SIEVE: An Online Collaborative Environment for Visualising Environmental Model Outputs

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EXTENDED ABSTRACT

Environmental process models simulate complex and dynamic information, relating to a range of natural processes including water flow, air movement and terrain deformation. While visualisation packages exist which allow experts to explore environmental process models and associated data in 3D, there are a lack of visualisation tools available to affected non-experts. Traditionally, model outcomes are communicated to the public and decision makers via tables, graphs and maps which may not be understood. Mainstream GIS (Geographic Information Systems) provide some visualisation capabilities but cannot keep up with the rapid development of computer graphics, available though game engines and other software. SIEVE (Spatial Information Exploration and Visualisation Environment) is being developed to provide virtual environments that are online, collaborative and contain visualisations of environmental process model outputs. SIEVE uses GarageGames' Torque Game Engine (TGE) to create virtual environments using standard raster and vector data from a GIS. Environmental process model outputs are converted to a 2D layer, or series of 2D layers, the properties of which can be transferred to visual effects on objects and terrain. Vegetation and soil can be rendered indicating the effects of salinity or other modelled processes such as impacts on biodiversity. The movement of terrain, water tables or geological features over time can be shown. SIEVE aims to allow exploration of spatial models by experts and non-experts simultaneously. A number of options will be available to users to perform tasks such as: choosing realistic or abstract visualisation, turning the terrain on and off to view the sub-surface or viewing satellite imagery or thematic surface textures. Experts may wish to view an abstract environment, where trees are represented by symbols, so they can make quantitative analyses. Non-experts may wish to see what the real world looks like, realistic tree textures would be used. SIEVE aims to enhance understanding of environmental process model outputs and associated impacts by allowing users to explore and discuss data collaboratively, in a form with which they are comfortable.

1. INTRODUCTION

Visualising information can improve its understanding. In terms of scientific data analysis, including environmental process modelling, visualisation may be used to interact with and maneuver through scientific data. This can provide an environment in which people can examine and classify data, as a part of an iterative process, the results of which can feedback into the model (Jankun-Kelly et al 2002) The advantage of linking models to visualisations is that the data is made more accessible and easily understood. This means increased exposure of important information and greater input, from a wider range of people, into the modelling and planning process.

Environmental process models are not generally realised in collaborative virtual environments. Traditionally, model outcomes are communicated via tables, graphs and 2D maps which may not be fully understood by affected non-experts. Realistic and abstract 3D visualisation of spatial data in a multi-user system can aid communication of processes and outcomes and enhance community engagement and decision-making. Current Geographic Information Systems (GIS) do not provide the sophisticated user interaction and graphics that can be achieved with real-time 3D virtual environment software. As such GIS are currently limited in their ability to provide a desired knowledge sharing environment.

This paper will discuss the development of SIEVE (Spatial Information Exploration and Visualisation Environment), which integrates a GIS, 3D CAD models, a Geodatabase and a game engine. The software creates virtual environments of user selected areas, such as a catchment, group of properties or a city. The size of the area selected will be flexible but less detail will be available for larger areas. Users may choose to simply view a location as a virtual 3D environment or to view the effects of an environmental process on that area (Figure 1). Using the outputs from spatial models, the software selects 3D objects and terrain textures that are either 'normal' or effected by a modelled event. The game engine software provides multi-user network functionality so users can then explore the environment collaboratively. Communication options, such as a chat window, and abstract and realistic visualisation options, including sub-surface display, provide an environment where people with varying levels of technical competency can collaboratively explore the data, learn and make decisions.

