2009 International Conference on Computational Intelligence, Modelling and Simulation

A Review on Techniques Applied to Modelling, Simulating and Visualising Evolution of Physical Landscape.

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***Abstract*—The paper considers contemporary physical landscape visualisation and simulation models that are used for impact analysis and decision making for geographical location studies. For this purpose a generic framework is presented that provides professionals with a tool to facilitate decision making. The main reasons for the framework construction are to provide a rigorous approach to the task of studying the evolution of physical landscapes, and to provide appropriate data for forecasting and scenario projections using computational simulations that reflect future changes.**
The framework is based on an in-depth analysis and assessment of a landscape monitored over time. On satisfactory completion of landscape models construction, the set of models developed are then used for the construction of visualisation images to represent the entire evolutionary process of the landscape. This framework includes functions through which users can generate visualisation models either with two-dimensional maps and/or interactive immersive three dimensional images.

Keywords-modelling; simulation; visualisation; landscape; framework; evolution

I. INTRODUCTION

The paper presents an investigation into current approaches available for developing a generic geospatial analytical framework consisting of simulation and visualisation methods integrated for visualising spatial and temporal changes on a given landscape. It includes an exploration of issues and strategies relating to the implementation of this new framework using available geo-coded data from multiple sources (and media) and with an added functionality to incorporate end-user requirements.

Geographic Information Systems (GIS) are increasingly becoming popular in landscape management and decision making processes primarily because of their functionality to store, analyze and display spatial data. There are several possible approaches to coupling GIS with simulation models, depending on the objective, availability of data and resources, and more importantly on the skills of the modeler.

Physical landscape visualisation models play an important role in the analysis of various geographical locations in a variety of context. The foremost of the many reasons for constructing a generic framework for modelling and visualising the evolution of physical landscapes is that the current models in use fail to provide adequate details for gaining an in depth understanding of any physical change of even a simple environment, for example, changes within a specific community, such as filter feeders of a coastal habitat. A common framework for creating such global models is to provide various professionals with a useful tool to facilitate their decision making processes. For instance, it could enable historians to conduct empirical research on the history of the use of a piece of land in relation to human settlement and economic change and in this case, they use GIS to visualise past landscapes and the change in the morphology of the built environment over time, an example for such a study is illustrated here in [13].

Also sociologist could use this software tool to analyze various vital occurrences in a society over time in a coherent and cohesive manner; examples of such use could be seen in the following:

1) land-use change as elaborated upon in [17],
2) study on changing employment patterns [15],
3) study of the examination of class consciousness [23] and neighbourhood analysis [18], and
4) planning process in rural development [22].

Furthermore, a common framework could be of significant boost to landscape planners, such as engineers, architects, and to a greater extent to policy makers, who are in urgent need of simulation models for visualising the potential evolution scenarios of a landscape based on their current decisions made on the land use/development of a physical area. Typical contemporary examples can be drawn from what are famously referred to as “Cross-cutting issues” [24]. These models could be used to determine the future scenarios, changes to the landscape of an area of interest under a given number of proposed developmental activities especially, in performing trade-off analysis studies on the options available to decision-making professionals, their potential benefits and disadvantages.

II. RELATED WORKS – REVIEW

From the review of previous work in this area, it becomes clear that the major processes developed for modelling, simulating and visualising landscapes, make use of different frameworks and factors for modelling landscape

978-0-7695-3795-5/09 $26.00 © 2009 IEEE
DOI 10.1109/CSSim.2009.25

evolution. A composite of these approaches has been used as a basis for constructing a unified framework for this paper. A common factor from the approaches relates to the continuous monitoring of physical landscape changes over time hence, this has been retained in the novel approach being developed here. The remainder of this section describes the major approaches reviewed in this study.

