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From BIM to geo-analysis: view coverage and shadow analysis by BIM/GIS integration

Azarakhsh Rafiee[a], Eduardo Dias[b], Steven Fruijtier[c], Henk Scholten[d]*

[a,b,d] *Department of Spatial Economics/SPINLab, VU University Amsterdam, De Boelelaan 1105, 1081 HV, Amsterdam, the Netherlands*
[c] *Geodan Amsterdam, President Kennedeylaan 1, 1079 MB, Amsterdam, the Netherlands*

Abstract

Data collection is moving towards more details and larger scales and efficient ways of interpreting the data and analysing it is of great importance. A Building Information Model (BIM) includes very detailed and accurate information of a construction. However, this information model is not necessarily geo located but uses a local coordinate system hampering environmental analysis. Transforming the BIM to its corresponding geo-located model helps answering many environmental questions efficiently. In this research, we have applied methods to automatically transform the geometric and semantic information of a BIM model to a geo-referenced model. Two analyses, namely view and shadow analysis, have been performed using the geometric and semantic information within the geo-referenced BIM model and other existing geospatial elements. These analyses demonstrate the value of integrating BIM and spatial data for e.g. spatial planning.

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* Azarakhsh Rafiee. Tel.: +31-(0)631798589
E-mail address: a.rafiee@vu.nl

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1. Introduction

A Building Information Model (BIM) contains very detailed and semantically rich information of a construction. The model is usually not integrated with its surrounding information. For example, when planning a new building in an existing environment, information from BIM models is generally not integrated with environmental information to calculate shadowing of neighboring buildings or to carry out view coverage analysis. Geographic Information Systems (GIS), on the other hand, are capable of performing spatial analysis using the physical and functional spatial representations of an environment.

It is expected that integration of BIM in a GIS environment results in a much more comprehensive system that can be used to improve decision making during spatial planning. Adding environmental information to BIM in GIS automates many analyses due to the complementary nature of the detailed construction information from the BIM and the information about the surrounding area.

There have been several researches and investigations on the integration of BIM and GIS. These researches have focused on different domains and applicability of BIM and GIS integrations. Examples of research are: modeling interior utilities[3], water utility network[4], low-disturbance construction[8], transformation from IFC to GML data model[9], optimization of tower cranes' location on construction sites[5], CityGML GeoBIM extension[1], site selection and fire response management[7], web services for the visualization and analysis of 3D building information[2], visual monitoring of construction supply chain management[6] and large scale (building) asset management[11].

We propose a method to automatically integrate an IFC BIM model of a building in a GIS environment. This integration will enable multiple analysis opportunities for effective and efficient spatial analysis where construction details relate to its surrounding environmental information.

This paper reports on two studies integrating detailed information from BIM and spatial data in a GIS environment. The first study explores positions of windows from a BIM model to determine the view quality of these windows (the type and amount of existing physical features in the view) using spatial data (3D buildings and 3D trees). The second study uses roof segments derived from a BIM model to determine shadowing effects from surrounding 3D buildings and trees on the roof. The studies can be used for economic research (house price analysis), energy potential analysis (rooftop and window irradiation) and design quality (position of windows for best view).

2. Methodology

In the first step, a BIM IFC format was converted to a vector geographic format using Extract Transform Load (ETL) process. This conversion is a geometric transformation from IFC geometry to the vector geographic geometry. Global ID of each object in the IFC model is allocated to its corresponding vector object as an attribute through ETL process.

The next step is to assign the semantic information from the IFC BIM model to the spatial information model. Within this process we developed a semantic conversion from BIM to GIS. This semantic conversion automatically relates object semantics within IFC data model to the corresponding object in geographic vector model, using the common Global ID. This semantic information appear in the form of vector attributes.

