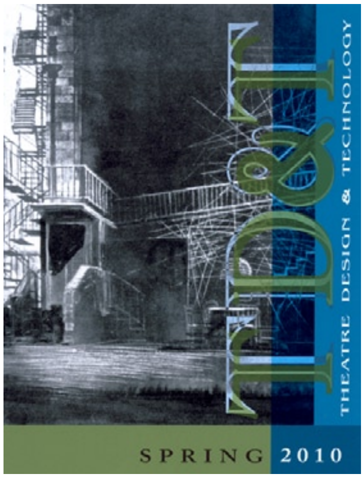

Lighting Simulation in Virtual Scenery

By Mark Reaney

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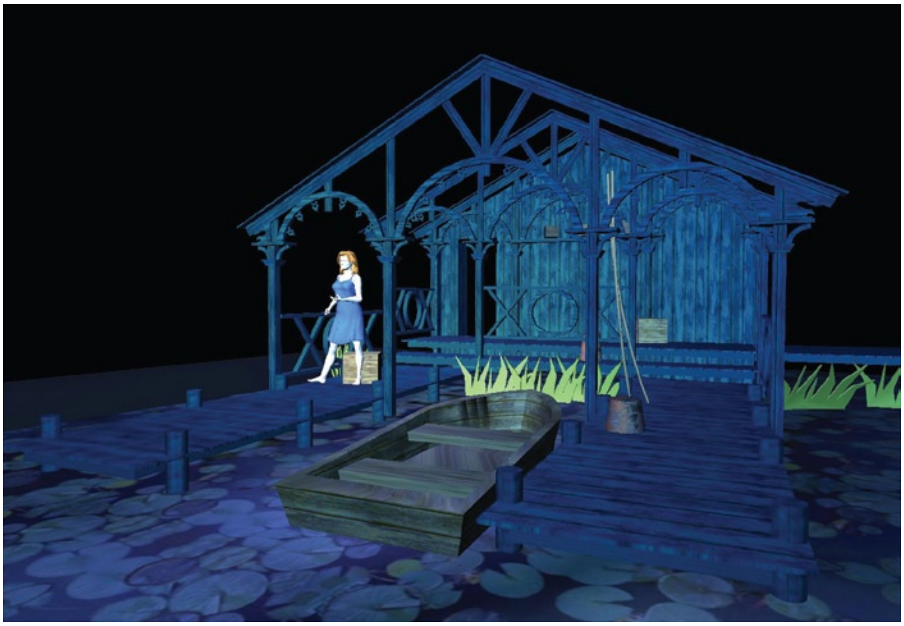

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Computer models have been an important and valuable tool for scenic and lighting designers for many years and in some cases digital models have completely taken the place of traditional balsa wood and paper models. For designers, there are many advantages to the use of computer models over the more traditional methods.

One advantage is the high degree of flexibility inherent in scenic models created in the computer. These digital models can be changed, turned, and viewed from vantage points that correspond to realistic views available from within the theatre. Multiple viewpoints can be saved as traditional-looking renderings which can easily be shared with collaborators via e-mail or on Web pages. These digital representations of various scenes can be presented in printed handouts or as slide projections during production meetings. Revisions that would usually require that a traditional model be completely rebuilt, can often be made in just a few minutes in a computer model.

Another important advantage of computer models, the one explored in this article, is the ability to mimic stage lighting, quite realistically, something very seldom seen when using traditional balsa wood and paper models.

At the University of Kansas we have taken computer modeling one step further by incorporating virtual reality simulations. A computer model in a virtual reality simulation can be manipulated and navigated in real-time as if the viewer were walking through the model. We use these real-time walk-throughs both as scenic design tools in the design of traditional scenery and as interactive scenic media projected onto the stage as part of the live theatre production. A short list of other articles by the author is provided at the end for those interested in more information about various uses of virtual reality the theatre.

