Interactive Visual Simulation of Coastal Landscape Change

Philip PAAR, Katy APPLETON, Malte CLASEN,
Maria GENSEL, Simon JUDE, Andrew LOVETT

Abstract

This paper describes and evaluates the application of the interactive landscape visualisation system Biosphere3D in a case study of cliff erosion in Norfolk, on the eastern coast of England. The study builds upon previous work on coastal zone management by the Tyndall Centre for Climate Change Research at the University of East Anglia. Biosphere3D is an open-source system, which supports multiple scales on a virtual globe, loads GIS data at runtime, and focuses on real-time rendering of vegetation and foreground detail. The 3D landscape model has been developed by using scientific modelling data on cliff retreat to define changes in digital elevation models and then incorporating other spatially referenced content to represent natural and man-made features. We compare the use of Biosphere 3D with previously-employed visualisation techniques and discuss the requirements of digital globes to support more convincing depiction of local visual landscape impacts of global change.

1 Introduction

Issues relating to sea level rise and flooding are widely recognised as an important aspect of hazards related to climate change in many countries (e.g. DEFRA 2008). Challenges also exist in communicating the issues and management options to local communities and it has been suggested that 3D landscape visualisation techniques could play a role in facilitating stakeholder engagement and more informed discussion of different policies (SHEPHERD 2005).

The capacity to produce 3D landscape visualisations has been transformed in the past decade by a combination of developments in computer performance, software integration and data availability (APPLETON et al. 2002, PAAR 2006). It is now feasible to take a range of spatial data in a GIS and produce visualisation products which include photorealistic still images, animated sequences and real-time models where the user can interactively alter their viewing position or the environmental content. Since the advent of Google Earth in 2005 interactive geobrowsers and digital globes have also become popular tools for the display of spatial data, particularly in the form of 2D maps or imagery draped on a terrain surface. More recently, the use of such geobrowsers has expanded to include 3D buildings and virtual city models[1], but little attention has been given to capabilities such as the ability to alter terrain or realistic visualisation of vegetation or other landscape features.

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[1] e.g. http://sketchup.google.com/3dwh/citiesin3d/index.html

A significant part of the challenge in creating a real-time landscape visualisation is the management of Levels of Detail (LoD) so that there is as good a balance as possible between interactivity (e.g. the ability to move through a scene) and the realism with which features are represented. This is important because several studies have demonstrated that the level of detail, particularly for foreground features like vegetation or water, is a key influence on how people relate to such computer-generated visualisations (APPLETON & LOVETT 2003). Particular difficulties can occur in heavily vegetated areas with thousands of individual plants or trees, or landscapes where the details of terrain elevation and texture are important, such as coastal areas. This paper illustrates an approach to tackling these issues in the context of representing local visual landscape impacts of global change, focusing on the issue of sea level rise and coastal erosion in part of eastern England.

2 Study Area and Data Processing

The study area is located along the northeast Norfolk coast in eastern England, where cliffs up to 40m in height are found between Sheringham and Happisburgh. These cliffs, consist of Quaternary deposits, are characterised by rapid rates of erosion of approximately 0.5-2m per year, and are potentially sensitive to climate change (NICHOLLS et al. 2000). The area is one where it is increasingly recognised that it will not be possible to protect all parts of the coast[2] and consequently there are issues regarding the assessment of erosion risk and policy formulation, which require careful consultation and communication between decision-makers and members of the public. Research using visualisation techniques to represent cliff erosion scenarios and policy options has been carried out as part of the coastal zone programme of the Tyndall Centre for Climate Change Research (e.g. JUDE et al. 2003; BROWN et al. 2006). Fig. 1 shows an example of a real-time visualisation created during this research using the Terra Vista software[3]. Display of land cover and water features in this model was achieved primarily with draped images incorporating different colours and textures, and the only vegetation shown as 3D models was selected trees. Navigation around the model was reasonably efficient but there were inevitably limits on realism, especially for ground level views.

The research by BROWN et al. (2006) linked a cliff erosion model to visualisation capabilities to produce representations of cliff change through to 2010 under different climate change scenarios. In this paper we have used the results of the low scenario from BROWN et al. (2006) which assumes that sea level rise occurs at an average rate of 2mm/year and the wind wave regime remains the same as present. Digital elevation models (DEMs), an ortho-rectified colour aerial photograph, Ordnance Survey digital mapping and simple 3D building models were taken from the database compiled by BROWN et al. (2006). Additionally, we used a DEM based on merged hole-filled SRTM V3 90m tiles[4] and a Blue Marble[5] satellite image for background areas.

