IFC and Buildings Lifecycle Management

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Abstract:
This paper presents an extension of the BIM technology that allows to manage information during the entire lifecycle of an AEC project. Usually, AEC projects and facility management are dissociated. Our Building Information System plays a central role in the improvement of the design and the management process. The building activity generates a great number of data and information of various kinds. The management and the communication of these data by the various participants is complex. Our design and management methods use IFC files to facilitate the sharing process for a better qualification and validation of data.

Keywords: product data interchange, Computer-aided engineering, Facility Management, Industry Foundation Classes (IFC), BIM.

1. Introduction

AEC (Architecture, Engineering and Construction) projects associate a set of teams from various domains. During this project, teams set up many business processes independently from other teams in other domains. Georgakopoulos et al. in [13] define Business Process as a collection of one or more linked activities which realize a business objective. The lifecycle of a business process involves everything from the capture of processes in a computerized representation to automating process. The lifecycle of a building is articulated in two parts. The first part is about the design in an AEC project. The second part concerns the exploitation that deals with facility management. Currently, these two parts are dissociated in the processes of building management. The teams which are concerned with the processes of facility management are rarely those that have participated in the conception and the construction of the building. In the AEC domain, a first step towards a computerized process and information interoperability has been developed in 1999 with the development of the IFC [14]. Until this year, computer programs for building design, analysis, and maintenance could usually not exchange data exchange data directly, even when the same team used them. Buildings, therefore, took longer to be designed and built. Thus, buildings were more expensive to construct and to operate. Information sharing should be the starting point when it comes to apply information technology to architectural design, construction, and use. Information sharing requires a software environment in which computer programs can exchange data automatically regardless of software and data location. Towards this goal, the International Alliance of Interoperability proposed a standard that specifies object representations for AEC projects. Industry foundation classes (IFCs) include object specifications, or classes, and provide a useful structure for data sharing among applications. For instance, an IFC door is not just a simple collection of lines and geometric primitives recognized as a door; it is an "intelligent" object door which has a door's attributes linked to a geometrical definition. However, many AEC engineer teams do not exploit the IFC. No central IFC database exists nor do tools for IFC analysis, comparison or visualization during the construction. Since 2000, new IFC based business processes have been developed in some domains, such as AEC and MEP (Mechanical, Electrical and Plumbing). The work described in the paper [10] emphasizes the need to consider issues of facility management at the pre-design stage of the construction process, rather than only when the building is completed. In this manner, the management of the building lifecycle takes into account all processes defined in the domain of facility management. Successful facility managers need a range of skills and need to be able to devise innovative strategies for the future of the organizations in which they work [1]. To reach these requirements, facility managers need powerful tools to organize knowledge on the various types of information generated during the building lifecycle.

In this paper, we consider the building as an information system. The lifecycle of a building can be divided into 4 main stages which are the design, the construction, the exploitation and the maintenance stage. Each stage is generally managed independently and is divided into superimposed layers. These layers represent aspects of the building which are handled by various methods, tools and specific business skills. The layers of the construction stage correspond to the various trade associations which intervene in the construction of the building. The layers of the exploitation stage correspond to the various services of management and production which use the structures of the building. The layers of the maintenance stage correspond to the outside contributors or to the services of maintenance and management of the building. Each layer has its own information. Each layer exchanges partial information with the other layers. Each stage exchanges partial information with the other stage. Unfortunately, numerical information is limited to spreadsheets, word documents and to a set of 2D vectors. Their formats are often related to a specific application and the modeled knowledge is very limited.

Our objective is to propose a method and tools which make it possible to collect and combine information of the various layers presented previously. Thus, we wish to store the information so that it becomes exploitable, organized and to enrich the knowledge throughout the lifecycle of the building. We base our approach on the standard IFC and a semantic indexation method on XML grammars. We use XML as a standard for the generation of the ad hoc data and the standard IFC for 3D numerical models. Our method makes it possible to build a semantic global diagram called an ontology. This ontology unifies all knowledge generated during each step of the building's lifecycle. The result is a cyclic semantic graph which contains multimedia data, rules, Web Service links and IFC objects. This graph can be regarded as a semantic hypermedia graph. To exploit this research, we have developed a collaborative platform called Active3D which is used as a support for data exchange and data repository. This platform won the technological innovation gold medal at the international show BATIMAT in Paris in November 2003. It has been marketed since this date. Currently, several modules are being developed, such as an Electronic Document Management (EDM). This application is used during the design and the construction steps to store and exchange documents (contracts, plans, invoices, pictures, etc.). It is also used during the exploitation and the maintenance steps to reach the documents which are attached to IFC objects of the Digital Mock-Up (DMU) in 3 Dimensions (maintenance contracts, user manuals, etc.). A module dedicated to the facility management has been developed which makes it possible to dynamically build a trade view of a building from an IFC 2x3 file. A set of tools has been included in this application (a query engine, a document generator, an alarm manager, a task planner and an IFC viewer). Each IFC object can easily be handled by any process. The IFC objects can be configured to contain Web service links from electronic catalogs of furniture and equipment, documents, ad hoc data or rules. All information can be managed by a 3D graphical interface certified IFC 2x3 by the International Alliance for Interoperability. This platform is currently used by thousands of users in France and it was bought by French administrations (e.g. the Administrative Council of Burgundy, the city of Paris, etc.) and by private companies. Currently, more than six million m^2 are being managed by Active3D (www.active3d.net).

