The applications of virtual reality for interdisciplinary planning

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Abstract

This paper evaluates virtual reality (VR) model implementations on their ability to inform and engage interdisciplinary groups in transportation planning. First we present a VR simulation system used by engineers and planners to share proposals and work with members of the public. The system consists of several elements: real-time simulation software for visualization, motion and audio hardware systems that allow users to take a driver's perspective, and output methods for presentation and collaboration. Applications are then described, including: visualizations of a new LRT system in Sakai City, Japan; simulations for road design in Busan, Korea, and Fukui, Japan; and an urban planning model of Phoenix, USA. These case studies are evaluated, and it is concluded that optimal implementation involves 1) structured integration of the VR model within the project planning framework, and 2) interactive presentation methods.
Keywords: virtual reality, visualization, transportation simulation, collaborative planning, driving simulator.

1 Introduction

Urban transportation planning requires delicate compromises between different stakeholders, budgets, environmental considerations and engineering constraints. In negotiating these factors, visualization serves as a tool not only for detailing technical plans, but also for informing non-experts so as to enable their participation in the decision-making process. Current systems for city and architectural modeling can be limiting when they display a built environment, but fail to include the moving forces that act against this background: human and vehicular traffic. Alternatively, traffic simulation programs are often driven by

WIT Transactions on The Built Environment, Vol 107, © 2009 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/UT090191

analysis, and may be visually unappealing, with results that are difficult to explain to non-engineers [1]. Despite advances in both large scale transportation simulation and environment modeling, there have been limited methods for merging the two in such a way that necessary visual and technical information can be used effectively for dialogue between planners and non-design professionals. As Hughes writes, modeling several elements of a system is not the same as modeling the dynamic real-time characteristics of a system "at work" [2].

In recent years, visualization technologies have made much progress: not only has animation become a mainstream part of popular culture, but it has also become a workable tool for various science and engineering industries. Visualization has "crossed a threshold" and become both practical and financially feasible [1, 3]. 3D modeling that used to require specialized rendering machines can now be performed on desktop PCs, allowing more room for creativity both in developing and presenting simulations [1]. Virtual reality and other recent technologies have added another dimension to visualization by allowing users to interact with a simulated world.

At the same time, public involvement in transportation infrastructure planning is becoming increasingly mandated, and is often regarded as necessary by different stakeholders [1, 4]. Even with the logistical difficulties of including many participants, collaborative planning has several benefits. Ideally, project time can be reduced if stakeholders are engaged and less resistant throughout the approval process. Also, with a variety of participants simultaneously negotiating a plan, earlier identification of problems and objections as well as better informed decisions can assist in reaching project goals [3].

Al-Kodmany writes about the failure of "traditional planning tools" to engage community members. He describes a working session in Chicago where visual presentations "lacked a means of visualizing what was being proposed within the context of what currently existed" [5]. When applied to planning projects, virtual reality has the potential to create a platform that allows users to not just view, but interact with a highly accurate visualization of transportation agents and environments. A virtual environment can reproduce different time intervals and scenarios, allowing presentations and interactions to encompass changes in space, time and activity.

In reviewing system functions and case studies, this paper will evaluate several applications of a virtual reality system. Applications will be considered successful if information is shared in a way that allows non-experts to contribute their own knowledge to the planning process. Under what circumstances can virtual reality implementation best enable collaborative planning?

2 Methodology

2.1 Visualization creation

Simulations are created within 3D real-time virtual reality software called UC-win/Road [6]. Providing the basis for a visualization begins with importing terrain information, inputting accurate road alignments, and pasting a satellite image or map over the terrain to orient the project (Figure 1). Roads and intersections are automatically generated with default cross sections, and traffic can be immediately generated.

In order to create more realistic scenes that can represent specific locations, a compelling cue environment is designed with 3D models and photo-textures. Textures can be applied to any model or surface, and settings such as texture magnification filters and visibility angles are adjusted.

