# Use of Computer Animation Technology for the Development of Interpretive Facilities on the San Juan Skyway

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It is important that the skills and experiences of designers be complemented with a collection of tools that allow them to deal with complex issues and problems. Landscape architects at Washington State University and the U.S. Department of Agriculture Forest Service are working to determine the potential use of computer animation as a design, visualization, and analytical tool. The San Juan Skyway, in southwest Colorado, was selected as a test project because of its national visibility and the high expectations concerning the planning and design of facilities along the route. Forty-nine sites along the Skyway have been designated as possible feature locations for interpretive facilities, the purpose of each facility being to enhance the experience of visitors by providing interpretation of the surrounding scenery, history, and forest management practices. The Weminuche Wilderness Overlook was selected from the 49 sites to be modeled and animated. Photo-realistic 3-D animation sequences were developed to simulate driving or walking through and around the proposed interpretive facilities in an attempt to understand the spatial experiences and dynamic interrelationships of the landscape.

The process of analyzing, creating, and communicating design solutions is often hindered by an inability to consistently generate adequate levels of reality recognizable to nondesigners. Exploring the use of computer animation to generate more effective representations offers the opportunity for designers to enhance design and communication skills.

Design professions have always relied on visual simulations to explore and communicate thoughts and ideas. Early techniques were dependent primarily on pen and ink, pencil, charcoal, watercolors, oil paints, and later photography (*1*). These techniques, rooted in tradition, were used to generate plans, sections, elevations, and perspectives and have remained virtually unchanged for generations. Research has indicated, however, that traditional graphics reflect only one component of the perceptual experience of landscape and, as such, are limited when it comes to modeling the manner in which people relate to the three-dimensional (3-D) aspects of a landscape (*2*). Traditional graphics ignore the environment's surrounding, engulfing nature, and fail to reflect the animated, dynamic character that people ascribe to their surroundings (*3*). They also ignore whatever psychological meanings may have become attached to physical elements as well as the nonvisual senses that occur in connection with ephemeral events (*4*). These spatial experiences are especially important along scenic roads and highways.

There has been a growing trend to adopt more sophisticated technological innovations to create simulations (*1*). Orland has given a thorough review of the technology through the mid-1980s (*1*). Sheppard reviewed more than 300 simulations of proposed landscape changes in the San Francisco Bay Area and studied 30 of them in detail (*5*). These landscape portrayals included renderings, models, photomontages, and computer graphics. Respondents placed greatest confidence in models and photographs and least confidence in line renderings and computer graphics. Lindhult and Dines suggested a strategy for using the capabilities of computers to generate multiple perspective sketches from diverse positions in combination with traditional hand-drawn perspectives (*6*).

Computer technologies are evolving so rapidly that compelling reasons for using or not using some technique today may not hold true 6 months or a year from now (*7*). The somewhat abstract nature of the state of computer graphics makes it difficult to determine its communications effectiveness. For designers, the most intriguing technological advancements may be in computer animation. Designers who work with exterior sites place emphasis on creating dynamic spatial experiences because sites are usually experienced by a moving observer (*8*). Not only are users of a site likely to move past, into, or through a space (on foot, in a car, on a bicycle, and so forth), the site itself is ever-changing. The sun, moon, and clouds are always on the move, playing games with light and shadow, vegetation grows and changes colors with the passing of seasons. A site can become alive as the eye of an observer scans the horizon for new vistas or focuses on nearby surface textures. A single view is not as important as the cumulative effect of a sequence of views, and the transitions from the human experience to large elements around us in the environment are critical (*9*). Once attention is shifted from object to experience, all kinds of environments that provoke aesthetic experience can be included in the discussion, and variations in the responses of individuals can then be recognized (*10*).

## PROJECT DESCRIPTION

Landscape architects at Washington State University (WSU) and the U.S. Department of Agriculture Forest Service are

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working to determine the potential use of computer animation as a design, visualization, and analytical tool. The assumption that aesthetically pleasing environments provide valued experiences that can improve people's quality of life underlies many government landscape policies (*11*), including those of the Forest Service. The San Juan Skyway, in southwest Colorado, was selected as a test site because of its national visibility and the high expectations concerning the planning and design of facilities along the route. The area is rich in cultural resources ranging from the Archaic and Anasazi habitations to the colorful mining era in the San Juan Mountains in the 1800s, including the development of the narrow-gauge railways through the area (*12*).

