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Towards an Inclusive, Safe, Resilient and Sustainable City: Approaches and Tools

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THE USE OF 3D VISUALISATION FOR URBAN DEVELOPMENT, REGENERATION AND SMART CITY DEMONSTRATION PROJECTS: BATH, BUCKINGHAMSHIRE, AND MILTON KEYNES

Stewart Bailey, Advait Deshpande, Alby Miller

Abstract

The aim of this paper is to discuss three different case studies related to the use of 3D visualisation for projects focussing on urban development, regeneration, and Smart City demonstrations. With each of the case studies, the problem statement, the approach adopted for 3D visualisation, and the outcome is covered. The paper concludes by discussing what 3D visualisation offered to each project. The paper discusses how in order to effectively use 3D visualisation the approach needs to be adapted according to the problem statement. Depending on the project requirement, 3D visualisation is likely to serve multiple purposes in urban development, regeneration, and Smart City demonstration projects. The paper suggests that the use of 3D visualisation adds an extra dimension to presenting data and also provides an effective tool for analysing the data.

Keywords: 3D visualisation, urban development and regeneration, Smart City

L'USO DELLA VISUALIZZAZIONE 3D PER PROGETTI DI SVILUPPO URBANO, RIGENERAZIONE E SMART CITY: BATH, BUCKINGHAMSHIRE, E MILTON KEYNES

Sommario

Obiettivo dell'articolo è presentare tre casi di studio relativi all'uso della visualizzazione 3D in progetti incentrati sui temi dello sviluppo urbano e della rigenerazione, e dimostrativi del concetto di Smart City. Per ognuno dei casi studio, sono individuati la definizione del problema, l'approccio adottato per la visualizzazione 3D ed i risultati. Nelle conclusioni viene esaminato il contributo che la visualizzazione 3D è stata in grado di offrire a ciascun progetto. L'articolo evidenzia come, per usare efficacemente la visualizzazione 3D, sia necessario adeguare l'approccio al problema in esame. In base alle esigenze del progetto, la visualizzazione 3D può servire a molteplici scopi nei progetti di sviluppo urbano, rigenerazione e Smart City. L'articolo mostra come l'utilizzo della visualizzazione 3D aggiunga una dimensione ulteriore alla presentazione dei dati e fornisca uno strumento efficace per la loro analisi.

Parole chiave: visualizzazione 3D, sviluppo urbano e rigenerazione, Smart City

1. Introduction

This paper discusses three different case studies about the use of 3D visualisation for projects concerned with urban development, regeneration, and Smart City (Caragliu *et al.*, 2009) demonstrations. The paper does not compare or debate the relative merits or demerits of various methods and technologies that rely on 3D visualisation for urban development, regeneration, and Smart City demonstration projects. The aim is to discuss Virtual Viewing's approach for utilising 3D visualisation. For this purpose, the following case studies are presented:

- an urban development housing project in Bath, United Kingdom (UK);
- the Buckinghamshire Thames Valley Local Enterprise Partnership (BTVLEP) Geographic Information System (GIS) project;
- a Smart City demonstration for Milton Keynes (MK).

For each of the above case studies, the paper covers the problem statement and the role played by 3D visualisation in the execution of the project. Although 3D visualisation formed an important part of the solution, the paper also considers how 3D visualisation was combined with other methods in order to achieve the required results. The concluding section analyses how Virtual Viewing (VV) adapted 3D visualisation to represent data in a meaningful way. The relevance of 3D visualisation for each of the projects is also discussed.

2. Urban development: Crest Nicholson Bath Riverside

This case study focuses on the requirements and the eventual solution offered to Crest Nicholson for their multi-phase real estate development project in Bath, UK. Crest Nicholson is a British house-building company listed on the London Stock Exchange and a constituent of the FTSE 250 index (London Stock Exchange, 2014). It has building operations mostly concentrated in the southern UK.