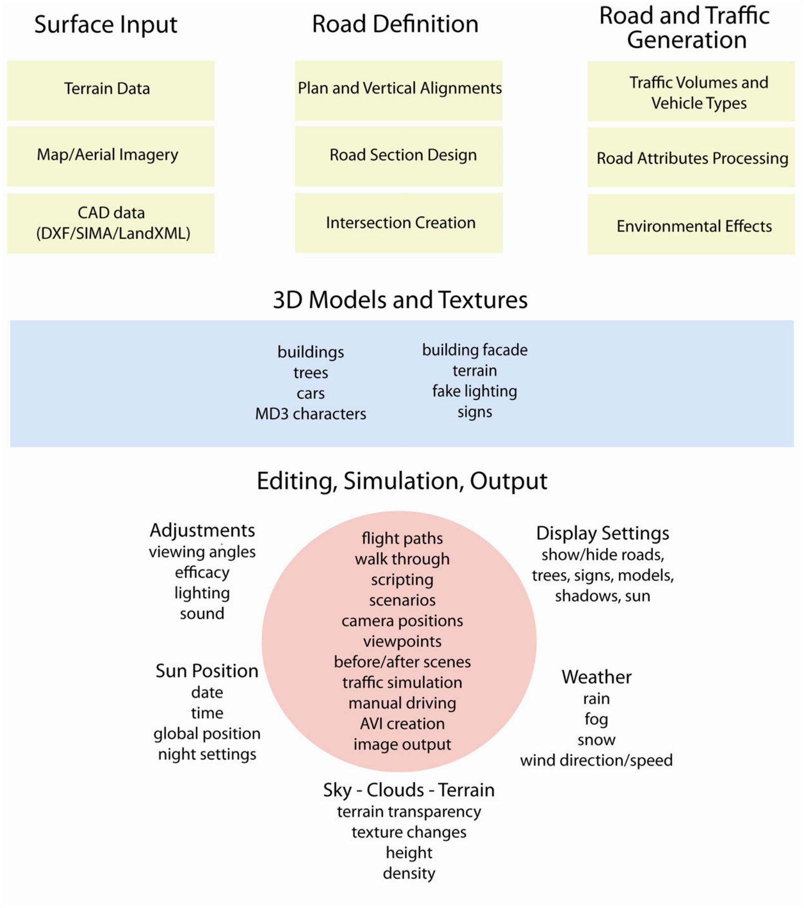

Figure 1: VR software work-flow.

Once static models and textures are set in place, environmental, traffic, and human movement patterns are further edited. Traffic is generated from the start and endpoints of roads, and traffic profiles are customized with a proportioned selection of vehicle models. Traffic settings are established so that cars stop in accordance with signals and abide by location-specific driving rules. Intersections are individually edited to adjust road leg lengths, markings, drive paths, stopping points, and signal phases. MD3 characters, enhanced by motion-capture animations, are set to penetrate the VR space on set “flight paths”. To give the effect of large crowds, still images are also used to save time and texture memory.

Finally, to tie all of the animated elements together, “scenarios” and “scripts” are composed to combine a series of events and environmental effects. In order to mimic a given area’s conditions, sun position can be set to the minute and shadows are accurately reproduced. Weather effects such as rain, snow, fog, and different cloud compositions can also be added. Display options include terrain transparency, spot light, eye light, compasses and dashboards. Some simulations are also be customized, not only by editing the visualization data within the basic program, but also through a Delphi Application Program Interface (API).

2.2 Presentation

2.2.1 On a desktop PC

The 3D VR space is often presented within the software on a desktop PC. Real-time free-form navigation through the visualization allows users to observe the environment from any location and angle. Scripts that move through the data can be configured and executed, roads can be driven down, and flight paths can be flown through. Before-after scenes also allow for quick comparison of different planning alternatives. For situations where access to the software is unavailable, video, image, and sound outputs are presented or posted online. Videos are created within the program’s interface, allowing modelers to create a script and record a series of moving scenes or saved camera still shots.

2.2.2 With a driving device

One of the built-in functions of the software is automatic traffic generation on the created road network. During basic simulations, traffic elements behave as intelligent agents. Cars obey traffic lights, change speed and lanes in accordance with surrounding vehicles, and can move around road obstructions. Yet when a vehicle is controlled by an external device, the user navigates freely through the road network. Such devices include gaming pads, steering wheel and pedal devices, and various full-size driving simulators.

Oftentimes different driving “scenarios”, or series of pre-programmed routes, events and alerts are created for use with simulators or other hardware devices. This presentation format is the most interactive, as the VR space responds to the user’s driving behavior. With adjustable traffic elements set for individual streets, subjects can drive through a given route in different traffic conditions. Hardware can also be integrated for driving behavior research, training, and road safety assessments.

