Exploring Future Coastlines – Initial Steps Towards the Development of an Integrated Coastal Simulation and Visualisation System

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1 Introduction

Recent research has illustrated how visualisations can be produced to represent future coastal change to members of the public and has also identified their potential value in participatory coastal management processes (JUDE, 2003; JUDE ET AL, 2003). The same research has also highlighted a number of potential requirements for additional functionality that has been expressed by coastal managers, and which pose interesting challenges to those involved not only in the field of visualisation, but also GIS and wider coastal science. Key to this has been the desire from coastal managers to have access to integrated decision-support and visualisation systems for use during the development and communication of future coastal management policies. For example, during interviews with coastal managers a common question has been:

‘How easy would it be for people to say what would happen if you did this? Is it possible to input data on the basic plan fairly quickly and a few seconds later a new image comes up illustrating what it would look like, or has it not reached that stage? That’s the sort of thing people are likely to ask in meetings?’

Coastal partnership representative.

In response to such needs, research funded by the Tyndall Centre for Climate Change Research has been addressing the challenge of assessing and visualising future coastal change. This paper describes how a multi-organisational and interdisciplinary research project has linked a number of component projects using a GIS framework with the aim of providing a new approach to explore the long-term implications of future coastal policies.

2 Initial Steps Towards an Integrated Coastal Simulator

The research presented in this paper contributes towards the development of a Regional Coastal Simulator which aims to bring together a number of Tyndall Centre funded coastal research projects to create an integrated tool that will enable coastal managers to assess and visualise the impact of future coastal management options on the coast. Whilst the ultimate aim of the Simulator is to facilitate assessments at the regional level, this paper describes the results of preliminary research that has developed methodologies to assess and visualise coastal change along cliffed sections of the North Norfolk coast that are suffering from erosion.
2.1 Modelling Cliff Recession

The first module to have been developed for the Simulator has been a cliff recession modelling component. Key to the cliff recession module (Fig. 1) is the Soft Cliff and Platform Erosion (SCAPE) process based model that determines the reshaping and retreat of shore profiles along the coast (WALKDEN AND HALL, 2002). As Figure 1 illustrates, key inputs to the model consist of data on the initial cliff profile and the cliff geology, with future wave and water level predictions for a number of climate change scenarios being used by SCAPE to identify future cliff top and toe locations.

![Diagram of the SCAPE model and related data inputs](image)

Fig. 1: The projects making up the cliffed coast assessment module, and the organisations providing the data/models.

One difficulty from a GIS and visualisation perspective is that the SCAPE model outputs numerical predictions of cliff recession at a particular point along the section of coastline.
under investigation in the form of an ASCII data file that lacks any georeferencing. To facilitate the integration of the SCAPE results in the GIS, an ArcView extension was developed that imports and transforms the SCAPE data creating cliff recession points, lines and polygons (Fig. 2). This enables the location of future cliff lines to be identified. When used with other GIS datasets it also provides the ability to quantify potential areas of land and properties at risk, together with the inputs into the local coastal sediment budget resulting from the eroding cliffs. Furthermore, by repeating the modelling process it is possible to investigate alternative scenarios, such as the removal of sea defences.

3 Visualising the Results

Whilst the 2-dimensional (2D) GIS analyses provided by the cliff recession module may prove to be adequate for coastal managers to interpret and understand, they may be of less use to members of the public who may be affected by future coastal change. Hence, the results have been used to create a number of visualisations representing the future landscapes identified.
The initial stage in the visualisation process involved deriving future landcover and digital elevation models (DEMs) that reflected the future changes identified at the study locations under the policy options being investigated. This was found to be particularly challenging because the 2D output from the SCAPE GIS had to be extrapolated into 3-dimensional (3D) DEMs representing the future cliff evolution. Furthermore, it became apparent that the recession lines provided insufficient detail to facilitate the production of visualisations because the recession points used by SCAPE lie 300m apart (Fig. 3). To overcome this, additional detail was added using linear interpolation of recession distances based on the nearest two SCAPE points to provide recession points at 5m intervals, thus retaining the detailed bays and headlands along the coast (Figure 3).

Two metre resolution LiDAR data was used to provide the underlying terrain for the visualisation of the cliffs because the 10m resolution of the Ordnance Survey’s Land-Form PROFILE DEM was found to be too coarse to adequately visualise the cliff profile. To represent future change along the coastline the area of the DEM between the future cliff base and the present cliff base was edited and lowered to an elevation representing the shore platform and beach to represent the cliff erosion. Due to the difficulties associated with predicting future cliff profiles over time, the current slope of the cliff was maintained by isolating it, applying an affine transformation using present and future SCAPE reference points. This was subsequently integrated with the zone between the future cliff base and cliff top by stitching the two grids together.

