
TOWARDS A BIM-BASED SERVICE-ORIENTED PLATFORM FOR A COLLABORATIVE MULTIDISCIPLINARY TEAMWORK

Anthony Cormier, research engineer, anthony.cormier@cea.fr

Sylvain Robert, research engineer, sylvain.robert@cea.fr

Pierrick Roger, research engineer, pierrick.roger@cea.fr

Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA), Laboratoire Intégration des Systèmes et Technologies (LIST), Saclay, France

Bruno Hilaire, research engineer, bruno.hilaire@cstb.fr

Centre Scientifique et Technique du Bâtiment (CSTB), Sophia Antipolis, France

ABSTRACT

With the growing trend in the building industry to use software tools able to handle Building Information Model (BIM), staffs are more and more confronted with workflows conflicts. In order to improve their efficiency, up-to-date techniques for dealing with BIM sharing are required. Attempting to address this issue, a web services platform, especially optimized to deal with the already well-recognized Industry Foundation Classes (IFC) open standard, has been developed.

This article describes the platform (architecture, software components, technologies), specially emphasizing on the strategies envisaged for collaborative work support. To illustrate resulting benefits for the building industry, it also gives an overview of the work already performed on a platform service dedicated to dynamic thermal simulation.

Keywords: BIM, Software-as-a-Service, simulation, IFC

1. INTRODUCTION

Carrying out a building life cycle, from design to construction, and from construction to operation follow-up, requires many stakeholders to intervene and interact, each having specific skills (architecture, engineering, construction commissioning, facilities management). The resulting working environment is therefore highly collaborative and multidisciplinary, which raises several issues related to information management: how to deal with the multiple and varied models and data formats used to represent the building? How to make those data visible and accessible to stakeholders? And last but not least, how ensuring building data integrity in such concurrent and collaborative workflows?

Unfortunately, current practices and support tools most of the time simply do not consider properly these issues. As a consequence, flaws often occur in the life cycle, e.g. recurrent and error-prone data replication or conversion, data “leaks”, redundant data processing and storage. These flaws have in turn undesired effects, ranging from (quite harmless) productivity losses and stakeholders communication disturbances to actual defects in the building.

It is our belief that Information and Communication Technologies may help here, by providing adequate software tools for dealing efficiently and safely with building data. Practitioners seem to be ready for such a cultural shift, since a growing number of them are already acquainted with the BIM (Building Information Model) and its related benefits. As an attempt to move towards that direction, we have started working on the development of a software platform for building life cycle support. This platform implements a standard and open BIM, and features services dedicated both to collaborative work and design tasks support (e.g. simulation). The platform is based on a server dedicated to building digital data storage, especially optimized for dealing with IFC (Interface Foundation Classes) BIMs. This server is completed by software components dedicated to interoperability management (e.g. models transformation, business views extraction), to design support (e.g. to help in performing thermal and environmental simulations), and to data flow management (e.g. BIM access and

modification rights). The platform implements a SaaS (Software-as-a-Service) strategy in order to be easily attainable: features are available remotely through the Internet thanks dedicated client software.