The Skyway itself is a 232-mi route through the San Juan Mountains of southwestern Colorado. It connects the historic towns of Durango, Silverton, Ouray, Telluride, and Cortez and includes the historic section of the Million Dollar Highway. Traversing some of the most spectacular, rugged, and primitive country in North America, the Skyway is often described as the most scenic drive in America (*12*). The Skyway was designated by Forest Service Chief Dale Robertson (*13*) as a National Forest Scenic Byway on November 11, 1988, and by the State of Colorado Scenic Byway Commission as a State Scenic and Historic Byway on October 3, 1989. Both were the first such designations in the state. The nationally popular drive is the second longest Forest Service scenic byway and represents one of the largest and most complex recreation development undertakings in southern Colorado. As a result, it requires creative and innovative planning, design, and management strategies.

In keeping with the primary goals of the national scenic byway program, the physical development of highway scenic overlooks for natural or historical interpretation is critical. Forty-nine sites (*12*) along the Skyway have been designated as possible future locations for interpretive facilities. Managing changes in the dynamic systems of these diverse landscapes poses the challenge of determining what kinds of change are acceptable in the landscape composition.

The purpose of the proposed facilities is to enhance the experience of visitors by providing interpretation of the surrounding scenery, history, and forest management practices. Three basic conceptual design modules were developed: (a) a camera point plan, (b) a standard plan, and (c) an expanded plan (*12*) (Figure 1). These modules are designed to allow continuity from site to site, to fit aesthetically on the landscape, and to be functional for the intended use. The camera point plan is intended for smaller sites and provides an opportunity for a brief stop with a simple interpretation or informative sign. The standard plan provides space for 15 to 25 visitors and parking for up to five cars and two recreational vehicles (RV). The expanded plan is essentially the same layout but is larger to accommodate 30 to 40 visitors and parking for eight cars and three RVs. Common to the standard and expanded plans are benches, interpretive signs, and a staging area between the parking area and viewing area that provides for a large landscape rock with a plaque attached crediting the partnerships responsible for the facility. Other improvements such as curbs, retaining walls, bicycle racks, and steps or ramps will be incorporated as dictated by the site.

The Weminuche Wilderness Overlook was selected by Forest Service landscape architects to be modeled and animated. Four classified wilderness areas are accessible from the Skyway, of which the Weminuche Wilderness is one. The Weminuche Wilderness is the oldest classified wilderness in the state and also the largest at 459,804 acres (*12*). It includes some of the steepest and most complex terrain in the world, including the Needles, the most precipitous terrain in the nation. Mining opened the area to settlement, resulting in many stories about lost gold and silver mines. Many legends were the result of illegal mining during the 17th century by the Spanish, who did not keep records of their operation lest they be taxed by the king of Spain (*12*).

## TRADITIONAL VERSUS COMPUTER ANIMATION

Traditionally, animation techniques were not an alternative for developing animation sequences of proposed interpretive facilities. Traditional hand-generated animation is very time-consuming and labor-intensive because a tremendous number of frames must be generated to create smooth, realistic movements. A minimum of 16 images per second are needed or movements will appear jerky. In traditional animation, 24 frames are typically displayed for every second of animation with computer animation requiring a slightly higher standard of 30 frames per second (*14*). Consequently, to prepare a realistic animation sequence for 1 minute requires 1,440 hand-drawn images or 1,800 computer-rendered images (*15*). Even classic cartoons from the past were tedious for the animators who toiled to create them, requiring months to produce the thousands of drawings necessary to give the illusion of fluid motion.

Computer animation was used on the Weminuche Wilderness Overlook project for several reasons. Computer animation systems eliminated much of the repetitive work associated with traditional animation and reduced the amount of time that would have been required for such a project. Computer animation also allowed designers and administrators to move around and through the proposed interpretive facility and to examine the site from a variety of views. Once 3-D computer models were constructed, the designers were able to visualize different design decisions and create simulations with real-world properties such as surface texture, transparency of objects, and the appearance of rain or fog (*16*).

## COMPUTER COMPONENTS FOR THE PROJECT

Three major components collectively make up an animation system: the main computer, animation software, and specialized peripherals (*9*).

