Jul 1st, 12:00 AM

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Abstract: It is expected that the structure of rural communities and the visual landscape of the Cudgewa Valley in northeastern Victoria, Australia, will change markedly within the next 20 years. We are creating a portable environment for landscape simulation, using geographic information systems and virtual reality technology. This will allow the community and stakeholders of this valley to propose alternative land cover configurations, move through realistic renderings of the consequent landscape, and review outcomes on a variety of environmental, economic and social scales. A detailed three dimensional visual model of the region will be rendered using OpenGL Performer. People will also be able to interact with the visual model, using personal digital assistants. The interactivity will include ability to move through the environment, mechanisms for input of land use change scenarios, and individual or group specification of values and preferences. The implementation of the landscape simulation environment has been realised using three screens to form a wide-angle view of the landscape and three main software parts. The landscape model is rendered by 'PA', a program based on OpenGL Performer. Land cover options can be selected using 'ArcGIS'. Any information exchange between ArcGIS and PA is handled by 'PA-server' through the local area network. Any incoming messages from the personal digital assistants will also be handled by PA-server via wireless networks. Finally, PA-server is responsible for coordinating the update of the rendered landscape. This project will develop techniques that help people to learn about their local landscape, examine the consequences of application of their values, and support informed decisions about land use.

Keywords: landscape simulation, virtual reality, decision support

1. INTRODUCTION

The addition of high performance visualisation capabilities to a combination of geographic information systems (GIS) and physical process models has been subject of considerable research over recent years [Graf *et al*. 1994, Liggett and Jepson 1995, Bishop and Karadaglis 1997, Verbree *et al.* 1999, Perrin *et al.* 2001].

We have followed the approach of combining GIS and virtual reality (VR) technology, to develop a portable environment for landscape simulation and exploration. This environment will allow community and stakeholders to propose alternative land cover configurations, move through realistic renderings of the consequent landscape, and review outcomes on a variety of environmental, economic and social scales. This will be possible in an individual or group decision making situation. The users can sketch changes onto maps or aerial photographs, and these changes will be visually presented in an immersive 3D environment. The users can then express their opinion on the outcome of the proposed landscape change. This allows the community to interactively change the virtual representation of their landscape, get visual feedback, and so form an opinion on possible future landscape scenarios.

Exploration in a workshop environment will require multiple input devices and mechanisms for integrating individual inputs. We choose to use personal digital assistant (PDA) technology with a wireless network to make the input process as natural as possible. This system provides immediate visual feedback on any scenario of change and an ability to record and respond to multiple inputs from the users.

The developed landscape simulation environment is to be tested on the Cudgewa Valley located in north-eastern Victoria, Australia. This valley is of national significance as a part of the Murray-Darling Basin. In this and many areas of the

country, livestock production is the dominant enterprise. However, there is pressure for change in many areas as tourism and lifestyle development push land prices higher or forestry becomes more economic. As a result, both the structure of rural communities and the visual landscape are expected to change markedly in the next 20 years. This change, which cannot be deferred indefinitely, should also not be purely driven by economic necessity without consideration of both local and wider community values, that is people's expectations for the visual character of the region and concern for its environmental health.
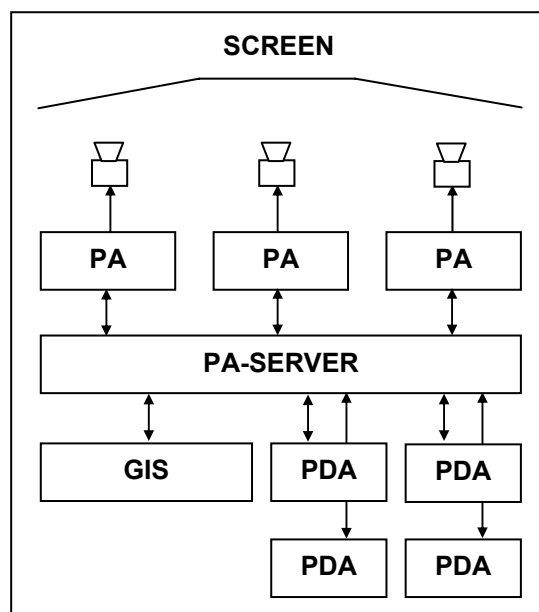
2. SIMULATION ENVIRONMENT

The developed simulation and exploration environment is illustrated in figure 1. The user's main view of the system is via the landscape simulation rendered onto three connected screens giving a wide-angle view. Interaction is also possible via the GIS or the PDA devices. The description of the system begins with the 3D display since this is the primary user view.

