Teaching and Learning Strategies for 3D Urban and Landscape Modelling

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SUMMARY

3D computer visualization of our world is becoming common place, appearing on the internet through popular map and geospatial information sites. Engineers and planners are becoming interested in the computer modelling of the environment to allow better visualization, greater understanding of the world, and for enhancing their decision making processes.

With the growth of a new technology or products there is a need for it to be introduced into the education system. Software providers are often the best source of providing 'training' in the software being used. What is often needed is a wider education in the concepts, principles, and applications to compliment the practical training in a particular software package.

For surveying educators the new technology and products associated with 3D modelling have caused a rethink of programmes of study. Often students are time limited and courses are already over-filled with content, so academics need to review whether the established methods of teaching and learning are appropriate.

This paper will present some of the methods that have been used to teach students at the later stages of undergraduate studies and at master's level, the basic concept, principles, viewing and applications of 3D urban and landscape modelling. Much of the student learning has been focused around the students developing an understanding through the practical experience of building models and gaining an appreciation of quality, through engagement with the 'real world' they are trying to recreate on the computer. This enables students to develop their skills in critical analysis and evaluation, in order to determine applications and fitness-for-purpose of the 3D computer models.

Much of this work has been undertaken as 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).

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1. INTRODUCTION

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With the growth of a new technology or products there is a need for it to be introduced into the education system. Software providers are often the best source of providing 'training' in the software being used. What is often needed is a wider education in the concepts, principles, and applications to compliment the practical training in a particular software package.

For surveying educators the new technology and products associated with 3D modelling have caused a rethink of programmes of study. Often students are time limited and courses are already over-filled with content, so academics need to review whether the established methods of teaching and learning are appropriate.

Landscape modelling is not new, in particular, photogrammetry and LiDAR have been producing landscape models for many years. These have been typically exported into CAD, surface modelling and GIS software for further use. 3D city or urban models and their merging with the landscape are often best viewed within a 'virtual reality' environment where a flythrough and 3D viewing are available. For surveyors, new methodologies are required to teach and produce these products which lead to new ways of preparing information for use and visualization.

The challenge of teaching the next generation of 3D urban and landscape modelers presents many unique challenges in an area where practical experience counts highly in understanding the requirements for a useful model. It is a field where a balance must be struck between modelling complexity, textural resolution, and available system resources. The different students and applications have different interests and requirements in 3D models. For example, the engineers may be interested in high quality measurement accuracy where as the geographers may be more interested in realism.

For the purposes of this paper we should define the word realism. The realism of a 3D model is a subjective measure combining some combination of physical accuracy, texturing, light and shade, surrounding environment, and seamless delivery. To get very high realism we arguably need a complex detailed model using high resolution photographic textures placed in an equally complex environment, and using ray tracing to give shadows and reflection, running at a high frame rate and at high resolution. All of these features however combine to create a heavy processing load, and we must be aware when modelling of the limitations of the delivery system. Real-time systems such as virtual or augmented reality have to render the models to screen at a high frame rate on the fly. This is only possible when the demands of the model do not exceed the available system resources in terms of graphics processing, and data transmission where the model is running online.

The approach taken at The University of Nottingham to get across these complex ideas involves a combination of traditional teaching and hands on experience with a range of data acquisition technologies, modelling techniques, real-time optimization techniques and presentation technologies.

2. SPATIAL LITERACY IN TEACHING (SPLINT) BACKGROUND

For many years, research activities in the Institute of Engineering Surveying and Space Geodesy (IESSG) and School of Geography have included the creation and visualization of computer based landscapes and urban models. This has now matured to the point where industry and the professions are becoming more interested in their creation and application. This has led to introducing this research into our teaching and learning. 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 (SPLINT, 2010a) is funded by the Higher Education Funding Council of England (HEFCE) (HEFCE, 2004).

2.1 SPLINT at Nottingham - 3D landscape and urban modelling

The 3D landscape and urban model building activities undertaken through SPLINT (SPLINT, 2010b) have focused on creation and visualization in both laboratory and field environments. By engaging students in field work activities and computer based modelling they have an opportunity to merge and understand the real and digital worlds, raising their spatial awareness. Augmenting the computer models of the real world with past, present, future information enables applications to be investigated, further raising the student’s spatial awareness. Having facilities to visualise the virtual environments particularly through stereoscopic viewing systems, provides the students with an opportunity to fully appreciate the model they have created and engage in an exciting way with geographical information. SPLINT with the aid of modern technological developments has enabled us to enhance the students learning experience in this way.