Users will initially be staff of Department of Sustainability and Environment, Department of Primary Industries, Geoscience Australia and
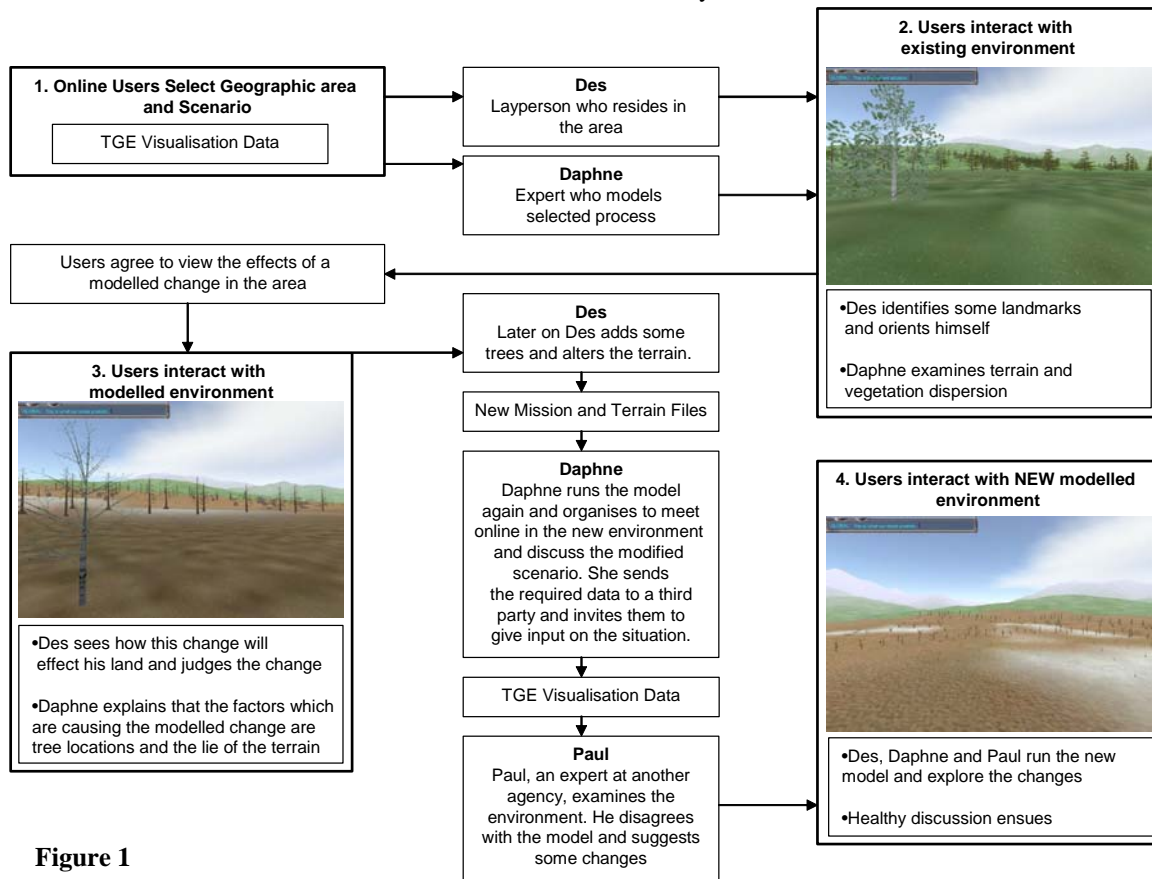

Figure 1

various catchment management authorities. These users may be familiar with the models being visualised or experts in other fields. It is assumed all users will have basic computing skills. Once the system is implemented online, users may include private sector users and laypeople. The visualisation options provided will be based on existing research (Rekittke & Paar, 2005, Dollner, 2000, Hofschreuder, 2004). These, along with the communication options provided and user interface design will be iteratively refined from user feedback as the various stages of system implementation.

2. EXISTING VISUALISATION TOOLS

"General-purpose GIS were originally designed for the classical 2D application areas, and hence do often not reflect the state of the art visualization. Moreover, if a GIS implements its own visualization subsystem, it will be difficult or even impossible to integrate cutting-edge visualization technology" (Dollner, 2000) GIS has traditionally used 2D maps for analysis and display. 2.5 and 3D analysis and visualisation of data has become increasingly popular, initially driven by mining and other industries that are involved with complex multi-dimensional relationships. "Due to the rapid development of computer graphics, visualization and animation techniques, general-purpose GIS can no longer satisfy the multitude of visualization demands. Therefore, GIS have to utilize independent visualization toolkits" (Dollner, 2000) While the need for advanced visualisations of GIS data, and their potential benefits are well understood, the precise requirements for community engagement need to be determined.

There are a range of tools in existence that provide 3D visualisation of spatial data. Virtual Reality Modelling Language (VRML) viewers, The Visualization Toolkit (VTK), and GeoViz International are a few examples. VRML viewers have the advantage of being freely available over the internet. VTK can deal with a wide range of scales i.e. real-world terrain down to nanoscale DNA. GeoViz can provide impressive fly through visualisations for a range of applications, such as mine sites and associated infrastructure. GeoViz products are custom designed for clients with little public access.