The problem statement

Crest Nicholson needed an interactive and innovative solution for their sales staff. In this case, the solution was expected to be customised for their site in Bath. This site was undergoing a multi-phase development of a riverside property including a block of flats. The work done by Virtual Viewing was specific to the second phase of this development project. Crest Nicholson expected the solution to combine animation of the actual site with real time data and live actors. To enable the sales staff to sell the houses off plan, Crest Nicholson had built a physical model (i.e. a small-scale replica) of the development site (6 ft. x 4 ft.). Crest Nicholson wanted their sales staff to interact with this physical model along with the software application to be developed.

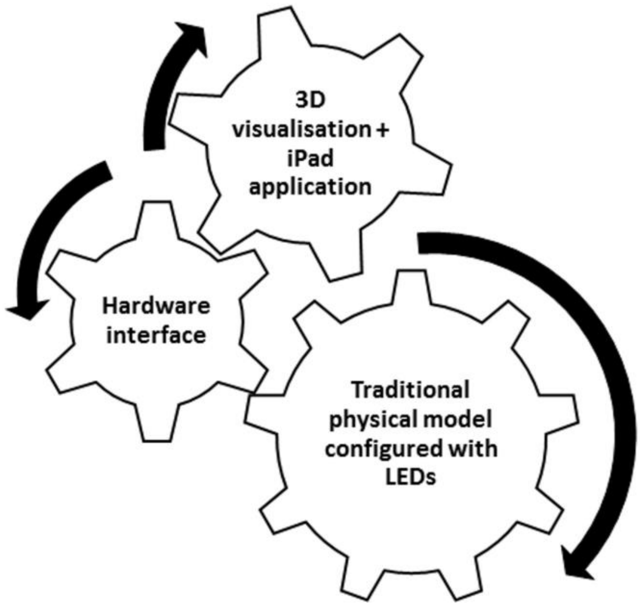
Although Crest Nicholson had previously used physical models on other developments, the interactivity between the physical models and any 3D rendering of the sites was very feature-limited. Existing systems to interact with the model had focussed on building simple functionality such as lighting up the entire model at the same time and did not offer any additional functionality. Crest Nicholson wanted a more sophisticated solution that integrated the 3D visualisation with the physical model further.

The Virtual Viewing approach

Virtual Viewing's solution combined three separate components to deliver Crest Nicholson's requirements (Fig 1):

1. an iPad application providing 3D visualisation;
2. a hardware interface to control individual model lights from the iPad application for improved demonstration capabilities;
3. a traditional physical model with embedded Light Emitting Diode (LED) lights.

Fig. 1 – VV approach for the Crest Nicholson Bath Riverside project



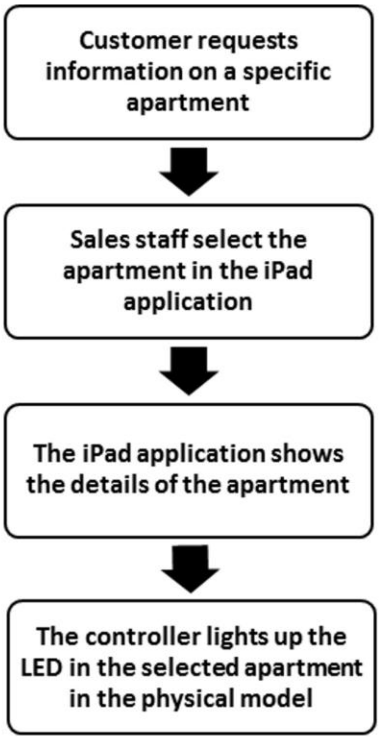
Virtual Viewing created an iPad application that provided site plans, including detailed information on each of the apartments, and a 3D flythrough of the development. This solution was created with Adobe Air and C#. C# was used to develop the web services for the application.

The hardware interface was designed to connect the iPad application with the physical model. The iPad application interacted with the hardware interface and could control parts of the physical model without direct contact. The intention was to allow the sales staff to use the iPad application during customer demonstrations to light up a specific part of the physical model. By installing LED lights inside the physical model and facilitating the hardware interface to manipulate the LED lights, the interactiveness of the demonstration was further enhanced.