3. TEACHING AND LEARNING STRATEGIES

There is a range of degree courses at Nottingham which include the creation or handling of 3D building and landscapes, for example; civil engineering and geography undergraduate courses, and the MSc in Engineering Surveying and Geodesy and MSc in GIS courses. Within each course there would be different learning outcome requirements. For some courses no more than a brief overview is required and for others there is a need for an in-depth understanding. Two broad teaching and learning strategies have therefore developed. The first is based on the requirement for an appreciation of the process of model building and the product produced. The second is based on the need for a more comprehensive understanding and a certain 'reasonable' level of skill and competence being achieved. Often the strategy is dictated by the time constraints imposed.

Fundamental to both of these strategies is a hands-on approach to enhance the learning experience and enabling the students to engage with 'computer' and real worlds. As these are undergraduate and postgraduate courses, as well as enhancing student knowledge, it is also appropriate to engage the students in some level of critical thinking. This may be through the activity itself, a review of the activity, or through the assessment process. Assessment is dealt with in a later section.

3.1 An appreciation of 3D modelling

To gain an appreciation of 3D model building whether it is for buildings or a landscape does not require much time to be committed to the activity of actual model creation. Often a short introductory lecture followed by a number of examples and some visualization is sufficient. An awareness of 3D models can be achieved through knowing what they are; how they can be created and the example visualizations enable the students to think about applications appropriate to their field of interest. Often we try and timetable a brief lab session where they are provided with terrestrial digital images of a building and they use some commercial software to create perhaps no more than one façade of the building. This gives them that deeper understanding of the technology behind the process, the issues that have to be addressed (such as the photograph requirements), the quality of the photograph geometry of the façade and time to think about applications. Often an introduction of three hours is followed by a three hour practical.

3.2 A comprehensive understanding of 3D modelling

We use two approaches to developing a comprehensive understanding of 3D urban and landscape modelling. Firstly we engage some students in extensive project work where a number of lectures are then supported by a substantial piece of practical work. This may be part of a much larger mapping and data collection project but a significant part is involved with landscape modelling and building modelling. This type of exercise often takes place around the university campus so that the students have easy access to the field work as they are required to collect ground control and terrestrial photographs. They are also close to the laboratory facilities where they can view the photography and create the 3D landscapes and building models.

More recently, particularly through the support from SPLINT, these modelling activities have been taken to field courses. This has been largely through the availability of powerful laptops that now enable the digital photogrammetric processes to be undertaken away from university computing facilities.

Often, the field work, activities take place as a group activity with 2-6 members dependent on course. This also helps develop both team working and project and time management; which are very important transferable skills.

Not only do the students increase their knowledge of the subject and develop their skills and experience but the project often entails the students undertaking some form of critical analysis. This may take the form of a quality assessment or a comparative analysis of techniques.

3.3 Assessment

By the nature of 3D modelling the product produced is normally of a graphical form and the process to achieve this is a practical experience. The traditional approach to the assessment of this type of learning is to get the students to produce some form of report based largely on a scientific style and structure. Modern technology now allows the students to present their work in a much more appropriate form. Although written reporting is still used students are encouraged to present their work for assessment in one of the 'comprehensive' courses through the use of video. The students are given a video camera and they compile and edit the video taken and then produce a final video for assessment. This gives the students great flexibility to go into the field and compare the real world with the computer generated world and talk over the video to explain the workflow, and quality issues. The videos can then be viewed with the students and discussions undertaken.

An alternative method tried with great success is the use of oral presentations by groups allowing screen shots and discussions to take place. This is normally in front of the entire class so that there is some good discussion and cross fertilization of knowledge and ideas.

The discussions by the students from both of these methods of assessment are some of the most productive learning experiences for the students.

