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# 3D-GIS Integration for Virtual NewcastleGateshead

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**Abstract.** *Tools and technologies are developing to help the simulation of our cities for visualization, analytical and information modeling purposes. In this paper the authors, as well as evaluating different applications for 3D GIS solutions, are investigating various stakeholder requirements in relation to the Virtual NewcastleGateshead (VNG) project. This case study shares findings of a working group set up specifically to explore the options for 3D-GIS integration for the VNG project, and will focus on issues relating to data exchange, CityGML, data accessibility and interoperability in piloting Autodesk LandXplorer.*

**Keywords.** *3D-GIS; Virtual NewcastleGateshead; 3D City Models; LandXplorer; CityGML.*

## Introduction

Covering large areas, cities are ever evolving and complex structures. In order to provide sustainable environments for future generations, understanding, interpreting and communicating this change is a challenge in itself. This challenge can only be tackled by multi disciplinary teams addressing the issues and embracing new tools, methodologies and technologies. The latter are developing to help the simulation of our cities for visualization, analytical and information modeling purposes. The concept of multiple three dimensional (3D) city models existing for one city, each addressing specific applications, is being challenged by the possibility of creating one digital city model which could be utilized for many applications. Such a model would need to be “information rich” as well as being based upon accurate geometric data. The increasing availability of “off-the-shelf” 3D model data is making city geometry

more accessible but such data needs to link to existing Geographic Information Systems (GIS) data if a shared collaborative virtual city is the goal.

## 3D and Virtual Reality (VR) City Models

3D and VR city models can be simply described as computerized graphical representations or visualizations of any city and their components (Thompson et al 2006). Whyte, J. (2002) emphasizes that the information that exists about a metropolis is hard to comprehend in its totality therefore good representations allow rapid understanding of the relevant features of a data-set. Various researchers have focused on the creation, and usage of a data-set required for 3D and VR city representations, (Day, 1994; Bourdakis, 1997; Day, Radford, 1998; Baty et al., 2000; Delaney, 2000; Dokonal, Martens, 2001; Peng et al., 2002; Horne, 2004; Pleizier, 2004; Discoe, 2005; Pritchard, 2005; Thompson et al., 2006; Horne et al., 2007; Charlton et al., 2008; PODEVYN et al., 2008

and others). The creation of accurate 3D city models is not as complex as it was previously with developments in aerial photogrammetry, 3D terrestrial laser-scanning technologies, and advancing hardware and software capabilities. "Off-the-shelf", low cost 3D city models are now more readily obtained (Table 1).

Off-the-shelf 3D City Model Providers
Aerodata ( <a href="http://www.aerodata-surveys.com">http://www.aerodata-surveys.com</a> )
Bloom Aerofilm ( <a href="http://www.blomaerofilms.com/aerofilms/en">http://www.blomaerofilms.com/aerofilms/en</a> )
Bluesky ( <a href="http://www.bluesky-world.com">http://www.bluesky-world.com</a> )
GTA ( <a href="http://www.gta-geo.de">http://www.gta-geo.de</a> )
Virtual City Systems ( <a href="http://www.virtualcitysystems.de">http://www.virtualcitysystems.de</a> )
Zmapping ( <a href="http://www.zmapping.co.uk">http://www.zmapping.co.uk</a> )

Horne 2009 and Thompson and Horne 2009 have also discussed issues emerging in the creation of a shared, multi-use digital city model, highlighting a need to address issues pertaining to model management, update and remote access to model data. The increasing requirement to develop more functional and flexible city models, which will be able to serve a range of applications to meet the needs of various stakeholders, requires models which can hold several layers of information. This, and also the data requirements imposed by emerging European legislation such as the INSPIRE directive [1] necessitate combining the data sets, whether geometric or semantic, into one centralized platform.

City models which have been based upon GIS from the outset often lack the geometric detailing required for urban planning. Furthermore most of the 3D and VR city models lack the spatial analysis capabilities that GIS offer. Since the ultimate vision of GIS is to integrate semantic and geometric data in one system and allow analysis in both realms, investigating the options now available to merge 3D city model data with GIS traditionally used by city authorities does become a requirement.

### Integrating Information in 3D City Models

In any urban planning activity or process, data, either semantic and/or graphical, is the key element. The

US Geological Survey [2] defines GIS as a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location. By definition, GIS sustains spatial information and offers methods of analyzing this spatial data, helping users to gain facts regarding geographic surroundings, whether rural or urban.