The resulting geographical dataset is not yet geo-referenced, meaning the model is still in a local coordinate system and not in a geographical coordinate system. In order to transform or geo-reference the local coordinate system to a geographic coordinate system we developed a transformation mechanism including scaling, rotating and translation. The attributes from the IFCSite class "refLongitude", "refLatitude" as well as "NorthDirection" in "IFCProject" class (IFCRepresentationContext) are used for this process. The centroid of the entire BIM model is taken as the reference point of the IFC model. In this way the BIM model is converted automatically to a geo-referenced object that can be used in geospatial analysis and visualization in GIS tools.

2.1. View analysis

The translated semantic properties of the IFC model are used to select all windows from the geographical dataset. Based on the geographical location of each window, 3D fields of view are defined. These fields of view are 3D solids, which are originated from windows and extended outwards for a specific distance. The FOV solid of each window might contain (portions of) one or more objects, e.g., buildings. Once the geo-referenced 3D models of such objects are available, the content of each window FOV can be determined.

Accurate 3D building and tree models of the Netherlands have been developed using accurate and detailed national height data of the country, called AHN. The second version of this dataset, called AHN2, with 5 centimetre planar and vertical accuracy and the point density of 8-20 points per square meter is used for developing 3D models of existing buildings and trees.

For each window FOV solid, all 3D building and tree solids, which fall within the FOV are determined using an "intersection" function of a GIS tool. The outputs of the intersection function are the 3D solids of building and tree portions. Calculating the volume of the intersected building and tree portions, for each window FOV we have estimated the ratio between the intersected buildings volume and trees volume. This ratio indicates the grayness/greenness of a view field.

2.2. Shadow analysis

The 3D representations of the buildings and trees are used to calculate shadow volumes for a specific date and time. From the integrated BIM-GIS information the real-world location of the roof top segments are derived. By intersecting 3D shadow solids of buildings and trees with the geo-referenced BIM rooftop, the total area of the rooftop portions lying in the shadow at the specific date and time is determined.

3. Results

A BIM model of a residential building in IFC format was chosen for BIM-GIS integration experiment (Fig. 1). This model has been developed by Zeep Architects in the Netherlands[10]. Geometric and semantic conversion to geographic vector format was performed on the IFC BIM model through ETL process and self-developed semantic mapping conversion, respectively. The absolute coordinates of the reference point from the IFCSite class are transformed (rotated, scaled and translated) from the local coordinate system to the geographic coordinate system. The result of this geo-reference process is presented in figure 2. Next to the geo-referenced building model, the surrounding environment is represented in 3D by the building blocks and trees derived from spatial data (see 2.1).

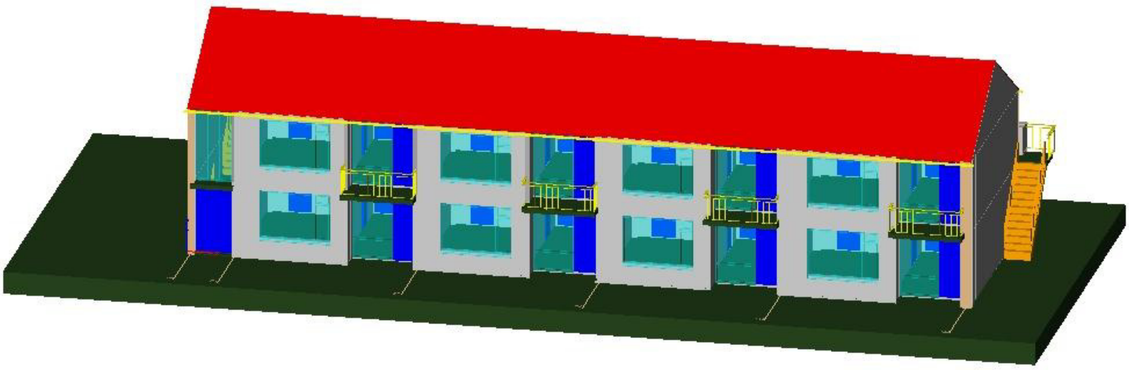

Fig. 1. BIM model in IFC format.

