

# BIM FOR GEO-ANALYSIS (BIM4GEOA): SET UP OF 3D INFORMATION SYSTEM WITH OPEN SOURCE SOFTWARE AND OPEN SPECIFICATION (OS).

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## ABSTRACT:

To address the challenges of sustainable management and development of the built environment, engineers and facility managers need to exploit the 3D City models which grown in recent years to include interior space. A crucial issue for facilitating interaction with these 3D city models is the ability to integrate 3D BIM into the geospatial context. This requires the use of specialized software and specific expertise. In order to simplify this process, we here propose an information system that facilitates the use of BIM for geo-analysis purposes. BIM4GeoA is a concept for combining existing open source software and open specification for efficient data management and analysis of Building Information within its boarder context. The core components are the spatial database PostgreSQL/PostGIS, the building information server, the industrial foundation class (IFC), the Google Earth 3D viewer, and the existing 3D OGC standard (KML, CityGML). This paper presents the procedure used to enable the development of this new expert system as applied to the context of 3D Web GIS. A thorough analysis of the strength and weakness of these different components has been undertaken to employ it is strength and override its weakness. The system architecture is operationally used in developing different applications for the management of a university campus; a large potential is provided for operational tasks of facility management department, such as utilities infrastructure, as well as public community (student, staff) like routing application, searching for a person with defined criteria.

## 1. INTRODUCTION

Since the advent of Computer-Aided Design (CAD) and Geographical Information System (GIS) tools, project participants have been increasingly leveraging these tools throughout the different phases of a civil infrastructure project (Akinci et al, 2008) e.g. professionals in urban planning, engineers, utility management are especially keen on talking about the advantages of third-dimension GIS capabilities for representing the 3-D structure of urban environments and for conducting 3D spatial analysis. Many of their tasks such as site selection, emergency response, and urban management are being conducted in geospatial context (Isikdag et al, 2008).

However, data conversion between these CAD/BIM and GIS systems is resulting in a enormous mismatch that are require a manual work to be undertaken, due to limitations associated with exchange of data and knowledge. In 3D, spanning a bridge between CAD and GIS is even more challenging (Oosterom et al 2006, Isikdag and Zlatanova 2009, Emgard and Zlatanova 2008, teghtmeijer et al 2009, Wu, and Hsieh, 2007). This is due to the following facts: existing CAD and GIS platforms have been developed independently with different purposes resulting in significant differences in terms of data formats they support, terminology they used, semantics of concepts they represent, reasoning techniques on which they are based, different scale representations, and transformation of the local (CAD) coordinates into reference system for both the horizontal and vertical coordinates, geometry modelling in both systems, CAD software provides all kinds of primitives to create geometric (and their visual attributes), it represent objects with different representations such as CSG and Sweeping, however these primitives are not supported in GIS (e.g. parametric

primitives)while geospatial models mainly use BRep as the main geometrical representation method; Furthermore, CAD models usually do not store topologic information which is in fact an important characteristic of geospatial models (i.e. geospatial models use topology to store geometric information in a more efficient manner)., For these reasons currently CAD and GIS platforms are not interoperable.

Recently and as a result of the developed building standard such as Industry Foundation Classes (IFC), the Integration between Geospatial information and BIM/CAD could have been achieved at semantic level (Isikdag et al 2007). Efforts deals with bridging the gap between BIM/CAD and geospatial information models are providing harmonisation of semantics that allowing the interoperability at the data level (IFC explorer, 2008, Paul and Borrmann 2008, IFG, 2006) and as web services (Lapierre and Cote, 2008). Current building models are capable to store semantic information and spatial relationships of building elements in an object oriented data structures.

As a result different tools are being developed that enable the transformation of building models to be represented using 3D City data model standards (BIM server 2009, IFC explorer, 2008) and thus enable the visualization within 3D geospatial context using GIS software which provide stand alone or add on extension which is limited for visualization purposes, and by doing so, neglects spatial analysis, the very core of a GIS system.

In this paper we present a web based 3D GIS solution that allow integration of the 3D building designs within 3D city models. Using the proposed solution it is possible to perform geo-analysis and provide direct visualization using geospatial

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browser, the system present a new concept to store, process, analyze and visualize 3D building models within 3D geospatial context including utility networks. Emphasis is laid on the integration of BIM information without loss of information and to use it further beyond 3D visualization - for spatial analysis. BIM4GeoA (Building information for Geo-analysis) is entirely built in an Open Source environment with components (OSI – Open Source Initiative, 2010), which can be downloaded from the Internet for free.

The paper is organized in 4 sections: After the introduction (section 1) section 2 provide a description of system components (IFC parser, Analysis functionalities and GUI for visualization and interaction). Section 3 defines OS, OSS, and interoperability and provides a brief background of the specific OS and OSS technologies used to create the 3D web-based spatial information and system architecture; in section 4 we present conclusions and suggestions for future research and implementation.