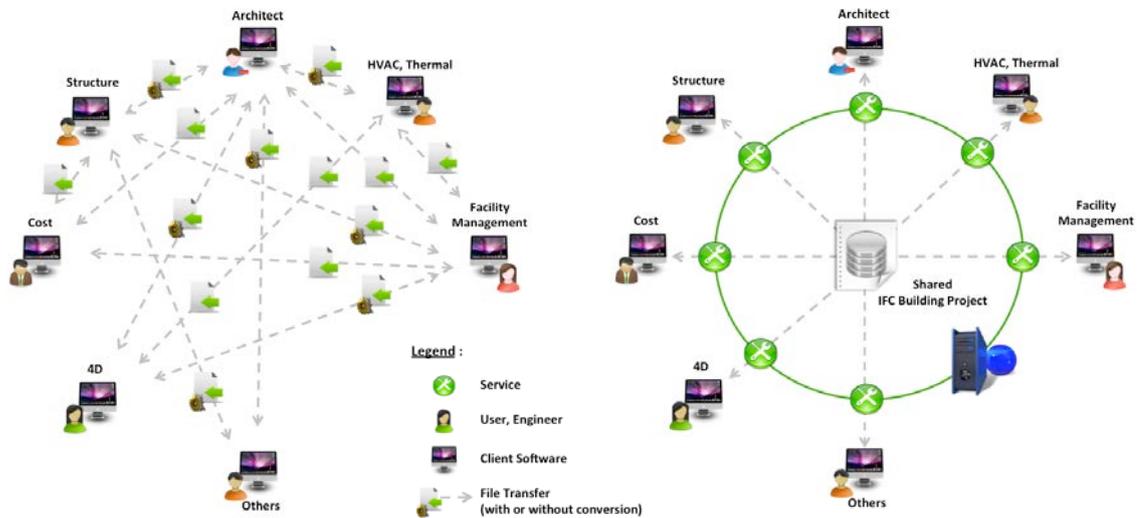


Figure 1: Advantage of a shared and standardized Building Information Model in a collaborative and multidisciplinary working environment

The purpose is to enrich iteratively the platform, by adding services to support as many building life cycle activities as possible, with a particular emphasis on the design stage. To facilitate this progressive enhancement, several crucial technological choices were made: the first is to rely on an open and standard data format, the IFC; the second is to implement and make available to external contributors an API allowing to manipulate objects expressed in IFC; the third is to implement a modular and evolutionary architecture enabling easy integration of additional services.

This paper is structured as follows: a first section gives an overview of the services provided by the platform for the BIM management in a multi-user environment and describes the main architectural choice. Then, business services specific to the thermal analysis and implementation of dedicated interfaces on reference client software are presented. At last, some related works are mentioned and a conclusion reminds our main achievements and opens some perspectives for future works.

2. SERVICES AND ARCHITECTURE FOR A COLLABORATIVE TEAMWORK

2.1 Collaborative BIM teamwork services

Sharing an IFC-based BIM in a multi-user environment means more than one user can work on the same building model and, even simultaneously on the same construction element. Therefore, it is required to manage potential conflicts between modifications from other various life cycle stakeholders. A simple and efficient way to reduce such conflicts is to rely on a reservation mechanism in the workflow, which enable stakeholders to manage read and write accesses to the models. The reservation mechanism implemented in our platform is based on the following rationale:

- An object must be reserved first in order to be modified,
- An object already reserved by a user can't be modified by another user,
- Once modifications on an object are performed, this latter has to be released prior to any reservation by other users.

Technically, reservation rights are effective on clearly identified objects; this means that only IFC elements inheriting from the `IfcRoot` type can be reserved, since they are the only ones to own a unique identifier attribute (the GUID: Global Unique Identifier). Therefore, in the scope of a given project, the list of reserved objects corresponds to the list of the GUIDs of the reserved IFC elements.

To enforce this mechanism of modification rights, and in line with the multi-disciplinary environment, the concept of role is introduced. One or more roles may be allocated to any stakeholder depending on his position in the project or his business domain. By way of illustration, the following roles have been defined: building owner, architect, thermal engineer, structure engineer, facility management engineer, etc.... A set of predefined rights is associated to each role: a user will be entitled to modify a building model only within the limits induced by his / her roles rights. When a user gets connected to the server and opens a work session on a building project, he has to endorse the role(s) that gives him rights on objects he/she wants to modify (or delete). It is quite obvious, for instance, that a cost engineer shall not handle modifications of a beam or bearing wall on a building, but that such modifications shall be performed only by an architect or a structure engineer. Depending on the project and the team size, the description of the IFC element type list associated to a role could be customizable and managed by the project administrator. In addition to this role-based reservation mechanism, two additional strategies have been implemented. The first enables users to reserve one or more IFC instances of the model (e.g. one specific wall). The second leaves the possibility to users to reserve all instances of one or more IFC types in the model (e.g. to reserve all the windows of the building).

2.2 BIM Platform Architecture

The platform is based on a server dedicated for the storage and the management of shared IFC models. At the core of the platform architecture is a Java API especially optimized to deal with the IFC2x3 specification. This API has been obtained by the mapping of the IFC EXPRESS schema data into a Model Object Facility describes as a XML Metadata Inter-Exchange (XMI¹) file. With the use of a code generator included in the Eclipse Model Framework (EMF²) a collection of java classes and interfaces counterparts of IFC2x3 entities has been created. For a developer, this API allows to manipulate easily building model elements. Furthermore, convenience classes to help the connectivity between the IFC-based building model and business software have been implemented in order to facilitate access, query and usage of IFC models java instances. For example, these convenience classes help to easily build the set of IFC entities needed in the definition of material properties or to return the IFC elements corresponding to a given identifier (GUID) in the building model.

