Interoperability between Building Design and Building Energy Analysis

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ABSTRACT

Lack of interoperability has been criticized as an impediment to improving productivity in the Architecture, Engineering and Construction (AEC) industry. For example, the current information exchange between building design and energy analysis models has numerous issues, including object parametric information deficiencies, geometric misrepresentations and re-input data confusion. As a result, it leads to huge money, time and effort losses in practice. The objective of this paper is to present an automated solution for the seamless information exchange between building design and energy analysis models. In order to achieve this objective, a file converter is designed. The file format converter is built upon existing open standards (gbXML and DOE-2 input files), which facilitates the exchange of building design and energy analysis information. Designers could use the converter to properly analyze building energy efficiency for their design models. Also, the design models could be automatically updated, if any modifications have been made in the corresponding energy analysis models. The converter has been implemented with Microsoft Visual C# Studio 2013 and its effectiveness has been tested with two popular design and energy analysis tools, Autodesk® based products and eQUEST®. In addition, the creation of a software plug-in component has also been proposed in order to execute the file converter application. The results have demonstrated the overall rectification of the geometric and the material misrepresentations resulted from the current software interoperability process.

INTRODUCTION

Building Information Modeling (BIM) along with Building Performance Analysis (BPA) is currently one of the most promising developments in architecture and engineering. With the current awareness of energy consumption and environmental impact of building construction where buildings account for 36 percent of total energy use and 65 percent of electricity consumption (U.S Green Building Council 2013), society needs building energy analysis in order to achieve sustainable development. One of the current major benefits of BIM and BPA is the ability to use

the building geometry from the model in applications for sustainable design purposes, such as energy analysis and energy retrofit solutions. This tendency is expected to grow dramatically in the following years.

Existing BIM and BPA software tools have improved and simplified the complicated energy analysis process. However, the lack of interoperability between the current tools is a major impediment in improving productivity in the Architecture, Engineering and Construction (AEC) industry (Becerik-Gerber and Rice 2010). The software tools do not exchange and interpret information seamlessly among each other. This represents long-standing inefficiencies where object parametric information deficiencies, geometric misrepresentations and re-input data confusion results in money, time and effort losses for the AEC firms. According to Young et al. (2007), a majority of the construction industry (62%) lists software incompatibility issues as the primary factor impacting build team members' ability to share information across software. The industry is struggling to find software tools that can interoperate well. Therefore, it is imperative to avoid oft-repeated problems by sharing knowledge and collaborating with all the members of a build team while working with different applications and platforms.

The creation of open schemas can facilitate the seamless exchange of information between tools in order to perform a successful building design and energy analysis simulation. These open schemas do simplify the transfer of building and energy information; however, the results they provide are not perfect. Tools, such as Autodesk®'s Green Building Studio (GBS), provide export capabilities from gbXML (Green Building XML) open schema to other open schemas available. This process presents numerous problems when the resulted files were imported into their respective software tool. Some of the issues resulted from this process include re-input data confusion, insufficient information provided by GBS to generate all the reports, loads of geometric misrepresentation and loss of parametric information.

The objective of this paper is to present an automated solution in the integration procedure between software tools in the energy analysis process. In order to achieve this objective, a file converter application is created. The converter provides the rectification between the software programs by properly transforming the information from the open standard schema. In addition, a software plug-in component was also created in order to execute the file converter application. The converter and the plug-in component have been implemented using Microsoft Visual C# Studio 2013. The preliminary results show that geometric misrepresentations and material data confusion resulted from the current software interoperability process could be successfully corrected with the proposed file converter application.

BACKGROUND

In the current practices of building design and energy analysis, a number of energy modeling applications are available today. These tools vary significantly in their levels of detail and complexity. The tools interoperability issues also vary depending if the building design and energy analysis tools are software programs from the same developer or not. This affects interoperability due to the fact that when the tools are owned by the same developer, they usually have integration capabilities

between them. As a contrast, the software programs developed by different companies do not. In the building design community the following programs are the current most popular used tools in performing energy saving analysis that are developed in collaboration with the same design teams (Krygiel 2008).

IES <VE> stands for Integrated Environmental Solutions, Virtual Environment. This robust energy analysis tool offers a high level of accuracy, detail and interoperability with a BIM model. This complete application can run from a total building environmental analysis to airflow studies for mechanical systems. The disadvantages of this application are its high cost and its high level of complexity for the user.