The Visulands project [14], is an example of an approach that is aimed at presenting 3D models of landscapes with computer software programs capable of handling GIS landform data. However, during the development stages of the project, Visulands researchers realised a need to add written information (text) to the visual depictions. They conducted a survey to obtain public preferences and then compared and contrasted the user requirements with the objectives of the land/ resources managers. This enabled Visuland to introduce a function for landscape visualisation with an ability to incorporate end-user interactions as inputs. This function allows a user to navigate through the landscape being visualised from various view points. The user can also manipulate the image being visualised depending on a single or multiple input/s and also at any rate increased-decreased (for example sedimentation) from the various factors that may affect any potential changes on the landscape being analysed.

Yorkshire Dales [19], another relevant study on landscape visualisation focused on creating future landscape scenarios for the Yorkshire Dales National Park for improving the understanding of and general awareness on the future potentialities of the said landscape. Instead of using computer packages for generating 3D models, this study made use of sketches to illustrate the future scenarios.

A study entitled 'Visualising Sustainable Agricultural Landscapes' being conducted at the University of East Anglia [2], also stressed the need for analyzing factors that could promote the inclusion of changes in landscape modelling. The study attempted to assess the effects of current or proposed farm management on the biodiversity of an agricultural landscape. In this work, instead of just formulating sketches or generating GIS images of the landscape, the researchers conducted an ecological survey across the study area in order to establish the state of the present environment. For this, they interviewed some local farmers and members of stakeholder organisations. Through these methods of consultation, the researchers were able to define several future scenarios based on the development reflected in entities within the subject area on the plans.

In a study conducted at the University of East Anglia [2], researchers examined various factors that could enforce some form of a change on landscapes. In another pilot study conducted at the University of Sheffield entitled as "Modelling Sustainable Landscapes for the Peak District," researchers used both scenario construction and visualisation methods to generate future landscapes. The latter study reported on the various components that may affect the future changes of a landscape and proposed methods to assess such factors, the proposed methods being interviews, workshops, the Delphi technique, and back casting. However, the study further recommended the use of visualisation methods, such as non-GIS based Software, GIS-based Software, and computer programs to allow for Photographic Manipulation.

III. Proposed Framework Construction

Based on the literature reviewed thus far for this research, a framework of processes for incorporating a variety of simulations, models and information sources, such as GIS and other geo-coded data, to generate visualisation models on the evolution of a landscape over time (past, present and future) has been developed and discussed in this section. Both scenario construction methods along with visualisation techniques are integrated in this generic framework.

The proposed framework takes into account of conceptualised system architecture and interfaces to allow for a variety of simulations, models and Geo-Information System (GIS) to be linked. This is made possible by data sharing and building a global model of the evolution of a landscape over time.

The development of visualisation images are enhanced to provide a variety of views suitable for a variety of users and media, from fully interactive immersive 3D models to traditional 2D town plans. Useful extensions to the proposed framework allow for user interaction in tuning inputs on the models and simulations. The Figure 3 shows a schematic diagram of the system architecture.

The conceptual framework proposed herein for modelling, simulating and visualising landscape evolution involves not just an analysis of future landscape but in addition, an assessment of the landscape from the past to the present as well. It is vital that the continuous monitoring of the present scenario is factored into the framework to present the changes that may occur on the landscape of the area being modelled in the future. For this purpose, the proposed framework looks at the approaches in a study conducted at the University of Sheffield [25]. Instead of just using photos or sketches that follow patterns in the evolution of a landscape, the framework promotes an analysis of the various factors that trigger such changes (see Figure 1).

Furthermore, scenario construction methods are used to provide a process for modelling the past and present state of a landscape. This is performed in alignment with the coordination data of GIS generated images which are used to develop the present models of the physical landscapes.

On satisfactory completion of a landscape model construction process, the set of models developed are then used for the construction of visualisation images to represent the entire evolutionary process of the landscape. The use of both scenario construction methods and visualisation techniques in generating the images for the evolution of a physical landscape is not made merely to create a whole picture of the evolutionary cycle. Instead, the framework will also allow the models and the visualisation images to provide a variety of viewpoints suitable for use by a wide range of users as well. These simulations of the models and visualisation images presented at various points are of significant benefit to a variety of users who would want to understand the evolutionary cycle for a range of purposes as stated in the introduction.