A VR simulation is similar to a theatre experience in that both are interactive, that is to say they exist in real-time. Virtual reality is kinetic as opposed to a static traditional model. One weakness in our virtual simulations up to this point has been our inability to create dynamic lighting. Therefore the work of the lighting designer has not been well represented in a VR simulation. Fortunately, now there are new techniques and technologies that allow us to incorporate the advantages of a VR simulation with the highly detailed and expressive work of lighting designers. In figure 1, a VR model of a setting for *Talley's Folly* shows basic lighting using highlights and shaded surfaces but without any cast shadows. Note the lack of depth and the way that complex, overlapping objects are visually confused.

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The first lighting technique to be used in VR is stencil shadows. Stencil shadows are written into the programming of a VR simulation in such a way that pre-designated light sources are calculated for their alignment with the geometry of the computer model and shadows are then cast on other parts of the model in the appropriate shape and position. These shadows are interactive. If you use inputs such as a computer mouse to move the virtual light source, the virtual shadows move correspondingly. They are not, however, very realistic. They are typically hard edged and the color does not respond to the color of the ambient light sources. The color is simply predefined or predetermined by the user. The amount of opacity is also predetermined before the simulation is started. In figure 2 we see the same setting for *Talley's Folly* using stencil shadows. In this case only two light sources are defined. These stencil shadows are very processor intensive. They require a great deal of computing power to paint these shadows from complex objects onto other complex objects. Therefore the number of light sources in a simulation is rather limited. Still, the animation frame rate drops from around 60 fps to 18 fps. The darkness of the shadows and the color are pre-determined and written into the simulation.

The second method of creating lighting in a VR simulation is something called light-mapping or texture rendering. In some applications it may also be referred to as texture burning. Most professional modeling applications include this feature. This form of rendering lighting is very detailed and realistic. In order to create texture burning, one builds a model in a favorite modeling program, sets up the lighting, and renders it with all the appropriate ambient light, colors, cast shadows, highlights, and shade. Then the appearance of each object is rendered as a material and reapplied to the object. For example, a platform modeled with a simple wooden texture can first be lit and then have the new texture of wood plus creative lighting effects re-applied to its surface. In this way the texture and lighting effects are "painted" onto the surfaces of the objects. In figure 3 another version of the *Talley's Folly* set is shown in which the texture of the dock has been lit in an appropriate manner and reapplied to the dock so that no matter how the lighting changes, the original lighting is still there because it has been painted onto the dock texture. All the shadows, highlights, textures and colors are applied as a painting and cannot be moved. This type of rendering is not processor intensive therefore there is no limit to the number of light sources that can be used to create the light-maps. But it is very labor intensive as one must completely set up the lighting beforehand and then render each surface and reapply the texture to that surface before sending it to the VR simulation. Therefore it is a good idea to render only the largest and most obvious surfaces such as walls, floors, ceilings, or in this case the docks. It is not necessary to render all of the small surfaces. In figure 3 the seaweed, the buckets and the small crates on the docks have not been light-mapped for this reason. This type of rendering is not interactive. Once put into the VR simulation moving the light sources will change the basic highlights and shading, but will not affect the colors and cast shadows painted onto the objects within the scene. Therefore, for best effect the direction of lights in the VR environments should generally correspond with the direction of the cast shadows mapped onto objects. If one wants to change the lighting one must go back to the beginning and relight the model before importing it again into the VR application.

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Computer modeling and Virtual Reality on the cheap

Computer modeling need not be expensive or complicated. There are commercial options for computer users that will allow you to create models and convert them to VR simulations for little or no money and require little or no experience.