4. EXAMPLES OF TEACHING AND LEARNING STRATEGIES

The following are some examples of the strategies that have been discussed in section 3 and they will include both 'appreciation' and the 'comprehensive' strategies and experiences with a range of students from different backgrounds. Further details on some of these activities can be found in Smith et al. (2008).

4.1 Building Modelling

4.1.1 Providing an appreciation of 3D building modelling

To provide an appreciation of 3D building modelling; 3 hours of lectures on general close-range photogrammetry are followed by a 3 hour practical specifically on 3D building modelling. This is focused for 3rd year civil engineering undergraduate students and some masters students attending the 'Geospatial Engineering 1' module. This short practical aims to give an overview of using close-range photogrammetry principles for the purpose of creating a geometrically accurate and photorealistic 3D model of a building.

Due to time constraints students are provided with a number of overlapping images of the Nottingham Geospatial Building captured with a Canon EOS 5D Mark II that has been previously calibrated. A brief introduction on camera calibration and the optimum ways of capturing the images is explained but due to time constraints no hands-on experience is gained concerning the data acquisition. Instead students form groups of 2-3 persons per workstation and are given the task performing the necessary processing steps to create the 3D model.

Students make use of the software package ‘Photomodeler’ to perform all the processing stages, which is accompanied by a basic but comprehensive step by step guide prepared by members of staff. Supervision is constantly required not only for solving issues regarding the use of the particular software but also to explain the underlying photogrammetric concepts. Providing a short explanation about the underlying concepts of precise image measurements, geometric stability of the network of images, bundle block adjustment and texture mapping is very important due the simplified graphical user interface of the specific software.

At the end of the practical most teams are able to; reconstruct a few facades of the building, model the geometry with 3D planes and draping textures for a photorealistic result. They have also gained an appreciation of the importance of precise observation of tie points and the parameters affecting the geometric quality of the bundle block adjustment. Figure 1 illustrates some of the student results.

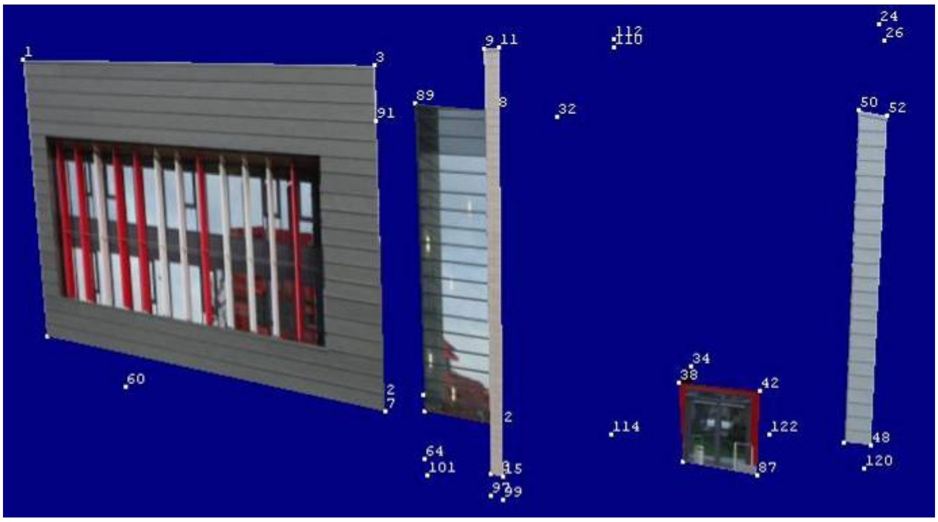

Figure 1. 3D facades of Nottingham Geospatial Building, created by students during a 3 hour practical on 3D modelling using Photomodeler

4.1.2 <u>Providing a comprehensive approach to 3D building modelling</u>

For a more comprehensive approach to the teaching of 3D modelling, The University of Nottingham have adopted the approach of combining taught lectures, with hands-on 3D model creation work and critical evaluation of the technologies used. The 3D modelling technologies applied vary dependent on the time constraints imposed by specific modules.

