Development of an Envisioning System for Rural Communities

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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. To allow the community to explore these changes and envision a future for their valley, we are creating a portable environment for landscape simulation. The landscape visualisation is built on virtual reality technology and links to a geographic information system and hand held computing devices that can be used for the exploration of future visions. Our system 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 onto three screens giving a full field of view. The model can be explored in real-time using hand held computing devices for navigation. The community will be able to change existing land cover using a GIS interface. The changes will be reflected visually in the 3D view immediately. The system also incorporates icon based indicators for non-visual impacts, such as water quality, employment, and soil erosion. We will use simplified models based on existing scientific and local knowledge to determine these non-visual consequences of the land use changes. Using the hand held computing devices the community will be able to express their opinion on the changes upon the visual and non-visual outcomes. People can then determine if the probable changes accord with their values and adjust the extent or nature of the change accordingly. 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.

Keywords: landscape simulation, virtual reality, decision support systems

1. INTRODUCTION

This study explores the level of landscape understanding and environmental values of rural communities. To achieve this task we have developed a portable environment for landscape simulation and exploration. Our environment is based on four components, geographical information systems (GIS), virtual reality (VR), physical process (impact) models, and mobile computing devices. The integration of high performance visualisation capabilities, 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].

In application, our environment will allow the community and stakeholders of a study area to propose alternative land cover configurations in the GIS, move in real time through realistic three-dimensional renderings of the consequent landscape, and review outcomes of a variety of environmental, economic and social results. The community and stakeholders can then express

their opinion on the outcome of the proposed landscape changes. This allows the community to interactively change the virtual representation of their landscape, get feedback on visual outcomes and non-visual impacts, and so form an opinion on possible future landscape scenarios. Our system is designed to be used in a workshop environment.

The exploration of virtual landscapes and the collection of feedback on opinions in a workshop environment with multiple users will require several input devices and mechanisms for integrating individual inputs. We are using personal digital assistants (PDA) with a wireless network to make the input process as natural as possible. Our system includes the ability to record and to respond to multiple inputs from the users and visualise feedback given by the users immediately.

2. CASE STUDY AREA

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.

Our system 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 a section 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.

3. 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 possible via the GIS or the PDA devices [Stock and Bishop 2002].
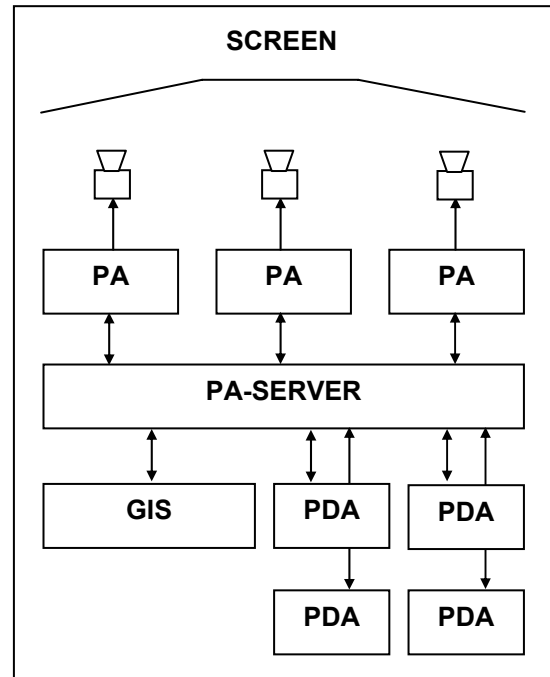

Figure 1. The simulation environment. PA is our 3D visualisation program and PDA stands for Personal Digital Assistant.

The landscape simulation environment is rendered in real-time onto three screens using three high-end desktop computers and three projectors to give a 135 degree field of view. 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.

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. PA is a major extension of the 3D object / environment viewer Perfly that ships with OpenGL Performer. We have extended the functionality of Perfly by 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].
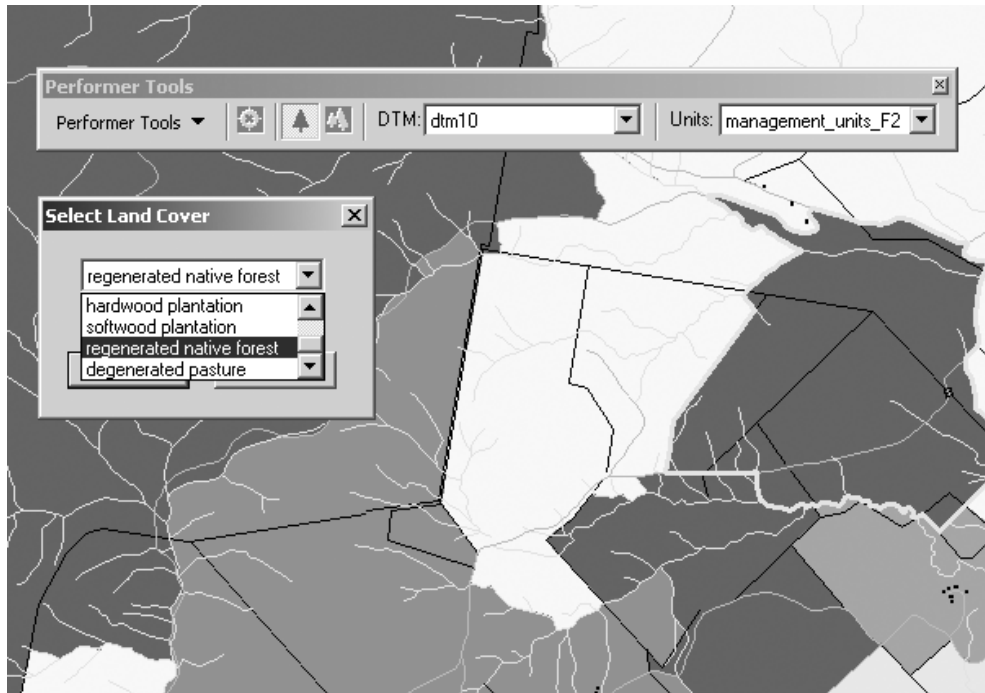
Figure 2. The ArcGIS interface. Shown are different management units and the land cover selection box.

