

# RAISING SPATIAL AND VISUALIZATION AWARENESS IN A TEACHING ENVIRONMENT

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## ABSTRACT:

The requirements for visualization of existing and designed worlds are of increasing importance in the world today to maximize space, and minimize impact on the landscape. 3D City Modelling for virtual reality visualization is not new but due to the increases in computer power and flexibility in software there is wider availability of resources for visualization and therefore an increase in demand. The general public now has excellent opportunity to appreciate the benefits of 3D landscape models over the internet with products such as Google Earth™ and Microsoft Virtual Earth™. With the ability to create 3D models of our environment within a computer system there is an increasing need to provide students with a range of new skills to build and use this geospatial information. Hugely dependent on computing and visualization capabilities the knowledge and skill base required by students is pushing the boundaries of our traditional scope of teaching in many disciplines. Fundamental to this learning experience is the need to develop a student's 3D spatial awareness. An excellent way to start this is through relating the 'computer generated worlds' to the real world. The boundaries are becoming blurred between the technologies and procedures involved in traditional survey, mapping, and geospatial information collection and management. Technologies of GPS, photogrammetry, laser scanning and GIS are not just the tools of the professional surveyor or geographer they are becoming tools for an increasingly wide range of users. At The University of Nottingham the Institute of Engineering Surveying and Space Geodesy (IESSG) (part of the School of Civil Engineering), and the School of Geography have been working together to merge some of these geospatial information disciplines to enable students to learn more about the collection of spatial information, the handling and management of the information and the way in which this information can be visualised. 2D presentation of information is the traditional mapping and GIS approach but now GIS and CAD systems offer a range of capabilities to handle 3D information. Some might argue we are now working in 4 or more dimensions but fundamentally this is based on 3D coordinated spatial data. This geospatial information is now of frequent interest to industry and the public at large. Through recent research activities at The University of Nottingham in 3D model building and visualization there is now motivation to assess and enhance spatial awareness with teaching and learning activities. Some of this work forms part of a large collaborative project with the University of Leicester (lead partner) and University College London. The SPatial Literacy IN Teaching (SPLINT) project is funded by the Higher Education Funding Council of England (HEFCE). The work packages at Nottingham are based on building and using computer 3D environments and visualization in the laboratory (or lecture theatre) and also taking this geospatial information into the field for further visualization. By undertaking visualization in the field students will be presented with an opportunity to gain an appreciation of merging the real and computer based worlds. This paper will present current and possible future work at Nottingham with examples of work packages that are being introduced into teaching and learning. The SPLINT project has not only provided funding for staff but also to improve the teaching and learning environment with the refurbishment of laboratories and the purchase of new equipment. Conclusions will be drawn and thoughts for the future will be presented.

## 1. INTRODUCTION

### 1.1 Background

There is increasing interest in the visualization of existing and 'designed' worlds. It enables a better understanding of spatial relationships to assist with decision making to for example, maximize space and minimize the impact of construction on the natural world. 3D City Modelling for virtual reality visualization is not new but due to the increases in computer power and flexibility in software there is wider availability of visualization resources. The general public now has an excellent opportunity to appreciate the benefits of 3D landscape

models over the internet with products such as Google Earth™ and Microsoft Virtual Earth™.

With the ability to create and manage 3D models of our environment within a computer system there is an increasing need to provide students with a range of new skills to fully exploit this geospatial information. The knowledge and skill base required by students is pushing the boundaries of our traditional teaching in many disciplines. Fundamental to this learning experience is the need to develop a student's 3D spatial awareness. An excellent way to start this is through relating the 'computer generated worlds' to the real world.

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The boundaries are becoming blurred between geospatial technologies such as those used in traditional survey, mapping, and geospatial information collection and management. Technologies of GPS, photogrammetry, laser scanning and GIS are not just the tools of the professional surveyor or geographer they are becoming tools for an increasingly wide range of users. Conversely there are a range of technologies that can assist the geomatics community in widening the appeal of the products that can be produced. The specifications of laptops, tablet PCs, PDAs and personal computers are increasing at a rapid rate. Digital cameras are relatively inexpensive, simple to use and widely available. They are developing a culture amongst the public of capturing large numbers of images that can be edited once downloaded into a computer. Even the use of aerial images is becoming routine with the availability of image archives, accessible over the internet particularly for route planning. They can be viewed alongside, and even superimposed on, a traditional vector map such as the OS MasterMap®.