In the early 1960s, when GIS was in its infancy, the first data rich representations in the form of two dimensional grayscale maps were used to portray this spatial information. Since then, with hardware and software developments, 2D, 2.5D have developed enormously, and latterly 3D GIS.

GIS is being used by various geo-related professions such as geographers, surveyors, cartographers, civil engineers, forest engineers, ecologists, landscape architects, urban and rural planners and the military. However as Sui D. Z. (1998) emphasizes, the integration of GIS with urban modeling did not take place until the late 1980s. 3D modeling, VR applications and Games Engine technology now offer different levels of modeling capability for urban planners. Whilst GIS's visualization capability is widely used, the modeling capability of GIS is relatively under-utilized. With the increasing supply and usability of spatial data, GIS has great potential to easily and accurately model the urban components and to systematize the modeling process (Kawabata, Ferreira, 2003).

Creating and representing 3D information is not a new concept for Computer Aided Design (CAD), and current CAD systems are designed to generate and manage photorealistic 3D representations almost effortlessly. However 3D visualization for GIS applications has not been identified as an important issue until recently. CAD tools allow Architecture, Engineering and Construction (AEC) specialists the create-edit-visualize functions quite easily and the distinction between high-end CAD, GIS and Map viewers is become fuzzy. Although 3D GIS and CAD software tools are getting closer to each other there are still application related issues that needs to be

*Table 1  
Some of the Third Party City  
Model Providers*

dealt with. Research (Ekberg 2007; Pu, Zlatanova, 2006; Oosterom et al., 2006, and others) shows that although CAD and GIS present more and more parallel functionalities there are still issues that needs to be dealt with for the smooth integration. Researchers have considered why 3D GIS is required (Stoter, Zlatanova, 2003; Zlatanova, 2000; Abdul-Rahman A, Pilouk M, 2008):

- We live in a 3D world
- 3D visualizations in the form of video games, movies, geo-browsers are now in everyday life
- Limitations of none 3D GIS in situations where volumes need to be considered for analysis such as: flooding, air pollution, noise mapping, sun/shadow analysis, geological analysis, real-estate marketing, disaster management / rescue operations, urban planning, landscape planning, etc.
- More accurate data extractions for visibility, line of sight (LOS), scale etc.
- Response to urban information requirements

Research also indicates that the challenges of 3D GIS in general are not much different to challenges of GIS in early stages. (Stoter, Zlatanova, 2003; Zlatanova, 2000; Sharrard, 2009):

- Base model
- Data acquisition, management, storage and performance
- Data consistency and maintaining spatial and non-spatial real objects
- Providing semantic, geometric and physical characteristics of spatial objects
- Spatial analysis and formulating spatial and non-spatial queries
- Supporting interrelationships among spatial non-spatial objects
- Sharing and dissemination
- Visualization, navigation and end-user interface

Although improvements are consistent in the software development area, Stoter J. and Zlatanova S., (2003) believe that 3D GIS does still need better 3D functionalities such as; querying 3D geo-objects, 3D structuring, manipulation and analysis. Ekberg (2007) also points out that the GIS community

demands; realistic 3D visualizations, 3D editing capabilities, better navigation possibilities.

Parallel to the development of off-the-shelf, low cost 3D city models, “two data models, the City Geography Markup Language (CityGML) and the Keyhole Markup Language (KML) have evolved as Open GIS standards, which can be used for storage and exchange of 3Dcity models” (Ross et al., 2009).

Kolbe T. H. (2009) explains that the purpose for the development of CityGML was to reach a common definition and understanding of the basic entities, attributes, and relations within a 3D city model. By providing a core model with entities which are relevant to many disciplines the city model can become a central information hub to which different applications can attach their domain specific information. Information exchange between different disciplines can then be aligned with the objects of the city model. CityGML does not only represent the graphical appearance of city models but also addresses the representation of the semantic and thematic properties, taxonomies and aggregations of digital terrain models (DTMs), sites, vegetation, water bodies, transportation facilities, city furniture. The underlying model differentiates five consecutive levels of detail (LOD) on a scale of LOD0 to LOD4, where objects become more detailed with increasing LOD regarding both geometry and thematic differentiation. (Dollner et al 2006). Different LODs often arise from independent data collection processes and facilitate efficient visualization and data analysis. In a CityGML dataset, the same object may be represented in different LODs simultaneously, enabling the analysis and visualization of the same object with regard to different degrees of resolution. The simplest level LOD0 is essentially a two and a half dimensional DTM. LOD1 is the well-known block model, without any roof structures. A building in LOD2 has distinctive roof structures and larger building installations like balconies and stairs. LOD3 denotes architectural models with detailed wall and roof structures, doors, windows and bays. LOD4 completes a LOD3 model by adding interior structures like rooms, stairs, and

furniture (Kolbe, 2009).