Figure 2 gives an overview of the platform developed. First of all, a “Project Management” component is dedicated to users, roles and BIMs. Each BIM project can be accessed by users through attributions of roles. A role can only be attributed to a user for a specific project according to his involvement (see previous section). In addition, this component is responsible for projects versioning, for storing in the database all versions committed by users, including all useful information (user login, used roles, date, description message...).

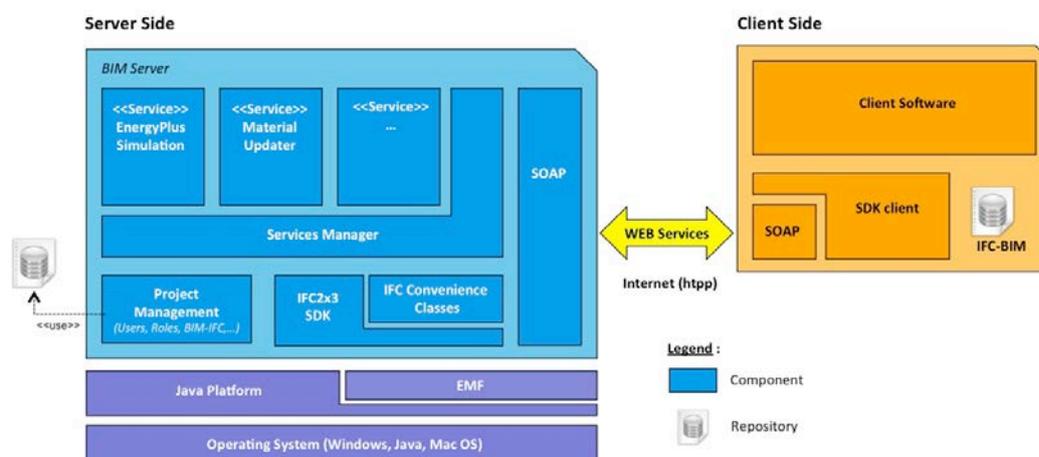


Figure 2: BIM platform architecture.

¹<http://www.omg.org/spec/XMI/>

²<http://www.eclipse.org/modeling/emf/>

Then, another platform component provides IFC files parsing and loading services. Once an IFC file is loaded and instantiated, further processing can be performed on the building model. These may relate to interoperability management (e.g. models transformation, business views extraction) or design support (e.g. to help in performing thermal simulations, to enrich the model content...).

The aim is to enhance iteratively this platform, potentially thanks to external contributions. The platform therefore enforces a modular and evolutionary architecture thanks to the “Services Manager” component: any additional service(s) may be integrated in the platform, thanks to a plugins mechanism and the implementation of a dedicated generic API. This API enables a service to communicate with the Project Manager and to gain access to the IFC model on which some processing is expected to be performed. Furthermore it allows defining – if applicable - the list of input parameters and output results. Services are activated by Project Manager through SOAP requests, and are able to call other services. These mechanisms facilitated a lot the integration of a first set of services in the platform dedicated to Building Energy Performances Simulation (see upcoming section for further details).

From the user point of view, the platform implements a SaaS (Software-as-a-Service) strategy in order to be easily attainable: features are available remotely through the internet thanks to a dedicated client software and to a straightforward distant communication protocol based on WSDL (Web Services Definition Language) and SOAP (Simple Access Object Protocol):

WSDL, a data model expressed in a XML-based language for documents, lists operations available on the server and defines the message format required in order to benefit of a specific services provided on the server side. Furthermore, it embeds any special data types uses, for example, as response to a server request. SOAP (Simple Access Object Protocol) is used as the communication channel allowing request message transmission from the client side to the server side. From the client side, it actually calls remote procedure listed in the WSDL file.

On the client side, the SDK client library allows an application to call distant services and to deal with downloaded versions of buildings projects.

3. SERVICES AND INTERFACES DEDICATED TO THERMAL ANALYSIS

The InPro³ project, a European industry-led collaborative research project aiming at the early design of a building, identifies the thermal analysis as one of a key processes. A major constraint of using a Building Energy Performance simulation tool is the huge time spent on simulation input preparation, in particular building geometry data (V. Bazjanac 2010). For the major part, this effort consists in manual duplication of already existing data, which is in essence an error-prone process. One other point is the definition of the minimum of information required to perform the simulation. A study of the average content of an IFC-BIM file populated by a computer-aided architectural design program (CAAD) shows that most of the time major information is missing from a thermal point of view; for instance, thermo-physical properties definition of building materials.