Any data exchange between PA and the GIS and PDA interfaces is handled by a program called 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 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 message types for different tasks. Using ArcGIS it is possible to change the current land cover or to change the view position. The PDA devices can be used to update the view position, or 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.

4. USER INTERACTION AND FEEDBACK

While the VR view is used to visualise the virtual landscape, the GIS and PDA interfaces are used to allow for user input. Although the GIS view is also used to show the study area in a 2D view, it's main use is to allow the users to manipulate the virtual landscape. We also allow the users to navigate around the 3D landscape in real time using the GIS and PDA interfaces. Finally, we use the PDA interface as a platform for feedback input on alternative land configurations.

4.1. Land Cover Manipulation

While it may be of advantage to be able to change the landscape arbitrarily in space this approach would impact computing times to a point where it wouldn't be real time visualization anymore. Instead we have divided the study area into 'management units'. Each management unit is defined as a polygon and each polygon can have one land cover type associated. Existing features that can be used for the generation of such management units are, for example, fences, roads, and streams. We have sent aerial photographs to the stakeholders of the Cudgewa valley and asked them to mark the boundaries to what they would consider to be a management unit. This way we can construct a management unit layer which would reflect spatially realistic land use changes.

We have written a plug-in for ArcGIS using ArcObjects. Using this plug-in a GIS user can

select a management unit and change its land cover by selecting from a predefined list of land covers (see figure 2). We have also allowed for the option to select multiple land management units to change larger areas to one specific land cover type. Whenever a management unit is changed the management unit id and the new land cover type is sent to PA-server and the VR view will immediately show the change.

We also allow the existence of multiple management unit layers. We refer to each layer as a 'scenario'. This way we can pre-build certain scenarios that may be of interest to the community of the Cudgewa Valley. This feature can also be used to save certain scenarios, for example, if during the workshop the participants would decide that the current land cover configuration would be an interesting option for the future of the valley. We have added functionality to our ArcGIS plug-in to select scenarios and send the existing land cover to PA-server. This way we can quickly compare the visual aspect between different scenarios.

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 base model (e.g. terrain with existing buildings), and sets of 3D models for each land cover option and management unit, which are used to represent the predefined land cover options. Whenever a management unit is changed in the GIS, the appropriate 3D model for that management unit is loaded into the scene graph.

In the workshop we will have one user controlling the GIS interface. We are going to project the management units as 2D maps next to the VR view so it will be visible for all workshop participants. The 2D view will also include some other features like roads and buildings so the workshop participants have a better spatial understanding of the map. During the workshop the participants can make suggestions for land use change and the GIS user will change the management units in the GIS interface accordingly. Having one central point for changing the landscape avoids a situation where the workshop participants will individually change the landscape without paying attention to other changes that are occurring in the same time.

4.2. Navigation

The GIS interface can also be used to do some navigational tasks in the VR view. The GIS user can click onto any point on the 2D map and the viewpoint in the 3D view will be updated. Another option is to select a location from a list of pre-defined viewpoints. There are a few viewpoints in the Cudgewa Valley that are of special interest, for example residential places of members of the community or viewpoints that are well suited to give a good look over the valley. This way the workshop participants can quickly navigate to locations that are of interest.

All workshop participants will be able to select a viewpoint from the pre-defined list using the PDA devices. This allows a greater number of the community to navigate around the landscape. There is also the possibility that we will add the functionality of adding new viewpoints to the viewpoint list while the system is running. This way, users could record the current viewpoint and return to it if they wish to do so later.

The PDA interface also allows the workshop participants to 'walk' around the virtual landscape. The screen of the PDA is divided into 4 quarters, i.e. top, bottom, left, and right. Holding the stylus onto the screen will result in continuous movement in the 3D view, e.g. holding the stylus onto the top part of the screen will result in continuous forward movement. The other quarters will result in backward movement and left and right turns. We have selected to only use this simple navigation model at this stage although more sophisticated navigation models would be possible. However, to achieve smooth continuous movement in the 3D view a lot of information has to be sent over the network, i.e. the current viewpoints has to be constantly updated. To limit network traffic the preferred option to move from point A to B is the viewpoint selection from the list of pre-defined locations or the viewpoint setting on the GIS interface. The continuous movement functionality on the PDA devices should be used as a supplementary possibility to vary the view a little at a given location, but it isn't really suitable to move along large distances. For example, it is suitable to see how the view may change 10 metres down the road or for looking into a different direction.