Section 2 is a brief state of art on the modeling of building information. This section presents common BIM features. We will show in this section that our proposal extends the common BIM definition. Section 3 presents our semantic indexation method used to define a global ontology. This ontology is used to merge all data during the building lifecycle in order to create a building information system. Section 4 presents the Active3D platform with its 3D scene management system. It presents also the method which is employed to link 3D objects to objects of the building lifecycle and electronic documents. Section 5 presents a sharing and exchange example between the platform Active3D and the CAD software packages. Section 6 concludes this paper.

2. Building Information Modeling Overview

Today, “Building Information Modeling (BIM)” is promising to be the facilitator of integration, interoperability and collaboration in the future of the building industry. The term BIM has been presented recently as a demarcation of the next generation of Information Technologies (IT) and Computer-Aided Design (CAD) for buildings which focus on the production of drawings. BIM is the process of generating, storing, managing, exchanging, and sharing building information in an interoperable and reusable way. A BIM system is a tool that enables users to integrate and reuse building information and domain knowledge throughout the lifecycle of a building [20]. A BIM system is a central system that allows to manage various types of information, such as the planning of enterprise resources, resource analysis packages, technical reports, meeting reports, etc. However, the main feature of a BIM is the 3D modeling system with data management, data sharing and data exchange during the lifecycle of the building. Indeed, a building is composed of geometrical elements which are the basis of a building’s design. Furthermore, parametric modeling provides powerful mechanisms that can automate the generation of the building information. Especially these mechanisms in conjunction with building object behavior and object-based systems facilitate the maintenance and the validity of the building's designs.

Several definitions of BIM can be found in the technical literature. The NBIMS divides the BIM categories in three axes which are Product, Collaborative Process, and Facility [24]. The Product is an intelligent digital representation of the building. The Collaborative Process covers business drivers, automated process capabilities and open information standards used for information sustainability and fidelity. The Facility concerns the well understood information exchanges, workflows, and procedures in which teams use as repeatable verifiable and sustainable information-based environment throughout the building's lifecycle. According to [23], a BIM is a computable representation of all the physical and functional characteristics of a building and its related lifecycle information, which is intended to be a repository of information for building owners and operators, to be used and maintained throughout the lifecycle of the building. According to [2], BIMs have three main features: They create and operate on databases to allow collaboration. They manage changes throughout these databases so that a change in any part of the databases affects all other parts. They capture and preserve information for reuse by adding industry-specific applications.

The next section presents the technology that influences the building industry through four dimensions. These dimensions are important in the implementation of relevant tools for AEC projects. The following section presents the main features of BIMs that we found in the technical literature.

2.1 Information technology influences building industry

According to [11], there are four different contextual dimensions that influence the form of information technologies in the building industry and in the building information modeling: the organizational dimension, the software technology dimension, the system architecture dimension and the building technology dimension.

Different organizational structures will have different information exchange and integration needs. A virtual organization team with dispersed members working on a single project does not have the same needs as an international building company with various divisions, such as internal design, engineering and construction divisions. The information technologies will orient the future of the building industry guided by organizational requirements.

Software technology is also able to control building information modeling. New languages, function libraries, exchange standards and other tools become available and facilitate new methods for information integration, reuse, management and sharing. Recently, XML technologies, Web applications and Web 2.0 technologies, Web services, Web semantic and Knowledge Management technologies, which have known an incredible growth in all economical trades, have become of value for BIMs.

The third dimension is also a technical one and deals with system architectures which are continuously evolving. Email has greatly improved data exchange during the last decade. Centralized systems, such as client-server have also improved exchange and sharing processes. Today, the World Wide Web is affecting the way in which BIM

systems are designed. New system architectures, such as Service Oriented Architecture (SOA) or P2P networks are also of interest for BIMs.
The last dimension deals with the modeling of BIM technologies. Form this point arises the interoperability issue. A company in a specific domain has its own integration needs. A global consortium is required to propose and to keep in constant evolution all integration needs from a global point of view in order to ease interoperability between BIMs.

2.2 BIM characteristics

This section attempts to describe the characteristics of BIMs which are, on the one hand, the data modeling used to describe information concerning the buildings, and, on the other hand, the model used to share and exchange the data model. Moreover, the following section will deal with other features which are common to BIM systems.

2.2.1 CAD data, CAD Object, and Parametric Building Modeling.

There are many technologies and software packages available that can be used by BIMs, such as CAD data, CAD object, and parametric building modeling. CAD is the least effective technology when it comes to accomplishing building information modeling because it demands a great amount of effort. At the same time, CAD is one of the easiest and oldest technologies used in the industry. However, CAD files require greater levels of effort when used in BIMs. Often the quality of the information depends only on the person who is inputting the data. CAD data requires individuals to go back and to modify every area affected by the design. A CAD object simulates building components from regular CAD data and focuses on the 3D geometry objects of the drawings. This enables the extraction of individual data from objects which provide information about the properties of objects. It does not ensure high quality, reliable, and coordinated information that the higher level of BIM produces. Many users of CAD objects use them primarily as design and documentation tools and not for the complete building modeling. The basic difference of parametric building modeling compared to CAD data and CAD objects is the real-time self-coordination of the information in every view. The self-coordination ensures that when a change is made in the design, it will be implemented throughout the entire project and will, thus, provide a security concerning the quality of information coming from the design.

2.2.2 Data exchange and sharing models.

The characteristics that distinguish data sharing from data exchange are the centrality of data and the ownership of that data. In the data exchange model, one software system maintains the master copy of the data internally and exports snapshots of data for other users. In the sharing model, there is a centralized control of ownership and there is a master copy of data. In theory, the data sharing model facilitates the revision control issue associated with the data exchange model [16]. The object model of BIMs is the logical data structure that defines all entities, attributes and relationships. Here, we present five different methods for storage and exchange of BIMs that were identified.