Here we can distinguish two kinds of services the platform could offer specifically in the scope of thermal simulation: the first is populating the IFC model with needed material properties and the second is performing an automatic mapping of to the data format required by the targeted simulation tool (following the methodology of V. Bazjanac 2008).

Assuming that an architect stores on the platform a first version of the IFC building model (and assuming that this model is well formed in terms of building geometry and space definition), a thermal engineer can launch the following process to perform his building energy performance (BEP) analysis:

1. Check-out the IFC model on his workspace to check its contents,
2. Update materials' properties,
3. Configure the BEP simulation (location for meteo file, simulation running period, convergence criteria...),

³<http://www.inpro-project.eu/main.asp>

4. Launch simulation (the service of translation of the IFC model into the data format of the targeted simulation environment is integrated)
5. Post-Process simulation results.

In order to be implemented, this process requires the following services to be made available to the platform users:

- A support to partially automate material properties updating
- A translator able to generate simulation-specific data formats from IFC models
- A service to execute the simulation and obtain results
- A nice and ergonomic HMI

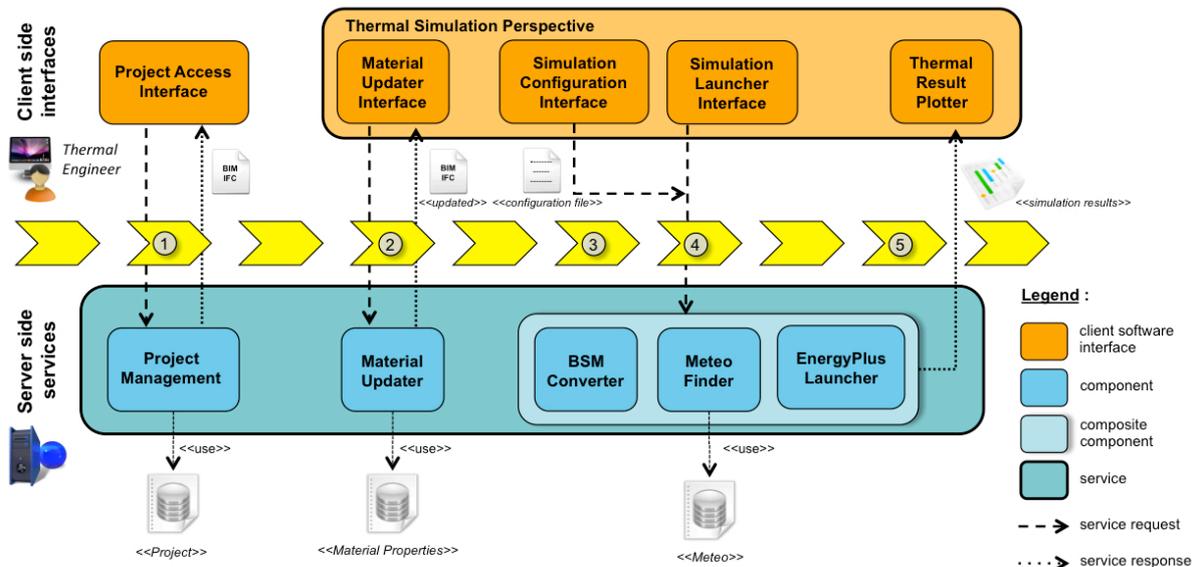


Figure 3: Building Energy Performance (BEP) simulation process.

This work has actually been performed⁴ for a widespread simulation environment, namely Energy-Plus⁵. The following sub-sections detail the software services that have been developed for this purpose.