TGE was selected for this research for a number of reasons. Apart from providing sophisticated rendering engine and multi-user capabilities, the source code was obtained so required

customisations can be made. Integration with other software in the future is also possible. There are a limited number of people involved in the development of SIEVE. Using software that already provides network functionality, chat windows, customisable user interface, in game editing and animation functionality allows the research to focus on selecting and providing the options deemed necessary for 3D visualisation of environmental process model outputs for collaborative data exploration.

A number of studies using visualisation in collaborative, multi-skilled user environments have been undertaken (Gouveia, 2001, MacEachren et al, 1999 and Stock & Bishop, 2005). These use available technologies in a number of ways. One study involved users at different physical locations, 'immersed' in the same virtual environment using 3D projection screens, head tracking devices and the internet (MacEachren et al, 1999). Users explored and discussed climate data and topography. In another study, groups of people at the one location interacted with a virtual environment, on a large screen, using personal digital assistants (PDA) (Stock & Bishop, 2005). In this case users could 'vote' on different land use scenarios affecting their community. Research questions arising from these studies, such as "how to share different conceptual perspectives on the problem context (e.g., that of a climatologist and a land use planner)" (MacEachren et al, 1999) will be explored in this research.

3. INTEGRATING GIS AND TORQUE GAME ENGINE (TGE)

The Torque Game Engine (TGE) was selected for the development of the SIEVE tool. The engine is multi-platform, has multi-player network code, a sophisticated rendering engine, animation functionality, GUI creation toolset, in-game editors, a Torque specific scripting language, C++ source code and a range of other features (see www.garagegames.com). The C++ source code is available to licensees of TGE. TGE permits users to explore the same environment, from different physical locations using the internet and also to communicate via a chat window. This, and other user interface features, will be customised and expanded to allow for discussion and exchange of information in a collaborative planning environment

Workshops and group meetings are often used for collaborative planning. A multi-user, online environment has been selected for this research to

encourage greater exposure to data for colleagues over local access networks (LAN) and allow for increased access to information to those in dispersed geographic locations. The public sector organisations involved in this project have expressed an interest in using this form of collaboration and data visualisation.

The basic functionality of SIEVE is explained in the following. Users will be able to select the spatial information they wish to see and an area on a map using a GIS thin client (Figure 2), SIEVE will then (on the GIS server) convert the required data from rasters and shapefiles, into TGE specific formats. SIEVE will then specify the textures that should be rendered onto the terrain and which 3D objects should be drawn where, i.e.: 'a mature pine trees' or 'gums showing the effects salinity', defined by the model outputs.

4. SIEVE SYSTEM COMPONENTS

The components of SIEVE can be seen in Figure 2. The 'Spatial Data' component will initially be populated with national, state and local satellite imagery and topology. The 'Texture and Object Library' will be a database of vegetation textures, 3D models (such as trees or underground geological volumes) and terrain textures.

'Environmental Process Model Outputs' will be 2D layers. If a user wishes to run different scenarios, for an area they have already viewed, they will only need to download a subset of additional data.

TGE runs with two files, the terrain file and a mission file. The terrain file is in hexadecimal format and the mission file is a text file. The terrain file specifies a grid of elevation, e.g. from a digital elevation model (DEM) and which textures to use on the terrain. The mission file specifies the objects that should be drawn on the terrain, and a wide range of other elements such as sun, sky, fog and water effects.