[2] e.g. http://news.bbc.co.uk/1/hi/uk/7567385.stm
[3] http://www.presagis.com/products/content_creation/details/terra_vista
[4] King’s College, http://www.kcl.ac.uk/schools/sspp/geography/research/emm/geodata/topoview.html
[5] http://earthobservatory.nasa.gov/Newsroom/BlueMarble

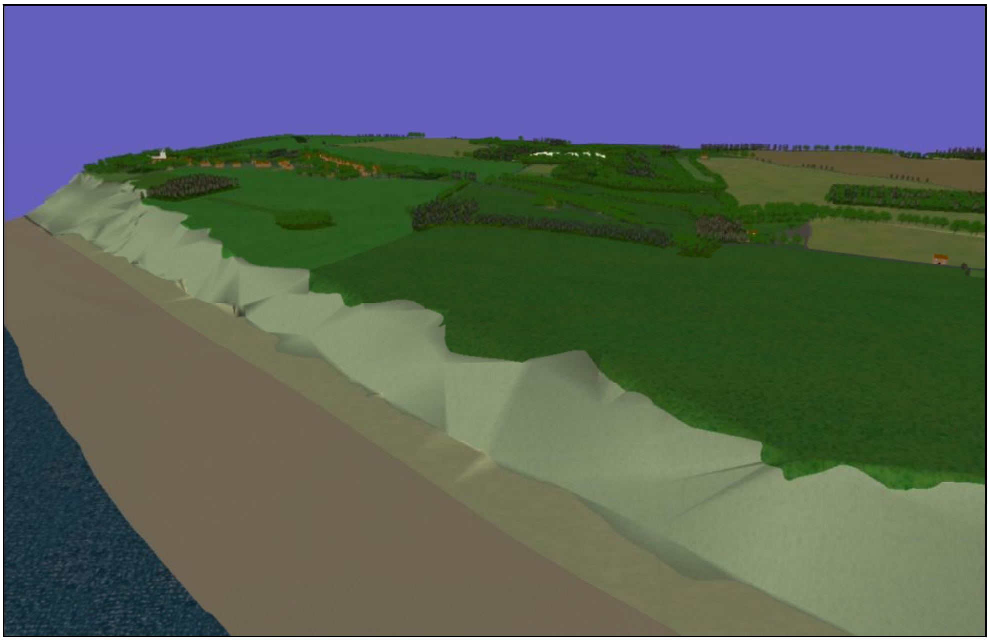

Fig. 1: Screenshot created in Presagis Terra Vista of an interactive visualisation developed by Brown et al. (2006) showing the coastal environment in 2001

3 Methods for 3D Landscape Visualisation from GIS Data

Biosphere3D has been designed as a pure visualisation system; user interaction is currently limited to the rendering settings such as camera position and layer management (PAAR & CLASEN 2007). Modelling of landscape features occurs in external applications such as GIS, simulation models with GIS data output and 3D CAD tools such as Google SketchUp. Unlimited terrain can be visualized due to the spherical terrain model and efficient data management (CLASEN & HEGE 2006, 2007). Satellite images, raster DEMS, and aerial photos of multiple terabyte size can be loaded and combined with precalculated vegetation plots (RÖHRICHT 2005) based on vector shapes and biological sample data to create photorealistic views, e.g. of before-and-after conditions. Three-dimensional plant[6] models are assigned to plant distribution maps and likewise 3D building models positioned on the terrain model.

4 Results

Figs. 2, 3 and 4 illustrate the results of processing the cliff dataset of BROWN et al. (2006) and enriching their 3D model with more detailed vegetation layers, a physics-bases

[6] Flora3D, http://www.lenne3d.com

atmosphere and a global DEM and satellite dataset for the background. Water shading was implemented in Biosphere3D to provide more convincing representation of the sea. PC system requirements to run the real-time model were a 64 bit Windows XP or Vista, a quad core PC with 4-8 GB of RAM and a gamer NVIDIA GeForce GPU (8 series or newer).

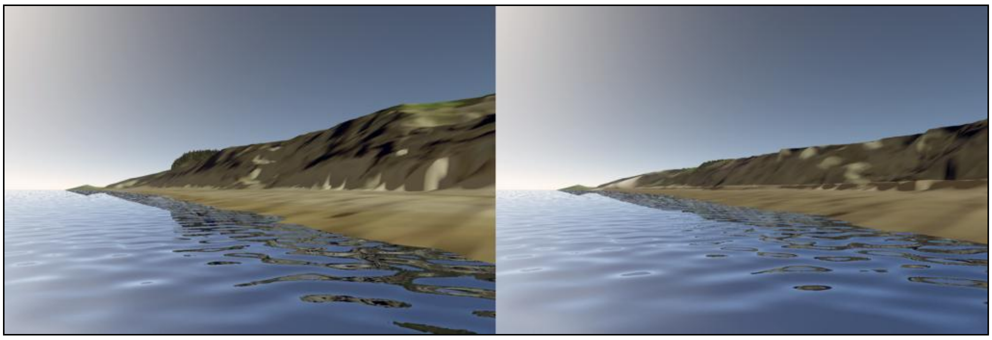

Fig. 2+3: Before and after views from the interactive visualisations of the Norfolk study area showing: (a) the coastal environment in 2001; (b) the simulated cliff recession for 2100 AD at the same location