The landscape simulation environment is rendered in real-time onto three screens using three projectors to give a 135 degree field of view. The scene is rendered by three high-end desktop computers, one for each projector, that are equipped with Nvidia Geforce graphics cards. A fourth 'master' computer is used as a server to control the network data flow and to send appropriate messages to the three 'render' computers. The master computer is also linked with another computer running ArcGIS, which will supply land cover information to the rendering system. Several PDA devices can also be connected to the master computer, using a Bluetooth wireless network. A change in the modelled virtual environment can be triggered from ArcGIS or purpose-developed decision support software on the PDA devices by the users of this system.

The landscape simulation environment consists of three main software parts. We have written a program called PA (Object Animation with Performer) based on OpenGL Performer [Bishop and Dave 2001] which we use to render the 3D representation of the landscape. As an input interface that allows changing the virtual

landscape we use ArcGIS and added the necessary functionality using ArcObjects (using C++). Both programs are linked via a server program (PA-server) that allows PA and ArcGIS to exchange land cover data.

Figure 1. The simulation environment. PA is our 3D visualisation program and PDA stands for Personal Digital Assistant.

To simulate potential changes in the landscape, we have divided the study area into management units. Each management unit is defined as a polygon within which the land cover can be changed to an alternative predefined land cover type. Thus each management unit polygon can have one specific type of land cover, which can be changed interactively. Existing features that can be used for the generation of such management units are, for example, fences, roads, and streams. To visualise different types of land cover, we use 3D models that represent features typical for that type of land cover (e.g. trees for forests). This means if we want a management unit to represent forest, we would place trees onto this unit. To render the landscape in PA we use a three dimensional model of the terrain, and sets of 3D models for each land cover option and management unit, which are used to represent the predefined land cover options.

PA is a major extension of the 3D object / environment viewer Perfly that ships with OpenGL Performer. Perfly has been extended to

Figure 2. The ArcGIS interface. Shown are different management units and the land cover selection box.

include the ability to render 'dynamic' objects, which will allow improved interactivity with the rendered 3D environment. Dynamic objects can be animated (e.g. move along a path) or be switched between different states (such as 'on' and 'off') using triggers and targets. The extended functionality of PA is achieved by the use of so called 'scene files'. A scene file consists of several sections that define the properties of the objects that will be loaded into PA. For each object that has a typical behaviour (e.g. trigger) there is a corresponding section in the scene file [Bishop and Dave 2001]. PA reads the scene file, and will treat the objects from each section correspondingly. For example, PA gives objects that are in the trigger section the functionality they need to act as triggers.

The scene file sections of importance for this study are a terrain section and multiple sections for the management units. Each section points to other object files (3D models) that Perfly/PA will understand natively (e.g. 3DS, OBJ, DXF, FLT formats). The terrain section points to a file that defines the DTM of the study area and the surface texture derived from aerial photography. Within each management unit section of the scene file are

entries that point to an object file for each land cover type. Each object file contains a selection of 3D objects that make up the specific land cover type (e.g. trees, buildings) and that will fit onto the DTM. When PA starts up it will initialise each object file as a group within the scene graph. After the start-up each group apart from the terrain will be invisible. Sending messages from ArcGIS will then switch the corresponding groups into visible state. Any visible groups that don't correspond to the land cover type selected in ArcGIS will be set to the invisible state. This set-up allows switching between different land cover configurations as defined by the user or users. After the initial initialisation of PA, it is also possible to use an existing land cover option for the whole study area, and to switch all corresponding land cover objects on. For example, this could be used to start with the existing land cover, when for each management unit the existing land cover is switched on.

The management units for the study area are loaded into ArcGIS as a layer. After a TCP/IP link to PA has been established, the user can select a tool that will allow the changing of land cover in one or more management units. The user

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can click on any management unit and a dialog will appear. From this dialog the user can select one of a list of predefined land cover types (see figure 2). There is an additional option that will allow the user to switch off the existing land cover. This option may prove useful for cases, where it is wished to keep the existing land cover, for example a farmhouse or major trees. The user can also draw a selection polygon onto the map and change the land cover type of multiple management units. After the user has selected a new land cover, the management unit id and the land cover type will be sent to the PA server. It is also possible to select predefined possible future scenarios that affect the land cover of the whole study area, and update each management unit with the corresponding land cover types.

ArcGIS is also used to automatically generate the locations of land cover objects, such as trees and buildings. We programmed a tool that generates locations of features within the management units and assigns 3D objects to them. The 3D objects are defined as text files in Wavefront OBJ format. These OBJ files can, for example, be built with third party software. The GIS tool will then export Wavefront OBJ files, which are populated with a number of 3D objects, for each management unit and each predefined land cover type. For a pine plantation land cover type, for example, a model with texture mapped pine trees with specified average density and specified average height (e.g. 30m) will be generated. The Tool also automatically creates a scene file, which references all auto-generated OBJ files. This scene file can be read by PA.