The modelling techniques used by the students have normally been at least two from the following list:

1. Google SketchUp - This is a modelling process which may be based on little or no real data or actual dimensions of the subject. Using a footprint of the building obtained from aerial photography and a personal knowledge of the building features, or ground-based photographs, a representation of the building can be created from simple primitive 3D shapes.
2. Photomodeler - In this ground-based Photogrammetry package, a collection of photographs around a building are taken, and used to semi-automatically create a 3D model of a building. The advantages of such a process are that the building can be created accurately in terms of both structure and textures.
3. Photomodeler Scanner – This is a version of Photomodeler which can automatically generate a 3D point cloud from a selection of ground based photographs of a building.
4. Laser scanner - Arguably the most accurate method for building modelling is to use a 3D laser scanner .The laser scanner uses reflected laser light to measure the distance between the scanner and an opaque object (e.g. building surface). It shines the laser in a pre-defined grid pattern onto the object measuring the distance to each target point, and is able to create a 3D point cloud of an object, for example a building façade.
5. Aerial Photogrammetry – Using Leica Photogrammetry Suite (LPS) and stereo pairs of aerial photographs, points can be observed in three dimensions to create building models.

For the past 2 years geography students on the 3rd year undergraduate and master's level 'Visualization' module have been required to produce models of a real building located on The University of Nottingham Campus as part of a group project. Groups of (usually) four students were asked to select a particular building and model it using both Google SketchUp and Photomodeler. They were given access to high specification desktop PCs and software hardware such as digital cameras, GPS, enabled mobile devices and measuring tapes (much of this courtesy of the SPLINT project).

Assessment on this module is based partly on the quality of the models produced, but also on an oral presentation given by the groups detailing their experiences and the relative merits of the software as perceived by the group from their experiences. Feedback was also given to the students in the form of a session in a passive stereoscopic visualisation theatre, where the students' models were loaded into a VR version of campus enabling an ability to toggle between the SketchUp and Photomodeler models created. Research and teaching staff were then able to use the students own models to highlight differences/inaccuracies in the models that enable reflection on strengths and weaknesses of the modelling methods used. Additionally, the importing of the model data into the stereo VR environment sometimes incurs loss or corruption of model data, and these failures in the conversion process can be highlighted to give additional insights into difficulties encountered by professional 3D modellers.

During the ‘Visualization’ module project, the students created models using only SketchUp and Photomodeler and had significantly more time than on the field course modules (see later in this section) to create them. For this reason the models were expected to be more detailed and capturing fine detail of any complex structure. Creating highly detailed models can cause further problems in the modeling process: for example in the case of Photomodeler, a more complex model involves more points which take a greater time to process.

Figure 2 shows some models from the final stereoscopic visualization session where discussions on the relative quality of the models created and the possible reasons for differences between them take place with the whole group of students.