TGE terrain currently contains 256 by 256 pixels. It is intended that this be expanded to provide more detail. For each pixel there is a specified height and an associated texture. The file also defines how the terrain should be scaled in xyz. These variables can all be written out from the GIS using a module that has been programmed for this purpose. The height values are simply converted from a specified DEM. Theme values are obtained from a 2D layer with, for example, land use classes or salinity levels. Each theme references a texture, this reference is also written to the terrain file.
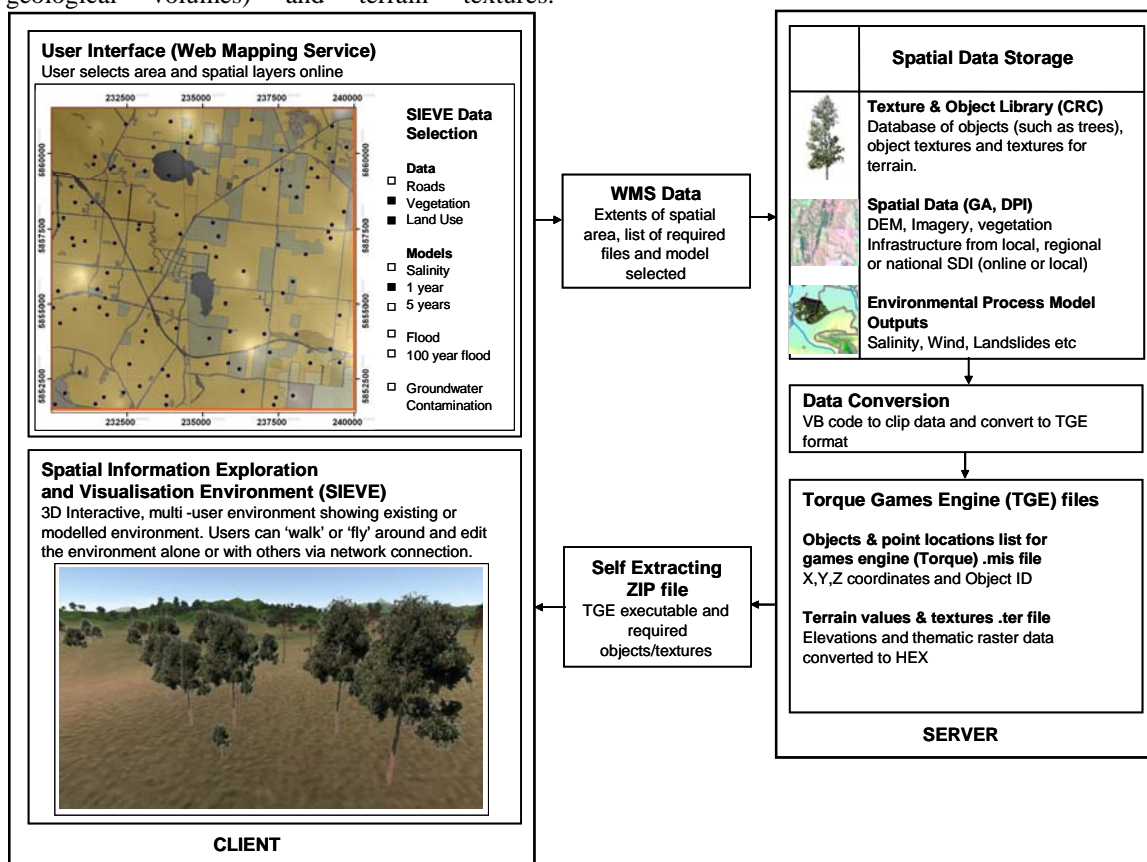

Figure 2

5. COMMUNICATING ENVIRONMENTAL MODELS IN A COLLABORATIVE ENVIRONMENT

Environmental processes can be defined as the actions, operations, and cycles that occur naturally in the environment. Groundwater flow, hydrology, salinity, erosion and estuarine cycles are a few examples. Environmental process models are used to simulate, explore and describe the dynamic information involved in these processes. There are vast numbers of models developed in both the public and private sectors. Models frequently involve isolated efforts with purpose built datasets. The models developed often have little portability to other similar scenarios and cannot be adapted to utilise different datasets. "Environmental models must "open up" in order to achieve a full integration with GIS and between models themselves" (Bain, 1997).

Environmental process models can have wide-spread effects and impacts on planning at many levels. There is a need for environmental process models to be shared with a variety of users. Communities of people affiliated by geographical location, special interest, or similar situations need to address issues affecting their well being. Stakeholders need to be better informed to help identify issues that may not have been considered and to encourage improvement of existing conditions (Charter for Community Engagement, 2001 and Effective Community Engagement Workbook and Tools, 2004). "Due to the diverse nature of people involved in the planning process, specialist software and platforms certainly do not meet the various requirements from different people" (Hofschreuder, 2004). There is currently a gap between environmental process model outputs and widespread access. There is a clear need for tools to facilitate information transfer.