The third part, the most innovative in this context, was the increased interactivity as a result of the hardware interface being linked to the iPad application. The LED lights in the

physical model could be switched on and off through the use of the iPad application and the hardware interface. These LEDs were installed on the physical model to make it stand out and add an extra layer of interactiveness as the sales staff walked the prospective customers through the physical model. With the LEDs, the sales staff could showcase the houses through 3D visualisation aided by the physical model.
Although the images from the actual project cannot be included here due to a confidentiality agreement with the client, the flowchart of Figure 2 shows the manner in which the interaction between the customers, the sales staff, and the solution developed by Virtual Viewing worked.

Fig. 2 – Flowchart for the Crest Nicholson Bath Riverside project



The outcome
The end-result with the integration of the iPad application, the hardware interface, and the LED lights in the physical model was a small scale control system. Not only did the solution fulfil the client expectations in terms of innovativeness but it also proved to be an invaluable tool for the sales staff for demonstration purposes. The fact that such an integrated software and hardware experience could be up-scaled for a more complex functionality suggests that this approach has further potential.

The strength of this approach lies in the way it combined the physical model with the 3D visualisation in the iPad application. It enhanced the sensory experience and complemented the computer-based 3D visualisation by adding a real-world 3D counterpart (real world objects are seen in 3D by default after all).

3. Urban development and regeneration: The BTVLEP GIS project

This case study is about a project executed for two stakeholders - Buckinghamshire county council and the Buckinghamshire Thames Valley Local Enterprise Partnership (BTVLEP). The Buckinghamshire county council is the governing council for the Buckinghamshire County in the Southeast of England. The county covers an estimated area of 1874 sq. km and has a population of 756,000 according to the latest census (ONS, 2011). BTVLEP is a partnership project between the local government (i.e. the Buckinghamshire county council) and the private sector intended to attract businesses and investment to the Buckinghamshire area (http://buckstvlep.co.uk/). In consequence, BTVLEP seeks out opportunities to showcase the infrastructural, commercial, and economic advantages of the Buckinghamshire area to businesses. The BTVLEP GIS project was aimed to be one such showcase.

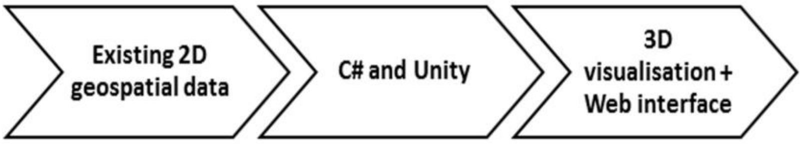
The problem statement

The main requirement was to create a platform for displaying existing 2D geospatial information held by the council in 3D format. Through this project BTVLEP aimed to demonstrate its intent about attracting investment. For the Buckinghamshire county council, the aim was to communicate data about the county in a visual, easy-to-understand manner. The data were intended to reveal various patterns and characteristics of the county such as voting patterns, woodland areas, parts that would be affected by the High Speed 2 (HS2) railway service, a planned high-speed railway between London Euston, the English Midlands, North West England, Yorkshire, and potentially North East England, and the Central Belt of Scotland, and areas of traffic congestion. The project was split into two phases. The first phase was about rendering the existing data through 3D visualisation and build a platform. The second phase was to build applications on top of the platform. This case study discusses the outcome at the end of the first phase.

The Virtual Viewing approach

At the core of Virtual Viewing's proposed solution was the position that the 2D geospatial data held by the council was of strategic importance. Instead of relying on Google Maps / Earth Application Programming Interfaces (APIs) to harness this data, the Virtual Viewing approach relied on a custom solution delivered by combining C#-based software development with Unity, developed by Unity Technologies, a cross-platform system for rendering the data (Fig. 3). Other approaches including Web Graphics Library (i.e. WebGL, a JavaScript API for rendering interactive 3D graphics and 2D graphics within any compatible web browser without the use of plug-ins, Tavares, 2012) were considered but not used after preliminary due diligence at the time of the project revealed them to be less flexible to programme in and difficult to maintain afterwards at their current state of maturity.