For the cliffed section of the coastline the visualisation process used 1:2,500 scale Ordnance Survey MasterMap Topology data incorporating additional editing based on MasterMap 25cm resolution aerial imagery to represent the landcover. Future land-cover change resulting from cliff recession was identified by using predictive scenarios based upon expert judgement regarding likely future conditions in the study area (JUDE, 2003), with building data provided by the Ordnance Survey MasterMap Address dataset. Visualisations representing the possible future coastal change were produced in the form of real-time virtual reality environments. This initially involved importing the GIS data into
the Terrex Terra Vista 3D terrain database creation software. A series of landcover textures based on the MasterMap aerial imagery were created imported into Terra Vista, as were 3D vegetation and building models produced using Bionatics REALnat and MultiGen ModelBuilder3D. Each of the models and textures were subsequently assigned to the GIS data, with OpenFlight terrain databases compiled to produce the real-time visualisations for the study area (Fig. 4 and Fig. 5).

Fig. 4: A real-time visualisation representing the present cliff location.

Fig. 5: A real-time visualisations representing the future cliff location (2100).
3.1 Challenges Encountered

Inevitably, the multi-institution and interdisciplinary nature of the project resulted in a number of challenges being encountered, not least when attempting to link the different elements together. Overcoming them has required frequent contact between those developing the different components of the models and has provided those involved with a greater understanding of the challenges facing the different disciplines working on the project. In the future it is hoped to make use of emerging Access Grid and Grid technologies to aid interaction not only between researchers, but also with stakeholders.

As with many GIS projects, data availability issues have been evident, particularly due to the requirement for high resolution elevation models such as LiDAR which is frequently unavailable for study sites. Furthermore, data format issues have been problematic with different input projects utilising a variety of data types that have required conversion and modification to enable their results to be fed into the other models. This situation has been further complicated by scale issues, and as the cliff recession modelling and visualisation has illustrated, that to produce high resolution visualisations that contain an acceptable level of detail for end users, additional detail has had to be added to the underlying scientific output.

4 Towards the Development of an Integrated Simulation and Visualisation System

At present the research has illustrated a loosely coupled process that enables the assessment and subsequent visualisation of future coastal change for a single distinct type of coastline. Using the methods outlined, a number of possible sea level rise and policy options have been assessed in a bid to further test and refine the process. This has provided a series of quantitative results and accompanying visualisations that illustrate the potential impact of future change along the coast.

Now that some of the methodologies are in place there is a need to move towards the development of a more integrated system to use them. To address this, preliminary work is currently underway to link the quantitative results with the visualisations enabling users to explore a number of predefined schemes, with another strand of research investigating the further coupling of the SCAPE model, the GIS analyses and the visualisations (Fig. 6).
In terms of the technical challenges facing the development of a truly interactive real-time system, it is already possible to manipulate the models (e.g. buildings or flood defence models) located within the VR visualisations in real-time. Unfortunately, in a coastal decision-making context this provides inadequate functionality because of coastal manager’s desire to modify the complex terrain elements that would result from the management interventions that they wish to explore. To overcome this, the potential exists to link Terra Vista with the GIS via the Terra Vista control API. However, this may be constrained by the build times associated with the compilation of the OpenFlight files that would prohibit the use of such a system in meetings or workshops.

Possibly the key barrier associated with the creation of an integrated system though is the requirement for manual intervention. This is particularly challenging due to the requirement for manual editing and judgement during the translation of the scientific results into landcover maps and DEMs that form the basis of the ‘future’ visualisations. This is further exacerbated by the requirement for any integrated system to account for possible future changes in coastal geomorphology, something that is yet to be incorporated into the current modules and which is inherently uncertain to predict even using expert knowledge. Furthermore, the coastal zone potentially represents a more difficult...
environment for which to develop an integrated system for. This is because of the requirement to modify the underlying data to represent complex multidimensional geomorphological features, for example barrier islands, that are not required when visualising other forms of policy options, such as future agricultural policies. Similarly, in terms of applying real-time systems, the representation of dynamic landscape features, of great importance in the coastal zone, would be difficult to depict due to the need to animate features in a real-time environment. Indeed, this is an example of where real-time systems may be unable to provide the functionality required by coastal managers, and where a suite of visualisation tools, in which real-time systems are only one element, should be encouraged.

5 Conclusions

The research has illustrated how it is possible to loosely link a number of research projects involving different disciplines, with the results being presented not only in quantitative and two-dimensional cartographic formats, but also using a range of visualisation techniques including real-time virtual reality representations. Whilst the research has made some initial progress towards the type of integrated coastal simulation and visualisation system that coastal managers are seeking, we are still some way from achieving such a goal. Until then a pseudo integrated ‘results explorer’ package combining quantitative scientific information and visualisations representing a number of predefined policy options represents an attainable target rather than a truly integrated system.

6 Acknowledgements

This research was funded by the Tyndall Centre for Climate Change Research and was conducted by researchers at the Universities of East Anglia, Manchester, Newcastle and Southampton. Data was provided by the British Geological Survey, the Environment Agency, the Ordnance Survey and HR Wallingford. All Ordnance Survey data are Ordnance Survey ©Crown Copyright. All rights reserved.

7 References