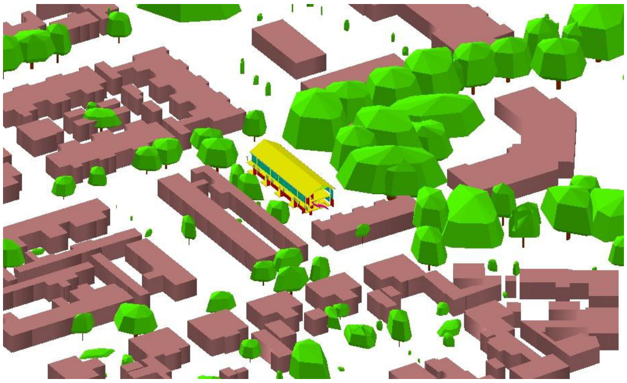

Fig. 2. Geo-referenced BIM model in geographic vector format among accurate 3D building and tree models.

3.1. Quality of view analysis

Semantic information from the BIM model has been transformed into the attributes of the geospatial vector model. In the GIS these attributes can easily be queried to select specific spatial elements. For example in the GIS environment roofs, ceilings, doors and windows can be selected by querying on these terms. In the case of the view analysis the windows are selected in the GIS tool as depicted in figure 3. The selected windows are positioned on their exact location on earth.

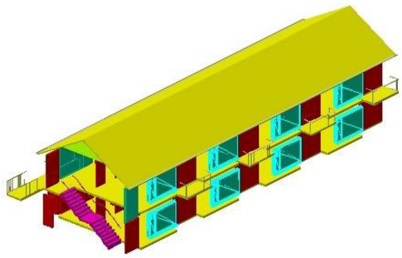

Fig 3. Selecting windows from the BIM model integrated in spatial data through a GIS attribute query. Elements whose "IFCTYPE" attribute field equals to "IFCWINDOW" are selected (blue).

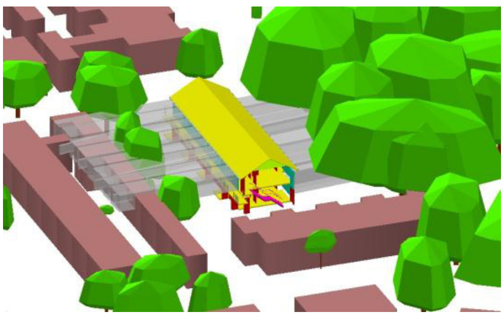

Fig. 4. 3D windows' FOV and 3D geographical objects.

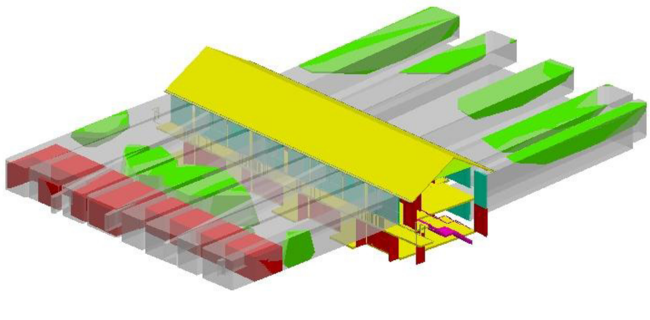

Fig. 5. 3D building and tree model portions falling within windows' field of view.

From each geo-referenced window a 3D field of view is formed to specify its view composition. Each window field of view is intersected with the neighboring 3D building and tree models (Fig. 4). Figure 5 shows the portions of the 3D building and tree models falling within the 3D field of view of each window. For each field of view, the ratio of total intersected building volumes to tree volumes is calculated.

3.2. Shadow volume analysis

For the second analysis, rooftop elements were selected from the building model integrated in the geographical vector model by querying these elements from the building attributes. The 3D building and tree models were used to calculate the 3D shadow models for a specific date and time. Shadow solids are developed based on the 3D object geometry, solar azimuth and solar altitude for a specific moment.