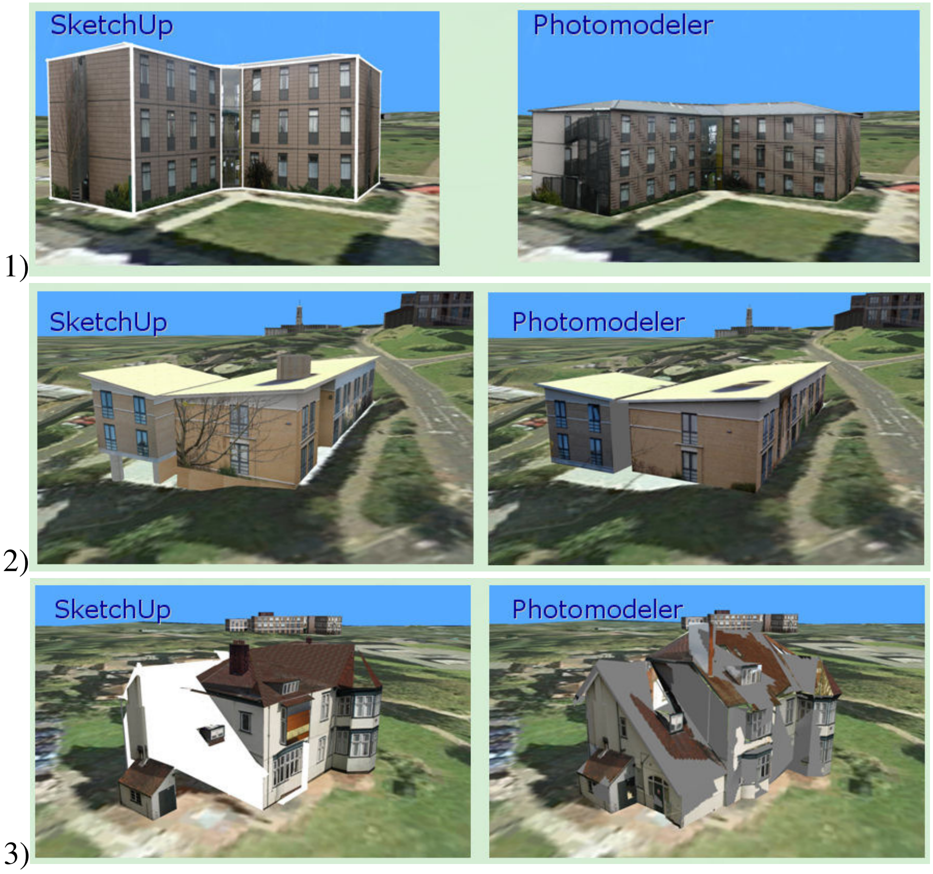

Figure 2. Models of buildings on the University Park campus created by groups of students: 1) difficulty in gauging correct heights in SketchUp; 2) Difficulty in replicating complex or curved features in Photomodeler; 3) Texture and geometry export issues experienced from both SketchUp and Photomodeler.

For the past 2 years a field course module entitled ‘Mobile and Field GIS’ has enabled students to undertake a 1 day group project on 3D Modelling. It is a team project where groups of around 4 students have been asked to select buildings from the locality and model them using Google SketchUp and Photomodeler. Field facilities would historically have limited the ability to undertake such process heavy work in the field, but the student's use a set of 18 high powered Dell M90 laptops, purchased as part of the SPLINT project, in the field centre. On the 2009 trip the groups were also asked to use Photomodeler Scanner to model a building. A demonstration of a terrestrial laser scanner was also implemented and the students were presented with the point cloud data from a fascia of the building and asked to process the data. A separate one day project was also undertaken in 2009 utilising a process of aerial photogrammetry with stereo pairs of photographs to collect both terrain and building data.

