3D BUILDING MODELS IN GIS ENVIRONMENTS

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Abstract:

It is up to us to explore more efficiently the meaning of the data as technology advancement brings improvements in the spatial data acquisition techniques. The demand for 3D building models has increased in the last years. The use of GIS services extended throughout a wide area of field from planning and design, transportation, noise analysis, disaster management to public safety/security and sustainability. Large areas are now maped in 3D in order to better understand the dinamics of the cities. In most of the cases, the destination of the 3D building models dictates the level of detail required.

The final accuracy of a 3D building model is strongly related to the quality of the primary data used, as one of the main sorce of spatial data for 3D models is photogrammetry, along with LiDAR and land survey spatial data.

Keywords: *GIS, ETL, 3D building models.*

1. Introduction

"The early days of GIS were very lonely. No-one knew what it meant" .

If the statement of PhD. Roger Tomlinson, considered the father of GIS is true for the 1960's, today, after more then 50 years since the notion of GIS was first introduced, the world of geographical information system become a real industry itself.

Generating multi-billion dollar revenues as one of the top ten technologies, GIS is the catalyst tool behind every domain that involves spatial data. The main reason for this aspect is that everything that surrounds us consist of information: size, shape, location, statistics and other proprieties that can be represented and made use of in a GIS application.

In the past years the majority of the GIS application were enhanced to provide the users the ability to visualize their data in an three-dimensional environment for a better understanding of the reality.

Triangulated irregular network (TIN) or Digital elevation models (DEM) frequently used to refer to any digital representation of a topographic surface [2], are just common examples of 3D products that can be viewed and analyzed in GIS.

More than that, a wide range of tools for editing, transforming and querying the data in three dimensional space emerged.

3D building models can be produces for large areas and by adding the statistics already existent as two-dimensional data, a complex and useful solution can be delivered.

Therefore, the use of GIS services extended even further throughout a wide area of field from planning and design, transportation, noise analysis, disaster management to public safety/security and sustainability[5].

The "virtual reality" offered by GIS become the play ground of every major stekeholder when it comes to decision making.

2. Data sources

The final accuracy of a 3D building model is strongly related to the quality of the primary data used. One of the main sorce of spatial data for 3D models is photogrammetry and LiDAR. The well known productivity of stereo-restitution is offered as an solution by a number of commercial software like ERDAS IMAGINE, ARCGDS or ImageMaster. Some of the newest software could even benefit from the considerable height accuracy of the laser scanner point cloud during the collection of the feature vertices[4].

For a flight height of about 1.5 km a ground sample distance (GSD) of 15 cm is easily achievable. This can generate a spatial accuracy for a point measured in the stereomodel under 20 cm on the X/Y/Z axis. This level of precision satisfies the needs for most of the 3D building models in term of accuracy of the roof surface positions. The required precision can vary depending on the destination of the 3D models.

An other aspect regarding the spatial data, concerns the spatial relations admitted between them. Commonly referred as topological relations or simply topology, it defines and enforce data integrity rules. In the case of roof surfaces of the 3D building models one of the basic conditions is that no gaps should exist between roof surfaces. Also, no overlapping between surfaces from the same category are allowed.

The most important condition refers to the planarity of the surfaces, therefore all the vertices of a roof surface must be coplanar within specified tolerance.