1. Data exchange by using files is commonly used and it is carried out by creating a physical file on a physical medium as CD/DVD or by sending it via Internet. The physical file is created by a CAD application and can be exchanged among various applications.
2. Data sharing by using an API allows users to access the BIM physical file according to their rights. This approach focuses on data sharing by using a proprietary API or a Standard Data Access Interface [30] which defines a low level application programming interface to EXPRESS defined data, such as STEP Application Protocols. STEP defines the set of general SDAI operations in ISO 10303-22. Other tools are mentioned here, BSPro COM-Server for IFC Files [18], IFCToolboX: Extended tool support for IFC implementations [15], JSDAI [17], TNO IFC engine [32].
3. Data sharing by using a central database allows multiple applications to access the product's data and to make use of the database features, such as query processing and business object creation. The database can be populated by importing a physical file or, manually, by creating entity instances. For example, EDM Model Server enables flexible and intelligent binding between design and production.
4. Data sharing by using federated databases is a solution that provides a single unified view of multiple distributed databases. In this approach, applications allow the use of different formats and keep the consistency of data throughout the entire building lifecycle. Bentley's federated database approach makes its BIM solutions very different from other solutions that use the centralized building model approach [4]. In Bentley's BIM solution, the project information can be stored in a variety of ways to feed many different workflows or setups that do not fit a preset standard. It is possible to create the entire model in one DGN file which is the native file format of the Bentley applications, and to store all the extracted 2D drawings, views, sheets, and so on within the same file (similar to how separate worksheets within the same Excel file), or the user can choose to create separate DGN files for the models, drawings, sheets, images, other documents, and so on.
5. Data sharing via Web services can be done in two ways, by giving access to the central project database where the BIM is stored, or by giving access to an API which provides access to a physical BIM file or a specific domain view. The SABLE Project [28] and the ACTIVe3D [31] project propose a solution based on three levels. The low level Web services which are Web interfaces to IFC processing components and model server databases. The high level Web services which are domain specific Web interfaces to an application server. The last level is called Business skill level or Application level. Its definition is a set of business skills that the company wants to sell through the client application.

2.2.3 Common BIM features

By analyzing the BIM definitions we have indexed a set of features common to BIM systems [8, 10, 25, 28, 33 and 35].

1. The main feature is the ability to store, share and exchange data. Many methods are used to realize these processes, such as methods used with files or databases. Concerning data exchange, BIMs are developed with the aim to keep open non-proprietary data format for exchange. In Active3D we use the Oracle 9i RDBMS to

store XML information. The diagram used is a metamodelling derived from our ontology. This metamodelling can store IFC objects and IFC relationships independently from the IFC norm. Thus, we can extract partial IFC files according to the user context. This system can export DWG, SVG (Scalable Vector Graphics) and KML files (Google Earth and Google Maps use KML code) from IFC objects.

2. Data managed in BIM processes concerns building geometries which are 3D data most of the time. It is very helpful for designers to visualize complex construction such as 2D geometries, and to communicate design intentions. The AEC industry visualizes the design using stereoscopic projection tools to create an immersive experience [9]. Spatial relationships between a building's elements are managed in a hierarchical manner. IFC objects in our database are stored with their 3D definitions. Moreover, our metamodel stores other types of information connected to IFC objects (data, files, rules, web service links). Thus, the result is not only a limited hierarchical structure but a complex cyclic graph where some nodes can be dynamically enriched using rules or web service activations.

3. BIMS are data rich and comprehensive as they cover all physical and functional features of a building. BIMs are also rich semantically as they store high amounts of semantic information on building elements. Moreover, the data model is fully object oriented to facilitate data management and process definition. Our solution is based on a generic ontology which defines a common structure both for the medamodel and for the domain ontology. The domain ontology represents knowledge and business skills of a specific association trade. With this solution, an actor of the AEC project is connected to a context of use (a dedicated language, access rights or a domain of intervention). Thus, the user can manipulate only information according to its domain.

4. Some of the BIMs are extensible to cover unimplemented information domains. For instance, the development of IFC 2.x has gone through a major change in order to progressively extend the range and the capability of IFCs by using modules. BIMs play a central role in the building lifecycle. In order to facilitate data exchange, a data format has to be widely used. It is a natural capability that BIMs enable interoperability among diverse applications using a shared universal information standard. Unfortunately, this relevant behavior is not simply applicable. To share information it is required to develop translators or to use a standard. The development of translators is very difficult, but some companies use an ETL [36] to Extract, Transform and Load data from specific databases or spreadsheets to a building referential. Nevertheless, prominent CAD editors are working very hard to integrate the IFC 2x3 standard. This is the reason why we have passed the certification of our platform to IFC 2x3 specifications even though we know that IFC 2x3 is not a panacea. Thus, during the certification meeting that we organized in Dijon in November 2007, some lakes object were pointed out (a limited set of objects, a wrong or incomplete object definition, problems in 3D, etc.). The IFC model enables interoperability between CAD software packages but Information Communication Technologies and Ontology Web Language are used in order to construct an integrated data model for Facility Management [29].

5. The lifecycle of an AEC project is composed of several phases which have to be validated by AEC engineering designers. BIMs cover several lifecycle phases and the state of these phases is processed by BIMs in order to sequence and schedule the process. BIMs support 4D analysis, where activities from the project schedule can be simulated and studied to optimize the construction sequence. Section 4.4 presents an example of interoperability using the Active3D platform. This example focuses on the design and the construction step of the building lifecycle. In the exploitation part, dedicated to facility management, the interoperability is done using ETL software to combine data from various databases developed in different services of a company. Actually, facility management can cover a wide range of services, including real estate management, financial management, change management, human resources management, health and safety contract management, in addition to building maintenance, domestic services (cleaning, security, etc.) and utility supply [3]. Each service develops its own tools without global coordination. For example, the City Hall of Paris in France used the Active3D platform and ETL software to coordinate the building knowledge from different services.