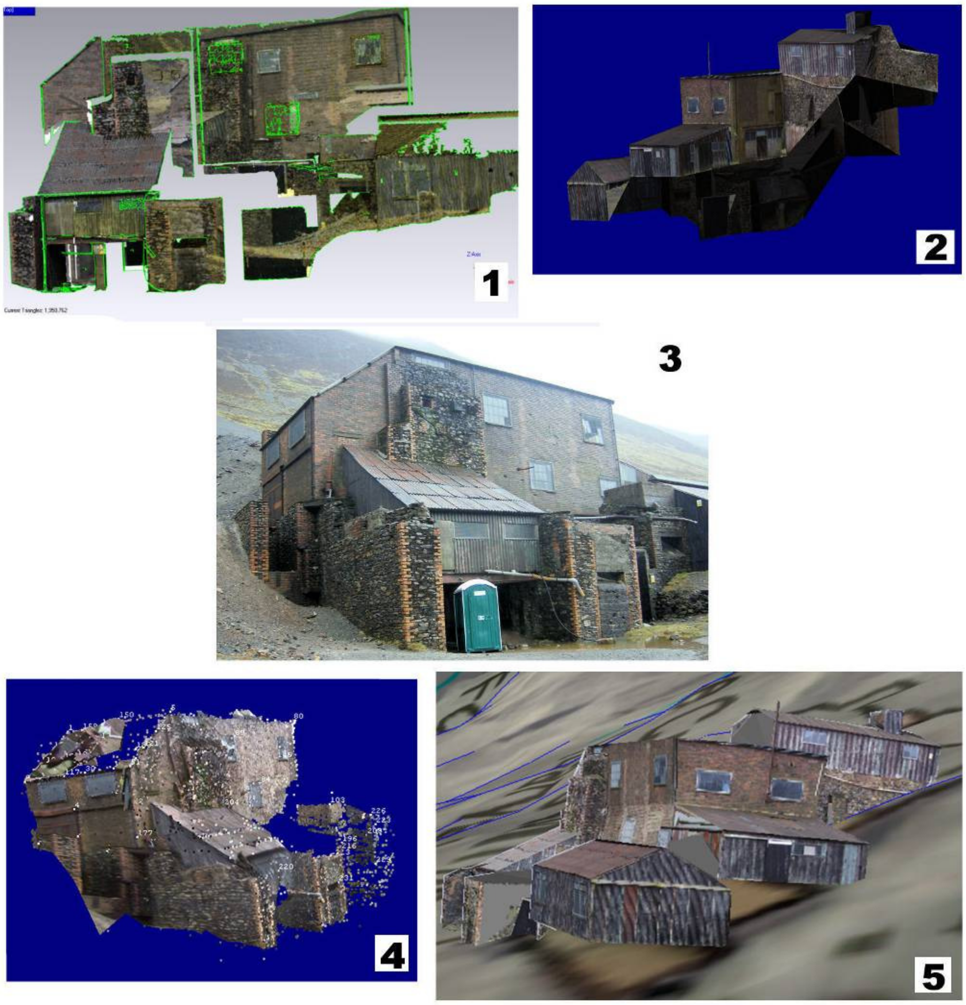

Figure 3. Models of Force Crag Mine created by a student groups on the Mobile and Field GIS field course: 1) laser scanned model; 2) Photomodeler model; 3) A photograph for comparison; 4) Photomodeler Scanner; 5) Google SketchUp model viewed in Google Earth

Assessment on this project was based on an oral presentation given at the end of the day by the groups detailing their experiences and their perceived relative merits of the processes based on their experiences during the day. The groups were given a digital camera, a video camera, and two laptops with which to undertake the tasks and to create their presentation.

Figure 3 shows models created by a single group during the modelling day of the ‘Mobile and Field GIS’ field course.

Mobile and Field GIS students noted very similar observations about Photomodeler and Google SketchUp to those observed in the visualisation module, but tended to be even more critical about the comparative accuracies of the techniques. This is probably due to the additional comparisons they could make with models from the more accurate scanning techniques.

One of the major advantages of the comprehensive approach to the teaching of 3D building modelling taken in these two modules is its ability to give students a real grasp of the issues professional 3D modellers encounter during their work. It is expected that hands-on experience with diverse software packages encompassing different forms of 3D data collection, manipulation and conversion enables students to understand the complexities and uncertainties within each modelling process to a greater degree than could be achieved by a more traditional lecture and demonstration approach.

Witnessing and experiencing the frustrations of a computer slowing and struggling to process highly detailed 3D data, such as laser scanned point clouds or whilst calculating positions of points from sets of photographs in ground based photogrammetry can instil a real understanding of the need for optimisation in 3D modelling.

It is hoped that getting students to examine the different modelling processes used and to compare and contrast the results that can be achieved can strengthen their understanding of the overall process of 3D modelling.

4.2 Landscape modelling

4.2.1 Providing an appreciation of landscape modelling

A further project on the ‘Mobile and Field GIS’ field course module, normally undertaken in the English Lake District, is to create a ‘geometrically accurate’ representation of the terrain using a stereo pair of scanned traditional aerial photographs. Students are given the images together with handouts, the necessary control points and camera calibration certificate in order to carry out digital photogrammetric processing using Leica Photogrammetry Suite running on Dell Precision M90 mobile workstations.

This task gives the students an appreciation of the photogrammetric tasks involved in extracting geometric features using aerial photogrammetry and familiarizes them with the following:

1. Co-ordinate systems and projections
2. Principles of aerial survey, overlap, importance of base to height ratio and scanning resolution
3. Ground Sample distance and radiometric quality of scanned images

4. Precise identification and measurement of distinct points and other features from aerial photos
5. Basic photogrammetric workflow procedures: camera calibration, aerial triangulation and stereo matching, automatic DSM generation, terrain filtering and ortho-image production.

The timeframe for the completion of the Digital Surface Model (DSM) and ortho-image production is usually one working day but can vary depending on the progress of each group of students. The outcome of this task is to create a DSM and an ortho-image of the area of interest that will be used for visualization purposes at a later stage, and to understand the quality issues involved in this process. This process provides the landscape for the students to add the 3D building model they also create in the module, see figure 4.