What is required is for our geospatial data and information to be presented and visualised in the most natural way. Much of the geospatial information collected has been collected as 2D + height. Now there is a significant move towards collecting data in full 3D form which is significantly raising the spatial clarity of the information particularly if it is visualised in 3D. The benefits of geospatial data can be more fully appreciated and understood if it is visualised in 3 dimensions, as this is how we view the world.

As a surveying and mapping community it is our role to support the development of 3D modelling and to educate the user to make the maximum benefit of the information.

### **1.2 SPatial Literacy IN Teaching (SPLINT)**

Through recent research activities at Nottingham in 3D model building and visualization there is now motivation to introduce more spatial awareness aspects in to teaching. Some of this work forms part of a large collaborative project with the University of Leicester (lead partner) and University College London. The SPatial Literacy IN Teaching (SPLINT) project is funded by the Higher Education Funding Council of England (HEFCE).

In early 2004 the HEFCE announced the opportunity to bid for Centres for Excellence in Teaching and Learning (CETL). 'The purpose of CETLs is to reward excellent teaching practice and to invest in that practice further in order to increase and deepen its impact across a wider teaching and learning community. We encourage institutions to define their own areas of excellence, evidenced by scholarly practice and a successful track record of excellence in teaching and learning outcomes. We invite institutions to demonstrate how their identified excellence is reflected in and advanced by the proposed focus of the CETL.' (HEFCE, 2004). This provided an opportunity to bid for capital and recurrent funding to improve and expand facilities and equipment, and to provide a staffing resource to develop teaching and learning materials. A key focus for SPLINT was the delivery of quality and range of teaching and general enhancement of spatial literacy of spatial information technologies particularly at postgraduate level. All three universities collaborating in SPLINT have established postgraduate courses. The considered 'spatial information technologies' include; Geographical Information Systems,

Remote Sensing, Surveying and Global Navigation Satellite Systems.

### **1.3 SPLINT at Nottingham**

The work packages at Nottingham are based on building computer based 3D environments and their visualization in a lecture theatre or the field. By undertaking visualization in the field students will be presented with an opportunity to merge the real and digital worlds and raise their spatial awareness. It will also allow students to merge past, present and future information into the scene (augment reality) to more fully understand the evolution or impact on the landscape. Visualization is critical in ensuring the students obtain the optimum experience. This has only become possible through modern technological developments in positioning, orientation, graphics and importantly computing hardware and software.

The SPLINT project has not only provided funding for staff but also to improve the teaching and learning environment with the refurbishment of laboratories and the purchase of new equipment. This part of the project has largely been completed and the development of teaching resources and introducing them into the courses are now the main focus. With activity initially directed towards teaching in the School of Geography it is now moving onto the School of Civil Engineering (through the IESSG) and beyond.

## **2. TAKING PHOTOGRAMMETRY IN TO THE FIELD**

### **2.1 Background**

The traditional way of generating mapping is through the use of air survey and this continues to be a valuable source of geospatial data for GIS analysis and presentation. Photogrammetry has often been seen as a very specialist technology particularly pre digital era. With the changes in photogrammetry brought about by the digital era there is a change in the skill base. The general level of computing skill of students and the public at large has enabled students to pickup the computing aspects of digital photogrammetry easily. Often the students are familiar with digital images through their own collection and through those freely available on the internet. It is not a surprise that the basic techniques of digital photogrammetry can now be quickly learnt by those already exposed to modern computer systems. The introduction of automation into the photogrammetric workflow has further changed the skill base. Although the principles of photogrammetry are still necessary it is possible, by focussing on selected areas of photogrammetry, to blend many of the geospatial data collection processes together. This would help remove some of the more traditional boundaries of ground survey, photogrammetry, laser scanning and CAD/GIS/visualization. In doing this the students are experiencing an integrated process. Workflows are being developed based on practical centred learning where students experience a complete process for 3D geospatial data collection. Integrating the photogrammetric process closely with field activities provides students with experience of working in reality and virtual/computer based worlds. So, two processes for model building need to be developed; one based on high quality for demonstration purposes and student application exercises and one based on time-limited student practical model building exercises.