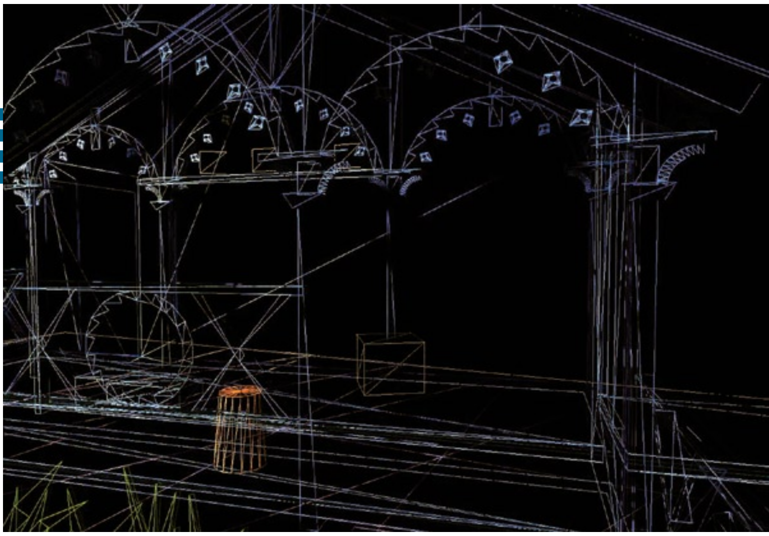
For modeling there are two options that are very interesting. The first option is Google SketchUp from Google Software. The basic version of SketchUp can be downloaded from the Google Web site for free. An expanded, paid version, SketchUp Pro, has advanced features useful to professionals. SketchUp is very easy to use and novices can quickly create models with it. A number of helpful, step-by-step tutorials are available on YouTube. SketchUp has a unique interface which makes for very quick models but some details—organic shapes, turned objects, circles, lathed objects—are rather complicated in SketchUp and are probably not worth the effort. There are plug-ins available that will allow you to do advance lighting simulations and add texture to your models such as wood and stone. Most of these third-party plug-ins cost a few dollars but might be well worth the cost if you like working with SketchUp. Be sure to try IDX Renditioner which features a cut-down free version (www.idx-design.com). In these plug-ins the lighting fixtures are architectural in nature rather than theatrical so it will take a little imagination to convert the architectural lighting fixtures into something that you can use for a theatre model.

Another interesting application, Blender, is a very powerful, professional modeling program. It's open-source software and is available for free from the Blender Organization (www.blender.org). Blender creates highly detailed models comparable to ones created in expensive modeling programs. The amount of detail, the amount of textures and materials that you can add to it are almost infinite. It uses professional lighting simulation, comparable to the type of lighting that you would find in a theatrical presentation. Blender does have a somewhat steeper learning curve than Sketchup. The user interface is somewhat unique. It has many of the tools and techniques that you are accustomed to seeing in commercial modeling applications, however they are put in unique formats and in places that can take a little while to learn.

For VR simulations—turning your computer models into VR real-time graphic simulations—there are a couple of options. The first is a plug-in for Autodesk's modeling, animation, and rendering software, 3-D Studio Max, called Eon Raptor (www.eonreality.com/raptor). If you are using 3-D Studio Max (sometimes abbreviated 3ds Max) you can put this free plug-in into your program and it will allow you to export models that can be navigated in real time. As outlined in this article, if you want to have professional looking lighting in your simulation you are going to have to use one of the techniques such as light mapping or vector mapping in order to create this light.

Another option is VR modeling language or VRML. VRML is a standard that was invented in the 1990s to put real-time VR simulations on the Internet so they could be shared with users all over the globe. VRML is available in almost all modeling programs, including SketchUp and Blender, as an export feature. Once you have created your model you export it as a VRML model, which can then be opened in a VRML reader application allowing you to navigate around the model in real time. Again if you want to have professional looking, detailed lighting you need to use one of the techniques discussed in this article. Most Internet browsing applications have plug-ins that will run VRML models in the browser or you can use stand alone applications such as Octaga Player (www.octaga.com) to move around in the VR world. These VRML models can be used as traditional tools in simulating a scenic model or they can be used as a scenic device projected onstage during the show and navigated in real time in front of the audience.

For more information on VRML and to download some scenic models that have been converted to VRML, see the author's Web site at www2.ku.edu/~ievr/alpha.html).