In 2009, Ecotect was acquired by Autodesk from its original creators, Square One Research. This application offers a great graphical interface that allows designers to simulate building performance in the earliest stages of conceptual design with an easy to use interface. The challenge of this application is to import model geometries into different applications. For example, importing geometries to applications like eQUEST® can be really challenging (Autodesk 2013).

Green Building Studio (GBS)**:** Autodesk Green Building Studio is a web-based energy analysis software that allows the user to upload a gbXML file for energy analysis simulation. This tool provides a quick, graphical feedback of the building's energy analysis. However, the energy analysis information obtained from this tool is not detailed enough (Autodesk 2013).

On the other hand, when solving interoperability problems between software tools developed by different owners, efforts towards solving these issues rely mainly on the proposal of general open schemas between the software tools. The reason behind the proposal of new open schemas to solve interoperability issues relies on the fact that developing integration solutions between software tools is a difficult and complex task. This solution requires lots of effort, heavy coding and accessibility of the tools for the end users and not only the software developers (Cate, Kolaitis, and Tan 2013). However, open schemas are not supported by every software tool. For example, the gbXML (green building XML) open schema is currently only supported by vendors such as Autodesk, Bentley and Graphisoft. Software programs like eQUEST® do not support the gbXML open schema and use the DOE-2 input file (INP file) instead. DOE-2 INP files store the building description input resulted from software programs that have a DOE-2 simulation engine. Therefore, file converters to another schema are necessary in order to interoperate with other programs. This encounters a vast problem when the exporting file process is not successful and arduous schema mapping is then required to solve the file converter issues.

As an evidence of the current issues of the open schema solution, the integration practices between two of the existing most popular used tools, such as eQUEST® (using DOE-2 input files) and Autodesk® based products (using the open schema gbXML), presents numerous problems. For example, object parametric information could be lost (Figure 1). The object geometry is misrepresented. The information provided by GBS is insufficient for eQUEST® to elaborate a detailed energy analysis report. Also, not all the building construction data imported can be easily modified in eQUEST®.

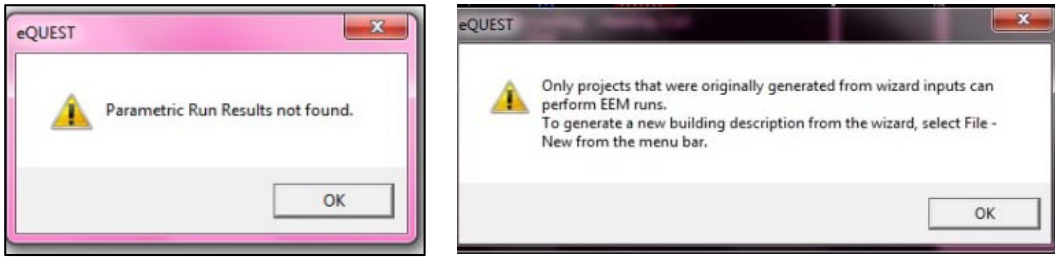

Figure 1: Some of the issues resulted from the integration process between Autodesk®-based tools and eQUEST®.

All these issues presented above resulted from the current integration practices of converting a gbXML (Green Building XML file) to a DOE-2 input file (INP file). Currently there is no evidence, to our knowledge, of any other approach besides using Green Building Studio to convert from gbXML to INP. Therefore, the creation of a direct file converter application is imperative in order to solve the interoperability issues between the software programs.

OBJECTIVE / SCOPE

The objective of this paper is to address the interoperability issues between Building Information Modeling (BIM) and Building Performance Analysis (BPA) tools. Considering the existence of open standard schemas, this paper is not to create an information refiner from the data obtained in the current integration process. Instead, the focus is placed on the design of a new file converter solution. The converter is expected to properly transform the information from the open standard schemas (gbXML and INP files) in order to correct all the issues presented in the current conversion solution practices.

On the other hand, the scope of this paper is limited to address the interoperability issues between Autodesk®-based products tools and eQUEST®, due to the large number of building design and energy analysis software available. Autodesk®-based products tools along with eQUEST® are currently two of the most employed tools in building design and energy analysis respectively. If the interoperability issues between these tools could be addressed, it would bring significant benefits to the AEC industry today.