## 2.2 Resources and Facilities

During lectures, laboratory and practical session's students are equipped with a range of photogrammetric and vision systems to enable them to carry out a comprehensive workflow for 3D modelling of the test site. Usually aerial photography is used as the basis for most deliverables and the students are exposed to a range of different aerial photographs with varying quality, ground resolution and geometry characteristics. Usually the aerial photographs between the different test sites are captured by different types of sensors, film cameras and digital sensors giving the students an understanding of different acquisition systems.

For practical work a block of aerial photos is usually provided and the students are asked to perform the necessary photogrammetric orientations. There are two main softcopy photogrammetric systems used BAE Systems SOcET SET (laboratory based only) and Leica Photogrammetry Suite (LPS). On the field courses they are equipped with a 'portable' photogrammetric system using a laptop computer and LPS. Since portability is of high importance for the SPLINT project the photogrammetric software is running on powerful Dell Precision M90 mobile workstations, with stereo capable graphic cards. Nevertheless active stereoscopic display is still problematic due to the limited refresh rate (response time) of the LCD screens and so external CRT monitors are used when stereoscopic feature extraction is performed (Figure 1).



Figure 1. Portable photogrammetric system configuration

The students carry out all the necessary pre-photogrammetric processing steps including identifying and co-ordinating suitable photo control points. These control point co-ordinates are determined using static GPS observation with a range of dual frequency GPS receivers.

The students then undertake a series of photogrammetric exercises where they gain valuable experience creating value-added mapping products including Digital Surface Models (DSM), Digital Terrain Models (DTM) and ortho-images using a combination of automatic and manual methods. Stereoscopic feature extraction takes place using an active stereoscopic system from NuVision capable of displaying both quad-buffered stereo as well as red/blue anaglyph mode. Students are becoming familiar with the concept of stereo plotting using both stereo display modes and extract three-dimensional geographic information for their map compilation and 3D building modelling requirements (Figure 2).

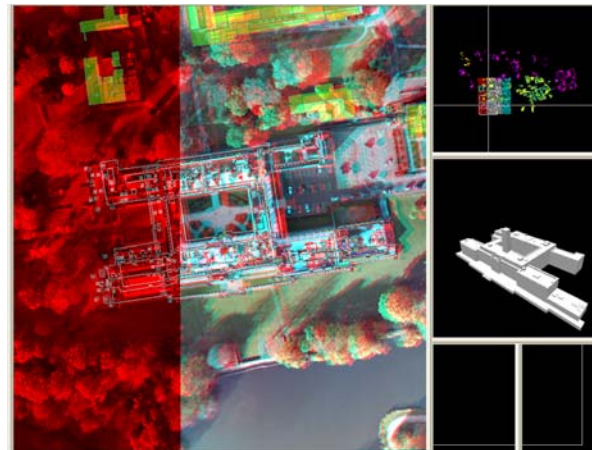


Figure 2. Stereo feature extraction in anaglyph mode and generation of 3D building models (Copyright of original UltraCamD images, BLOM Aerofilms Limited)

## 3. 3D MODELLING

Modelling of a 3D environment can be carried out in numerous ways dependent on the software available, the required output resolution and display media, the level of detail required to be represented, the available input data and the proposed output use for the model. Modelling for delivery over the web for example would require a more optimised, possibly less detailed, model than modelling for a high resolution stereo screen presentation system. Modelling a street to be shown in an overhead fly around requires a focus on different parts of the model than developing for a street level walk through. The aerial model could focus on roof textures whereas street level walk through needs high resolution fascia textures.

An awareness of these factors is vital in the development of fit-for-purpose 3D models. In the SPLINT CETL there is a dual focus on the development of both urban and rural landscape models. These models are being developed with a number of output goals in mind ranging from real-time widescreen stereo displays, through mobile stereo systems on tablet PCs and laptops, to captured stills or video on a PDA or smart phone.