Fig. 3 – VV approach for the BTVLEP GIS project



The existing 2D geospatial data was held in a proprietary format for use in a desktop system. In contrast the client requirement was to render it on the web in 3D. This meant that in order to effectively harness this data, the Virtual Viewing solution needed to import, combine, and recut the aerial image data. This repurposed data then needed to be presented in a compressed form. This was done by combining the existing topographical data with aerial photos in multiple layers. The challenge lay in importing and loading the existing geospatial data into a web application. Further complexity was due to open-ended non-functional requirements and limited visibility of the kind of devices end-users may rely on to access the web-based interface.

The outcome

The solution developed by Virtual Viewing delivered 3D rendering of the data providing various statistics for different areas of the county. To do so 160 GB of images and topographical data was reprocessed, thinned out, and compressed to about 50 MB download size. The existing data held in PostGIS and PostgreSQL was imported for rendering it in a grid system across multiple layers.

The use of 3D provided an extra dimension to represent the existing 2D data and enabled the various data sets (including aerial images and SketchUp models of key towns in the county; SketchUp is a 3D modelling software known for its capability to work with Google Maps and Earth file formats) to be displayed simultaneously rather than requiring offline data analysis first. Given the BTVLEP's intention of demonstrating openness for business and its preparedness to embrace technology for economic revival and growth, the first phase achieved the goals defined at the outset. The following images show the final results and how the web interface conveyed the statistical data held by the council in a geospatial context. These images indicate how applying different filters enabled the results to be displayed according to the end-user's interests. As a tool for attracting investment, these images also showcase the capabilities it offered to BTVLEP when interacting with investors and businesses.

Figure 4 shows an example of the overlays for the traffic routes and congestion as rendered in the web interface.

Figure 5 provides a view of the Aylesbury area. The information specifically displayed in this image is: urban area, woodlands area, infrastructure, and voting boundaries within Aylesbury.

Fig. 4 – BTVLEP GIS, traffic routes and congestion patterns

Source: Virtual Viewing Ltd. (2014)

Fig. 5 – BTVLEP GIS – Aylesbury area

Source: Virtual Viewing Ltd. (2014)

4. Smart City demonstration: Milton Keynes

This project was intended to be a demonstration of the Smart City concept for Milton Keynes, a large town in the Buckinghamshire County with 89 sq. km area and a population of 229,411 according to the latest census (ONS, 2011).

The problem statement

The main aim of this project was to display the potential of the Smart City concept to deliver intelligent, interconnected systems and associated functionality. The demonstration was intended for a number of potential stakeholders including government institutions, property owners, and marketing agencies (Table 1). For building the demonstration, the 3D visualisation was expected to rely on an existing offline software-based model of Milton Keynes. A key characteristic of the existing offline model was that it was not connected to any geospatial data. Thus it was important to take into consideration the offline nature of the landscape being used as a baseline for the 3D visualisation.

The Virtual Viewing approach

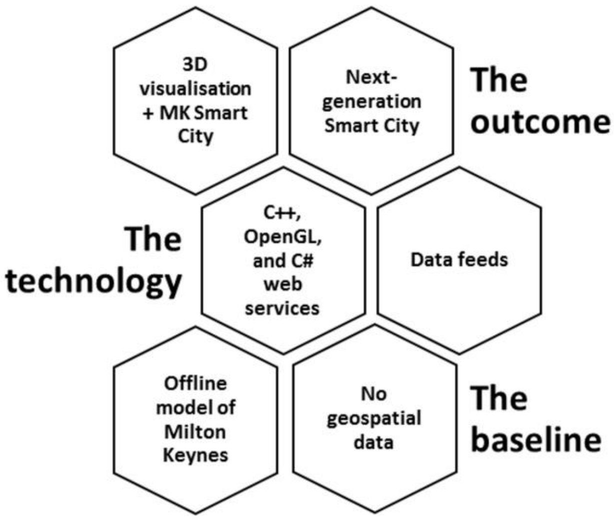
The main purpose of the project was to showcase the capabilities of Virtual Viewing vis-à-vis a Smart City demonstration. For an efficient and expedient development process, Virtual Viewing used C++, Open Graphics Library (i.e. OpenGL, a cross-language, multi-platform API for rendering 2D and 3D vector graphics, The Khronos Group, 2014), and C# web services as the development platform. The resulting Smart City demonstration was intended to facilitate further development of data driven applications and 3D models. An important consideration was for the OpenGL-based 3D visualisation to enable future dashboard application concepts and cater to a wide range of prospective end-users such as housing residents, county councils, and property developers. In doing so, the demonstration was also intended to address three potentially different markets with varying business requirements and priorities as Table 1 shows.