Any data exchange between ArcGIS and PA is handled by PA-server, which is running under LINUX. ArcGIS will talk to the server as a TCP/IP client. Land cover data from the ArcGIS client will be sent to the PA server which will then process the data and send it to PA for rendering. The PA program is also implemented as a client. PA server can talk to multiple clients at the same time, e.g. for rendering the scene graph onto more than one screen. PA server has been programmed in a way that the PA clients will stay 'in sync', i.e. the PA clients will render a section from the same frame of the scene graph.

The server is also able to receive messages from multiple devices, e.g. the ArcGIS client and multiple PDA devices. The server will understand several different messages. Using ArcGIS it is possible to switch objects within a management unit on and off (to reflect changes in land cover) or to change the view position. The PDA devices can be used to update the view position, or (after some further development) to express an opinion on a specific land change outcome. The server is listening for all incoming messages in a multi-threaded environment, i.e. all messages sent from other devices will be received, even if they were sent at the same time, and be handled accordingly. The server will then pass the messages onto the PA clients which will render the changes in the next frame. The server will make sure that the changes are rendered in all the PA clients, i.e. the scene graphs of the clients will match.

3. CASE STUDY AREA

The portable landscape simulation environment will be used to study possible landscape changes in the Cudgewa Valley. It will be used in workshops with members of the community and stakeholders of the valley participating. The participants of the workshops will be exposed to different alternative land cover scenarios within which they can move around freely and upon which they can express their opinion and preferences using PDA devices. They will also be able to explore landscape changes of the virtual environment by changing the land cover of selected management units. For example, stake holders can change the land cover of their own property and assess the visual outcome.