### 3.1 Methodology and workflows

The SPLINT CETL funded the installation of a 3D stereo visualization suite at The University of Nottingham. The suite consists of a set of four projectors producing a polarised light passive stereo image on a 5m wide, 2.5m high screen. The suite was designed for use with Multigen-Paradigm Vega Prime and Bionatics Blueberry software to produce high quality landscape and urban visualizations. This software is highly specialised and used mainly by the military for their hardware simulations. It has therefore required a reasonable amount of training even for experienced 3D modellers at the University to be able to create high quality optimised models for the system.

The process of the development of models for use in the VR theatre was far from straightforward. This section will highlight the difficulties encountered by the authors while creating a VR landscape.

The main constraint on virtual world development was the software for which the distributed rendering hardware set-up (of image renderers, image blenders and projectors) was designed. The laboratory was built for use with Multigen-Paradigm's Vega Prime used in conjunction with the terrain optimisation package Blueberry (by Bionatics). These packages rely upon very specific model formats and have a large number of variables which change the rendering characteristics and performance of the application. Applications must be optimised to use the powerful hardware processing capabilities to the maximum without ever becoming over-demanding which would result in dropped frames and loss of smoothness in the virtual world.

The typical model is build up using a DTM, overlaid with both generalised vegetation and landscape features and a collection of specific models such as buildings which add integrity and realism to the world. Firstly, a georeferenced digital terrain model was converted by a Blueberry 'terrain tiler' to its specific terrain representation. This broke the landscape up into tiles, and created these tiles with many levels of detail so as to allow the Blueberry Run-Time Environment to render a highly detailed terrain close to the viewer, and fade that down to a much less detailed terrain in the distance. Secondly, a set of georeferenced aerial photographs were added to a Blueberry 'image tiler'. This applied a similar process to the imagery as the DTM. From experience, this process can take upwards of a week to complete – even on a high specification machine. Pre-processing, by halving the size of the image tiles reduced processing time to hours rather than days.

Features such as woodland, hedge lines, power cables, and waterways were then added. A Blueberry 'plug-in' called RealNat was used to create vegetation models with suitable variable levels of detail for use in the Blueberry environment. These general features were imported to Blueberry at points, along vectors, or within areas. The level of detail settings for each model and vector were adjusted manually to optimise performance in the Blueberry Run-Time Environment. An equally important part of the modelling process in a rural landscape was to create specific models, which may be key features in a landscape, such as a building. In an urban landscape this may be visually the most important feature in creating realism.

There are several options when it comes to building specific models for an application. The authors have identified some specific workflows to produce models usable in Multigen Paradigm Vega Prime in the visualization suite, summarised in Figure 3.

These involve the following four key tasks:

1. Obtaining initial wire-frame data for modelling buildings: Though sometimes already available in a usable form, this can be extracted from pre-existing vector data or from imagery by photogrammetric methods.
2. Fine Tuning Models: To add realism to a model, it is often necessary to refine its features, including building parts that may have been omitted by the initial modelling methods.
3. Texturing Models: Optimised textures can be created by manipulating digital photographs with a package such as Corel Paint Shop Pro. Important features are; correction of lens distortion and perspective, cutting and sizing appropriately for the level of detail required, and editing out obstructing features.

4. Converting Models: Reliable conversion methods are necessary to get models from the source format to the editing format, and from the editing format to the display format used by the VR engine. Experience has shown that exporters and importers rarely convert the model without the loss or corruption of some data. Common problems include faces becoming inverted, textures being lost or distorted, rescaling, repositioning, a reduction in simplicity of the objects and loss of certain faces.

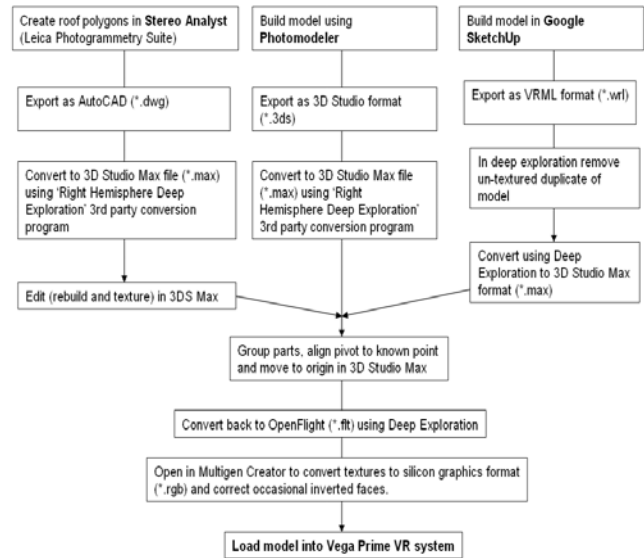


Figure 3. SPLINT Modelling workflows (after Burton, 2008)