Table 1 – Target audience for a Smart City demonstration

Market	Business requirements and priorities
City councils and planners	Overlay general information and statistical data with cityscapes; Provide visual tools for strategic planning and management of smart cities.
Property owners	Smart managing the estate; Real-time tracking of data feeds; Identification and resolution of problems.
Marketing agencies	Create interactive marketing campaigns for a range of industries including restaurants, manufacturers, and construction companies

Figure 6 shows the building blocks of the bottom-up process used by Virtual Viewing.

Fig. 6 – VV approach for the Smart City demonstration



The time taken for development of the 3D visualisation in C++, OpenGL, and C# web services along with further updates was 18 months. The result was a desktop system capable of running on modern Windows-based platforms with support for OpenGL and hardware acceleration.

The outcome

The main strength of this Smart City demonstration was the interactive features it offered in relation to understanding, exploring, and analysing a Smart City landscape. The resulting 3D visualisation allowed multiple viewing angles combined with the ability to zoom into specific locations and retrieval of site-specific data – an indispensable feature for a Smart City demonstration. The capability to display site-specific data was made possible by allowing another application to be embedded within the 3D visualisation. By showing the capability to read data feeds available at sites equipped for transmitting them, the demonstration provided a glimpse of how real-time monitoring of sensors would function and aide decision-making, interventions for local councils and individual owners alike. For example, based on its capability to read sensor data, the demonstration could be made capable of identifying the floor(s) affected in the event of a fire. Following images show various aspects of the Smart City demonstration. Figure 7 displays energy data for the Church of Christ the Cornerstone located in Central Milton Keynes. The demonstration also showed the granularity of functionality the Smart City concept could achieve whether it was in terms of providing a panoramic aerial perspective of the city locations or focussing on a specific data set (such as power usage, fire and safety events, or live traffic data). When combined with geospatial data, this kind of Smart City demonstration offered further opportunity to understand, evaluate, and conceptualise the way planning and implementation for a Smart City could take place. More crucially however, this demonstration also provided key inputs and techniques for the next-generation Smart City demonstration currently being developed at Virtual Viewing.

Fig. 7 – Energy data from the Church of Christ the Cornerstone

Source: Virtual Viewing Ltd. (2014)

Figure 8 shows the capability of the Smart City demonstration to geospatially link and embed an application about a specific site or location (in this case the Red Bull factory in Milton Keynes).

Fig. 8 – The Red Bull factory

Source: Virtual Viewing Ltd. (2014)

5. Discussion and conclusions

This paper has covered three different case studies related to the use of 3D visualisation for urban development, regeneration, and Smart City demonstration projects. In each case study, the approach adopted by Virtual Viewing has been discussed along with the output produced. In this section, each of these case studies, the variations in the approach taken, and the extent to which 3D visualisation was crucial to the project execution are analysed.

Different purposes converging with 3D visualisation

With each of the case studies, 3D visualisation served a different purpose:

- for the Crest Nicholson Bath Riverside project, 3D visualisation needed to be coupled with a hardware interface and a physical model to significantly augment the existing visualisation aides available to the sales staff;
- for the BTVLEP GIS project, the 3D visualisation acted as a visual filter for large amount of geospatial and statistical data. 3D visualisation was crucial to allow the data to be presented and understood quickly by third party users. With the main aim of attracting investment, the 3D visualisation also enabled BTVLEP to demonstrate its intent about emerging and advanced technologies;
- with the Smart City demonstration for Milton Keynes, 3D visualisation provided the flexibility to experiment with various ideas about how a Smart City could and should function. This is important given that the concept of a Smart City is still evolving (Zygiaris, 2013). The nature of interconnected, intelligent systems that could exist in a Smart City and the functionality that could be implemented is also part of an ongoing discussion between the industry and academia.