The framework that is generated from the combination of visualisation techniques and scenario construction or modelling methods as well allows for user interaction. Users can generate a visualisation model depending on their input/s the factors that may trigger a change over the subject area. Through the use of simulation and visualisation techniques, such as photographic sampling of the actual area and the use of computer generated visualisation images using GIS-based software, the framework also provides its users with either traditional two-dimensional maps and/or fully interactive and immersive three dimensional images.

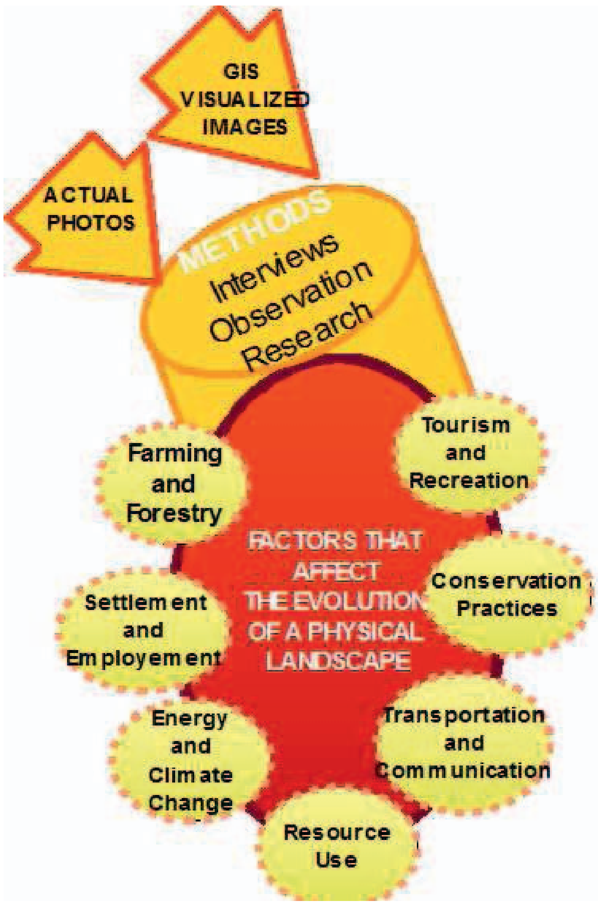

Figure 1: Regular Monitoring process for the visualisation of physical landscape

To be able to monitor the evolution of a physical landscape though visual images, there is a need for a regular monitoring process for the visualisation of the landscape. As such, continuous monitoring of the various factors that may affect or prompt changes in a landscape should be done through interviews of the entities involved, observations, and research on the data, statistics and policies that may be pertinent to the study at hand. To complete the modelling, simulating and visualisation of the evolution however, actual photos of the physical landscape and GIS generated images should be taken as well. The analysis of the various evolutionary catalysts should be analysed in coordination with the actual appearance of the subject area. When all of such has been taken into account, only then can a comprehensive model and visualisation of a physical landscape can be achieved.

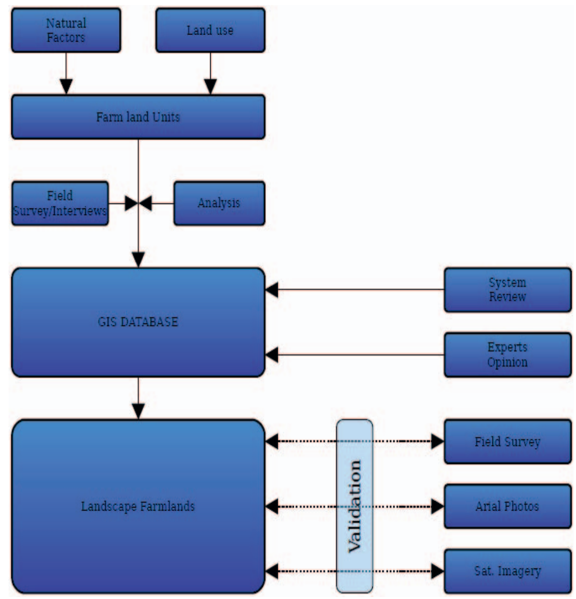

Figure 2: Evolution of Farmland, monitoring process

Figure 2, Schematic diagram which looks into processes of monitoring and validation of the evolution of farmlands where farming and forestry are the main factors affecting the evolution of physical landscape.