Our building lifecycle management (BLM) system takes into account the various phases and participants of a project. These phases are described in our data model. It also takes into account the management and the electronic documentary division. The memorization of documents and information allows the management of the project as well as the management of technical inheritance. The application of this method in a tool will make it possible to automate the processes of document exchange, of building management, and of participant management. This tool used by all actors of the project, will be the vector of interoperability between the information system and will be fed during phases and project stages. The objectives of this tool are the storage of information, the structuring of heterogeneous documents, and the interoperability between actors of the building lifecycle [34].

3. A Semantic indexation method

Since the advent of information systems, numerous data models appeared to resolve the problems of data persistence. These models take into account requirement depending on the real system to be modeled. For that purpose, the partial description of the elements of the real world and the interactions of these elements among each other are defined in the model on two levels. These levels are the syntactic level and the structural level. In this case, the management of the lifecycle of the building requires a third management level. Indeed, the problem consists not only in describing the elements and the interactions of the real world but consists also in validating all the elements, their states and their interactions. This means that the system retains during the conception time supplementary information about the elements. This information concerns the various types of states and interactions. Consequently, the model management of the building lifecycle has to describe the constituent elements of a building project which contains all the concrete elements (such as walls, actors, furniture, etc.), as well as the abstract elements (costs, projects, phases, actions, etc.). Furthermore, the interaction between elements is modeled by links, as for instance, when a wall which contains a window is moved, the window moves as well. Indeed, a wall and a window are connected by the relation of contents. This relation will determine the possible interactions between these

elements of construction. Finally, the building model has a description of the states in which the real system can be and all the information about elements and states of the building relations during the conception.
The following section is composed of three parts. First, it will deal with IFC as a model defining elements and relations of a construction project. The second part will then define the model as this definition is necessary in order to handle data to handle data generated from the IFC. The third part gives an instance of the resulting application. The last part presents an example of BIM interoperability using this method of indexation.

3.1 IFC Model

The "Industrial Foundation Classes" (IFC) is an ISO norm that defines all components of a building in a civil engineering project. An example of an IFC 2x3 file structure is given in script 1. This file describes a building with more than 2.300.000 business objects (one line per object with an identifier number).

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('ArchiCAD 10.00 Release 1 generated IFC
file.','Build Number of the Ifc 2x3 interface: 63045 (25-04-
2007)\X\0D\X\0A'),'2;1');
FILE_NAME('C:\\Documents and Settings\\gkiss\\My Documents\\ifc\\Plan
fra IFC-fil 20061219v3.ifc','2007-05-
15T17:55:04',('Architect'),('Building Designer Office'),'PreProc - EDM
4.5.0033','Windows System','The authorising person');
FILE_SCHEMA(('IFC2X3'));
ENDSEC;
DATA;
#1= IFCORGANIZATION('GS','Graphisoft','Graphisoft',$,$);
#5= IFCAPPLICATION(#1,'10.0','ArchiCAD 10.0','ArchiCAD');
#6= IFCPERSON('KGy','Kiss','Gyula',$,$,$,$,$);
#8= IFCORGANIZATION('GS','Graphisoft','',$,$);
#12= IFCPERSONANDORGANIZATION(#6,#8,$);
…
#111029 = IFCRELCONTAINEDINSPATIALSTRUCTURE
 ('25wKeWex98fQp5Pukf_Ilc', #6, 'BuildingStoreyContainer',
'BuildingStoreyContainer for Building Elelements', (#111007),
#110989);
#111030 = IFCRELAGGREGATES ('216Bv$yJj3tQjFeDohe6fQ', #6,
'BuildingContainer', 'BuildingContainer for BuildigStories', #30,
(#34, #16236, #29699, #56800, #62077, #67336, #72633, #91702,
#110989));
#111031 = IFCRELAGGREGATES ('17XMUtNDr8FeFMtR6rOcy5', #6,
'SiteContainer', 'SiteContainer For Buildings', #28, (#30));
#111032 = IFCRELAGGREGATES ('0pMN8yq8vDRfwN_tnJREKC', #6,
'ProjectContainer', 'ProjectContainer for Sites', #26, (#28));
…
#2397053=IFCRELAGGREGATES('0XAE$DZW109vnUdID6jbSd',#13,'SiteContainer'
,'SiteContainer For Buildings',#64,(#77));
#2397055=
IFCRELAGGREGATES('0cMCuBtY91mhMKaaalCb$C',#13,'ProjectContainer','Proj
ectContainer for Sites',#54,(#64));
ENDSEC;
```