## Project Area: Newcastle and Gateshead

Newcastle upon Tyne (north of the River Tyne) with a population of 259536 and area of 11507 hectares and Gateshead (south of the River Tyne) with a population of 191151 and area of 14304 hectares, are neighboring urban centers in the North East of England.

Virtual NewcastleGateshead is a 3D model of both the above urban areas, covering 8.45 sq km at present, with a view to extend the coverage approximately to 40 sq km. Aerial photogrammetry and 3D modeling technologies were used to create this model. It can be said that it is significantly more precise than alternative global visualization engines such as Google Earth and provides an appropriate tool for planning related activities. Both local authorities have accepted the accuracy of the model

VNG Model	
Currency	Data captured in 2009 (soon to be updated)
Data capture	Aerial photogrammetry and laser scanning survey techniques (with the view of model to be based upon a database structure to facilitate regular update procedures and efficient management).
Terrain accuracy	0cm-25cm for 70% of points
Terrain	Presenting small and large grassy areas, wooded areas, main and minor roads, railway pathways, bridges, car parks, rivers, water bodies, trees, vertical embankments
Building detail	Initially high detail with features (roof structures, chimneys, pitched roofs, flat roofs, parapets, dormer windows, separation of individual buildings, etc.). Facades, textures added to achieve LODs when needed.
Format	Initially dwg for the Context model, 3DsMax and VR4Max formats used for detailing and interactive presentation purposes. Other formats such as SketchUp etc. is provided for the councils as required.

Table 2  
Details of the VNG Model



Figure 1  
Current VNG Model extents.  
(Context Model © Zmapping Ltd., 2009.)

data for the purposes of urban planning. The virtual model is hosted by Northumbria University's School of the Built Environment and both local authorities are able to access the model through secure remote access (128bit encrypted FTP server) (Table 2 and Figure 1).

The aims of the VNG project have been defined from the outset to support the urban planning process for both local authorities, currently challenged by significant levels of regeneration activity. These have now grown to such a degree that it would be inefficient for both local authorities to develop digital models independently, each using differing standards, procedures and protocols (Horne M., 2009).

The project is evaluating how an existing 3D city model can be enhanced in order to assist communication and decision making processes for urban planners. The sharing and maintenance of the virtual city model and creation of opportunities for 3D analysis are also being investigated. In order to achieve a sustainable city model, discussions over a three-year period, 2007 to date, between key parties have been held to share the common vision of the potential value of VNG. Urban planners have acknowledged the usefulness of three-dimensional computer representations when these have been presented alongside more traditional visualizations, as a part of development proposal submissions (Horne, 2009).

A systematic analysis of client requirements was conducted in 2008, and the integration of GIS was identified as key requirement. This rigorous evaluation of the benefits and requirements identified several topics that needed to be investigated more, such as; legal issues, technical issues (origin of data, remote access, version control, level of detail, accuracy, standards), and financial issues (Horne M, 2009). The following section describes work in progress for GIS integration into the digital model.

### **Management**

VNG is directed by a Steering Group composed of members from both local authorities and

Northumbria University. A GIS Integration working group was formed and regular meetings held to recommend a preferred solution for the integration of appropriate GIS data into the VNG model. This GIS working group is made up of GIS officers from both councils and academics from Northumbria and Newcastle Universities. The main aims of this working group are:

- to understand the needs and requirements of the main stakeholders and identify a set of criteria to align with these goals
- to identify tools and technologies oriented towards the integration of GIS data into digital city models
- to screen potential tools and technologies with required functional requirements and performance characteristics
- to recommend a preferred solution, including financial implications and implementation strategy.

### **Pilot Work**

Visits were conducted to both local authorities in order to establish a better understanding on their day-to-day GIS operations and different data types they collect and how they utilize this data. Although CAD and GIS resources, both in man power and hardware, vary, both councils use a similar software solution for GIS which is ArcGIS 9.3. AutoCAD and SketchUp 7.1 are also utilized. Both are also in the process of evaluating LandXplorer Professional.

For a consistent business process, upon request both local authorities have supplied their requirements for the proposed GIS integration. These requirements can be classified under the below headings:

1. Coverage
2. Data format
3. LODs
4. Geo-referencing existing data
5. Management of updates and changes to the model
6. Version control, change register

7. INSPIRE compliant metadata tags
8. User requirements with regards to tools and skill sets.

According to the above requirements a GIS cycle of “data authoring-storage and publish-utilize” were customized (Figure 2).