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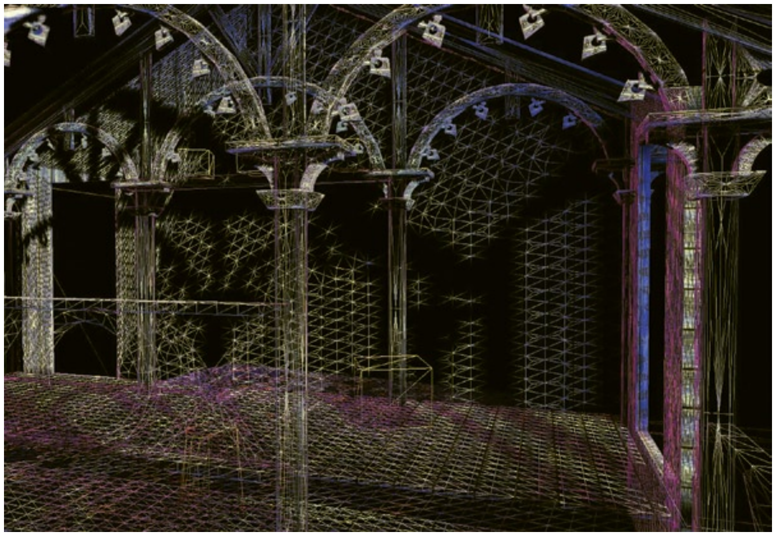
In the technique of vector lighting, one presets the lighting in the computer model and then through a set of commands assigns the lighting qualities to each vector.

Another type of technique used to recreate lighting within a VR simulation is called vector lighting. In this technique one again presets the lighting in the computer model and then through a set of commands assigns the lighting qualities to each vector. All objects in computer models are made up of various polygons, typically triangles, and color and brightness values can be added to each corner of each polygon, its vectors. Then after the surfaces are textured, adding wood grain or stone or marble for example, the vectors inform how brightly or dimly that texture should be rendered at each corner. Once again, most professional modeling applications have this feature.

Unfortunately, the vector lighting technique has a tendency to create jagged looking pools of light and cast shadows. In order to smooth out this jagged quality one must add more and more vertices. For example, a simple box that would be made up of basic triangles will have to be divided and subdivided until it is made up of hundreds of triangles so the detailed lighting



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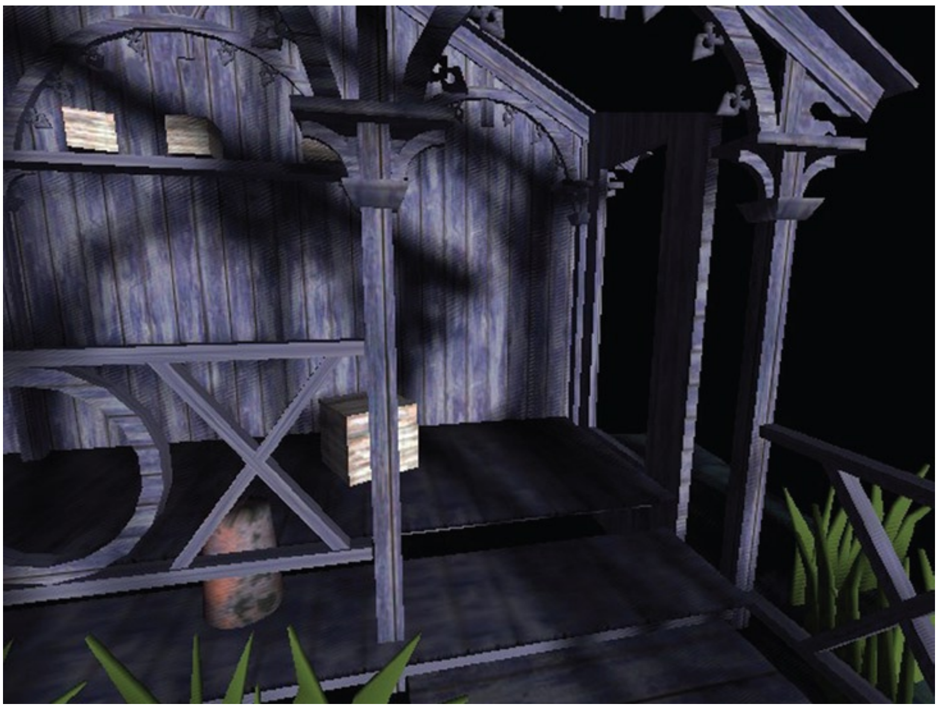