```
END-ISO-10303-21;
```

Script 1. IFC File sample.

This building model was realized by engineers and it describes all concrete and abstract elements for a building conception. Thus, it allows each actor of a building project to share and exchange information with the same description. This solves the problem raised by the syntactic exchange level between CAD software packages. Moreover, all relations between the different elements are defined by elements prefixed by `IfcRel`. In fact, these relations define how elements can interact. For instance, `IfcRelVoidsElement` defines a relation between a wall element and a set of opening elements. Consequently, only wall elements have opening elements, and opening elements have no reason to exist without a wall element.

Several IFC files can coexist in the same civil engineering project. Due to their size, their handling and sharing is a complex task. In this section we present an approach that allows to automatically identify business objects in IFC files and to simplify their visualization and manipulation on the Internet. Our approach defines an IFC Model Extension that allows to define new kinds of elements and relations between elements and documents. Consequently, new elements and new relations compose the Building Lifecycle IFC Model Extension.

IFC files are made of objects and connections between these objects. Object attributes describe the “business semantic” of the object. Connections between objects are represented by "relation elements". The IFC model is an object model modeled with the EXPRESS language. This model describes approximately 600 classes. There are three kinds of IFC classes: object classes, relation classes and resource classes.

[1] The object classes consist of a triplet (GID, OS, FU), where GID defines the general identifier of the current IFC object, OS defines the ownership features of this object and FU are the functional units. These functional units define the context of use of the classes (i.e. the geometrical representation, its localization, its composition, etc). For instance, in the Script 1. IFC File sample the element identified by the number `#12` is a type of `IfcPersonAndOrganisation` and it references the elements `#6` and `#8`.

[2] The relation classes represent the various relations (relation of capacity, relation of aggregate, etc.) between the object classes and their functional units. `IfcRel` prefixes the corresponding elements. The `IfcRelAggregates` element from Script 1. IFC File sample which is identified by the number `#111030` constitutes a relation of aggregate between the element #`30` and the following element list (`#34`, `#16236`, `#29699`, `#56800`, `#62077`, `#67336`, `#72633`, `#91702`, `#110989`). The element `#110989` is referred also to the element `#111029` which is a link called `IfcRelContainedInSpatialStructure`. This means that if an element can referred to several elements, then two elements can be cross referenced among each other by the intermediary of one or more relations. This mutual reference forms a cyclic graph.

[3] The resource classes constitute the set of attributes used in the description of the functional units. These resources are organized in a hierarchical graph.

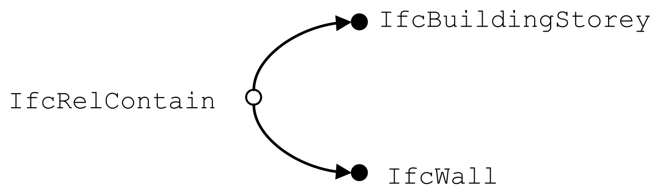

Figure 1. A building storey and a wall are connected by an `IfcRelContain` element**.**

The study of IFC instances reveals the complexity of the overlap between instances of relation classes and instances of object classes. A relation element links a set of semantic elements and a semantic element links a set of resources. At this level, there are two types of links between objects. We have called them the indirect links and the direct links. The indirect links are defined by the instances of the relation classes called relation element. The indirect links are symbolized by gray lines and a white dot in the next figure. The direct links are defined by the instance of resource classes. There are two types of direct links. The first type defines the resources of the element. They are characterized by gray lines and a black dot. These resources are structured using a tree structure. The second type defines a direct link between two semantic elements. These links are characterized in the next figure by black discontinuous lines. The IFC model defines only one type of link between two semantic elements. This is the placement link between the semantic elements for building design in a 2D/3D scene. This relation is carried out by the `IfcLocalPlacement` attribute of the semantic element. It defines the reference mark of the current object compared to the reference mark of the father object of the direct relation. The set direct link formed by the `IfcLocalPlacement` attribute forms a tree structure of the 2D/3D scene. The main difficulty is to handle at the same time the cyclic semantic elements and the hierarchical structure of the 3D elements.