3 Case studies

3.1 Urban revitalization in Sakai City, Japan

3.1.1 Model attributes

The Division of Energy and Environmental Engineering at the Osaka University Graduate School has created a simulation in order to assist the local government in reviewing and building consensus for a planned light rail transit (LRT) and urban improvement project in Sakai City (Figure 2). The government is planning to include several sustainability initiatives such as public bikes, green areas, and solar paneling of public buildings [8]. As the visualization includes traffic, buildings, and pedestrian movement, it allows for a more holistic pre-view of the city's future. An outstanding feature of the model is the extent to which it has been edited to stay up to date with current plans. A variety of "scenes" include details such as different options for foliage lining the sidewalks near the town center [7, 8].

3.1.2 Informing and involving

In recent monthly presentations to the public, this VR model has been loaded on a laptop computer, and projected onto a screen for presentation. Videos are also shown together with maps and other relevant charts and diagrams. These images were saved as textures within the VR space, and could be displayed in the form of slides at town meetings [7].

Initially, the VR model was not used to receive public input; it had instead been created to convince citizens that constructing an LRT was a good idea. Since then, the model has come to serve as a flexible 3D space upon which the public projects their concerns and authorities return with edited changes. Issues such as truck delivery to homes bordering on the LRT line, or bike parking near the station are discussed [9]. Alternatives can be immediately presented in the visual model; the use of a "before" and "after" scene function makes it possible to compare alternatives and see what the city might look like after the proposed changes.

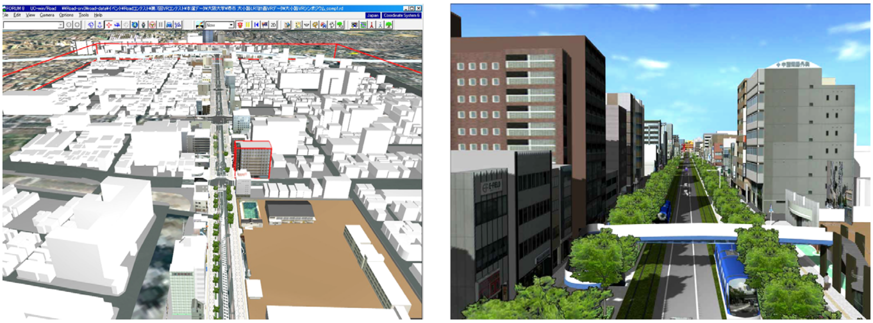

Figure 2: Sakai City LRT Implementation Simulation - model editing interface *(left)*, LRT line *(right)* [7].

www.witpress.com, ISSN 1743-3509 (on-line)

This month's meeting was attended by about 300 citizens who are still questioning basic effects of the LRT design (e.g. how emergency vehicles will access homes that border the rail line and how driving shoppers will be able to park near stores [9].) Viewing the project from a non-engineering lens, the public can apply their local knowledge to double check potential problems. Although citizens may not be interacting with the model directly by editing it or using a driving device, their involvement in the planning process has been both valued and structured from the onset.

3.2 Urban planning in Phoenix, USA

3.2.1 Model attributes

The Digital Phoenix VR model covers a 1 mile x 1 mile square area and visualizes traffic patterns and future infrastructure developments (Figure 3) [10]. Scenarios can predict what the traffic grid may look like in a few years on a day when the stadiums, convention center and opera hall all have events at the same time. An LRT rail line was also simulated prior to construction. Most of the buildings, lane conditions, traffic signals, lights, and stop signs in the area have been implemented in the model and are visualized in the real-time 3D environment. The Digital Phoenix Project is a still a work in progress at Arizona State University with the goal of mitigating Arizona's urban sprawl problems by facilitating smarter planning and group decision-making.

Figure 3: Traffic visualization - aerial view (*left*), highway close-up (*right*) [11].

3.2.2 Informing and involving

Although the Digital Phoenix model itself is visually rich and informative, there are still networking gaps to fill in before the model can be used practically as a part of the decision-making process. There has been a lack of communication between those who are funding construction projects, developers, planning authorities, and the VR project team at Arizona State University. Nonetheless, the model has been shown to city officials responsible for new development (real estate and building) projects as well as used in collaboration with smaller planning projects such as the Jackson St. Entertainment district. It was displayed on Channel 11 News and used during the mayor's State of the City Address to show 2000 onlookers how the area will change in the coming years. Animations are available online, and the project team is still developing different ways to make the simulation available to the public. In addition to integration with a driving simulator, they are also experimenting with the use of an immersive theater and tangible interfaces.