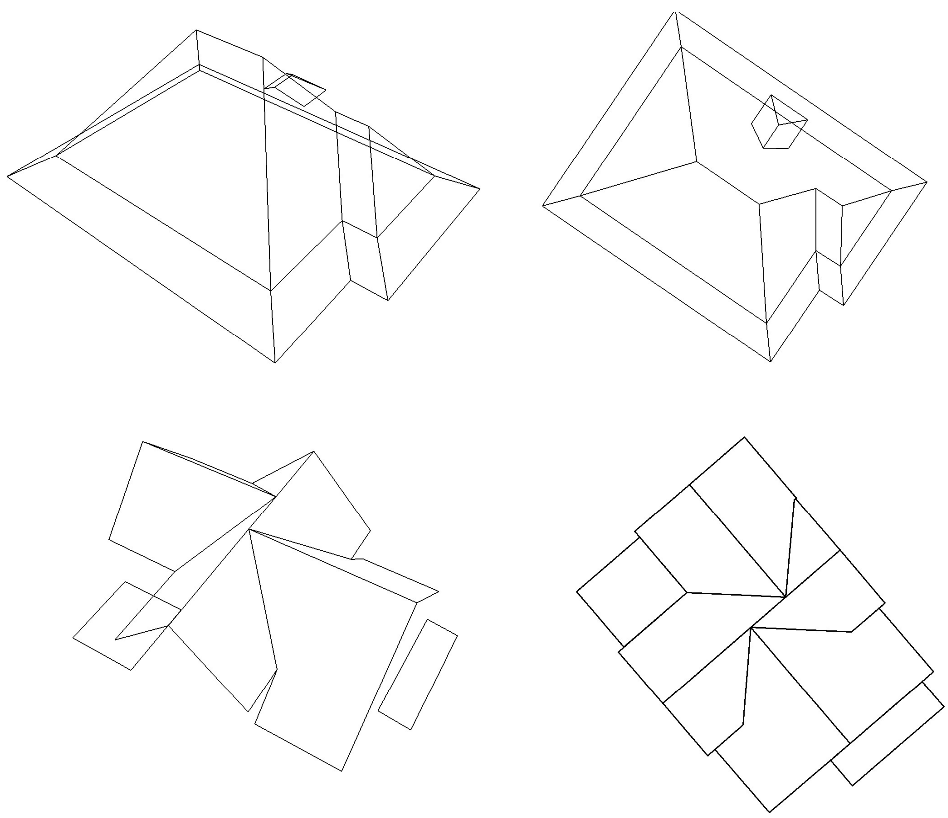

Fig. 1. Roof building examples

Technology advance brings improvements in the data acquisition techniques and along with this the increase in the diversity of the data formats.

Not only the issue concerning the accuracy of the data is pointed out, but also other problems as data consistency and compatibility are raised.

The main concept about consistency is that further processing of the data must have the same result regardless the data source. For 3D building models it has a direct influence on the final product, as spatial data is subjected to various transformations. Wrong orientated surfaces or duplicate surfaces are a few of the consequences of data inconsistency.

3. ETL Tools

Nowadays, in order to promote their products, software vendors provide import and export options for a variety of data formats. Large and complex 3D GIS projects can be carried out by more then one company often situated in different countries or even continents. In most of the cases the data formats used by different organizations are not the same. Therefore, the information must be able to migrate from one format to an other without losing it's integrity.

In order to overcame interoperability issues a new class of tool was created in the early 1990s in shape of ETL tools (Extract, Transform, Load). This tools were designed to overcome limitation regarding data formats. More then that a series of transformations can be performed on data during this translations. Reprojection (convert data between coordinate systems), spatial transformation, geocoding (convert attributes into spatial data), or data merging and attribute joining are a few of possible ETL tools application.

Today, one of the most complex ETL tool is made available by Safe Software under the name of FME. Thanks to it's ability to convert data between over 300 formats and perform over 400 distinct transformations, FME is a very powerful tool for data manipulation. Standard transformers can be joined together in very complex schemas that can be modeled according to the project specifications. Custom transformers can be also created and made available to other users in an online market. An entire community dedicated to data transformation was created.

This sort of tools came in handy for 3D building models, were complex data structures need to be created and converted.