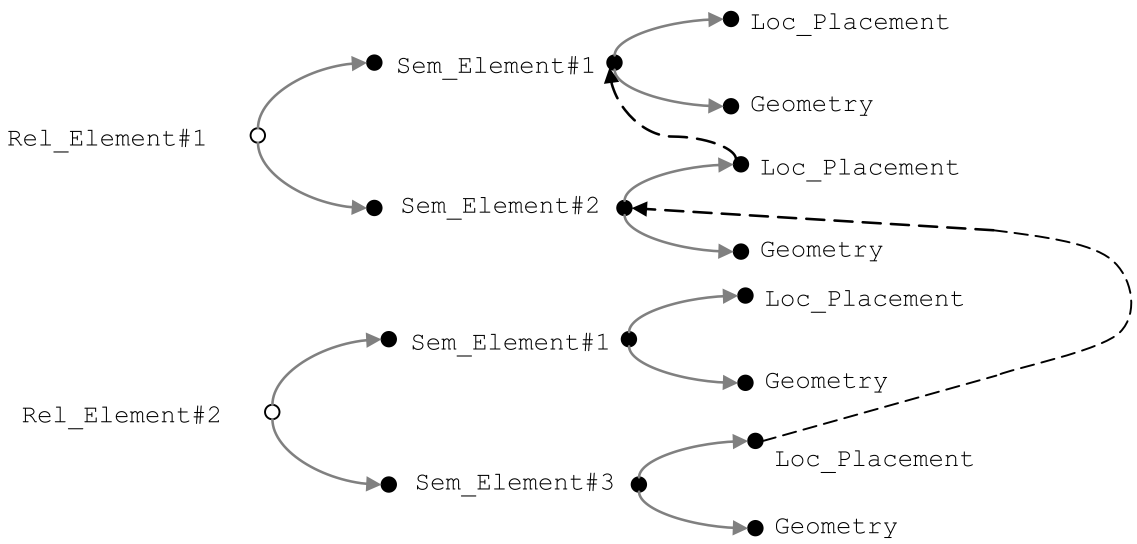

Figure 2. Example of direct links and indirect links between semantic elements.

3.2 Building Lifecycle IFC Model Extension

The last section explains the IFC model extension that defines semantic elements, relation elements and resources. Thanks to this extension, new semantic elements, new relation elements and new resources can be easily added to the IFC management system. On the one hand, the scalability of the system makes it possible to establish links between building elements and electronic documents of the project. On the other hand, the scalability allows us to bring another field of skills on the existing elements without changing the system. The management of files is carried out thanks to new kinds of relation elements. If the system of management takes into account a new kind of document, then this new relation creates a link between an existing IFC element of the building and a document which has to be integrated into the information system. Moreover, the properties of this new relation will make it possible to realize the dating and the versioning of documents. Each update of the document is then dated in the information system.

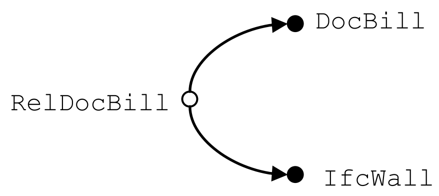

Figure 3. Example of a new link between a semantic element and a new element.

For each new type of electronic document, like an invoice or an estimate, a new type of semantic element is created. This element establishes the link between properties of this document and the document of the electronic document manager. This electronic document manager contains all structured documents in a simplistic way. Thanks to this new way of structuring, research is carried out starting from the structural components. In this manner, 2D/3D graphic scenes form an additional index of document retrieval.

In the following case, we intend to manage information concerning the building lifecycle like a skill field. This information is described by the MOP law (cf. 3 Building lifecycle management). This law proposes to divide the lifecycle management process in phases. Consequently, each phase is defined using a type of semantic element. For example, the Draft phase (defined in the MOP law) is defined by a semantic element named `MopDraft`. This phase has properties, which are described in the resources of the semantic element. Now, in order to carry out the link between existing IFC elements of the building and these new semantic elements describing a field of competence, new relation elements will be defined. For example, a wall is attached to the draft phase; in this case a new `MopRelDraft` relation is necessary.

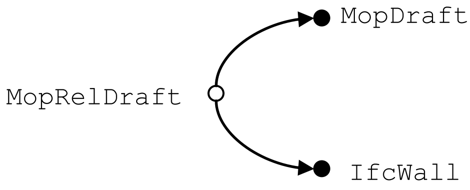

Figure 4. Creation of a new link between a semantic building element and a new semantic element.

Actually, these new kinds of links create a relation between two skill fields, which are the building description and the building lifecycle description of a building. The description of the lifecycle has also relations between these proper types of elements. As an example, after the draft phase the succinct project phase (`MopAPS`) follows. In the new phase new elements can be found, such as documents and finer building element definitions. To define these links between semantic elements of the same field of skills, we define new kinds of relation elements. For instance, the relation class `MopRelFollow` is a kind of relation. This relation means the "following phase" and it can be used by all kinds of semantic elements that represent a phase.

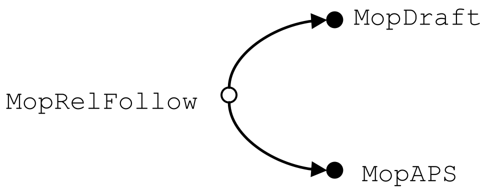

Figure 5. Creation of a new link between two semantic MOP phase elements.

When it comes to passing from one phase to another, the semantic IFC elements of the preceding phase have to be included in the following phase. This means that the elements are linked across the two phases. Consequently, if the semantic element evolves during the following phase, then this evolution intervenes in the preceding phase and the system loses its coherence. This is true if the dating and the versioning are not taken into account by the elements. Now we are developing a solution that will allow the problematic transition to another phase. This tool allows the automatic transition from one phase to the other with the dating and the versioning management.

4. The Active3D platform

The mechanisms that manage and handle the IFC files, like the fusion of two files in one, the partial extraction of data from one file, visualization or storing, must take into account the multiple semantic values of the objects, which depend on the context of use. To achieve this goal, we defined a hierarchical structure of context called contextual view. The solution consists in reducing the complexity of a cyclic multiple-context graph in an acyclic mono-context graph.