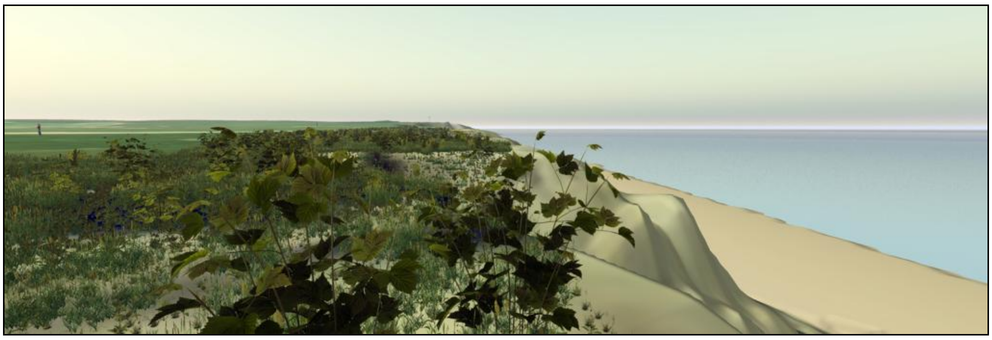

Fig. 4: Screenshot from the interactive visualisations of the coastal study area showing the simulated cliff recession for 2100 AD with 3D vegetation

4 Discussion

The visualisation produced using Biosphere3D illustrate how the technical capabilities of real-time visualisation tools and virtual globes are continuing to advance. Compared to the previous visualisation generated with Terra Vista it has been possible to place the study sites within a background setting and incorporate much more realistic representations of vegetation and water features. Such attributes are very important if such software tools are going to be used more widely to support local and regional communication of information and decision making on global change issues (SHEPPARD et al. 2007).

The experience of undertaking this research has nevertheless highlighted a number of issues where further improvements are required. One concerns the representation of cliff features. The existing terrain model approach is 2.5 dimensional. Cliffs tend to have overlapping areas where a real 3D model is required. This could be solved either by overlaying custom modelled 3D data, or by extending the terrain renderer itself. Since there is no standard way in GIS applications to tackle such a problem, the solution might be affected by the tools that generate the data. A second visual deficiency is related to the current wave model. Our water surfaces are disturbed isotropically with a single wavelength. Waves are usually caused by a directional source, for example wind or flow, so an anisotropic approach would improve the appearance for rivers and near coasts. The single wavelength restriction leads to smooth waves, whereas real waves have an almost fractal appearance with rapidly diminishing amplitudes. Since reflections depend on the derivative of the surface, this results in a well perceptible difference.

Other aspects of interactivity are also important in the context of decision support. The software used here generates a landscape where the user can easily alter their viewpoint, but change within the landscape is conveyed only on a comparative static basis (i.e. comparing one scenario with another) rather than via a more dynamic approach. Sets of still images could be combined to produce an animated sequence showing cliff erosion, but including such animated change directly within a real-time model would pose major challenges in terms of data integration and processing power. More broadly, what is needed in many consultation and decision-making situations is a 'what if' capability where users can request alterations to underlying data or scenario parameters and see the outcomes virtually instantaneously as a 3D landscape visualisation. Researchers are now starting to develop systems with such capabilities (e.g. STOCK et al. 2007), but substantial challenges remain in terms of dynamically linking simulation models and realistic 3D landscape visualisations.

6 Conclusion and Outlook

Biosphere3D is an advance on current geobrowsers and some expensive visualisation tools in its ability to incorporate large numbers of 3D plant models and so provide more realistic interactive depiction of landscape and landscape change from eye-level viewpoints. It also illustrates how interactive landscape visualisations on Digital Earth have the potential to be developed into more perceptually efficacious and 'natural' user interfaces for environmental planning processes, e.g. for local and regional mitigation of climate change. In the future it is likely that many scientists, planners and landscape architects will publish their projects on such digital platforms addressing stakeholders and the general public. Currently, mainstream tools like Google Earth or Microsoft Virtual Earth offer easy and wide access to Internet users. Biosphere 3D illustrates how this 'digital tool box' can be extended to provide necessary support for professional environmental planning processes through state-of-the-art representation of vegetation and advanced processing of terrain.

Acknowledgements

The Biosphere 3D open source system has been developed and used to visualize forests within the German research project SILVISIO, funded by the Federal Ministry of

Education and Research. The authors would like to thank BROWN et al. (2006) and the Tyndall Centre for Climate Change Research for providing the cliff data set.

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