The lack of standards in environmental models make creating visualisation tools for multiple models a difficult task. Some modelling may be conducted within GIS packages, and have 2D layers as their outputs. Some models may use other software. This research will assume that data from models can be converted to 2D layers, the values of which can be transferred to visual effects on objects and terrain by SIEVE (Figure 3). This architecture will hopefully mean SIEVE is open to
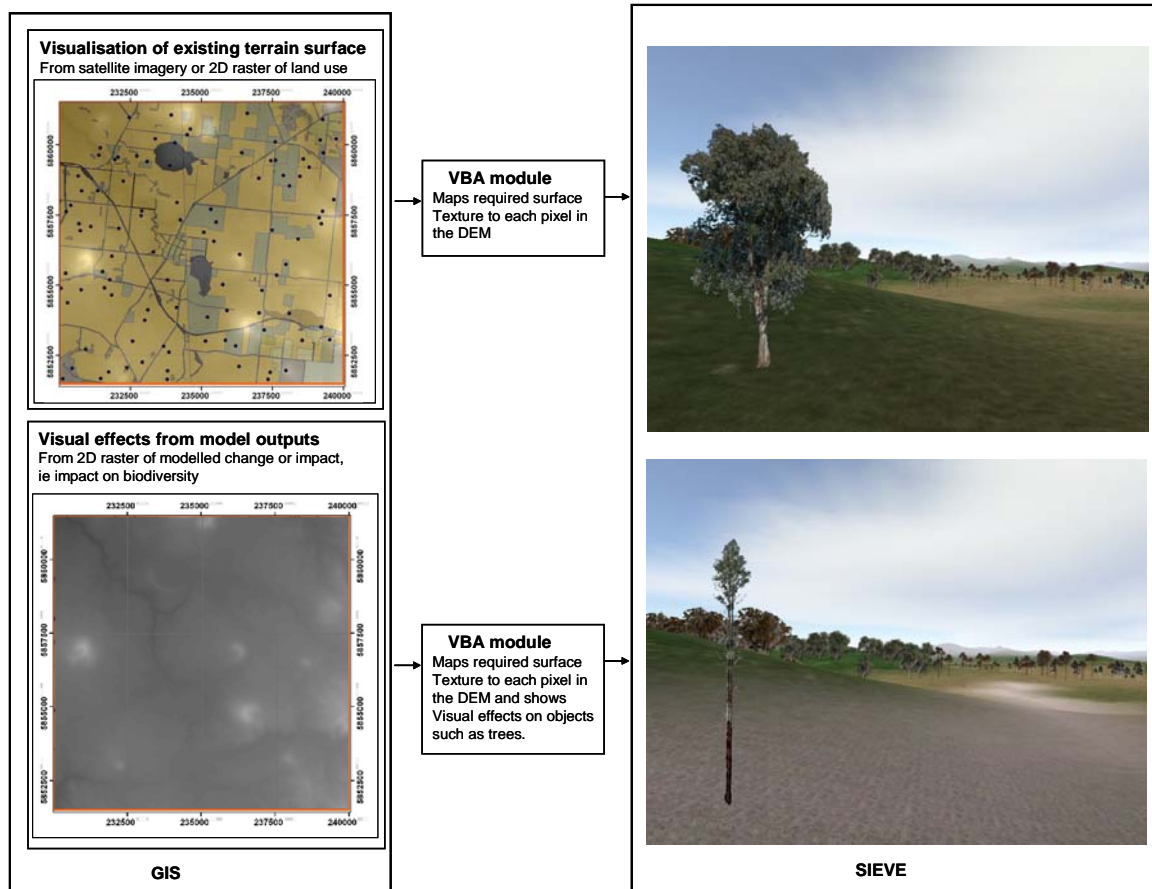

Figure 3

input from a wide range of models.

SIEVE will use the 2D outputs from environmental process models to create a virtual environment where the objects and terrain show realistic or abstract effects of the model. Subsurface objects, such as the water table, or geological features may also be created under the terrain surface. The virtual environment may be a flooded valley, a farm affected by salinity or an eroded dune area, as a few examples. As a case study, outputs from The Catchment Assessment Tool (CAT) including impacts on biodiversity and crops, will be used.

Ancillary information pertaining to the environmental process models will obviously be of interest to users. This will include data used, details of model parameters and assumptions. SIEVE does not currently provide access to this information explicitly but the web interface will provide links to existing model explanations and metadata.

SIEVE is currently limited in that it can visualise environmental process model outputs but does not allow for direct interaction with the models. The loose-coupling of the tool means that the download time for a virtual environment may take up to a few minutes, downloading subsequent scenarios for the same location is much quicker. Once a virtual environment has been downloaded, the user works with data residing on their own computer, the network is used for multi-user collaboration. To allow for direct interaction with models, the models would need to reside on the users system, requiring much longer initial download time, or continuous data transfer would be required. Both these options would increase the computational power required and thus exclude access to some users A tool that linked live to the models and allowed alteration of model variables would provide a valuable tool but is not currently supplied by SIEVE.