Figure 6 presents the 3D scene management system which builds a specific user interface made up of a tree of contain, of a 3D scene and of a technical chart on a semantic element of the scene. The navigation between the elements is carried out using hypermedia links which associate a set of semantic elements to a trade object. In this case the trade object is a semantic element “stair” called “escalier” in french (Figure 6). Certain contextual trees are generated dynamically by the system starting from IFC files. Others can be created specifically by the actors to structure their data according to their own format (starting from an IFC file or starting from existing trees). The principal tree is the geometrical contextual tree which contains the topological relations of the various objects. The resulting 3D scene corresponds to a particular trade view [12]. This view corresponds to the professional trade association. This scene is customized by the user according to his needs, his rights, and the size of the data to be transmitted on the network. Starting from this interface, the actor can update the model while adding, modifying or removing parts of the principal tree. The selection can also be carried out through the 3D scene by selecting the 3D objects. This 3D representation and tree structures allow facility managers to deal with all users and tools employed during the lifecycle of a building.

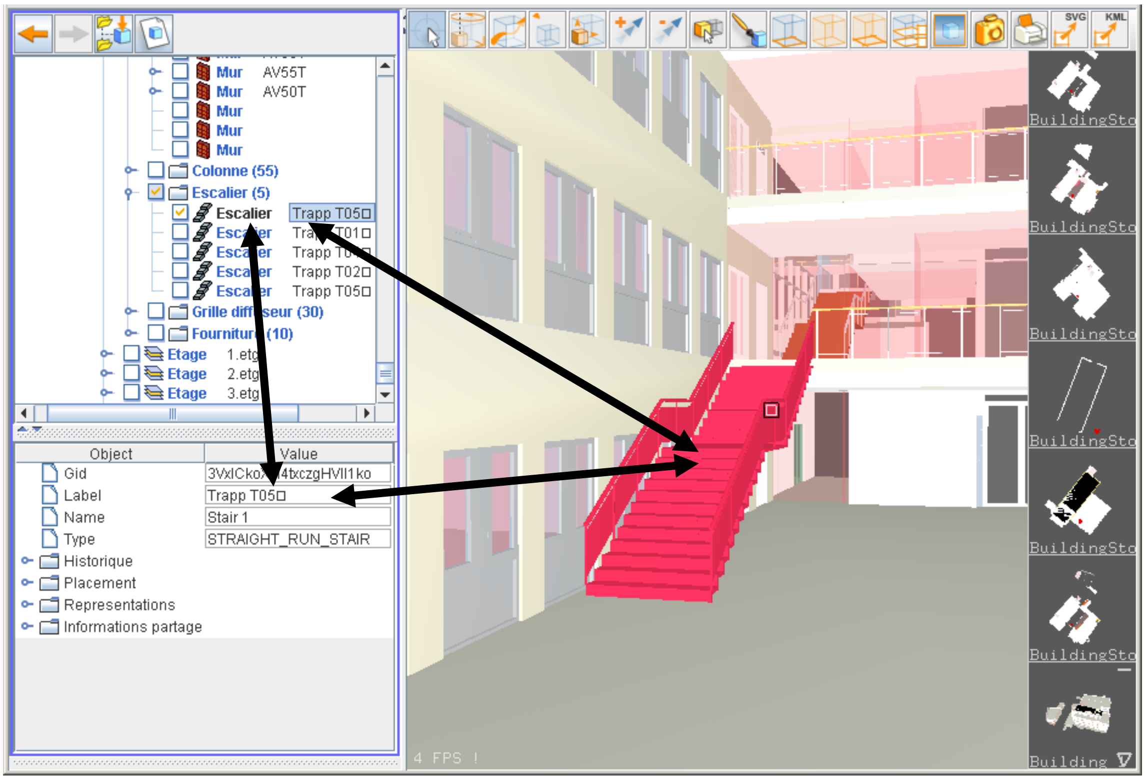

Figure 6. Snapshot of the 3D scene management system

Figure 7 shows the 3D scene management system in its context in order to present the Electronic Document Manager in the bottom right corner linked to the 3D scene. Accessing electronic documents can be done by two main procedures. The first procedure consists in accessing the tree of documents for each project phase. In this tree, all documents are handled in order to keep a relevant access to those documents.

The second procedure consists in accessing the documents through the 3D digital mock-up. It can be done with the help of the tree of objects on the left of the scene management system, or directly with the help of the 3D objects in the 3D scene. Actually, the 3D scene can be seen as a graphical index on the project documents. In figure 7, the black arrows show the links between a 3D object "slab" (Dalle), an object of the tree of objects and a document from the tree of documents concerning the current phase of the building lifecycle.

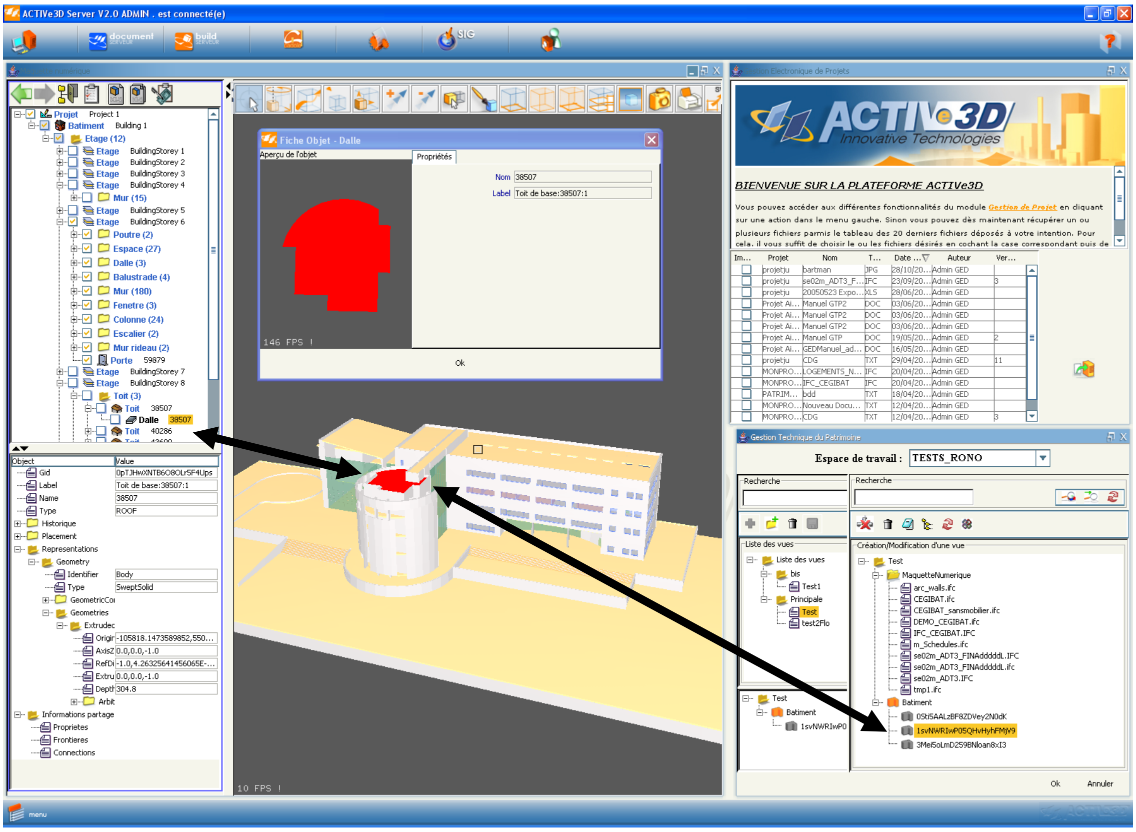

Figure 7. Snapshot of the Active3D platform and its 3D scene management system

5. Sharing and exchange example

This section will focus on the processes of design concerning the extension of an existing building. The design is usually divided into four phases. The first phase consists in bringing a ground statement of an old building to the Active3D platform. The second phase consists in defining an extension to this building. The third phase carries out the extension and the last phase defines the building's floors raised in the first intervention. This example is a combination of different situations met during industrial uses of our platform.

Viz'all® is an automated solution for building statements, associating the use of a laser meter, a pocket PC and software on a pocket PC. The principle consists in tracing by hand a sketch of the room on the touch screen of a pocket PC. After the connection and the deposit of the foundation, the model of the building is updated and is available for all the other actors of the building restoration project. The other actors of the project can now visualize the building starting from the 3D interface of our platform. Once the foundation has been placed, other actors of the project connect themselves to the BIS platform to retrieve this information and to enrich the mock-up. For this, the architect defines new spaces by using ADT (Autodesk Architectural Desktop). Once the architect has finished his updates on the model concerning the future building extension, he adds these new data to the platform. Following the architect's updating of new spaces in the extension of the building, the engineers of the civil engineering connect themselves to the platform to collect the last information. These engineers work on ArchiCAD® from Graphisoft. When they have completed their work of building design, these new data are added to the digital building mock-up that is designed on the BIS platform.

