ONTOLOGY-BASED 3D MANAGER SYSTEM

Christophe Nicolle*, Christophe Cruz**, Renaud Vanlande**

*Laboratoire LE2I UMR CNRS 5158
Université de Bourgogne
BP 47870, 21078 Dijon Cedex, FRANCE

**ACTIVe3D-LAB
2 rue rené Char
BP 60066 21066 Dijon Cedex FRANCE

cnicolle@u-bourgogne.fr, c.cruz@active3D.net, r.vanlande@active3d.net

Abstract. The "Industrial Foundation Classes" is an ISO norm used to define all components of a building in a civil engineering project. IFC files are textual files whose size can reach 100 megabytes. This paper describes a practical method to automatically create hypermedia networks from a semantic and physical analysis of IFC files. The concrete application of this work is a web-based platform called ACTIVe3D BUILD SERVER. This platform lets geographically dispersed project participants—from architects to electricians—directly use and exchange project documents using a 3D Manager system. This system, which evolves during the life cycle of a civil engineering project, is dynamically built according to user models (a combination of semantic trade and access rights).

Introduction

The exponential development of Internet tends towards two fields which seem opposite. On the one hand, the visual aspect, where the text which initially composed the pages of the first Web sites was replaced by images and animations. One notes in this field the opening of software such as Flash of Macro-Media. In other hand, the informative aspect has been developed considerably. The information given by the sites becomes intelligent, adaptive, according to the behaviors of the Net surfers. The new projections as regards interconnection of data bases with HTML pages allowed the creation of new dynamic sites. To date, a Web site must be animated, therefore attractive and intelligent, active and interactive. Nevertheless, there are many limits. In the field of the visual aspect, the 3D representation is in full growth on Internet. Nevertheless it is often limited to small animations, because the resources necessary to use the 3D on the network are too significant. As for the informative aspect, it is still too often limited to the interfacing of a data base with HTML code, using a poor hypertext network to associate part of textual information. The construction of complex systems inter-connecting several heterogeneous data bases is still developed only at the stage of research. Moreover, the association of multimedia information is often organized in a predefined scenario (such as in the Flash Software) and is not dynamically generated according to a semantic view defined in user models. To answer these problems, we developed a new technology called ACTIVe3D. Its principal objective is to create a dynamically generated hypermedia [1, 2] network between the visual representation and various heterogeneous information sources. Our Approach is based on the "Industrial Foundation Classes" [3, 4] which is an ISO norm to define all components of a building in a civil engineering project. IFC files are textual files whose size can reach 100 megabytes. IFC files are cyclic graphs combined with hierarchical graphs. Due to their size and their structure, their handling and sharing is a complex task. To resolve this problem we have developed a method based on a specific ontology to analyze and to decompose the IFC structure. From this ontology [9], we have developed context trees. These trees are user models that allow to dynamically building hypermedia networks according to the business domain of each group of users. The main advantage of this hypermedia network is to associate various business objects derived from IFC files with semantic trade, documents and 3D representation. Moreover, our system is adaptative and based on the user and the context in which it is used. The users of our platform do not have the same level of knowledge nor the same objectives and access rights. The system adapts thus navigation, the presentation of knowledge for each user according to his profile filled by the user with the inscription.

This paper describes a practical method to automatically create hypermedia networks from a semantic and physical analysis of IFC files. The concrete application of this work is a web-based platform called ACTIVe3D BUILD SERVER. This platform lets geographically dispersed project participants—from architects to electricians—directly use and exchange project documents using a 3D Manager system. This system, which evolves during the life cycle of a civil engineering project, is dynamically built according to user models (a combination of semantic trade and access rights).