There are three modelling pathways in Figure 3 which represent ways to get data from different capture sources into the stereo visualization suite. The left hand path uses airborne photography and photogrammetry via Leica Photogrammetry Suite's Stereo Analyst to capture the building wireframes. The central route uses ground based photography for the photogrammetry in the package Photomodeler. The right hand route uses the less accurate method of extruding models from aerial photography using Google SketchUp.

### 3.2 Students Workflow

There are numerous workflows that are possible to follow to create 3D models. These largely depend on the type and structure of the input data, how the models are going to be used or visualised and the software available. The left hand route in the flow diagram (Figure 3) is the one option selected for students to work through, and this is summarised again in Figure 4.

The 3D building models are created by initially plotting 3D polygons of most roof details visible on the aerial photos and the entire selection of polygons per building are extruded on the ground surface to create the final polyhedral building model. The students also gain an understanding of texture mapping concepts using a combination of automatic and manual techniques. Automatic texture mapping is used to texture the roof polygons by back-projecting them on the aerial photos. For manual texturing the students can use a selection of digital SLR cameras available in the IESSG/SPLINT from the low-end Nikon D100 up to the state-of-the-art Canon Eos mark II to capture the building facades. Manual texture mapping is

performed after the pictures are pre-processed. The pre-processing stage included cropping the images, correcting for radial lens distortions and any effects from the perspective geometry. The pictures are then draped using an affine or projective transformation on the building facades (Figure 5).

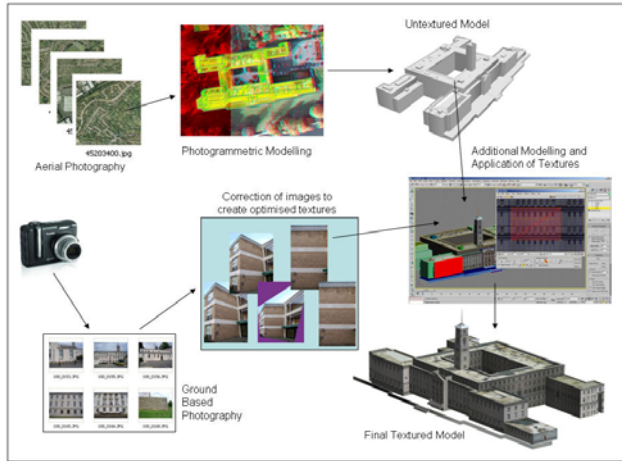


Figure 4. Diagram of the workflow to obtain textured models from aerial photogrammetry



Figure 5. Student attempt to create a photorealistic 3D scene of part of the University Park Campus, using textured models, trees and ortho-images draped on DTM's.

As an alternative to this process but very similar, workflow has been produced for the creation of 3D models for non-stereo visualisation which is more suitable as a time-limited student exercise. This is based on the use of ERDAS imagine Stereo Analyst and allows the students to experience automatic rendering from aerial images as well as rendering from terrestrial images. Figure 6 shows the work flow for this activity. As this involves manual texturing of facades the students have to examine the buildings in relation to the computer based model quite carefully to ensure there is no or minimal features, such as trees, covering the facade to imaged. If there is masking then 'photo' editing is necessary to remove the obstruction from the image. The final visualization is in VirtualGIS.

