Building Lifecycle Management

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Abstract: Our proposal concerns ongoing research at the University of Burgundy, in collaboration with Active3D-Lab Company, for the development of a method to manage civil engineering projects and corresponding facilities management. This method is made up of processes, specific models and tools. The processes make it possible to structure the various phases, codified by professionals, which organize the lifecycle of buildings. Construction and a building's life information comes from heterogeneous sources (heterogeneity of professions, heterogeneity of data formats, and heterogeneity of validation processes). We propose an innovative approach which gives a global view of a buildings lifecycle including facilities management aspect. This approach is based on a data model standard called IFC which was developed by the International Alliance for Interoperability. A collaborative Internet platform was developed to support the building lifecycle. 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 an adaptive hypermedia graph, 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. This platform won the technological innovation gold medal at the international show BATIMAT in Paris in November 2003.

Keyword: Information systems, IFC, CAD, Building

1 Introduction

The lifecycle of a building is articulated in two parts. The first part is about the construction into a civil engineering project. The second part concerns the "use of the building" which deals with facilities management. Currently, these two parts are dissociated in the building management processes. The Teams which are concerned with the processes facilities management are rarely those who have participated in the construction of the building. The facilities management step often begins with a physical analysis of the building to obtain a numerical representation of this building in CAD software. To avoid information loss acquired during the construction of the building, it is necessary to develop a building information system at the beginning of its lifecycle.

A civil engineering project associates 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 [7] 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 capturing the process in a computerized representation to automating the process. In the civil engineering domain, a first step towards a computerized process and information has been developed in 1999 with the development of the IFC [9]. Until this year, computer programs for building design, analysis, and maintenance typically could not exchange data directly, even when the same team used them. Buildings therefore took longer to be designed and built and were more expensive to construct and operate. Information sharing should be the starting point when it comes to applying information technology to building 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 [9] proposed a standard that specifies object representations for construction projects. Industry foundation classes (IFCs) include object specifications, or *classes*, and provide a useful structure for data sharing among applications. An IFC door, for example, is not just a simple collection of lines and geometric primitives recognized as a door; it is “aware” that it is a door and has a door’s attributes. However, many construction project teams do not exploit the IFC. No central IFC database exists nor do tools for IFC analysis and comparison or visualization during construction. Since 2000, new IFC based business processes have been developed in some domains of civil engineering.

This paper presents an ongoing research about the development of a global method, which proposes to organize all heterogeneous processes of civil engineering lifecycle in a uniform way. This method is made up of processes, specific models and tools. The process makes it possible to structure the various phases codified by professionals, which organized the lifecycle of the buildings. Construction and a building’s life information comes from heterogeneous sources (heterogeneity of professions, heterogeneity of data formats and heterogeneity of validation process). We propose an innovative approach that gives a global view of the building lifecycle management including the facilities management aspect. A collaborative Internet platform was developed to support building lifecycle management. 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 an adaptive hypermedia graph, 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 [1]. This platform won the technological innovation gold medal at the international show BATIMAT in Paris in November 2003.

2 Information systems

This section gives a brief overview of concepts and definition related to information systems. The building information system (BIS) developed in our work presents a systemic vision of the organization and the building processes [6]. BIS can be cut out in three sub-systems. The first is the operative system (OS) where raw material is transformed into manufactured product. The organization seems like a factory working: a raw material to carry out a product. In BIS the OS is devoted to actors who physically work in the building. The control system (CS) allows the organization to achieve goals; CS fixes the management rules and makes decisions. The CS has to control the information system to make decisions. In BIS this role is devoted to architects, control offices, and other administrative advisors. The information system (IS) is charged to store and process the data. Stored information will be redistributed with the SP and the SO. The next section shows that information system must be adapted to the domain managed, both in the process and the model.

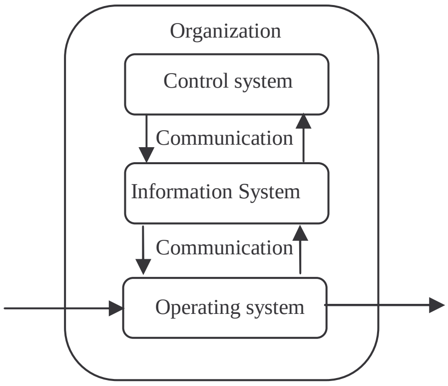

Figure 1 Decomposition of a system

An information system is a set of structured data, a set of treatments and a set of communications [3, 4, 5]. These data will be described using structures, procedures or protocols. Moreover, the information system is a set of hardware and software. Three principal objectives emerge from IS. The first objective is to memorize the data resulting from the treatments. The second objective is the communication. Actually IS must distribute information between the actors. The last objective is the automatic and mass treatment of data like arithmetic calculations or comparisons.
In civil engineering projects only CAD software and some specific calculus tools are used without real coordination. In this environment data exchange and process comprehension are difficult to define and to maintain. Thus BIS requires the definition of methods, allowing a complete, consistent, and comprehensible description of the civil engineering and facilities management domains. These methods have to describe the characteristics of the real world and the objectives of the system to achieve this goal. A method must have the following components: models, languages, a phase, and tools to do its objectives.