A virtual 3D model of the existing features of valley has been produced as a first step [Chen *et al.* 2002]. The model includes a terrain model and 3D objects representing the existing features in the valley, such as buildings, trees, fences, and roads. The 3D objects were exported from ArcGIS, using topographic data from Victoria's department of Natural Resources and Environment, into Wavefront OBJ files. The terrain is made of a ten metres DTM and has been textured with orthophotographs, which were derived from aerial photographs from Qasco-VicImage. The existing terrain is used as a base onto which new land cover objects can be placed. It is also possible to remove existing 3D objects, i.e. in general it will be desired to remove existing trees if, for example, a pine plantation would be 'planted' onto the same management unit.
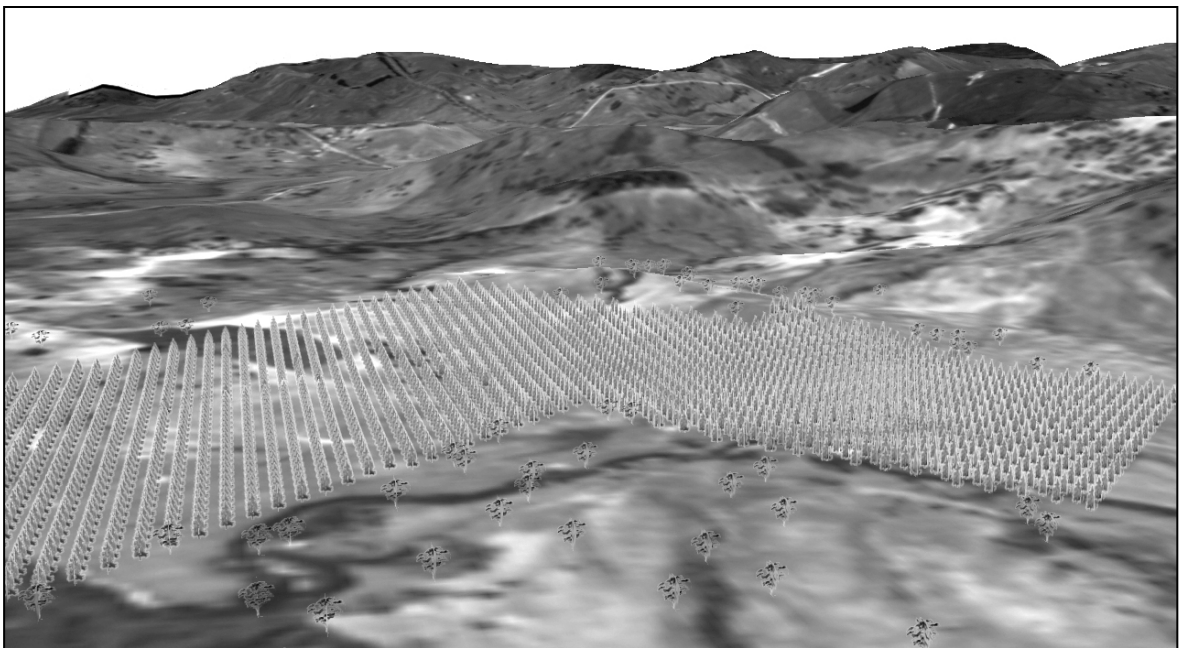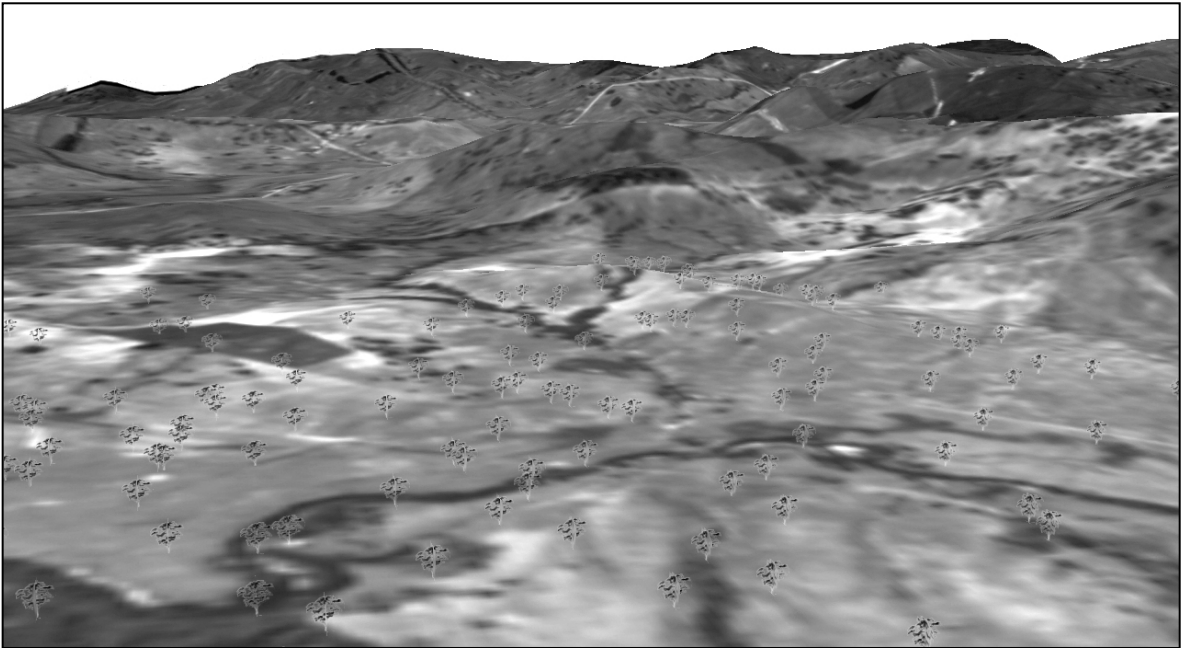
Figure 3. Two views of the virtual Cudgewa valley with different land cover. Some marginal farmland has been replaced with pine plantations.

One of the problems in this valley is weed infestation. Using a weed grow simulation in ArcGIS, we can give a virtual impression of the valley, for example, after ten years of undisturbed weed growth. Another scenario could be a significant amount of change from livestock production to timber production. This would involve the development of hard / soft wood plantations on marginal farming land (see figure 3).

4. SUMMARY AND OUTLOOK

We have developed a landscape simulation model that allows the user to explore alternatives to the existing landscape in an interactive, immersive virtual environment. This is achieved by using GIS technology as an input option for land cover changes that will be rendered in real-time, using PA, onto 3 screens that give a 135 degree field of view. Using PDA technology, the users can explore the alternative landscape environment, and assess and express their opinion on the outcome.

In a second step we will implement simplified models to determine probable consequences of the landscape changes (eg. jobs, amenity, water quality and quantity). Those non-visual outcomes of changes in land use will be visualised with the help of icon based indicators. People can then determine if the probable changes accord with their values (eg. if land use is intensified in this area, will water quality deteriorate?) and adjust the extent or nature of the change accordingly. Using questionnaires and a series of community workshops we will also learn a great deal about local landscape knowledge and values and the effects that clear presentation of options may have on learning and understanding.

The methodologies presented in this paper can be easily adapted to other study areas. The first step is currently being fine-tuned and will take about one year to implement. We estimate that the second step can be implemented within half a year.

Individual and community values are often poorly communicated and understood. This project will develop techniques that help people to learn about their local landscape, examine the consequences of application of their own values (or those of others) and support informed decisions about land use. Identification of community perceptions and values will also help to contribute to policy development at all levels of policy making from the catchment to the nation.

5. ACKNOWLEDGEMENTS

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