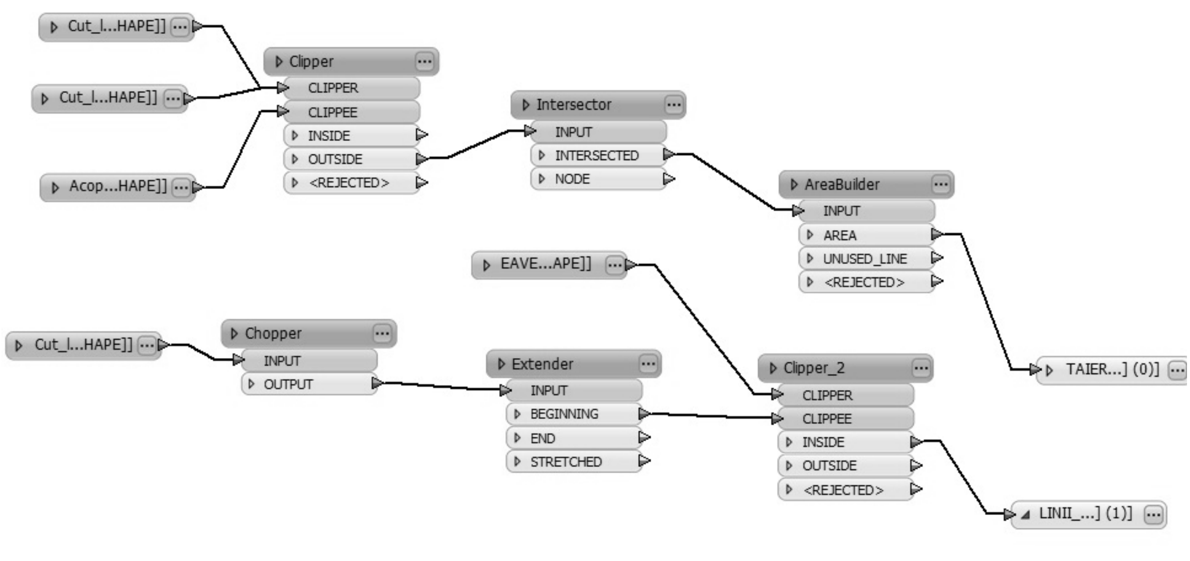

Fig. 2. FME schema

Using FME or any other ETL tool entire stages of the 3D building modeling process can be performed in just one action for wade areas.

This allows for savings in time and resources invested into the project. The only real limitation are imposed by hardware characteristics.

Nevertheless, the most important job comes in the hands of the ones how design the schema to guide the date through its steps.

4. 3D building models

Around 75% of the population from the EU have chosen urban areas as their home. In areas with such a high population density planning and managing changes in the landscape becomes a real challenge because a good urban environment is a precondition for a good quality of life[3].

The environmental elements of quality of life include good air quality, low noise levels, clean and sufficient water, good urban design with sufficient and high-quality public and green spaces, an agreeable local climate or opportunities to adapt, and social equity[3].

Statistic analysis must be conducted for every factor that has a direct influence on the urban environment.

In effect the demand for 3D building models has increased in the last years. Large areas are now maped in 3D in order to better understand the dinamics of the city.

In most of the cases , the destination of the 3D building models dictates the level of detail required.

For the computation of noise immission maps [5] for example, 'grey models' are used (flat roof buildings without texture) . This models are equivalent to LOD 1 in the CityGML standard.

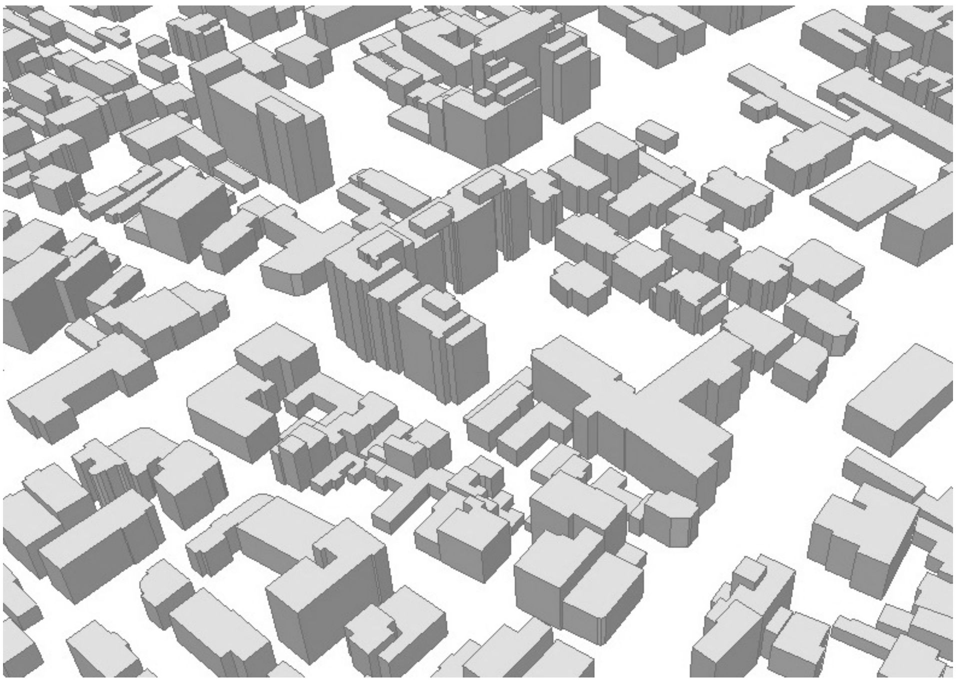

Fig. 3. LOD 1 3D building models

The grey models can by enhanced by texturing from orthoimage and adding differentiated textures to the building's facade based on building's classifications.