IFC Files Description

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 described a building with more than 111000 business objects (one lines per object). To understand the complexity of the IFC, this section presents the IFC model level and the IFC instances level.

```
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 authorising 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., $, .METRE.);
    …..
#111029 = IFCRELCONTAINEDINSPATIALSTRUCTURE ('25wKeWex98fQp5Pukf_Ilc', #6, 'BuildingStoryContainer',
    'BuildingStoryContainer for Building Elelements', (#111007), #110989);
#111030 = IFCRELAGGREGATES ('216Bv$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. Example of IFC file

IFC Model

IFC files are made of objects and connections between these objects. The attributes in the objects, describe the "business semantic" of the objects. The connections between objects are represented by "relationship elements". The IFC model is an object model modelled with the EXPRESS language [5]. This model describes approximately 600 classes. There are three types of IFC classes: object classes, relationship classes and resource classes.

1. The object classes consist in a triplet (GID, OS UF), 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.

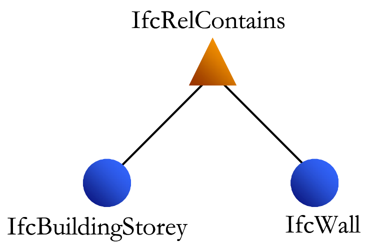

Figure 1. A building storey and a wall are connected by an element IfcRelContains.

3. The relationship classes represents the various relations (relation of capacity, relation of aggregate, etc.) between the object classes and has functional units. The corresponding elements are prefixed by IfcRel. The 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.

IFC Instances

The study of the IFC instances reveals the complexity of the overlap between instances of relationship 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 relationship classes.

The direct links are defined by the instance of resource classes. The indirect links are characterized in the figure 1 by ▲. The object instances of the architecture field become semantic elements. In the figure 1, these elements are graphically represented by ●. The resource instances are represented by ◆.

Figure 1 shows the indirect links between the semantic elements using a relationship element. Figure 2 shows the direct bonds between semantic elements, they 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 design of a building 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 the semantic elements and the hierarchical structure of the 3D elements.

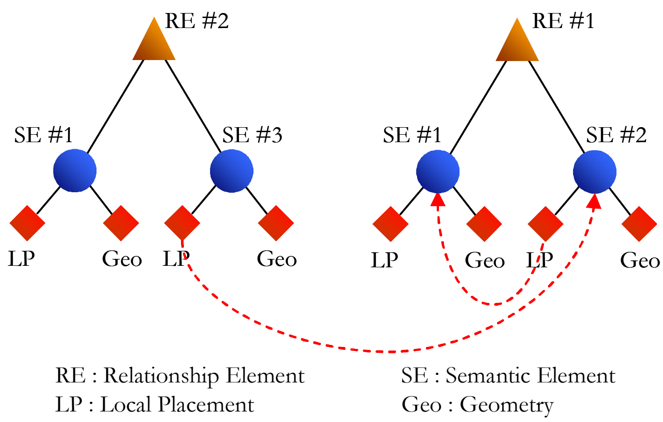

Figure 2. Example of direct link between semantic objects

Active3D Methodology

The handling and management mechanisms for IFC files (such as fusion of files into only one, extraction of partial files dedicated to only one context, the visualization and the storage) will have to deal with a multitude of semantic values for the same object, according to the context of use. To achieve these goals, we defined a hierarchical structure of context called the contextual view. This solution reduces the graph complexity translating a multi-contexts cyclic graph into a set of mono-context trees. This process is done using business rules. An example of a business rule is "*a door is in an opening element in a wall*". Resulting from this process, many contextual trees are built starting from the IFC files, such as the contextual tree of capacity defining the object composition (a building contains two floors, a floors contains beams, walls, and so on). The figure 3 presents the 3D Manager systems which build a specific user interface made of tree of capacity, 3D scenes and object card file. The navigation between this element is made by hypermedia links which associate a set of semantic elements to a business object (here a slab). The main tree is the geometrical contextual tree which contains the topological relations between the various objects. From these trees, the resulting 3D scene corresponds to a particular business view [6].

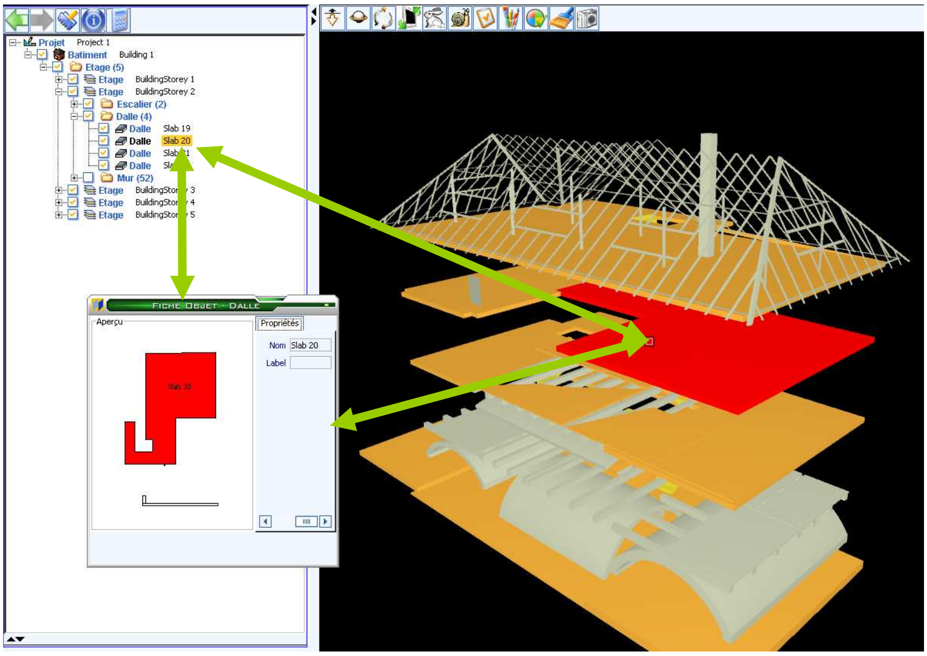

Figure 3. A snapshot of the 3D Manager System