3.1 Material Updater Service

As a first step in the process to perform a BEP analysis, the thermal engineer should have to ensure of the definition of thermal properties of all building structure. So to realize the BIM completion, a service has been developed which research thermal properties into separated material database from the material name defined in the building model. In a real context, constructions are supplier company dependent and different libraries can be allocated (Thomas Luaine 2010) but in our case, as an example of the features, we realized a simple XML database including thermo-physical material data (density, conductivity, heat capacity...) for building element (wall, slab, door, window...). When the engineer uses the service, material properties values are populated automatically in the IFC file with the appropriate existing element the IFC2X3 specification offers.

```
// Information populated with a CAD software
#1138=IFCMATERIAL('Plaster partition');
#1141= IFCMATERIALLAYER(#1138, 0.1, .U.);
```

⁴ This work was funded by the French ministry of Research in the scope of the CLIMB collaborative research project)

⁵<http://apps1.eere.energy.gov/buildings/energyplus/>

```

#1143= IFCMATERIALLAYERSET(#1141, 'Plaster partition 100');
#1145= IFCMATERIALLAYERSETUSAGE(#1143, .AXIS2., .NEGATIVE., 0.05);

// Information populated with the CLIMB Material Updater Service
#3633= IFCCLASSIFICATIONNOTATIONFACET('opaque_surface');
#3634= IFCCLASSIFICATIONNOTATION((#3633));
#3635= IFCMATERIALCLASSIFICATIONRELATIONSHIP((#3634), #1138);
#3636= IFCEXTENDED MATERIALPROPERTIES(#1138, (#3638), $, 'opaque_surface_extended_properties');
#3638= IFCPROPERTY SINGLEVALUE('ROUGHNESS', $, IFCTEXT('smooth'), $);
#3639= IFC THERMAL MATERIALPROPERTIES(#1138, 830., $, $, 0.16);
#3640= IFC GENERAL MATERIALPROPERTIES(#1138, $, $, 784.);

```

Figure 4: Example of material properties updating in aIFC-STEP file.

3.2 IFC-EnergyPlus Translation Service

The second step for the thermal engineer is to generate a Building Simulation Model (BSM) into the format of his simulation tool and based on the Building Information Model (BIM). The simulation tool targeted here is EnergyPlus. The EnergyPlus model format consists in an Input Data File (IDF). An example of the current practices is to use the Design Builder environment to obtain this file by manually re-building the 3D model of the building. In order to automatize the IDF generation from the IFC file, we developed an automatic translation service. For the moment, this service only maps site information, geometric component (wall, slab, window...) and material information into his equivalent in the IDF building simulation model (the mapping of HVAC equipment is not yet realized). Note that even of this service only targets EnergyPlus the part of the translation process which deals with extracting relevant data from IFC models could be shared between several BIM to BSM conversion services, as mentioned by (Vladimir Bazjanac 2001).

3.3 Weather File Service

A third service was developed to provide the simulation tool with weather information. It relates the site name where the building is located to the corresponding weather file. In our case, the simulation tool uses an EPW file format (EnergyPlus Weather), a generalized weather format used by two major simulation programs (EnergyPlus and ESP-r) and derived from the Typical Meteorological Year 2 (TMY2) weather format. Note that another service could be implemented for conversion from a standard to a specific weather format. However, EnergyPlus web site provides a collection of EPW files (10 for France) and an EnergyPlus Weather Converter utility to read and translate weather file from various type (TMY2, TMY3, IWEC the format from ASHRAE). For our study, we have considered a building site for which we have directly the EPW file in our weather database.

3.4 Implementation of the client interface

In order to implement the client side of our solution and to provide remote access of services provided by the server, the eveBIM software tool (developed by the French research institute CSTB) was chosen as a base. This software tool is in itself mainly an IFC viewer: it enables viewing IFC models in 3D and offers a comprehensive support for IFC models properties edition. However, one strength of the tool is its ability for customization: dedicated perspectives (set of specific windows, menus, etc) may be added to the tool in a “plugin-like” way in order to specialize it for other purposes. In our scope, we developed an eve-BIM perspective, which includes all interfaces required to use the thermal simulation service.

With the implemented interfaces, the thermal engineer can access all collaborative works management services (opening a user session on the CLIMB server, opening an authorized project and import his related IFC file, reserving (and releasing) building elements...). A specific eveBIM perspective gathers interfaces to use services dedicated to the building energy performance simulation (in order to update material, to define simulation configuration parameters, to launch the simulation and post-process the simulation results with a plotter dealing with CSV file format).

The following example presents the results obtained with a simulation performed on a building, which includes six thermal zones. The dock on the left side shows properties of an IFC element selected on the BIM and in particular thermo-physical material properties integration. The dock on the right side allows to configure the simulation and to activate the Material Updater or the EnergyPlus Simulation services. On the center, a 3D view of the building and the plotter displaying the variation of the mean temperature in each of the building zones along the time period defined in the simulation parameters.