PROPOSED METHODOLOGY

In order to achieve the objective mentioned before, a novel file converter application is designed. Figure 2 shows the overall framework of the proposed converter. The converter takes the gbXML open standard schema as input. Specifically, the information in the gbXML schema is first explored. The converter transforms the input gbXML file through the creation of an XSLT style sheet. This style sheet comprehends a set of code instructions created in order to properly compare the gbXML file and transform it to the format of an INP file. Based on the unique ID or Name of the building component, its correspondence is transformed into the INP format. The contents of both components in the schemas are checked. Some

of the contents include the geometric, material, and location information of the components.

Theoretically, the contents for both components should be matched. For example, if the building component in the gbXML schema is made of concrete (material information); then, the corresponding component in the INP schema should also be made of concrete (i.e. same material information). Therefore, a validation of the XSLT style sheet is then required. In the validation process, any inaccurate information in the INP schema is identified and corrected. Also, any missing information in the INP schema is added. The implementation of the conversion process is employed through the creation of a Windows form application. Finally, a plug-in software component is created inside Autodesk® Revit 2013 to execute the proposed file converter application.

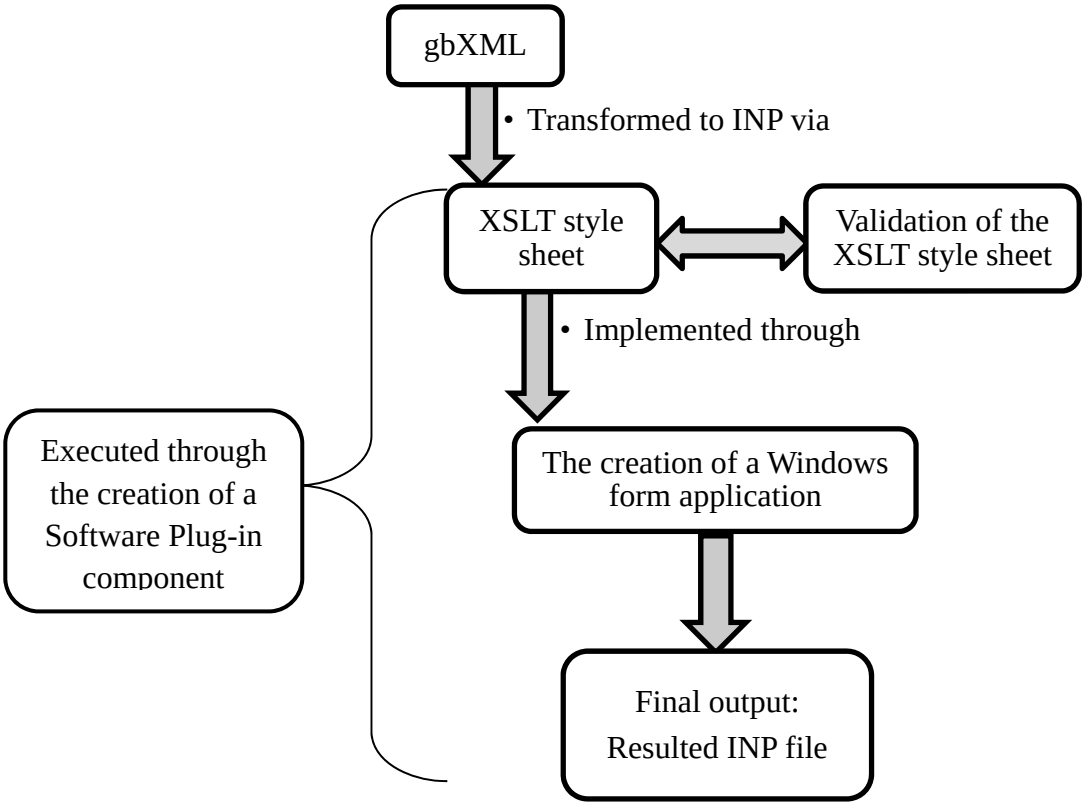

Figure 2: Proposed Framework

IMPLEMENTATION AND PRELIMNARY RESULTS

The proposed file converter application and the software plug-in component have been implemented in Microsoft Visual C# Studio 2013. Their effectiveness has been tested with a residential house. The test was performed using a laptop. The laptop is equipped with Intel ® Core ™ i3 CPU @ 2.20 GHz and 6.00 GB of installed memory (RAM). The operating system is Microsoft Windows 7 Home Premium 64-bits.

The set of code instructions needed to transform the gbXML file to an INP format have been created using a XSLT. XSLT, which stands for Extensible Style sheet Language Transformations, is a language for transforming XML documents. Its validation has been tested using <oXygen/> XML Editor Version 15.2.