The figure 4 shows the 3D representation of plumbing view of an IFC file. From this 3D view, the users can reach directly the various functional units composing the IFC file. Through this interface, trade information can be manipulated. These business views are textual information, from which specific documents can be generated or associated (technical reports, management information, etc.). In the 3D scene generation process, all the geometry defined in IFC trees is converted into triangular surface model [7]. During this conversion, the 3D objects are associates with the GID. The GID is the general identifier used to identify each business object of an IFC file. In the script 1, the GID of the IFCRELAGGREGATES object is #111032. This GID is used to link the 3D visualization with the information stored in the databases. All insertion of new data in any base is reference by a GID correspondent to an IFC object. All trees generated in the platform are XML trees [8]. We have developed a specific database schema dealing with the semantic and the 3D aspects of the IFC. The trees and the component elements are stored in a relational database and manipulated using the SQL. From this database and the GID, all types of information can be attached to the 3D visualization of business Object.

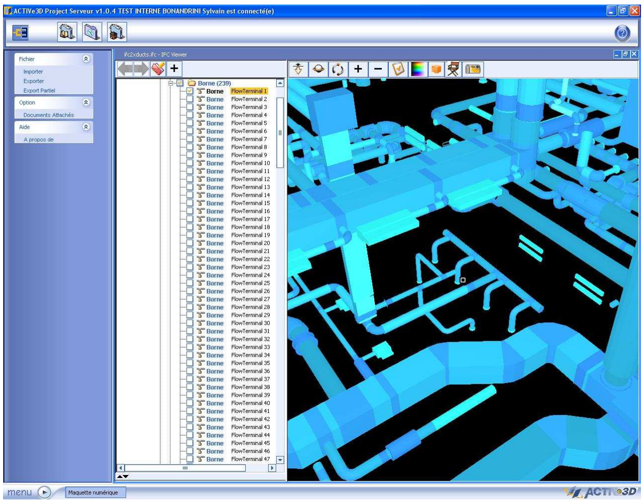

Figure 4. A 3D scenes corresponding to the plumbing context

From the definition of the contextual trees, we have defined the corresponding XML grammars. Thus, each functional unit and each context are manipulated as XML documents. These grammars, specific to a civil engineering profession, are used to format IFC data exchanged during the life cycle of a civil engineering project. The contextual trees are transformed using XSL style sheets. These transformation processes are web services. IFC Services provides on the ACTIVEe3D server are XSL processes associated with a context. The use of XSL is extended to generate other documents such as technical reports and so on. In the same way, the graphic contextual trees are transformed into X3D documents. Thus, the 3D scene is personalized according to the service called. Moreover, the graphic elements preserve connections with the information system containing management information. These connections allow the 3D scene to carry out queries on the information system concerning the graph elements.

A complete description of this method and the presentation of the resulting IFC schema from our relational database are beyond the scope of this paper.

Conclusion

This paper describes a practical method to automatically create adaptative networks from a semantic and physical analysis of IFC files. The industrial result of this work in a Web collaborative platform called ACTIVe3D Build Server. In this platform, the Hypermedia network is based on a 3D visualization which lets participants move around in the building being designed and obtain information about the objects that compose it. 3D Objects, trade objects and other documents are connected in the network by semantic links defined in context trees.

Currently, 126 people use the application daily and manage sixteen projects. The ACTIVe3D was rewarded for the technological innovation gold medal to the international show BATIMAT in Paris, November 2003.

Now, we are study the update of the IFC database from multiple IFC sources. This multiple update of IFC files generates structural and semantic conflicts (for example, a heating pipe crossing a door). The resolution of these conflicts passes by a semantic and geometric analysis of the associated contextual trees.

Bibliography

[1] Aspects of Hypermedia.
http://ateos.it.teithe.gr/~cs1msa/docs/aspects_of_hypermedia.htm

[2] Adaptive Hypertext &Hypermedia
http://wwwis.win.tue.nl/ah/

[3] International Alliance for Interoperability.
http://www.iai-international.org/

[4] IFC, Industry Foundation Classes.
http://cig.bre.co.uk/iai_uk/documentation/IfcR2x_Final/

[5] Express Language.
http://www.iso.org/iso/fr/CatalogueDetailPage.CatalogueDetail?CSNUMBER=18348

[6] Boon-Hee Kim, Jun Hwang, Young-Chan Kim, The design of high-level database access method in a Web-based 3D object authoring tool, The Fourth International Conference on Distributed Communities on the Web, 3-5 April 2002, Sydney, Australia.

[7] Rémi Ronfard, Jarek Rossignac: Full-range Approximation of Triangulated Polyhedra. Computer Graphics Forum 15(3): 67-76 (1996)

[8] Extensible Markup Language (XML).
http://www.w3.org/XML/

[9] Ushold M., *Ontolgies: Principles, Methods and Application* - 1996