- A model is a set of concepts and rules which will make it possible to explain and build the representation of the problem.
- A language makes it possible to create specifications and to facilitate the communication.
- The phase proposes a process, detailing stage by stage the objectives to be realized.
- A tool helps users to realize the previously described tasks.

These methods are defined to facilitate the construction of information systems. Moreover, these methods increase the productivity during the phase of design. Indeed, they will support the communication between the users during the computerization process. As a result, methods are used to facilitate the evolution and maintenance actions of the system. The next section presents a method to develop BIS based on a model, a language, a set of phases, and a collaborative tool. The model takes into account all information generated during the lifecycle of a building. All participants of the project base this model on a common understandable language. In our proposal, the lifecycle of the building is organized in phases codified by the profession. To support our environment, we developed the Active3D Build Server, a collaborative Internet platform that allows each user to participate in the building lifecycle management.

3 Building Lifecycle Management

This part deals with the building lifecycle management. Information of the civil project is generated during all the building lifecycle. It is essential to structure information for a better management. We will see that the information management of buildings is similar to an information system. The building activity generates a great number of data and information of various natures. The management and the communication of these data by the various participants are complex. We will present here the process defining the work, as well as the methods employed by the various actors to manage information.

The complete process of design defining all the successive states of construction is regulated by the law of the public control known as MOP law. This law refers to the public work control and its relation with the control of private work. This regulation cuts out the building lifecycle in successive phases: design, consultation, construction, reception, and exploitation. Each one of its phases is composed of successive and dependent phases. An event initiates a phase that produces data which will be necessary during all the lifecycle.

During these phases, the participants of the construction project interact around significant information and documents set like plans, meeting minutes, estimates, invoices, etc. The creation method of textual documents consists in employing an office software suite. Geometrical design information is generated starting from specific trade software's (CAD). The information exchange method employed today consists in forwarding the paper documents by fax or by standard mail. The electronic documents are sent by electronic mail. The documents storage method is often limited to plan cupboards for the paper documents and to CD-ROMs containing an approximate tree structure of the electronic documents. Moreover, during the lifecycle, the plans, the documents, etc., have to be modified and validated. This means that actors must know at any moment who has modified and who has validated this information. All people concerned by this information will be informed of the publication of a new version. A history of each document has to be preserved.

This working method is only effective for small size projects of construction. When these projects are much bigger and with a wide set of participants and exchanges, consequently this method is not recommendable.

The exchange of information: Generally, all participants have to exchange information. If information is not structured then it is harder to find relevant information. Structuring documents for traceability is not enough because the problem is the validation also the reception. Actually it happens that documents are neither received nor read.

Integration: Each actor works with his own process tool on a closed information system. When you want an identical data in each information system you must re-enter the information. These incompatibilities appear with tools like CAD software because each tool uses an owner format.

Poor Semantic: Current CAD softwares have a two-dimensional building representation with a vectorial modeling. The objects of the building thus modeled have a poor

semantics. The modeling of the building objects with semantic makes it possible to bring intelligence to the "drawing". Then it will be possible to stick information to each building object with data which will be necessary during all the lifecycle. There is no automated collaborative management between the various actors, whereas the building lifecycle is precisely based on a good coordination of the work team.
The solutions for the problems exposed in the preceding section consist in defining a method for the building lifecycle management. This method will make it possible to centralize structure and exchange information like the information systems. Our method takes into account the various phases and participants of a project. It also takes into account management and the electronic documentary division. The memorizing of the documents and information allows management of the project and technical inheritance management. The application of this method in a tool will make it possible to automate the documents exchange processes, building management, and participant management. This tool common to all the actors of the project will be the vector of integration of the information system that 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 [2].

4 BIS design method

Since the start of information systems, numerous data models appeared to resolve the problems of data persistence. These models take into account needs 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 between them 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 also consists in validating all the elements, their states and their interactions. This means that the system keeps during conception time supplementary information about the elements. This information is the kind of the states and the kind of the interactions. Consequently, the model management of the building life cycle has to describe the constituent elements of a construction project which are all the concrete elements (as walls, actors, furniture, etc.), as well as abstract elements (as the costs, the projects, etc.). Furthermore, the interaction between elements, as a wall contains a window and if the wall is moved the window moves as well, are modeled by links. Indeed, a wall and a window are connected by the relation of contains. This relation will determine the possible interactions between these elements of construction. Finally, the model of building has a description of the states that the real system can take and the information about elements and relations states of the building during the conception.