In this case, the VR model is very well developed and presentation methods allow for user interaction, but the visualization has not been integrated into planning process in a way that allows for participation. The model has only been used loosely as a means of thinking about smaller projects in the context of the surrounding urban environment. Users might interact with the model and become better informed about future developments in Phoenix, but there is no structure for them to act upon any information gained.

3.3 Route planning in Busan, Korea

3.3.1 Model attributes

Last year in Busan, Korea, there were clashes of opinion over the route for a new national highway planned for construction. The Busan Regional Construction & Management Office simulated the Sancheong-Sudong area, and this visualization was used to present plans and gain feedback from residents. Citizens were torn between whether the route should go through farmland or in front of the town through a more urban area. The visualization creation was uncomplicated, and consisted mostly of road alignment input from CAD designs as well as placement of basic housing models in populated areas. The two alternate routes and their traffic flows were distinctly represented (Figure 4) [12].

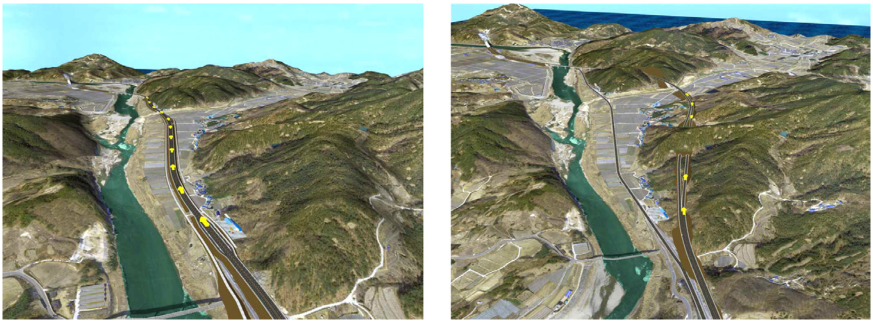

Figure 4: Sancheong-Sudong VR Simulation - screenshots of alternatives [12].

3.3.2 Informing and involving

The Sancheong-Sudong 3D VR visualization was used in pre-construction phases to explicate the options to residents during explanatory meetings. They were able to discuss different factors that contributed to the decision-making process: road cutting and banking; sound insulation and retaining walls; difficulty of performing road construction in certain locations; possibility of flooding, etc. They also indicated areas where the Kwandong relics are located, and discussed sound pollution and construction vibration issues. Residents ultimately voted in favor of a route that passed behind the village as opposed to in front of it. The VR model was presented as a video file and the program itself, running live, was also projected. The visualization was deemed cost-effective in that it allowed several opinions to be heard simultaneously, and resulted in a stronger impetus to move forward with the project. Design issues were straightforward and presented to the people in such a way that they could make a reasonably well-informed decision and see it implemented.

3.4 Public notification of road safety in Fukui, Japan

3.4.1 Model attributes

The Fukui coastal highway route in Japan is renowned for being the site of many accidents. In the process of constructing a safer road, a customized simulation and hardware setup was created to present driving scenarios and educate people about the road. Currently, the stand-up driving simulator, as seen in Figure 5, is placed in a rest stop along the highway. Drivers can stop by to take a break and try driving virtually down the highway. They may learn about upcoming dangerous curves and prepare for traffic trouble areas, as categorized by the Kinki Regional Development Bureau planners. In addition, they can test driver visibility under adverse weather conditions.

Figure 5: Fukui Coastal Route Drive Simulation - rest stop in VR space *(left)*, public use simulator *(center)*, driving interface *(right)* [13].

3.4.2 Informing and involving

This application has several positives. Access to the model is directly available to the appropriate audience: people that use the road in real life. The road improvement work is still in progress, so visualization is implemented at a stage early enough for citizens to become aware of future changes. Instead of watching a scripted movie of the model, users can take a driver's perspective and interact with the visualization. This would be an ideal opportunity to solicit feedback on areas of the road that drivers would like to see improved. A formal system for receiving feedback has not been established, but the simulator is placed in the same building as the road authority offices, perhaps facilitating casual communication between drivers and planners. Although users are not involved in editing the model themselves, they do gain a high-level of familiarity with the project via the simulator experience.