Figure 6a presents the geo-referenced building model and the calculated 3D shadow of buildings and trees. The selected/queried rooftop elements of the building were intersected with the 3D shadow models. The surface area of the intersected rooftop portions lying in the shadow during a specific date and time were estimated relative to the total roof area (figure 6b). This determines the rooftop area percentage, which is unexposed to solar radiation.

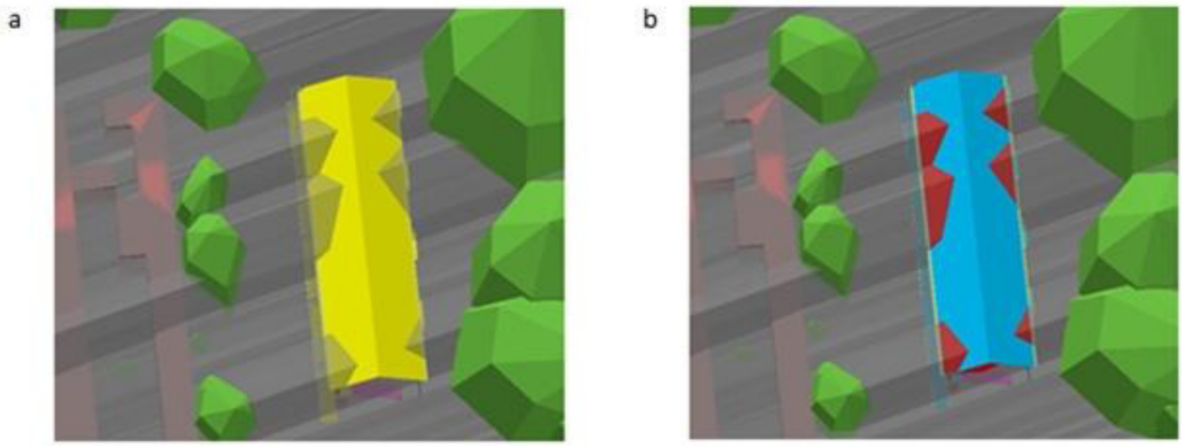

Fig. 6. Shadow analysis on the building rooftop (a) geo-referenced building model and 3D shadow model; (b) Rooftop portions intersecting with shadow models (red).

4. Discussions and conclusions

While BIM contains very detailed and semantically rich information about a construction, GIS focuses more on the real geographical coordinates and spatial analysis. Integrating these two leads to a more comprehensive system where detailed and semantically rich information is connected to its exact location. There is a vast domain of applications where the integration of BIM and GIS plays an important role. In this research we have performed two analysis, which benefits from BIM-GIS integration, namely, view and shadow analysis. Detailed geometry and semantic information of the BIM model was converted to a geo-referenced vector graphic model and GIS functionalities were applied to the resulting model for the mentioned geospatial analysis. The process has been automated using self-developed scripts as well as existing tools.

Calculating the view contents of a window can help urban planners, architects, etc. for different analysis purposes, like house pricing. Once the whole process is being automated, one can benefit from fast and accurate analysis on a large scale. Shadow analysis plays important roles for different purposes, for example in energy sector. Solar panels, as important renewable energy sources, are becoming more popular in the world. Geometrical characteristics of a building are important for an optimal energy gain from solar panels mounted on its rooftop(s). In the case of non-flat roofs, the horizontal orientation, steepness angle and rooftop area are important factors for, among others, calculating the gain potential of a solar panel. This information can be extracted from a BIM model. However, the potency of a building or a solar panel is not restricted to the building characteristic alone. Shadowing effects on the rooftop play an important role on the solar energy potential. This information cannot be extracted regardless of its environment context. Integration of BIM and GIS makes such a comprehensive analysis possible.

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