The second part of the project on this building is the rehabilitation of the existing building. For that, a team of engineers manages the design of this part. As the other teams do, this one is connected to the BIS platform to extract information concerning the principal building. This team works with the software AllPlan® from Nemetschek Systems Inc. Once the updates have been carried out, the engineers put this new information on the platform. Thanks to the BIS platform, a whole set of actors can exchange information on the building design and this can be done between various types of CAD software. The IFC 2.x standard is used to format the data sent to each actor. All the data flows forward through the BIS platform because it allows each actor to have all data up to date, once they have been placed on the server. The effectiveness of this exchange process and the centralization of information involve an important time saving because the data exchanges take place on a daily basis in design projects. Moreover, waiting for data updates can block the work of other teams, therefore the access to the up-to-date digital mock-up on the platform makes it possible to resolve these emergencies more quickly.

During the design of a building, the structures like the beams and the columns must be validated. Indeed, if the structures are too weak and they do not respect the standards then the plans must be modified accordingly. For instance, RoboBAT is a structure calculus software. This software makes it possible to optimize and validate the structures according to national and European standards about reinforced concrete, wood, steel, aluminum, etc. The main advantage of this software concerns the import of IFC data. Consequently, the structural engineering and design departments can validate information of the digital mock-up that is being designed on our platform. In order to realize this study, the engineers must connect themselves to the platform and select all the elements that belong to the structure. These elements are the walls, the slabs, the beams, etc. For that, they use the definition of the contextual tree "structural analysis".

There are standards for the validation of heat exchange between difference spaces in a building. The thermal module of the software CLIMA-WIN®, made by the company "BBS Slama", makes it possible to carry out the calculation considering the heat loss "Th-D 1991", as well as the statutory coefficients of the buildings according to "ThBât/ThU" rules of 2001. This software imports and exports IFC data. These processes allow to update and to validate the digital mock-up by taking into account the heat exchange field. Windesc® is a tool for the calculation of surfaces from the company ATTIC+ which imports IFC files. This software provides reports/ratios and estimates in connection with surfaces of walls, grounds, etc. This tool is essential when it comes to establishing the revaluation of the costs for the building construction. The reports/ratios and the estimates carried out on the digital mock-up are then added to information concerning the building and the phase of design.

This section has underlined the importance of a centralized tool which helps engineers to design and to manage civil engineering projects. This tool is materialized by a BIS platform in which engineers add/extract/validate design data.

6. Conclusion

In this paper we have focused on a semantic indexation method based on the IFC which allows to build an information system dedicated to the building lifecycle. A collaborative Internet platform has been developed to support this information system. This platform is mainly used to federate all the actions realized on a building during its lifecycle, to merge all information relating to these actions in semantic graphs, to extract some trade views of the building by combining information collected during the lifecycle from heterogeneous sources, and to handle all these views through a dynamic and adaptive 3D interface. Currently, the Active3D platform is supporting more than 100 specific building information systems where more than 400 actors from all civil engineering domains collaborate at each step of the building lifecycle. In 2008, more than six million square meters of buildings are managed with our architecture.
Our indexation method is limited to the static aspect of the building lifecycle. It allows to model and to merge heterogeneous information but it is not well adapted for the management and the evolution of data. Indeed, query writing for these two points proves to be difficult. During the design and construction phases, these limitations are note really important. Queries developed in this phase consist only in ‘insert’ or ‘delete’ operations.
During the exploitation phases, especially for facility management, this proposition is not satisfying. In this phase, the dynamic aspects of information systems are required, such as business skill modeling and context definition. In order to deal with these requirements we are developing an extension of our proposal based on a new framework called CDMF. Dedicated to facility management, CDMF includes both a semantic definition of IFC and XML language and operators to build management rules on these heterogeneous data. CDMF is based on OWL, RDF, SWRL and Named Graph.

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