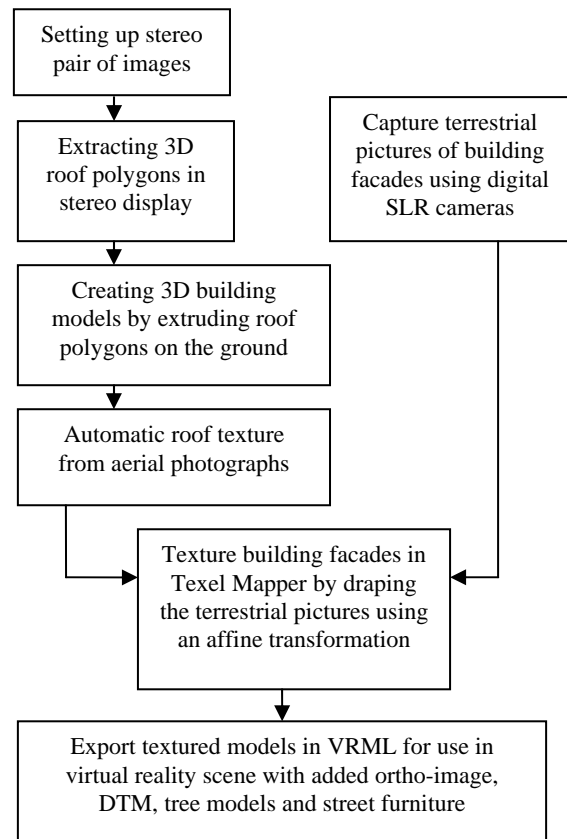


Figure 6. Simplified student's workflow for creating 3D building and a virtual reality scene of the University Park Campus

## 4. FIELD VISUALIZATION

### 4.1 Background and Early Methods

From a teaching and learning perspective it is important to encourage students to consider how well digital models represent their real world counterparts. For a number of years simple techniques have been used to allow students to augment a real scene in the field with computer-generated perspective views derived from a range of digital models (Priestnall, 2004). One such exercise involves students creating 3D views of a landscape from known points that they could visit that day in the field, allowing them to make a direct comparison with the real landscape. This engaged students in issues of data resolution and quality and allowed them to assess the types and scales of features which can, and cannot, be represented faithfully by certain digital model products. The NEXTmap 5m IfSAR Digital Surface Model has been used for this purpose on field trips to Cumbria, NW England. The terrain data is textured with colour aerial photography (Orthophotos from Getmapping) and 3D views are rendered from points chosen by the students in the modelling package Bryce. In addition to the contemporary view of terrain draped with photography, 3D glacial ice models are also made available so students can produce 3D views representing past landscapes. Printouts of such images were taken out into the field along with acetate versions of the glacial views to allow a simple augmented reality technique to be explored (shown in Figure 7).





Figure 7. Simple Augmented Reality Technique



Figure 8. Augmenting scenes through handheld Personal Digital Assistants (PDAs)

#### 4.2 Using Mobile Technology

The technique described above has been updated for recent field trips through the use of mobile technologies. PDAs (Figure 8) were chosen as a compromise between the portability of a mobile phone and the large touch screen of a tablet PC. The students upload the 3D views onto the PDA to give a series of georeferenced waypoints which are followed in the field. The use of geology data draped over the terrain is an additional representation which allows students to assess the influence of hidden geology upon the surface landscape they see before them. As the students approach a waypoint in the field the images are served up and they can switch between *contemporary*, *hidden* and *past* landscape views. A sketch facility has been developed to allow in field annotation of views. Other media served up to accompany these images include audio tracks describing the landscape history of areas that should be visible from that point on the Earth's surface, using pre-generated composite visibility maps to trigger the appropriate files. A description of the PDA application can be found in Priestnall and Polmear (2006).

#### 4.3 The way ahead

A range of alternative technologies continue to be explored with a view to augmenting real scenes, including the use of Head-Mounted Displays (HMDs), inertial devices, GPS and laptops in combination to deliver real-time 3D representations in the field. Experiments here would be considered to be partial Augmented Reality (AR) as there is currently no attempt being

made to overlay computer-generated models onto a video stream of the real scene for display on a translucent visor. The form of AR to be deployed will allow students to explore the various building models described in earlier sections out in the field as well as provide a real-time equivalent to the PDA technique.

### 5. CONCLUSIONS AND FUTURE ACTIVITIES

The refurbishment of laboratories and the purchase of equipment through the SPLINT project are now complete. Some student exercises have been developed and the student experiences are being evaluated to enable improvements and developments to take place. 3D modelling workflows need further optimisation to improve; the quality of the models, minimise the time student spend on the exercise and enhance the learning experience. Field visualisation will be explored through cost effective head mounted displays and further graphical representation on PDAs, tablet PCs and laptops.

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