## 2. INFORMATION SYSTEM- BIM4GEOA

The prototype named BIM4GeoA is composed of three components: The IFC parser, the graphical user interface (3D viewer) and the 3D functionalities implemented in RDBMS. The following will provide brief information about each component and its functionalities.

### 2.1 IFC parser.

The IFC parser is developed in php scripting language using a combination of DOM and XML-reader libraries. The user can interact with the BIM server and query specific building element; and, when the output is delivered to the server as IfcXML file, the file is parsed on the fly and the required information is extracted. The parser has conversion functionalities that allow the translation of geometry representation from Swept Solid to B-Rep. Moreover the IFC-Parser performs geometry transformation from local coordinate systems to the real word coordinate system. After performing the transformation operation, the parser inserts the building object into the database as a 3D object. Figure 1 provides an illustration of parser running in a web browser.

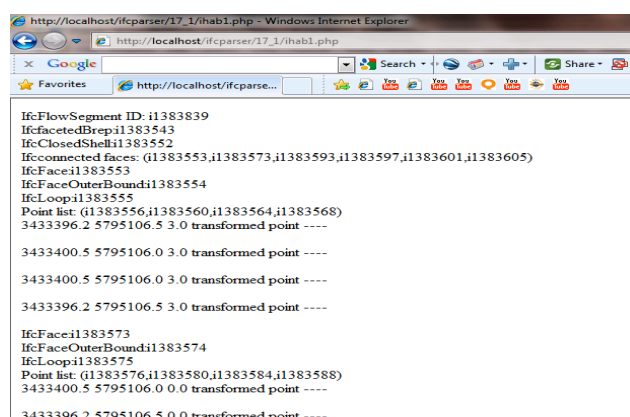


Figure 1. The IFC parser.

### 2.2 Analysis functionalities

BIM4GeoA offers simple geometric and topological analysis functionalities, the functions is implemented within PostgreSQL environment. Most of the commercial DBMS enable users to create a new user-defined data type and functions. In this research, the user-defined data type and functions are written in PlpgSQL. These functions include:

- 3D object creation function (Polyhedron)
- Graph creation functionality of true 3D utilities network objects.
- Reachability analysis functionalities for utilities network
- Shortest route analysis functionalities including graph creation functionalities for networks with x,y,z coordinates
- Selection by location function allows the selection of objects within a 3D distance from specific object.

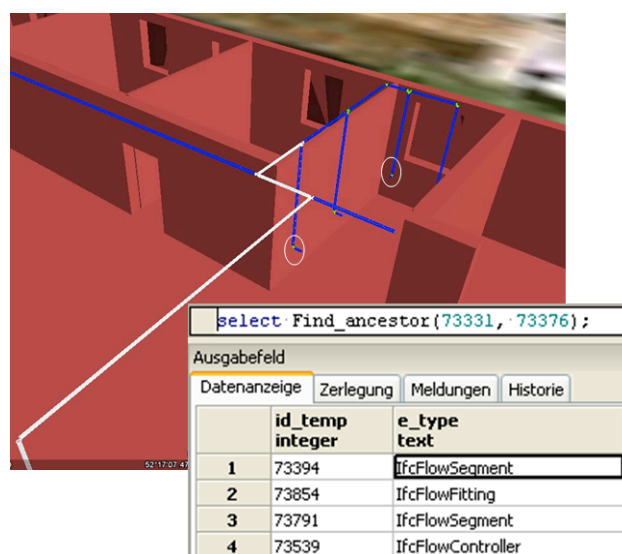


Figure 2. SQL statement runs a find ancestor function on 3D utility network.

### 2.3 GUI for query and visualization.

To allow a system user to both interact with and visualize the analysis result in 3D, a web site is customized that can be accessed from any client's PC or mobile device. It is organized in two mainframes (Figure 2 & 3). The right frame include a drop-down menu, which provides analysis functionalities and a text field to enter functions parameters, while the lower part of the display provides a space where the textual result of the query is displayed.

The 3D viewer is located in the right frame. It is based on the Google Earth plug-in. Several functionalities was customized and added to the viewer using Google Earth APIs, e.g. zoom-in and zoom-out, and a special functionality that provides smooth movement and keys that allow the user to change the camera view. The user can interact with the 3D view and click on any 3D objects and get the attribute of this object.