4.3. Voting

One major component of our system is to allow for collecting feedback from the workshop participants. This has been realized via voting using the PDA devices. The GIS user can at any stage type a question into the GIS interface and call for a vote. The question will be sent to the PA-server and each PDA device. A vote dialog will appear on each PDA device showing the question and giving some options to answer that question. Each member of the workshop will then be able to select their preferred choice. Once the

voting is done the results will be sent back to the PA-server and will be passed on to PA for display on the VR view. The results will also be written into a log file and thus be stored for later evaluation.

Our system supports two general types of votes. The first one is a simple yes / no question. For example, the workshop participants could be asked if they would consider the current shown land cover scenario as a viable option for the study area. The answer options would be 'yes', 'no', and 'undecided'. The other type of question is for rating the subject of the question from one to five. For example, the audience could be asked to rate the scenic beauty of the current view.

It is anticipated that the number of PDA devices can be smaller than the number workshop participants. In this case the workshop members will have to share the PDA devices. Every participant will be allowed to make one vote and then will have to pass the PDA device on to another participant. Once everybody has voted a 'done' button will have to be selected on each PDA device. Once every PDA has recorded that the voting is finished the results will be sent to the server. The server will evaluate the results and send the numbers of the yes and no votes to the main VR view. In case of a rating vote the average rating value will be sent to the VR view instead. This way the workshop participants will get instant feedback and can discuss the results further if this is wished.

Obviously, the voting procedure is based on an 'honor' system, i.e. it relies on workshop participants only voting once and not multiple times. Since this system is designed for future explorations of the study area the participants live in, it should be in the interest of an individual not to vote more than once.

5. IMPACT MODELS

Our system is not only designed to give visual feedback of the virtual landscape in the VR view, it also allows for indicating non-visual impacts of landscape changes. Stakeholders and the community of a study area are not typically interested only in the visual outcome of landscape changes, but also what other impacts those changes might have. There are certain concerns in the Cudgewa valley which we have incorporated into our system, such as water quality and quantity, salinity, weeds, soil acidity, soil erosion and population numbers. For each of those items we are able to run a model on the GIS system which will estimate a value for a certain scenario.

Since we want to have our system running in real time we cannot use very complex models that

would take hours (or even minutes) of computing time. A computing time of ten seconds may just be justifiable but everything above that will stretch the patience of the audience unnecessarily. Thus, in most cases we cannot produce very accurate models, but our main goal is to give a correct general indication. Rather than showing real numbers for each scenario, the users can only compare two scenarios with each other. Our computations will only indicate if the second scenario has a higher or lower value than the first scenario, and if the difference is low or high. For example, a scenario using extensive grazing may produce better water quality than a scenario using intensive irrigated horticulture. While for most impact models we will have slightly different ways to compute the values, the common approach will be that we will have a certain value associated to each land use type for each impact of interest. Those values will be determined from talking to experts of the respective fields (e.g. North East Catchment Management Authority of Victoria). Finally, those values will be integrated in one way or the other to give a global estimate for the whole study area.

Figure 3: This shows a screenshot of the virtual Cudgewa Valley with a proposed farm forest in the VR view. On the bottom of the screen are a compass which will help the users to navigate, a place holder for the voting results (the two zeros) and three impact model icons (water quantity, water quality and employment).

At any time the GIS user can select a tool on the GIS interface to compare two management unit layers (scenarios). After the selection the user can select the impact models that are of interest for the comparison. The GIS will then compute the relevant values and send the results to PA-server for display on the VR view. For each impact model we have a small 2D icon which we can display on the VR screen. The icon will be

coloured according to the difference between the two compared scenarios. If there is a change to a larger value between models one and two the icon will be bright green or dark green (bright green being the stronger change). If there is a change to a lower value the icon will be red or orange (with red being the stronger change).

The impact modelling combined with the possible visual assessment should allow users to quickly assess the given scenarios. There may be a concern that the simplified impact models can lead the workshop participants to making wrong decisions. However, we do not see the actual accuracy as the major problem. While there may be existing models that produce greater accuracy our system will still give a rough estimate that should qualify the user to make an initial assessment. However, the negligence of the spatial distribution of the impacts can be a much bigger problem in cases where local impacts may be of relevance. In any case a more thorough analysis should be done after this initial assessment.

6. SUMMARY AND OUTLOOK

We have developed a landscape simulation model that allows the users 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 onto an 3D immersive VR view. Using PDA technology, the users can explore the alternative landscape environment, and assess and express their opinion on the outcome. We have also implemented simplified models to determine probable consequences of the landscape changes (eg. population, soil erosion, 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.

The methodologies presented in this paper can be easily adapted to other study areas.

7. ACKNOWLEDGEMENTS

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