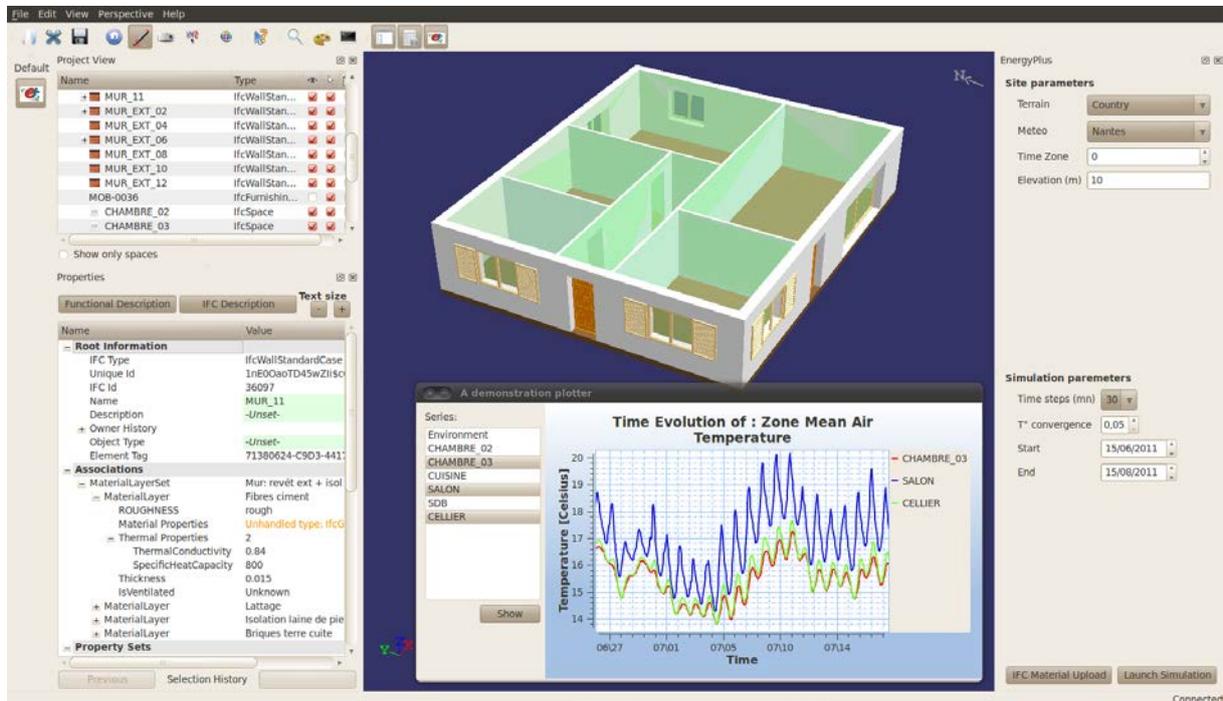


Figure 5: EnergyPlus Simulation Perspective on eveBIM.

4. RELATED WORKS

Over the past decade, several projects have been initiated to provide a software platform to use and manage an IFC-BIM shared model.

One of the main is the Active3D platform, which presents itself as a collaborative Internet platform to optimize building project efficiency, work coordination and real estate holding technical management (Christophe Cruz 2002). An example of service provided on this platform is the connection to various databases available from Internet (Electronic catalog...). Such a service gives a user the ability to relate a BIM object as window or a wall to a constructive product defined in a database as EDIBATEC⁶ (association working for facilitate access to industrial products database). However, the solution does not provide any mechanism to integrate services from exterior contribution nor offers any fine-grained support for BIM modifications management.

As part of an effort to enhance interoperability, the middleware BS-Pro COM-Server provides an API to achieve Industry Foundation Classes compatibility with software tools (thermal simulation, CFD simulation, product selection, HVAC CAD...), with a quite reasonable amount of developer work (Antti Karola 2001). Based on this middleware, a client module software named IFC2IDF and developed by the Lawrence Berkeley National Laboratory, permits to directly import building geometry from an IFC file into EnergyPlus. This software, however, suffers from various limitations: the BS-Pro COM is a sole API, which does not provide any easy-to-use interfaces; there is no clear methodol-

⁶<http://www.edibatec.com/>

ogy to integrate additional modules; the IFC2IDF software is provided as a client software and does not offer any SaaS interface.