This section is composed of three parts. First, it will deal with IFC as a model defining elements and relations of a construction project. Then the second part presents the model that we have to define to handle data generated from the IFC. The last part presents how to use the model and to spread the IFC to take into account the management of the building lifecycle through the concepts of the MOP law.

4.1 IFC Model

The “Industrial Foundation Classes” (IFC) is an ISO norm to define all components of a building in a civil engineering project. An example of IFC file structure is given in script 1. This file describes a building with more than 111000 business objects (one lines per object).

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION (('ArchiCAD generated IFC file.'), '2;1');
FILE_NAME ('Karlstr.IFC', '2002-06-19T15:48:48', ('Architect'), ('Building Designer Office'), 'PreProc - IFC Toolbox Version 2.x (00/11/07)', 'Windows System', 'The authorizing person.');
FILE_SCHEMA (('IFC2X_FINAL'));
ENDSEC;
DATA;
#1 = IFCORGANIZATION ('GS', 'Graphisoft', 'Graphisoft', $, $);
#3 = IFCPERSON ($, 'Undefined', $, $, $, $, $, $);
#4 = IFCORGANIZATION ($, 'OrganizationName', $, $, $);
#5 = IFCPERSONANDORGANIZATION (#3, #4, $);
#7 = IFCSIUNIT (*, .LENGTHUNIT., $, .METRE.);
…..