Figure 3 shows the Autodesk® Revit 2013 model of the house. If the INP schema converted directly from the Autodesk GBS software is used in the eQUEST® Version 3-65 environment, it could be seen that the entire roof and some wall information of the house is misrepresented (Figure 4). This misrepresentation could be successfully addressed with the converter proposed in this paper (Figure 5). Figure 6 presents the interface inside Autodesk® Revit of the proposed software plug-in component that executes the file converter application. Although is not shown in figures, the material information from the gbXML file was also rectified in the proposed converter application due to the fact that the current version of eQUEST® now requires the specification of the material TYPE keyword in their INP files.

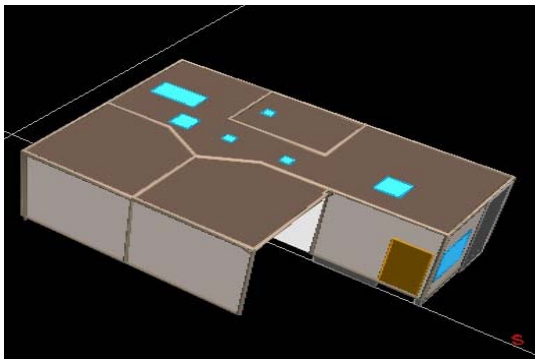

Figure 4: 3D Model of a Residential House in eQUEST Version 3-65 without the proposed file converter application

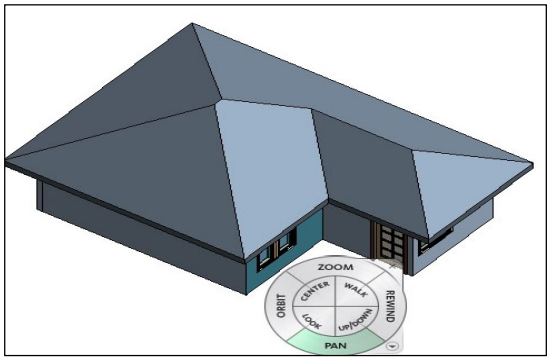

Figure 3: 3D Model of a Residential House in the Autodesk® Revit 2013

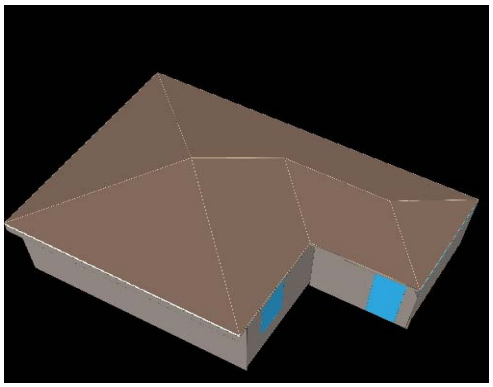

Figure 5: 3D Model of a Residential House in the eQUEST® Version 3-65 with the proposed file converter application

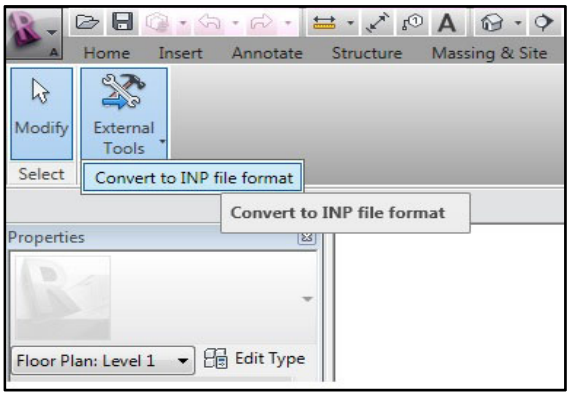

Figure 6: Interface inside Autodesk® Revit of the proposed software plug-in component

CONCLUSIONS AND FUTURE WORK

A novel file converter application has been created in this paper to facilitate the seamless building information exchange between building design and building energy analysis. The converter was built upon existing open standard schemas. The effectiveness of the proposed application has been tested with a residential house. Based on the test results, it could be found that the misrepresentation of the roof information and the material data confusion of the house could be corrected with the proposed converter. The proposed converter application is expected to reduce the money, time and effort losses in the AEC industry due to the interoperability issues between current building design and energy analysis software tools. In addition to the file converter application, the creation of a software plug-in component facilitates the execution of the proposed application inside software tools like Autodesk® Revit. Future work will focus on testing the converter with more case studies.

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