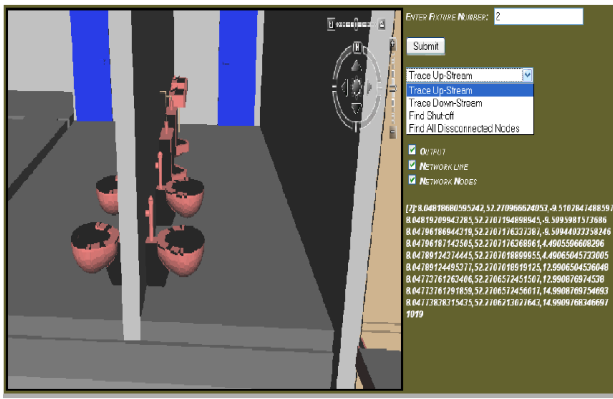


Figure 3. General view of utility Application

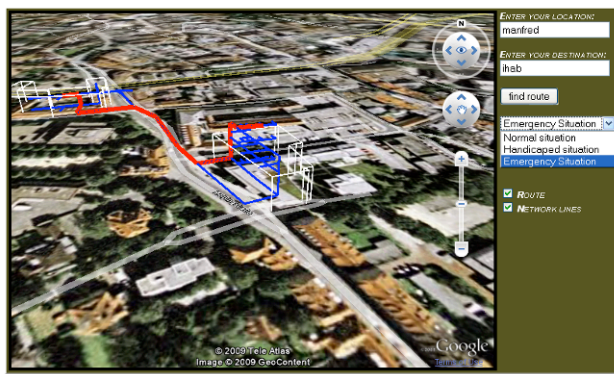


Figure 4. General view of routing application, the optimum path between two entities.

### 3. THE UNDERLYING TECHNOLOGY

The system is developed using open source software and specifications. OSS is defined as computer software whose license “permits users to use, change, and improve the software, and to redistribute it in modified or unmodified form. It is very often developed in a public, collaborative manner” (OpenGIS, 2010) they present a healthy competition with proprietary software and may lead to affordable pricing and increased access (Moreno-Sanchez et al, 2007).

Among the well known OSS projects are the Linux operating system and the Apache web server. A comprehensive list of GIS related OSS can be found at (<http://opensourcegis.org/>). As of January 2010, the open source GIS website has listed more than 247 of GIS related OSS projects (OpenGIS, 2010) .

OS promotes interoperability through its public availability (OGC, 2010), it provide software developers with information about a given specification as well as specific programming rules and advice for implementing the interfaces and/or protocols. It allows the systems to work easily with each other and overcome tedious batch conservation tasks, import/export obstacles (Anderson et al, 2010). Among OGC specifications are KML and CityGML, two standards for 3D GIS. This section provides background information about the origin, relationships among the OS and OSS, and their relevance for the creation of the 3D geoprocessing web GIS.

#### 3.1 Reasons for an Open Source Information System

There is a growing interest in the use of OS, the term open source gains more attention (European Commission – IDABC work programme, 2006; Boulanger, 2005; Wheeler, 2005).. According to Lowe (2002), the OSS market is growing rapidly; it is products fed by small organizations and regional government agencies that cannot afford proprietary software’s.

The idea of creating the system based on OS emerged from the need to address two sets of challenges. Firstly, current commercial GIS software does not offer 3D functionalities, developing a system with new functionalities is much flexible with OS, developing such system based on commercial software is expensive and require special training to become professional on their software operation and maintenance. Moreover, Open standard and fully transparent software solutions lead to a stronger cross linking of knowledge and data itself. Secondly, there is a demand for a flexible and low-cost system, due to limited funding. License fees have to be paid for commercial systems and spatial add-ons. Cost-saving solutions are especially required by institutions with low budget.

#### 3.2 System Architecture, design and developments

An important phase was the selection of the open-source software and technologies (Hijazi and Ehlers, 2009), where Different aspects have been considered to select the appropriate OSS. We concentrated on mature OSS projects with clear identification core development teams and wide development and broad active users communities (particularly at the international level). We also sought projects with well-established records of success in developing simple prototype systems as well as large mission-critical applications. Other important aspects were the available resources such as books, user forums, user conferences, and online documentation (Moreno-Sanchez, 2007).

After considering several options we decided to use the OSS described below. The key principle is to use existing functionalities and combine them in an optimized way for the requirements of urban management (e.g. the visualization capabilities of KML). CAD users can interact and update their design using a building information server at the same time The GIS users can retrieve the up-to-date CAD data and use it in the analysis. The current version of the BIM4GeoA is the result of a first development cycle. Figure 5 presents the system integration.

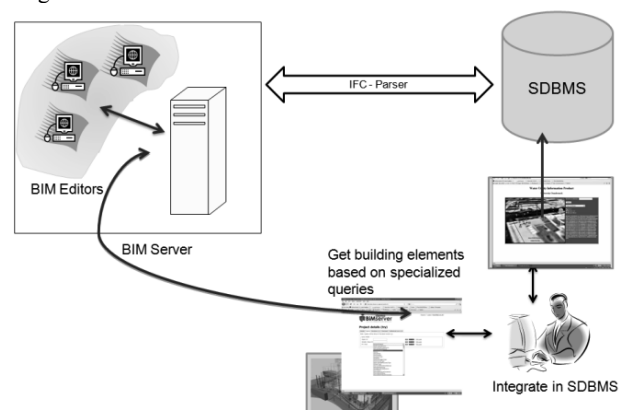


Figure 5. Architecture of the prototype- BIM4GeoA

Google Earth plug-in is a JavaScript API that allows for the embedding of Google Earth into web pages, and visualizes 3D

models in standard web browsers (Google, 2010). It provides powerful 3D web visualization functionalities.