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of the box will appear smooth between all the various vertices. Figure 4 shows the same VR simulation rendered using vector lighting. Note the jagged edges of the shadows. This technique of lighting is somewhat more interactive than light mapping. Materials can be changed easily. One can swap wood for stone and the lighting effects will still exist. However the lighting itself cannot be changed unless one goes back to the original model, relights it and reassigns the lighting qualities to every vertex. Vector lighting is somewhat more processor intensive than texture rendering because of the hundreds or thousands of additional vertices. The computer has to slow down to accommodate this increase in geometry and render it in real-time frame rates. Figure 5a is an image of the boathouse model showing a normal number of vertices. Figure 5b shows how an additional number of vertices added in vertex lighting can achieve a somewhat smoother look to the lighting.

An effective way of achieving lighting simulations that are both detailed and interactive is to combine methods. One of those combined methods is to combine light-mapping (painting the surfaces with basic shadows, lights, and color) with stencil shadows that are created by the VR application itself. This gives you some lights that are predetermined and can't be changed and others, a few of the more important lights, which can be added to the VR simulation and are therefore interactive and can be moved about. The high quality of the light-mapped textures offsets the more simplistic look of the stencil shadows for a satisfying simulation in which the most important lights remain interactive.

Finally, the most advanced form of lighting within a VR simulation—the holy grail of real-time rendering—is called real-time radiosity or radiance rendering. Radiance rendering consists of analyzing the resulting picture on the screen pixel by pixel and defining the lighting for every single part of the picture. It does this by analyzing not only what light is coming from obvious light sources but what light is being reflected by all the other surfaces. Therefore, if a strong light hits a glossy red wall, the wall itself emits red light causing a red glow to fall on objects that are close to that wall. In order to achieve real-time radiosity in a VR simulation many short cuts have to be taken in the programming. In this case very few light sources can be used because every surface that those lights hit becomes a light source in itself. The direction of light is determined by the angle at which the original light hits it and the color is determined by the color of the object in combination with the color of the light. Also, the intensity of the light is determined by the reflectivity or glossiness that has been pre-determined for that particular object and the materials that are painted onto that object. For example marble might be more reflective and therefore emit a stronger light than wood. In real-time simulations it is possible to achieve lighting that is nearly photo realistic using real-time radiosity. Figure 6 shows the same setting for *Talley's Folly* rendered with real-time radiosity and a single light source. Note the soft shadows filled with ambient light bouncing from various objects. Also note the penumbra shadows that are more hard-edged the closer they are to the objects casting them and the softer they become further away as ambient light sneaks in. This type of rendering is very processor intensive. It is extremely slow and only one or two light sources can be used. This type of rendering is still in the experimental stage but is rapidly being developed by the electronic video gaming industry. Currently some of the best lighting simulations that exist are in simulation-based video games. Those of us who are creating our own simulations still have to catch up.

The methods listed here and shown in the illustrations for the show *Talley's Folly* can be used as a powerful tools for visualizing scenery and lighting combinations when planning traditional theatre productions. When viewed with suitable projectors and projection screens, they can also be used to create virtual scenery for media-enhanced productions. Interesting combinations can be achieved by matching the lighting in the virtual scenery to the lighting in the actual space occupied by the actors. Truly fantastic effects can be achieved by creating lighting as well as scenery in the virtual settings that do not adhere to the laws of physics but are only limited by one's imagination. ❖

Mark Reaney *is a professor in the department of theatre at the University of Kansas where he has been designer and technologist for eight VR/theatre productions. More information is available at the Institute for the Exploration of Virtual Realities Web site: www.ku.edu/~ievr.*

ADDITIONAL PUBLICATIONS ON VIRTUAL REALITY IN THE THEATRE

Stephen Hudson-Mairet, Mark Reaney, Delbert Unruh. 2004. "The Edge of the Illusion." *Theatre Design & Technology*, Vol. 40, No. 4: 10-19.

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