This GIS cycle, from a business point of view, also refers to roles and responsibilities and the skill sets of the users whether they are 3D city modelers, GIS analysts, data distributors and publishers, consumers who utilize the end product and the tools that are needed in order to run this cycle. It is suggested that application specific skill sets are required for authoring and publishing points of the cycle but the consumers of this data shouldn't need any training

in order to utilize these end products and this can be achieved by utilizing lightweight viewers.

In order to carry out a pilot on data compatibility data-sets for lighting columns (points), listed buildings (polygons), trees with tree preservation orders and park areas were received from Gateshead Council. This data will be integrated to the existing 3D data.

Work is also being carried out to determine the capabilities of converting existing 3D city model to CityGML format. A small part of the model is converted to CityGML by using a SketchUP plugin which was created by University of Applied Sciences Gelsenkirchen, Germany. This process involved by importing a cleaned context map in Collada format



Figure 2  
GIS-Cycle

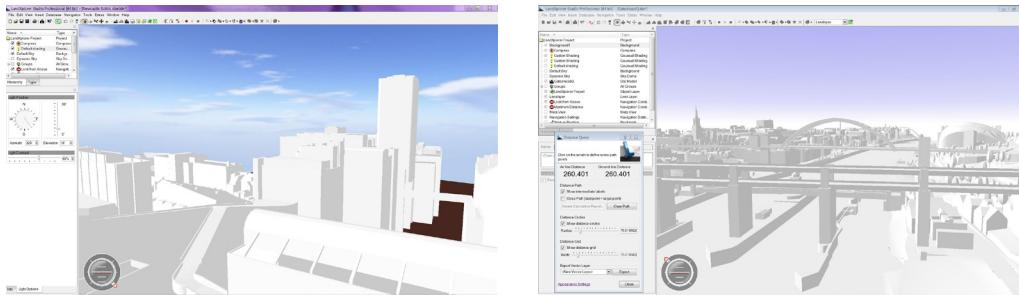


Figure 3  
Different parts of the City Model within LandXplorer Professional 2011, first one inserted as a 3ds and the second one as CityGML.

to SketchUP (7.1) and exporting this file to CityGML. Although export process was successful, the partial city model was converted as a single building as oppose to indentifying every single building on its own in the city model. This is obviously not ideal and more work is ongoing to fix this process. MetGeo Info's CityGrid [3] is being evaluated and appraisals are also ongoing with LandXplorer 2011 and ArcGIS 10 to assess data integration, easy access, performance and functional characteristics.

#### Emerging Issues

Bringing three large organizations with differing hard and soft skills and technological applications is never an easy practice especially in this uncertain economic climate. Therefore there are topics which need to be handled patiently and carefully. Issues that are arising with regards to 3D GIS integration are mainly on the technological side such as network compatibility, data format and conversions and software selection, interoperability etc. Most of these issues are in the process of being resolved. However file conversions and interoperability are universal problems that need to be tackled by following technological developments such as improvements on open formats, network standards, data management etc. The concept of being able to manage, store, disseminate and utilize 3D information with regards to whole of the built environment from a macro to a micro scale by connecting GIS with Building Information Modeling (BIM) technology is another emerging theme that will be influencing 3D GIS integration. It is important to point out that "data", whether it is in 2D or 3D format or in micro or macro level with different ownerships needs to seamlessly joined together in order to generate an information rich city model.

#### Conclusion

This project is ongoing work. In this snapshot, the authors have offered an insight into a real-life example of bringing different organizations together in order achieve a more sustainable 3D city model

with GIS integration. In general, expectation of 3D GIS is increasing. Software developers are trying to address these expectations by providing better solutions, such as LandXplorer Professional 2011, ArcGIS 10 and Bentley's 3D GIS information modeling software V8i. Faster rendering in 3D, editing GIS data directly in 3D, more accurate LOS analysis, better data conversion between different file formats (Collada, SketchUP, 3DsMax, etc) and database formats (CityGML, IFC) will be possible. Achieving different LODs with less process and being able to share data via different visualization platforms and the web will make 3D GIS more acceptable to wider communities.

#### Future Work

A selection process for a 3D GIS application with regards to preferred software and file type is ongoing and a report will be created by September 2010 when recommendations will be given to the both local authorities. Future work will also include joining surrounding landscape data to 3D building data. Decisions will be made on whether and how the different accuracy required for building data (approx. 20cm) and landscape data (approx. 1m) will merge and whether there is a need for more accurate landscape data.

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