

Interoperability: A Data Conversion Framework to Support Energy Simulation [†]

Luís Paiva ¹, Pedro Pereira ^{1,2,*}, Bruno Almeida ¹, Pedro Maló ^{1,2}, Juha Hyvärinen ³,
Krzysztof Klobut ³, Vanda Dimitriou ⁴ and Tarek Hassan ⁴

¹ CTS-UNINOVA; luismpaiva@uninova.pt (L.P.); bma@uninova.pt; (B.A.); pmm@uninova.pt (P.M.)

² Department of Electrical Engineering, Faculty of Science and Technology-Universidade NOVA de Lisboa

³ VTT Technical Research Centre of Finland Ltd; Juha.Hyvarinen@vtt.fi (J.H.); krzysztof.klobut@vtt.fi (K.K.)

⁴ Loughborough University; v.dimitriou@lboro.ac.uk (V.D.); t.hassan@lboro.ac.uk (T.H.)

* Correspondence: pmp@fct.unl.pt; Tel.: +351-21-294-85-45

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Abstract: In this paper an interoperability solution is proposed, aiming to go from (building) construction models to energy simulation. Moreover, the energy simulation results will feed the KPI's analysis of a designed building. The proposed solution will be used to translate different data formats allowing the communication between different systems in an automated environment. The solution presented in this paper exploits the concept of Plug'n'Interoperate (PnI), that is supported by the principle of self-configuration as to automate, as much as possible, the configuration and participation of systems into a shared interoperability environment. In order to validate this approach two different scenarios were taken into account, translating from a CAD (Computer-Aided Design) model data format to an energy simulation data format.

Keywords: Interoperability; Building information model; model transformation; energy simulation

1. Introduction

Building Information Model (BIM) is widely used for the representation of buildings over its life-cycle. Although, there are no computer application that supports all the tasks related with building design and production [1]. Interoperability is the way to interconnect different computer applications, in order to exchange data between them, allowing either experts and/or multiple applications to cope aiming a better building design [2]. Nowadays, the Industry Foundation Class (IFC) and Green Building XML (gbXML) are the dominant informational infrastructures in the architecture, engineering and construction (AEC) industry. Both IFC and gbXML, are the most used data exchange between AEC applications, such as CAD and building simulation tools.

The Green Building XML (gbXML), is the most recent one. It is an XML schema developed aiming to simplify data exchange of building information stored in CAD-based BIMs. Such schema provides the semantics for building and construction information. Its main goal is to empower interoperability between distinct building designs and engineering analysis software tools, by defining a common language for both sides [3].

Intermediate Data Format (IDF) data model, as its names implies, was originally defined as an intermediate data format aimed to exchange data between electrical and mechanical CAD/CAE software systems [4]. Shortly, an IDF file can be seen as a way of two distinct software interoperate between each other.

The main purpose of the present work is to provide a framework to support data conversion driven interoperability amongst different tools. This Plug'n'Interoperate (PnI) solution is the key scientific base, and its goal is the adaptation and proof that this solution can be adapted to different scenarios, regarding building energy simulation.

To enable the PnI concept, there is the need to devise a reference architecture that provides interoperability as a service in the required environment. PnI uses a mediated approach where interoperations are not executed directly by the systems but by other entity, the mediator.

In order to validate the proposed approach, two different scenarios were taken into account, translating from a CAD (Computer-Aided Design) model data format to an energy simulation data format. First scenario: Autodesk Revit was used to create a CAD model data format as input for EnergyPlus (energy simulator). The issue that needed to be addressed is the fact that EnergyPlus only accepts IDF data formats and Revit does not export into this specific data format. Second scenario: the same data format exported from EnergyPlus, can be translated into other data formats. Specifically, a data format aimed at prototype KPI tool in Energy sector. Both scenarios results are a web framework prototype aimed at helping players from architecture/energy sectors.