More complex task require as well sophisticated and close to reality models. Therefore the spatial data used as input has to be more detailed. As an example 3Dmodels can be constructed by enforcing the measurements from the official survey as the footprints for the building along with the spatial data from stereo-restitution representing the actual roof of the building. Usually ground hights are deduced by interpolation using DEMs. All other metric characteristics are calculated based upon the geometry of the model.

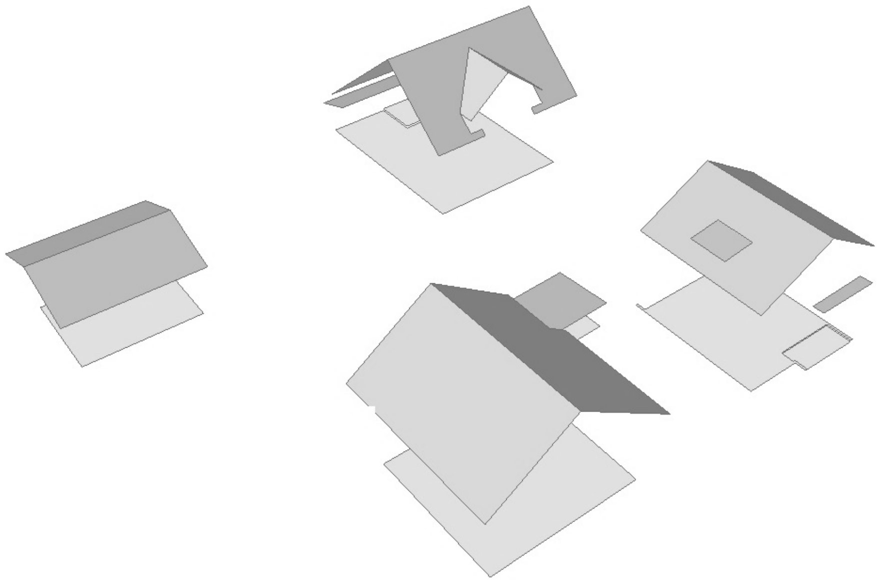

Fig. 4. LOD 2 3D building models – spatial data input

For the final product to be a better representation of the reality, the footprints has to be taken into account starting with the stereo-restitution process. That means that the specifications for spatial data restitution have to be adjusted to fit the project demands. Topology definition has to allow overlapping between roof's surfaces in the eaves area, as shown in the figures below. As a result, 3D buildings model with real eaves will be constructed.

Fig. 5. Topological relationships for 3D building models - example 1

Fig. 6. Topological relationships for 3D building models - example 2

In order to relate all the surfaces in the final model, unique identifiers has to be assigned to each individual structure. Also, each surface has an parent ID that defines the superior structure that is part of, in this case the individual building.

Unfortunately the buildings came in a great variety of shapes and some of that shapes are posing problems to the automated structure designed to process the models. For more complex structures an operator has to interview and manually edit the data, this is the reason why the human factor can not be completely removed from this process.

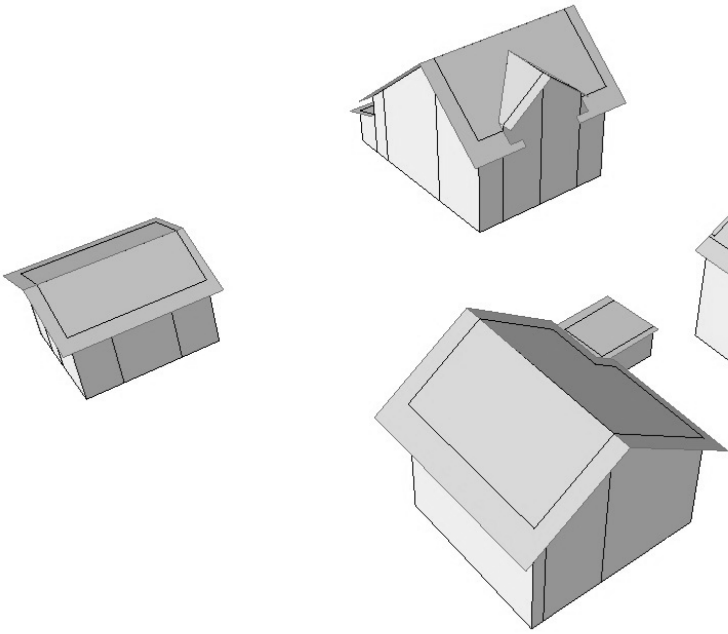

Fig. 6. LOD 2 3D building models

Attributes such as address, height, datum, ground height, unique identifiers and many others can be introduced into the model.