6. CATCHMENT ASSESSMENT TOOL (CAT) CASE STUDY

The Catchment Assessment Tool (CAT) is a suite of catchment analysis tools that has been developed by Department of Primary Industries (DPI) in conjunction with the Cooperative Research Centre for Catchment Hydrology. CAT is capable of assessing impacts of landscape intervention on catchment hydrology, biodiversity, water quantity and quality. The model incorporates the widely used models to simulate forest production, grazing enterprises and cropping modules all explicitly linked to a three-

dimensional groundwater model. The framework can operate from the broad scale to the land management scale and is capable of assessing the trade-off between agronomic and engineering options to control recharge or groundwater discharges. The objective of the model is to provide information regarding the external impacts of landscape change on salinity and water quality, impact of landscape change on biodiversity (terrestrial and aquatic) and on-site costs of landscape change (CAT Model Summary).

The current research focus is to visualise outputs from CAT. CAT can provide detailed process-based assessment of the impact of land use on ground water as well as identifying impact over time from various reforestation scenarios. The outputs of CAT include a range of 2D raster surfaces. These outputs are suitable for SIEVE which can create virtual environments showing the visual effects of different impact scenarios. Initially a pre-run of 40 years of CAT outputs will be used. Users can select different combinations of variables etc. In the future, these could be live runs on a server.

All environmental process models have limitations in terms of accuracy and their predictive capabilities. Research is being undertaken, under other program areas within the CRC-SI, that will investigate visualising uncertainties. SIEVE will initially provide a tool that can visualise model outcomes from CAT and other models without considering inaccuracies. SIEVE can potentially be adapted in the future to also visualise uncertainties.

7. SUMMARY AND OUTLOOK

SIEVE is currently running on a number of PCs with multi-user functionality over a LAN. By carrying out a number of steps, a user can select an area in a GIS, then view the virtual environment created by TGE for that location. Automation of this process is underway. Provision of display choices (realistic or abstract), integration of CAT data and development of communication protocols are the current focus of research. Once this functionally has been added and tested, SIEVE should provide a needed 3D visualisation tool for spatial data and environmental process model outputs intended for community engagement and collaborative data exploration.

8. ACKNOWLEDGMENTS

9. REFERENCES

Bain, L. (1997). Opening Environmental Models. International Conference and Workshop on Interoperating Geographic Information Systems, 1997, Santa Barbara, California.

Dollner, J. K. H. (2000). "An Object-Oriented Approach for Integrating 3D Visualisation Systems and GIS." *Computers and Geosciences* (26): 67-76.

Charter for Community Engagement (2001), Community Engagement Unit, Queensland Government, Department of Emergency Services, Brisbane

Gouveia, L. F. G. (2001). A Visualisation Proposal to Assist Knowledge Sharing. International Conference on New Technologies in Science Education - CINTEC, Aveiro University

Effective Community Engagement Workbook and Tools (2004), Community Engagement Unit, Resources and Regional Services Division/Catchment and Agricultural Service, Department of Primary Industries, Department of Sustainability and Environment, Victoria

Hofschreuder, J. (2004). Visual Criteria in Detail: Correlation between the required level of detail of 3D-landscape visualisations and visual criteria. Land Use Planning, Wageningen University, The Netherlands.

Jankun-Kelly, T., K-L. Ma & M. Gertz (2002) A Model for the Visualization Exploration Process, Proceedings of the conference on Visualization '02, October 2002, Boston, Mass. USA

MacEachren, A. M., R. Edsall, D. Haug, R. Baxter, G. Otto, R. Masters, S. Fuhrmann & L. Qian (1999). Virtual Environments for Geographic Visualization: Potential and Challenges. ACM Workshop on New Paradigms for Innovation Visualization and Manipulation, Kansas City.

Rekittke, J. & P. Paar (2005): Enlightenment Approaches for Digital Absolutism – Diplomatic Steping-Stones Between the Real and the Envisioned. -In: Buhmann, E., Paar, P., Bishop, I.D. & E. Lange (eds.), Trends in Real-time Visualization and Participation. Proc. at Anhalt University of Applied Sciences, Wichmann, Heidelberg: 210-224.

Stock, C. and I. D. Bishop (2005): Helping rural communities envision their future. In *Visualization for Landscape and Environmental Planning: technology and applications,* eds. I. D. Bishop and E. Lange. Taylor and Francis, Oxford: 145-51.