**KML (Keyhole Markup Language):** KML is an XML data format that has a tag-based structure with names and attributes to display geographic data in an Earth browser, such as Google Earth. KML allows the definition of styles to specify feature appearance, icons, and labels to identify locations. It can also display textured objects. The KML file has been generated on the fly to visualize the result of the suitable queries and the 3D model of the campus building (Wilson, 2008). Through java script code it is possible to adjust several visualization properties of these models such as 'hide texture' and 'change visibility'.

**PostgreSQL/PostGIS** is a powerful, OSS object-relational database system, supporting almost all SQL functions including sub selects, transactions, and user defined data types and functions (PostgreSQL, 2010). The PostGIS extension offers the capability to store spatial features with x,y,z coordinates and to perform more than 80 spatial and geoprocessing operations including limited 3D spatial analysis such as 3D BOX (PostGIS, 2010). It is used to process spatial and attributes queries and to store the network and other building element as spatial tables with its attributes.

**Pgrouting** is a set of C++ libraries that provide routing functionality to PostgreSQL/PostGIS. Its tools provide shortest route functionalities for real road networks including considering restrictions with heuristics. The tools are based on the well known Dijkstra shortest route algorithm (Pgrouting, 2010). Some modifications were performed on the Pgrouting functions to be able to create a 3D topology (graph), and to perform the network analysis of the indoor and outdoor spaces. This considers the different level of space (3D) and the characteristics of the indoor environment such as door types, elevators and stairs.

**PHP** was used to create inter-application communication and to process the user's input and send it back to the web interface. An SQL query to the attributes and the network that are stored in PostGIS spatial tables is built using customized user interfaces, such as buttons, checkboxes, or text fields. The query is then submitted to the server using an HTML form that captures the user's input. At the server, a PHP script converts the user's input into an SQL statement that is submitted to PostgreSQL/PostGIS for processing. The geometry texts that are returned by PostgreSQL/PostGIS are converted to KML code format using PHP and then visualized in the Google Earth plug-in.

**IfcXml** (Industry Foundation Class or IFC) has been developed by the international alliance for interoperability (IAI) since 1994. Its latest release is IFC 2x3. The IFC 2x release has introduced the ifcXML specification by using XML schema to define the IFC models in parallel with EXPRESS. The target application of this standard is to provide a comprehensive description of the building and the construction site (Nisbat and Liebich, 2005).

**CityGML** is an OGC standard, which provides a specification for the representation of 3D urban objects (Groger et al., 2008). The standard was used as a guideline for organizing and mapping building objects in RDBMS.

**BIMServer** it is an open-source project enabling the centralization of the information for a construction (or other building related) project. The core is based on the open standard

IFC, and therefore knows how to handle IFC data. The BIMserver is not a fileserver, but uses instead the model-driven architecture approach. The main advantage of this BIM server is its ability to query, merge and filter the BIM-model and generate IFC files ad hoc (BimServer, 2009).

#### 4. CONCLUSION AND OUTLOOK

In this paper we present a valuable approach to integrate BIM into more comprehensive 3D Geo-information System. The approach is highly important to both AEC and geospatial industry. It is a combination of open source of tools which used to create a vehicle to integrate BIM data (IFC) into a user accessible 3D navigation and viewing environment, which also provide some analytical operations- such as routing and utility network analysis.

The prototype demonstrates the potential of using OS to provide highly interactive 3D GIS applications on the web. Postgres/PostGIS provide a robust database management system that offers a considerable and continuously increasing number of 2D geoprocessing functions, the lack of 3D query/analysis capability put some limitation on the options due to the current lack of 3D functionalities (as compared to the 3D query/analysis capability provided in the commercial software Oracle), specific data type as well as query functionalities is developed to meet the requirement of these 3D applications.

Google Earth and KML standard proved to be an easy way to use 3D visualization tools with powerful functionalities. Pgrouting libraries provide easy to use function via PostgreSQL/PostGIS. It is possible to modify these libraries to be used in 3D network (non-planar graph) analysis. This could be demonstrated by the feasibility of computing routes through graph theory and modified 3D Disjkstra algorithms.

Our future research will concentrate on implementing more analysis functionalities required by the 3D application of web campus. In addition the prototype will be open for use by the real campus community for testing. Therefore, the system will be modified based on their feedback.

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