IV. System Architecture – Design and Implementation

The framework proposed takes into account conceptualised system architecture and interfaces allowing for a variety of simulations, models and Geo-Information System (GIS) to be linked. Within this framework all these operations and function are able to share data and to build a global model on the evolution of a landscape over time.

System Design and Implementation

Figure 3 presents the main components of the generic framework design for modelling, simulating and visualising landscapes and their dynamics. The framework design incorporates ESRI ArcGIS, Java applets and MySQL Database Server employing modules of Object Oriented Design to aid in easy component development and integration.

MySQL Server, an open source software is used as it is flexible in connecting to most of the applications. It is also much compatible with Java programming language as Sun MicroSystems (developers of Java) are major contributors to updates of MySQL.

Remote Sensing data of the landscape monitored over a period of 20 years is analysed using ArcGIS and derived parameters are used to model the features that affect the evolution of the landscape being modelled (Figure 1). To accommodate for differences in features or elements of the landscape, new and novel computational models are developed. ArcGIS is used as it can effectively handle the spatial – temporal changes of landscape/s over time.

A database design and implementation in MySQL Database Server are employed to enable the integration of ArcGIS, all models and simulations to the main framework for queries and data sharing.

Integrating GIS, simulations, models and visualisation into a system is performed through loose coupling for the purpose of sharing common data. Loose coupling is advantageous when adding other components to the system.

The external layer is a versatile, intuitive and user-friendly visualisation interface developed using Java programming language. This design is aimed at making the software tool user-friendly, so that a wide range of users even with minimal computer literacy especially with low GIS expertise, are able to easily access the models and simulations integrated. The software interface includes tools for selecting a model, and to input parameters for simulation and visualisation options, such as 2D or 3D. The visualisation presents the dynamics of simulated model in a realistic environment.

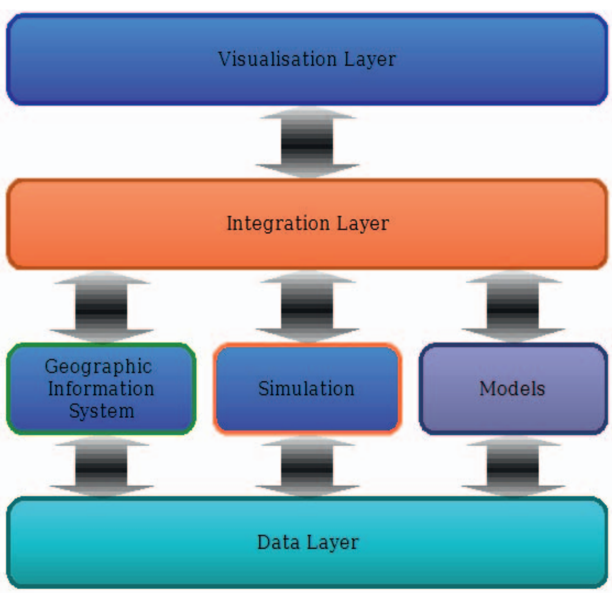

Figure 3: System Architecture – Schematic Diagram

V. CONCLUSION

In conclusion, it could be stated that a framework similar to the one presented in the paper would certainly serve as a useful software tool especially as an interface for a variety of simulations, models and Geo-Information Systems (GIS) allowing for data sharing and building global models for studying the evolution of physical landscape over time.

In the authors' view, the framework's ultimate aim to develop such a generic modelling tool for users across many diverse fields will be realised in its implementation stage during which professionals from the example areas are to be consulted.

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