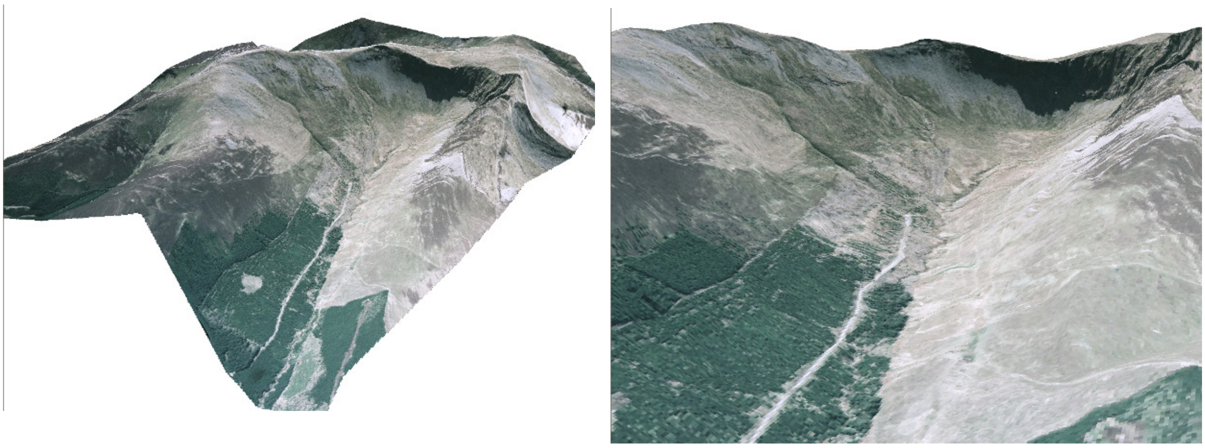

Figure 4. Landscape model of part of the Lake District, created by geography students during the "Mobile and Field GIS field course"

4.2.2 Providing a comprehensive approach to landscape modelling

During a two semester practical module, students on the MSc in Environmental Management and Earth Observation are given the task to create a number of mapping products using airborne photogrammetric principles. This is the most comprehensive photogrammetric practical for creating landscape modeling undertaken by students at Nottingham. The students also undertake modules that provide the background theory of the tasks they are performing.

Students are provided with a block of 84 overlapping aerial photographs collected from state of the art airborne digital sensors covering the University Park campus. The aim of this module is to give the students a comprehensive understanding of the issues and processes involved when creating a number of mapping products, namely:

1. Digital Surface Models and Digital Terrain Models
2. Ortho-images and large scale topographic maps
3. 3D Models and texture mapping

During this module the students work independently with access to a powerful workstation and related software to carry out the modelling tasks. By the end of the module students gain a comprehensive understanding of the following key topics:

1. Local co-ordinate systems and map projections
2. Principles of aerial survey, overlap, importance of base to height ratio
3. Ground sample distance and radiometric quality
4. Precision identification and measurement of distinct points and other features from aerial photos
5. Principles of Stereo display and stereo plotting for 3D feature extraction
6. Defining camera models and camera calibration
7. Aerial triangulation with self calibration, direct geo-referencing, GPS & IMU integration
8. Stereo matching, automatic DSM generation and terrain editing
9. Ortho-image mosaic production
10. 3D modelling using stereo plotting and 3D model editing
11. Texture mapping and visualization.

Figure 5. 3D building models merged with the terrain model, ortho-images and building texturing of the University Park campus

Students are asked to present their work by combining the DTMs, ortho-image and geometrically accurate, photorealistic 3D building models of the University Park campus (see figure 5) in a 3D rendering engine thus gaining an appreciation of the issues involved with real time 3D rendering of detailed 3D models. For assessment these students are given the option to produce a traditional written report or produce a video.

4.3 Presentation strategies

Models created can be presented in a number of way for example, as detailed images or for a video flythrough. This is a common use for 3D models and one that is often employed by students in PowerPoint presentations. Students gain experience in capturing stills and exporting and/or capturing video. They often also gain some insight into video formats and codecs when trying to make their videos play in their presentations. Video flythrough exports from most 3D modelling packages play irrespective of the level of optimisation of the model, although the package can take hours to render for a few seconds of video. Real-time applications however are a very different proposition.