#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));
ENDSEC;
END-ISO-10303-21;
```

Script 1 IFC file sample

Professionals realized this building model. It describes all concrete and abstract elements for building conception. In this way, it allows each actor of a building project to share and exchange information with the same description. This solves the syntactic exchange level between CAD software. Moreover, all relations between elements are defined by elements prefixed by IfcRel. In fact, these relations define how elements can interact. By example, 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 to automatically identify business objects in IFC files, and simplify their visualization, and manipulation on the Internet. Our approach defines an IFC Model Extension that allows us to define new kind 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 in a triplet (GID, OS, FU), where GID defines the identifier of the 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). In the script 1, the #5 element of the type IfcPersonAndOrganisation reference the #3 and # 4 elements.
2. The resources classes constitute the set of attributes used in the description of the functional units. These resources are organized in a hierarchical graph.

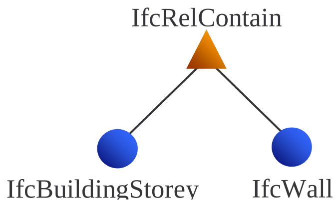

Figure 4 A building storey and a wall are connected by an IfcRelContains element.

The relation classes represent the various relations (relation of capacity, relation of aggregate, etc.) between the object classes and its functional units. IfcRel prefixes the corresponding elements. IfcRelAggregates element from Script 1 having the identifier #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 also referred by the element #111029 which is a link called IfcRelContainedInSpatialStructure. This means that if an element can be referred by several elements then two elements can mutually refer them by the intermediary of one or more relations. This mutual reference forms a cyclic graph.

The study of IFC instances reveals the complexity of the overlap between instances of relation classes and instances of object classes. At this level, there exist two types of link between objects. We called them the indirect link and the direct links. The indirect links are defined by the instances of the relation classes.
The direct links are defined by the instance of resource classes. The indirect links are characterized in the figure 4 by ▲. The object instances of the architecture field become semantic elements. In the figure 5, these elements are graphically represented by ◆. The resource instances are represented by ● .

Figure 4 shows indirect links between semantic elements using a relation element. Figure 5 shows direct links between semantic elements which are noted in red. There are two types of direct links. The first type defines the resources of the element. These resources are structured using a tree structure. The second type defines a direct link between two semantic elements. The IFC model defines only one type of links 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.

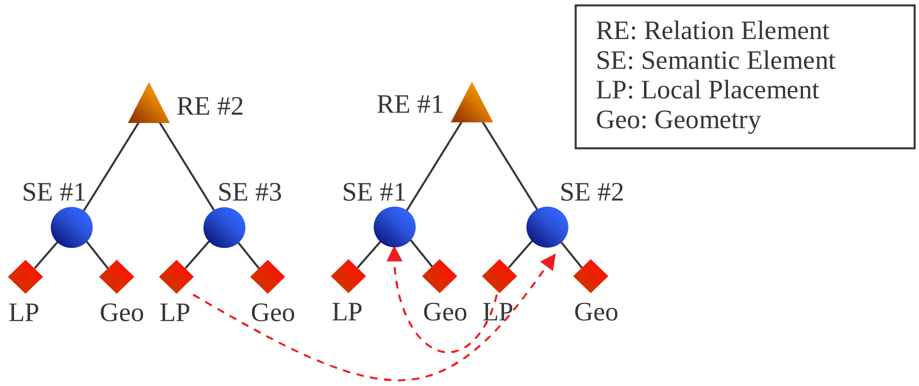

Figure 5 Example of direct link between semantic elements

4.2 Building Lifecycle IFC Model Extension

The last section explains the IFC model extension defining semantic elements, relation elements and resources. The extension of this model contains semantic elements, relation elements and resources defined by the IFC model. Thanks to this extension, new semantic elements, new relation elements and new resources can be added easily 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 elements existing without changing the system.

The files management 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 element IFC of the building and a document which it is necessary to integrate into the information system. Moreover, the properties of this new relation will make it possible the dating and versioning of documents. Each update of the document is then dated in the information system.

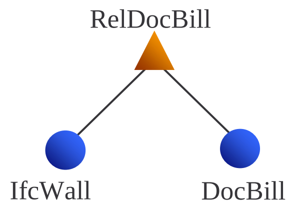

Figure 6 Example of a new link between a semantic element and a new element

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 the whole of the structured documents in a simplistic way. Thanks to this new structuring, research is carried out starting from the structural components. In this manner, graphic scene 2D/3D forms an additional index of document retrieval.

In this 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 in phases the lifecycle management process. Consequently, each kind of 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 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.

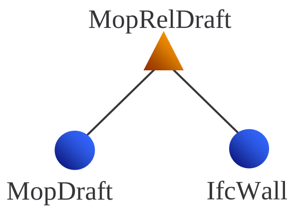

Figure 7 Example of a new link between a semantic building element and a new semantic element

Actually these new kinds of link create a relation between two skills fields, which are the building description, and the building lifecycle description of a building. The description of the lifecycle also has 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 elements definitions. To define these links between semantic elements of the same skills field, we define new kinds of relation elements like the new kind of relation MopRelFollow. This one means the “following phase” and it is usable by all kinds of semantic element that represent a kind of phase.

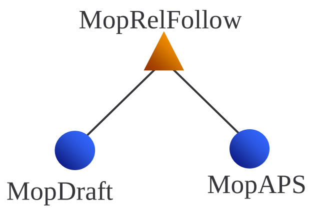

Figure 8 Example of a new link between two semantic MOP phase elements

When time to pass from one phase to another arrives the semantic IFC elements of the preceding phase have to be included in the following phase. This means that the elements are linked by 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 in account by the elements. Now, we are developing a solution allowing the passage of a phase another. This tool allows the automatic passage with the dating and the versioning management.

5 Conclusion

In this paper we have presented a method and a tool to build a Building Information System. This BIS is a basic framework used to support building lifecycle management from the design to the destruction of the building. This approach is based on a data model standard called IFC which was developed by the International Alliance for Interoperability. A collaborative Internet platform was developed to support the building lifecycle. 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 an adaptive hypermedia graph, 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 supports 80 specific building information systems where more than 300 actors from all civil engineering domains collaborate at each steps of the building lifecycle.

References

[1] C. Cruz, C. Nicolle and M. Neveu, (2002) "*The Active3D-Build: A Web-Based Civil Engineering Platform*", IEEE Multimédia, Tiziana Catarci Editor, pp 87-90, Vol.9 No.4, October 2002.

[2] R. Vanlande, C. Cruz and C. Nicolle, (2003) "*Web Cooperative Application for Civil Engineering Project*", 22th International Conference on Conceptual Modeling, ER'2003, Chicago, Illinois, USA, 13 October 2003.

[3] J.L. Lemoigne (1977) "*La théorie du système général théorème de la modélisation*", PUF Paris

[4] D. Nanci, B. Espinasse, B. Cohen and H. Heckenroth (1992) "*Ingénierie des systèmes d'information avec Merise, vers une deuxième génération*", Sybex.

[5] C. Rolland and A. Flory (1990) "*La conception des systèmes d'information état de l'art et nouvelles perspectives.*", in: Actes du congrès Inforsid 1990 , Eyrolles, Paris, 3-40

[6] A. Laaroussi and B. Vinot (2004) "*Les outils de visualisation et de simulation comme vecteur de coopération: le dynamisme de la conception en architecture.* ", 2ème Atelier de réflexion sur l'assistance à la coopération en architecture coordination et maquette numérique, Ecole d'architecture de Nancy.

[7] D. Georgakopoulos and A. Tsalgatidou (1998). "*Technology and Tools for Comprehensive Business Process Lifecycle Management*", In Dogac, A., Kalinichenko, L., Oszu, T. & Sheth, A. (Eds.), Workflow Management Systems and Interoperability. NATO ASI Series F. Springer-Verlag.

[8] IFC Model, International Alliance for Interoperability, http://www.iai-international.org/iai_international/