Despite the different purposes, 3D visualisation was a core part of the execution strategy adopted by Virtual Viewing. As the next section discusses, despite some of the technological constraints and partly due to the nature of the problem statement, Virtual Viewing employed different approaches while using 3D visualisation.

Adapting 3D visualisation to the problem statement

With the Crest Nicholson Bath Riverside project, due to the problem statement requiring an innovative solution, only presenting 3D visualisation would not have been sufficient. The existing physical models contained very rudimentary LED functionality. It was only by building a small control system with a fit-for-purpose hardware interface that the criterion for an innovative solution was fulfilled. To do so, Virtual Viewing adopted a more iterative process than most 3D visualisation projects in order to ensure seamless integration with the hardware interface and the LEDs installed in the physical model. As part of Virtual Viewing's approach, the interaction between the 3D visualisation, the hardware interface, and the physical model was central to the outcome.

With the BTVLEP GIS project, the most important requirement was to deal with a large existing data set held in a proprietary format. Given the strategic importance of the data to BTVLEP and its focus on urban development and regeneration, an additional important requirement was to do so as a web application. This required a more structured, linear approach given the complexity of the existing data set and that dictated the solution provided by Virtual Viewing. Such an approach was also important in view of the longer-term requirement to build scalable applications on top of the platform for the proposed second phase of the project. Since the end-user would only interact with the 3D

visualisation presented in web application, Virtual Viewing's approach was driven by ensuring an effective representation of the large quantity of data through 3D visualisation.
The Milton Keynes Smart City demonstration dealt with an evolving concept that could have yielded multiple implementations. To highlight the 'Smart' aspects of the demonstration, Virtual Viewing used multiple building blocks to create the 3D visualisation. The existing offline model of Milton Keynes, although it did not provide geospatial data, formed an important part of the final deliverable. The most important aspect of the 3D visualisation however was the ability to use data feeds from sensors. Coupled with the capability to zoom into any location and granularity of control vis-à-vis the sensor data, the data feeds were the most important building blocks of the final deliverable. This is reflected in Virtual Viewing's approach and also in the ongoing work about the next-generation Smart City demonstration.
Table 2 summarises the problem statement for each project and the way 3D visualisation was adapted for each project.

Table 2 – Adapting 3D visualisation according to the project requirements

Project	**Problem statement**	**The VV approach**
Crest Nicholson Bath Riverside	Create an interactive and innovative solution; Combine animation with real time data; Provide interaction with the physical model.	Iterative process; iPad application for 3D visualisation; Hardware interface between the iPad application and the physical model; Physical model configured with LEDs.
BTVLEP GIS	Use the existing 2D geospatial data; Deliver 3D visualisation for presenting statistical data and attracting investment; Create a scalable platform for further customisation.	Linear, structured process; Import, combine, and recut aerial image data; Render data in 3D in a grid system across multiple layers; Use C# and Unity for a customisable web interface.
Milton Keynes Smart City	Demonstrate the Smart City concept; Use an existing offline model of Milton Keynes as a baseline; No geospatial data.	Bottom-up process with multiple building blocks; C++, OpenGL, and C# web services; Granular functionality and capability to read data feeds from sensors; Foundation for the next-generation Smart City demonstration being built by Virtual Viewing.

3D visualisation – the extra dimension

In each of the case studies presented in this paper, 3D visualisation was required not only to provide visuals but also functioned as an important tool for marketing (Crest Nicholson), implementing a strategically important platform (BTVLEP), and conceptualisation and analysis of an emerging, evolving concept (Milton Keynes Smart City). Although the implemented solutions differed significantly in terms of execution and technologies used, without 3D visualisation none of the projects could have achieved their stated goals. 3D visualisation not only made the projects possible, it also added an extra dimension without which their outcome would not have met the requirements set in the problem statement.

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