The final buildings models can be exported to any XML-based encoding. The most common format used for the representation of 3D building models is CityGML format that is defined as a standard for describing 3D objects with respect to their geometry, topology, semantics and appearance, and defines five different levels of detail [1].

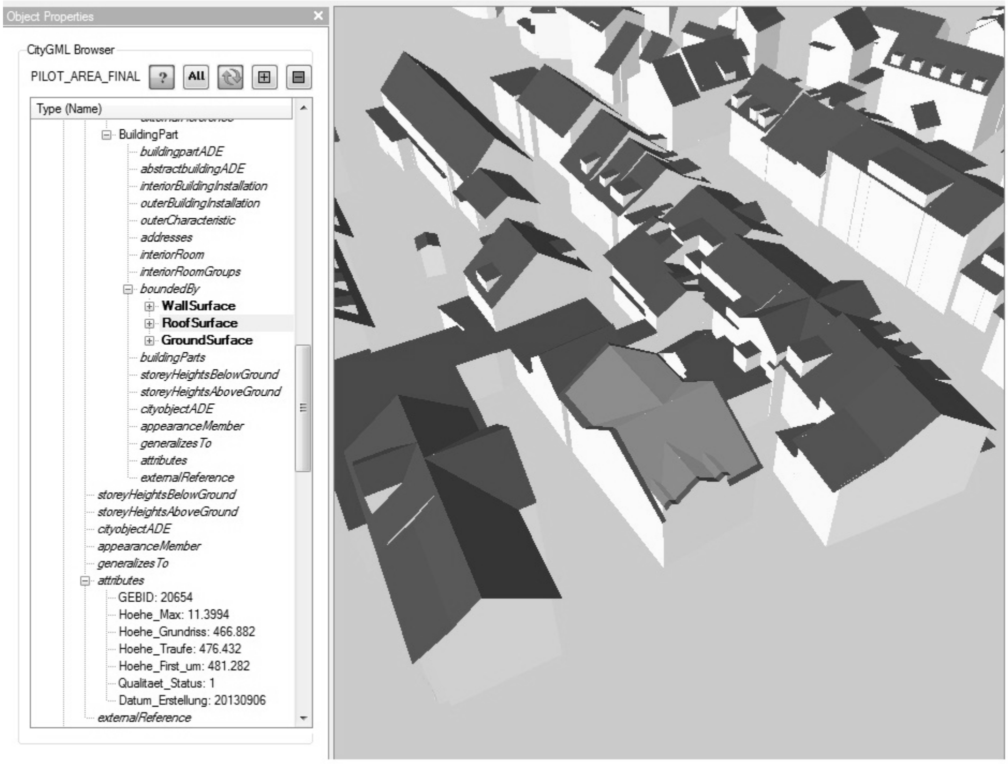

Fig. 7. 3D buildings in CityGML standard

5. Conclusions

3D building models are the next logical step in the evolution of spatial data representation as GIS industry adapts itself to changes in the fields of engineering and energy.

The characteristics of the spatial data, also know as metadata are of extreme importance, as any further transformation of the data rely on it's initial definition. 3D building model generation usually require the use of multiple data sources and in most of the cases this aspect raises interoperability and integrity problems.

For every projects, the process for 3D building models generation has to be adapted to match the required specifications. Depending on the complexity of the project these modification can be minor adjustments of the model's parameters or can require a change in spatial data capture methodology.

In most of the G.I.S. software, limitations regarding the tools associated to 3D editing are still raising problems. Many of the operation associated to 3D building models production are performed using auxiliary instruments, such as ETL tools.

The 3D visualization offers superior understanding of the urban area, or any other environment for that matter and provides more powerful tools to conduct studies that improve our way of life.

Based on the research and statistical analysis of the spatial data, the actual state of the urban area is translated into numbers, in the shape of relevant indicators.

These indicators are the key elements in projects that aim to urban area development.

In this context the most important question regarding spatial data still stands: "How can we truly benefit at full of the actual meaning of the data?"

6. References

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