There are various methods used to optimise models, which are introduced to the students, so as not to overload the processor in real-time VR and AR applications. These include:

1. Levels of Detail (LODs), where a number of versions of a model are created at different complexities, the loading of which is controlled in real time in order to optimise performance. More complex models are loaded only when the viewer is close to them, the model being replaced with less complex, lower resolution versions at distance (see the trees in figure 6)
2. Photographic representation of detail, where complex modelling is avoided by using photographic textures, giving an impression of actual geometric detail being present.
3. Landscape tiling, where a terrain is broken down into tiles in terms of both its elevation data and texture in order to allow highly detailed terrain representations in real-time applications.

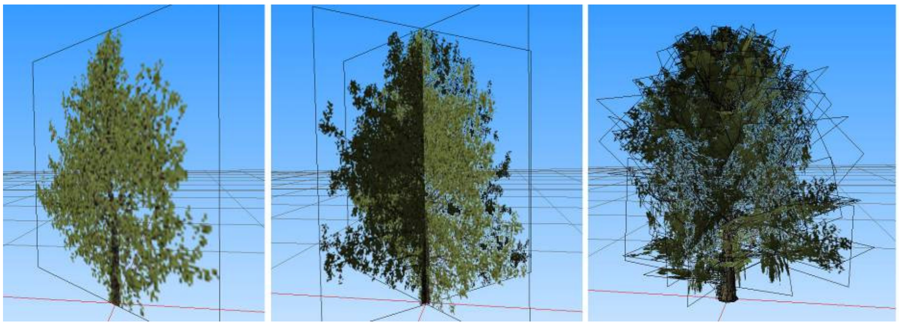

Figure 6. Three levels of detail for a tree model

These factors are best demonstrated using the stereoscopic visualisation theatre or a mobile stereoscopic viewing system, both of which are available as a part of the SPLINT facilities. The students gain an appreciation of these issues through exercises such as; locating a wind farm, intervisibility studies, or in physical geography studies showing the relationships between geology, landform and vegetation. The tiling of a landscape model's terrain and elevation meshes can be demonstrated by moving through a virtual landscape in the SPLINT visualisation theatre faster than the design maximum speed. As movement through the model is then slowed, the aerial photography used as ground textures will be seen to increase in resolution revealing the tiled nature of the 'active degradation' approach.

The visualisation theatre model can also be switched to a wireframe mode which reveals the changes in the ground mesh as the viewer moves through the model. The active degradation approach here uses the highest detail terrain model close up and much lower resolution data for distant landforms. After moving very quickly through the model a low resolution landform will be present close to the viewer and will be seen to increase through the resolution set to the highest available.

Vegetation with multiple levels of detail, such as the trees in figure 6 is also used in the visualisation theatre models. When used perfectly, the process should be almost unnoticeable to the human eye. However, by moving faster through the model than the design maximum speed, or by altering the distances at which the LOD change, changes can be made obvious as a method of demonstrating the process.

During these demonstrations students are encouraged to question what they are seeing and ask about any phenomena they witness that they do not understand. Questions from students often bring to light interesting issues, such as z-buffering effects, issues of time of day/lighting in model textures and issues of correlation between models and their underlying landscape in terms of both the terrain and the imagery.

5. CONCLUSIONS

The developments of these teaching and learning strategies have now been through at least one cohort of students. The experiences have shown that being realistic in what the students can learn in the time available is important. Often we are not trying to make surveyors into computer modelers but trying to impart the knowledge or experience to suit the student’s particular course and interest. What has started to come out of the experience to date through the student questions and discussions are the beginnings of identification of the key factors required for a good understanding of 3D modelling tasks. These include the following:

1. The importance of modelling for purpose
2. An ability to weigh up accuracy in relation to; measurement, completeness of model and realism
3. Ways of efficiently representing detail
4. Understanding the limitations of specific rendering hardware
5. The relative advantages of different modelling thechniques.

In the future there is a need to teach the importance of meta-data, develop an appreciation of how real can the computer representation be and how transferable are the models between application software.

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