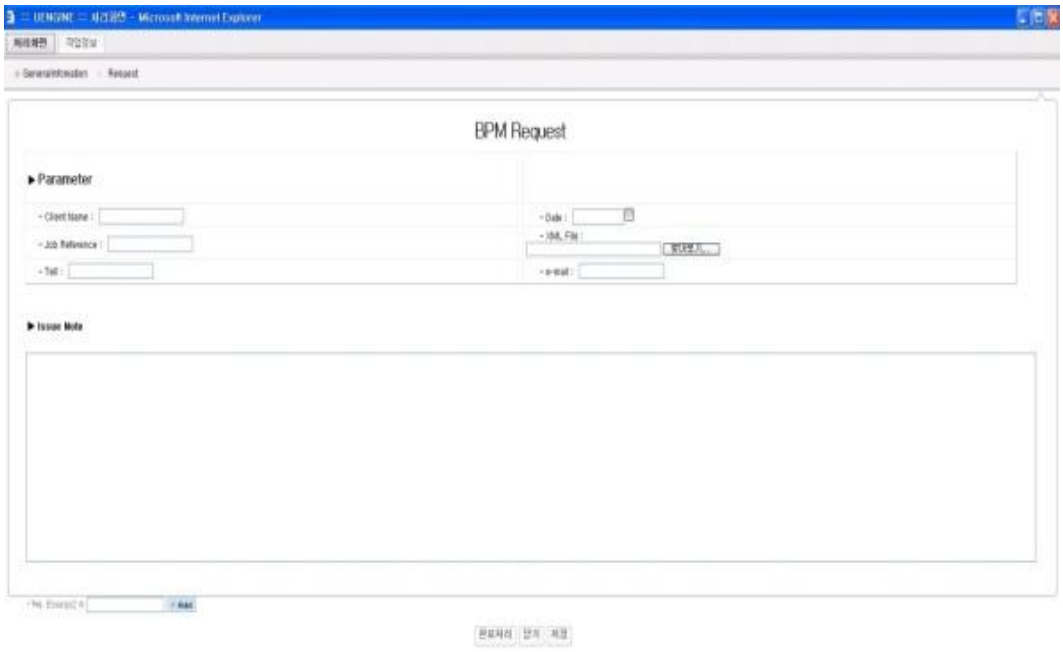

Fig 3. Web browser for the geometry information

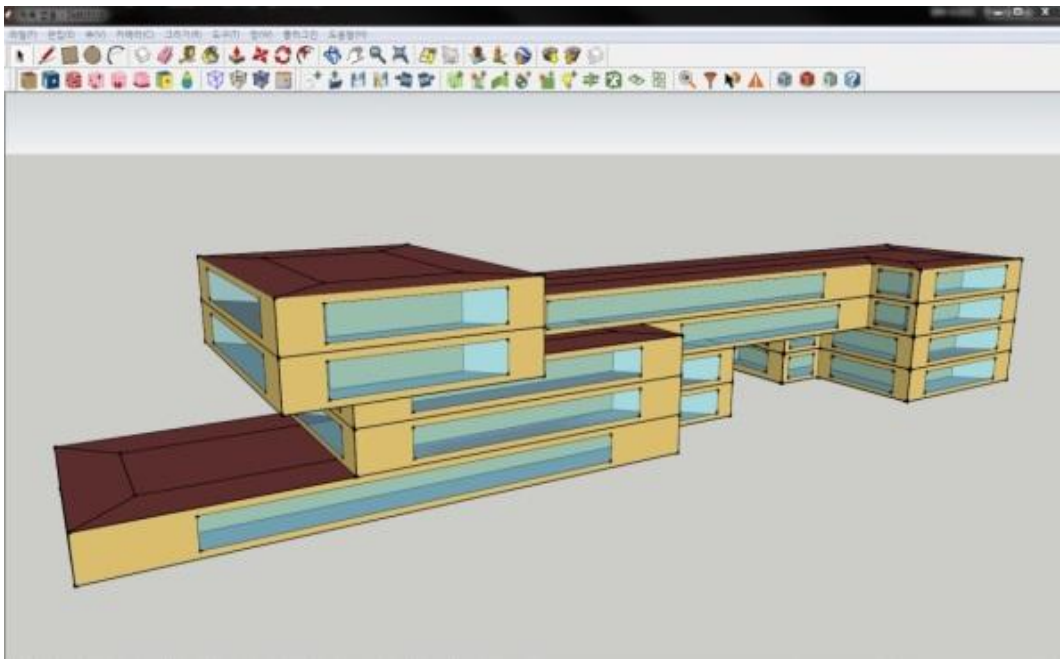

Fig 4. EnergyPlus model

The IDF files managed by the process driven energy simulation interface is constructed through data exchanges and communications among various experts, and

the EnergyPlus model may be able to provide energy performance assessments with high level of quality. The process driven energy simulation interface based on the server-client system in the WWW environment allows multiple experts with their respective domains to participate in the modelling tasks. With changing the existing vertical information structure to the horizontal information structure, the interface works can avoid data repetition and redundancy due to the parallel data transfer. In particular, it is possible to easily monitor the task progress on the WWW environment. Figures 5-6 show the results of cooling and heating energy demands in the given target building. The building stakeholders can access and obtain the results on the WWW environment. The predicted outputs and information stored in the interface program can be used as sources for future interoperability works.