An important model server to mention is the SABLE server (Simple Access to the Building Life-cycle Exchange). The project is being managed in Finland by EuroSTEP and is supported by the International Alliance for Interoperability. It aims to provide one standard interface to enable connection of all model servers with a SABLE server interface. Another level of implemented standardized API is to handle information exchange needed by specific domain client application (business view). Such an API allows extraction of sub-model categorized by disciplines in addition with a query language to the retrieval of model subset (Arto Kiviniemi 2005). Such business interfaces will be implemented on our platform and usable as services.

The Bauhaus University Weimar (BUW) has developed a set of four multi-platform tools (GNU-LINUX, Windows and Mac-OS) dedicated to IFC and open-source java development. Open Java ToolBox for the reading of ifc2x3 step files and manipulating of in-memory IFC java instance; J3D IfcLoader for Java3D for a 3D view of the building model; Boolean Modeller for manipulating product representation with Constructive Solid Geometry operations; 4D Schedule Assistant for building project planning. This project offers only API's to deal with IFC file but neither a way to manage it nor an environment to use it.

The Open Source (GPL v3) IFC development framework, bimserver.org, encourage the use of shared building information models and offer a development environment for academic researchers and commercial software developer. As a reference implementation a web-browser based client has been created for operation such as creation and management of users and their access rights, creation of project, inspection of the model content... Furthermore, a module based on Google O3D format allows graphical visualization of the IFC data (Jakob Beetz 2010). This initiative is clearly highly relevant in the scope of IFC-based collaborative platform. However, the scope is strictly on the IFC whereas our aim is to link IFC support with business-oriented services (energy simulation, etc...).

CONCLUSION AND PERSPECTIVES

In this article, we have described a software platform dedicated to building life cycle activities support. The platform relies on a client – server scheme, where services are provided on a dedicated server and used remotely thanks to light client software. It relies on the IFC as a reference data format for building representation. Among the provided services, a strong focus has been put on collaborative work support. This support consists mainly in an implementation of a users accesses and rights management, relying on a multimodal IFC objects reservation strategy.

The platform is an open platform: external contributions are accepted and encouraged. In order to facilitate integration of additional services, the platform enforces a multi-layered and modular architecture, and a dedicated API and convenience classes have been also implemented.

As a first step to enhance the platform's services, a service offering to effective Building Energy Performance simulation support was developed and integrated. A dedicated client interface was also implemented, relying on an existing IFC viewing software tool.

As future works for the enhancement of the platform, an integrated suite of plug-in implementing generation of domain-specific sub-model ("business views") is envisaged, and studies related to IFC models versions management are under way. Furthermore, we undertake to do robustness tests on the BSM converter using a suite of test models and the mapping of the HVAC system has to be realized. At last, an IFC checker of relative thermal "view" consistency is planned to be integrated in the BEP simulation service.

ACKNOWLEDGMENTS

The work presented in this project was performed in the scope of the CLIMB research project, funded by the French Ministry of Research, and was also based on the work performed in the SIMBIO study, funded by the French Environment and Energy Management Agency (ADEME).

REFERENCES

- Vladimir Bazjanac (2001) "Acquisition of Building Geometry in the simulation of Energy Performance." Proceedings of Building Simulation '01, Rio de Janeiro, pp. 305 – 312.
- Vladimir Bazjanac (2007) "Reduction, Simplification, Translation and Interpretation in the exchange of model data" Accepted for publication on the 24th W78 Conference Maribor 2007.
- Vladimir Bazjanac (2008) "IFC BIM-based Methodology for Semi-Automated Building Energy Performance Simulation" Paper LBNL 919E, Berkeley, California, United States.
- Jakob Beetz, Ruben de Laat et al. (2010) "Towards an Open Building Information Model Server" Eindhoven University of Technology
- Arto Kiviniemi et al. (2005) "Integration of Multiple Product Model: IFC Model Servers as a Potential Solution" *Proceeding of the 22nd CIB-W78 Conference on Information Technology in Construction*.
- Christophe Cruz, Christophe Nicolle (2002) "Active 3D: Vecteur de collaboration pour les métiers du bâtiment"
- Antti Karola et al. (2001) "BS-Pro COM-Server Interoperability between Software Tools using Industry Foundation Classes" *Presented at the 2001 IBPSA Conference in Rio de Janeiro*.
- Tuomas Laine et al. (2010) "Energy and Thermal Performance Management Through Utilisation of Building Information Models"