2. Plug'n'Interoperate Architecture

The Plug'n'Interoperate (PnI) solution is essentially a dynamic-interoperability enabling platform. The PnI provides interoperability enabling methods, in order to ensure interoperability between systems that need to communicate but follow disparate data formats, even with newly created systems (that were not thought at start) that hold new data formats not foreseen in the environment. Plug'n'Interoperate solution allows systems to plug into it and seamlessly interoperate with other systems. The goal of the PnI Solution is to enable interoperability in environments where the system Data Formats prevents them from interoperating with each other.

In this work, the proposed PnI uses a mediated approach where interoperations are not executed directly by the systems but by other entity, the mediator. The mediator is an entity, present in the environment that executes the interoperation between two data formats as it is requested. By following the mediation approach, the scalability is addressed since in any environment the heterogeneity of devices is greater than the heterogeneity of data formats. It also doesn't require any modification of systems in the environment, as the mediator has the role of interoperations execution, which are defined as Interoperability Specifications (Figure 1).

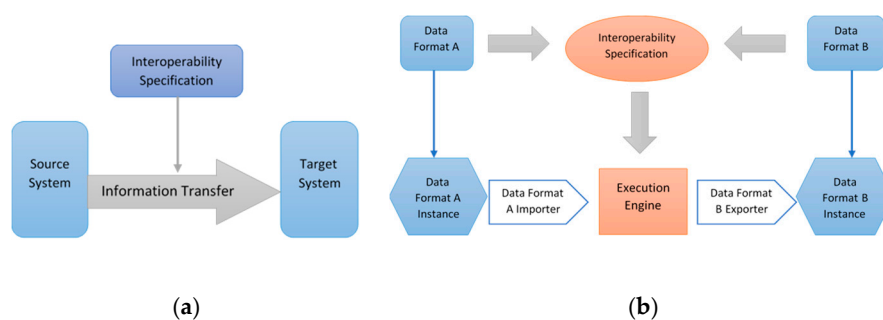


Figure 1. Plug'n'Interoperate Architecture: (a) Interoperability Specifications; (b) Interoperability Execution.

2.1. Data Transformation Module

The Data Transformation module acts as a bridge between two distinct systems (computer application) such as a design and simulation tools. This module is responsible for transforming a BIM model into a data source that can be used by, a simulation tool, with enough quality to ensure that the output results from these tools are reliable. To do this, the BIM models generated, must pass through a set of validation stages, specifically the verification of file extensions compliance, bad formatting and content absence. In this data transformation process was also introduced an entity between the service caller, which can be an user or an application, that was called "mediator". This mediator allows the applications, i.e., each module, to remain standalone (since these are independent from each other) while maintaining, from the point-of-view of the caller, a unique service.

The proposed data transformation architecture will be tested in the abovementioned two different scenarios.

2.1.1. GbXML to IDF Conversion

The data export file format from the selected BIM software (i.e. Autodesk's Revit) is gbXML. To proceed with building energy performance analysis, it was required a building representation in an EnergyPlus Input Data File (IDF) format. To overcome interoperability limitations of existing conversion methods and increase the transparency of the conversion process, a conversion tool has been developed.

The conversion tool developed follows a two-step conversion process [5]: first, using the instructions included in the 'idfXML_template', the 'idfXML' file is created, including all the IDF file objects; second, the new 'idfXML' file is used to write a text file which is the final tool output and input to EnergyPlus IDF file. The two-step process enables the user to easily access and control all the defaults set for building representation and for simulation by editing the 'idfXML_template' file increasing the transparency of the conversion process.

2.1.2. CSV to XML Conversion

For optimization of building design, a holistic approach is advised, as opposed to considering building as an isolated unit without a context. Methodologically, this leads to a multi-criteria decision making problem. In D4E project, an indicator framework for managing project strategic objectives has been set up, with Key Performance Indicators (KPIs) to assess buildings' performance in use. Selected performance, economic and environmental indicators, enriched with neighbourhood energy efficiency indicators are defined with assessment criteria and metrics [6].