4 Evaluation

Table 1 summarizes several VR application attributes. Although every model makes certain compromises in visual details, in each case sufficient information was provided to accurately convey a transportation environment to non-experts. At a minimum, citizens were informed by presentations. Yet the extent to which each application paved the way for collaborative planning varied greatly depending on project framework and presentation methods.

Table 1: Case study application attributes.

VR Model	Visual Quality		Project Integration		Presentation Methods	
	Conveys necessary information	High level of detail	Incorporated into planning structure	Interdisciplinary feedback is solicited	Visual	Interactive
Phoenix, USA	X	X	O	O	X	X
Sakai, Japan	X	X	X	X	X	O
Fukui, Japan	X	X	X	O	X	X
Busan, Korea	X	O	X	X	X	O

4.1 Planning for VR integration

One major challenge to the implementation of VR for planning, as particularly demonstrated in the case of the Digital Phoenix project, is that visualization is often not considered necessary from the start and therefore not incorporated into planning structure from the project incipience (Table 1). When VR models are brought into play late in the planning process, it becomes increasingly difficult for planners to adjust their work flow to take advantage of editing a new model. In addition, it becomes more difficult to incorporate feedback. As we see with the Digital Phoenix VR model, despite rich details and high potential for use, it has primarily remained an academic research project. Similarly, even though the Fukui VR model was applied to improving road safety and citizens were well-informed of the process, there was no structure for involvement. The Busan and Sakai models remain the most successful as they were the two cases where public input actually influenced project designs. Both VR models had well-structured implementation methods and were prepared to integrate feedback.

4.2 Presentation for collaboration

The remaining questions are: How can VR implementation enable non-transportation experts to participate in a way that incorporates their knowledge into the decision-making process? And how can presentation methods complement the technology?

Although the visual presentation functions in these case studies were used effectively enough to convey ideas, the system's drive simulation functions often remained unused. Perhaps for architectural visualizations, a walk-through scenario may suffice. Yet for assessing road and rail plans, a driver's perspective adds an essential level of understanding that can contribute to better design. Integrating the software with inexpensive steering controllers can allow users to drive in the same way they would actually handle the road in real life. As much as visual details can contribute to an understanding of a project's end goal, without interaction, non-experts will still be limited to a purely visual understanding of plans and may only be involved in making straightforward or aesthetic decisions. As shown in Table 1, only in the Fukui and Phoenix case studies do we see the public benefitting from interactive presentation methods. These participants would be capable of making recommendations based on experiences and not just reactions to imagery. (Unfortunately for both cases, a fundamental framework for public involvement was lacking.)

Presenting the VR model in video format also disengages the editing functions available in the interface with 3D space. In order to initiate more equal dialogue, it may be best to edit the VR model live in front of a vocal audience. The lack of live editing in these case studies means that options are usually presented to the public, as opposed to enabling different stakeholders to propose alternatives themselves (and see their options immediately in the VR space). The engineers/planners still hold the power to begin and shape a planning consensus meeting. In this sense we see presentation methods failing in two ways: 1) maintaining an expert / non-expert dynamic where only experts can draw up solutions, and 2) limiting participants to a purely visual perception of plans.

5 Conclusion

The described implementations serve as case studies for future VR applications that inform and engage interdisciplinary groups in transportation planning. Even with advances made in 3D technology, until visualization is better structured into project planning, its potential as a communication tool will remain untapped. Future applications should consider presentation methods that go beyond projected images and animations. Technical explanations that include immersion in an environment, as opposed to passive viewing, may lift barriers to understanding and participation. The goal is an interactive model that will lead to a more balanced dialogue for shaping future infrastructures, environments, and shared resources. Ideally, non-transportation experts will be able to contribute, drawing on their own local knowledge and experience to provide insights into the planning process.

Acknowledgements

We would like to thank T. Fukuda, T. Kawaguchi, A. Maruhashi, Y. Nishimura, H. Izumi, and S. Fujimura at Osaka University's Graduate School of Engineering, Division of Sustainable Energy and Environmental Engineering. Thank you to the members of FORUM8's Road Support Group, and especially to Reid Baker and Sam Marginson, for their help.

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