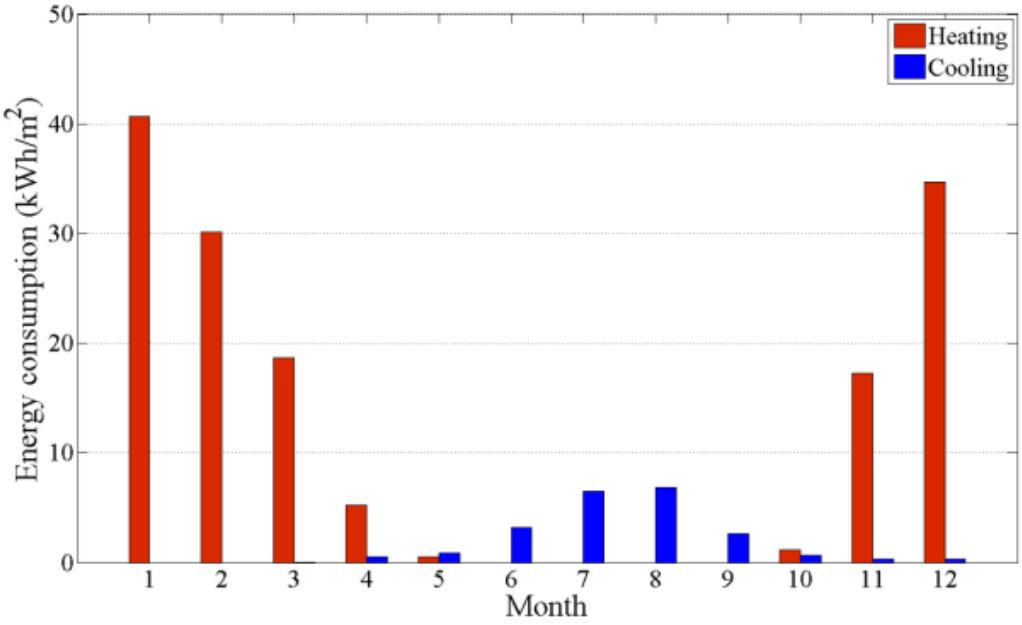

Fig 5. Monthly cooling and heating energy demand (*kWh/m*^{2})

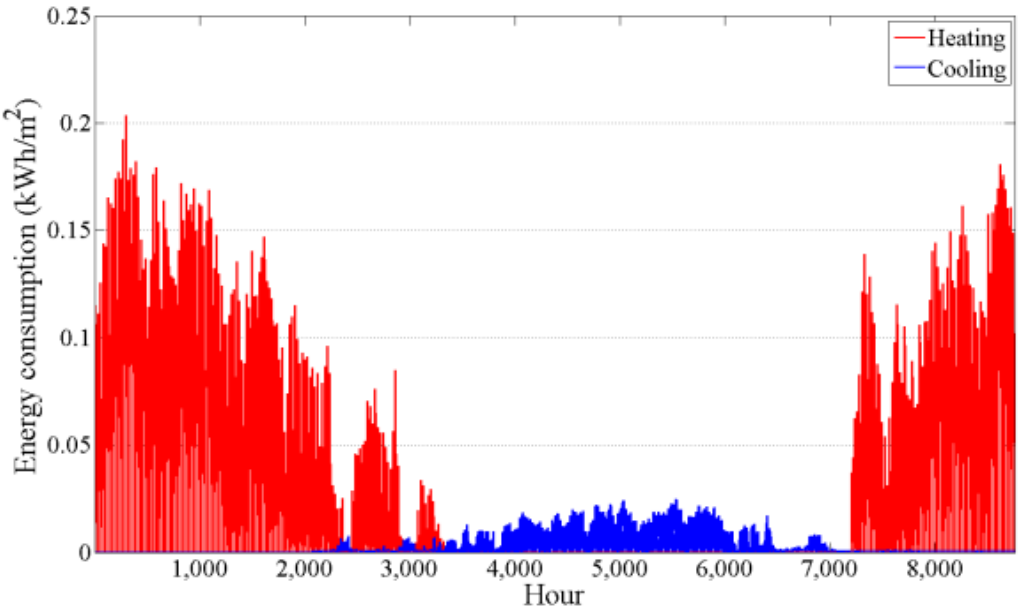

Fig 6. Hourly cooling and heating energy demand (*kWh/m*^{2})

6 Conclusions

In this study, the issues associated with data driven and process driven approach were tackled to ensure BIM to BEM interoperability during building design process. Unlike the data driven approach, the process driven approach ensures data transfer and horizontal communications among the experts under the design context and then it can provide lessons and knowledge for future interoperability. With this minds, the author developed the process driven energy simulation interface throughout a business process model in WWW environment. The interface program with server-client system provides the following merits: (1) transparent and objective data transfer environment, (2) horizontal communication environment, (3) management of the workflows on the WWW environment, and (4) reduction of bottleneck effect using parallel data transfer. The future study will focus on validation of the developed process driven energy simulation interface.

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