2.2. Plug'n'Interoperate Platform

Services detailed above can be used independently through a web version of a user interface (i.e., UI). Such UI is divided in two operations, Interoperability Suite (IS) and KPI Integrator (KPI-I).

The IS interface proposes three options to the user: *simulate*, executes simulation of an IDF file against some weather conditions file using one of the simulators available; *convert*, executes conversions of BIM files (i.e., gbXML into IDF files); and *Composed service*, executes both (Figure 2).

The KPI-I tool is aimed at using EnergyPlus information in a KPI evaluator. Such as the tool will receive a CSV file and convert it to an XML file that will be used by the KPI evaluator tool.

The screenshot displays the 'Composed Service' tab of a web application. It includes instructions for converting a BIM file to an XML file for energy analysis. The interface shows a 'Choose a file to be simulated' section with a 'Browse' button and a file named 'REVITExport.xml'. Below this, there's a 'Choose a weather file' section with a 'Browse' button and a file named 'GBR_London Gatwick.037750_1WEC.epw'. The 'Choose a converter' section shows a dropdown menu with 'LU_gbXML-IDF Converter' selected. The 'Choose a simulator' section shows a dropdown menu with 'Energy+ (v6.4)' selected. A 'Simulate' button is at the bottom. On the right, a 'Simulation output file' window is open, displaying a table of energy values gathered over 8760.00 hours.

Values gathered over 8760.00 hours			
Site and Source Energy			
	Total Energy [GJ]	Energy Per Total Building Area [MJ/m ²]	Energy Per Conditioned Building Area [MJ/m ²]
Total Site Energy	18.03	179.42	270.92
Net Site Energy	18.03	179.42	270.92
Total Source Energy	63.30	629.94	951.18
Net Source Energy	63.30	629.94	951.18

Figure 2. IS: Composed Service; from data conversion to energy simulation.

3. Validation and Results

Both abovementioned platforms were tested as part of the design process, depicted in the flowchart presented in Section 2.1. Initially a BIM model was obtained through Autodesk Revit, as a gbXML file. Such file was used as an input file to the IS, as well as a weather file (London). Converter and the simulator chosen, following a press of the "simulate" button. The IS provides then a zip file

with all the simulation results. A small part of the simulation results is shown in Figure 2, as well as the validation of all steps of the Composed Service process (marked as green bullets).

The KPI-I provides in abstract a similar UI with similar buttons to present the user a familiar environment. However, as the tool was aimed as a proof-of-concept, the UI lacks some usability. For instance, the filenames need to be in alphanumeric and underscores. This was noticed at the test/validation phase. Although this can be a problem, when the user respects the filename rule, the main functionality of the UI is achieved. In other words, the conversion of an Energy+ export CSV file into a proprietary XML file type is successful, and it produces a valid file to be later used.

Multiple limitations exist when using BIM to perform Building Energy Modelling (BEM) due to lack of transparency of data transfer. Facilitating tools were developed to enable transparent exchange of data at different stages of the BIM to BEM process. A series of tools developed bridges the data transfer gap between BIM and BEM, such as the “Format Checking”, “Enhancer” and “Conversion” tools.

The interoperability tools were tested and validated in a case study building. For this validation, a comparison between simulation output and real-life values was made. As real data, utility bills for three consecutive years have been used for both electricity consumption and heating oil. Electricity consumption error between real and simulation data is lower than 5% (KWh/m²). The estimation of heating consumption shows an error of 10% (kWh/m²) when compared with real data (bills).

4. Conclusions

In this paper an interoperability solution was presented, aiming to go from (building) construction models to energy simulation. Furthermore, the energy simulation results is used for the evaluation of the KPI's analysis of the designed building. In this work the technical interoperability issues were addressed, then an architecture for the Plug'n'Interoperate (PnI) platform, along with the Data Transformation modules, was offered.

The solution presented in this work exploits the concept of PnI, which is supported by the principle of self-configuration to automate, as much as possible, the configuration and participation of systems into a shared interoperability environment.

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