### Computer

Historically, only mainframes or minicomputers were used for computer animation because animation is one of the most demanding computer graphics applications in terms of memory and processing power. In the past few years, however, microcomputer hardware and software have advanced to the point where animation is becoming affordable. Microcomputer platforms still cannot render as fast as mainframe sys-

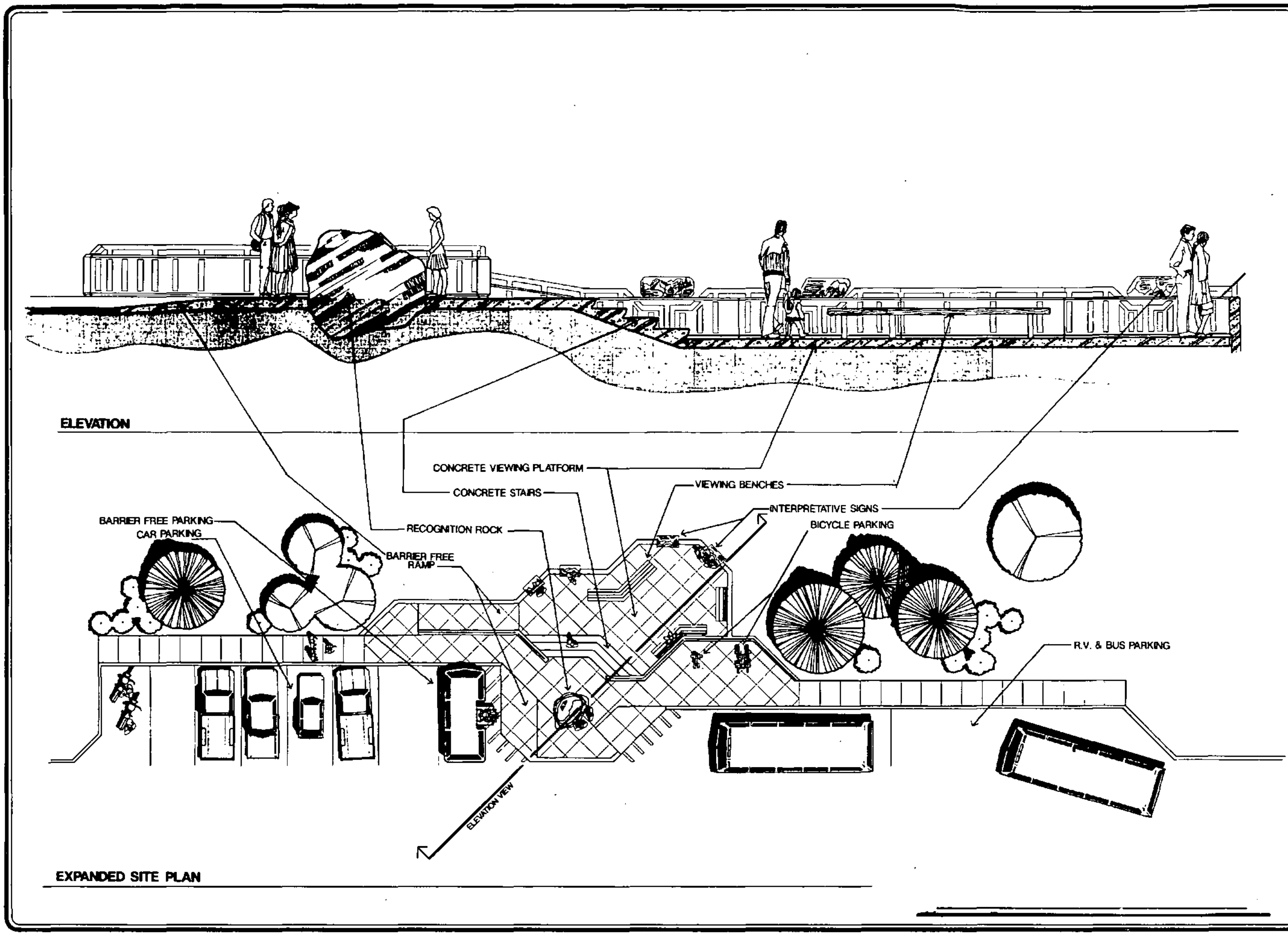


**FIGURE 1 Section detail (*top*) and plan (*bottom*) of standard plan for proposed interpretive facilities.**

tems, but now that hardware has increased in power and software has incorporated sophisticated animation features, it has become virtually impossible to distinguish a microcomputer animation from a mainframe animation (*17*).

Microcomputers were selected to create the animation sequences for this project for several reasons. Even at a major university such as WSU, only a handful of mainframe computers are capable of generating animation sequences, and getting adequate time on one of these computers for a project such as this one is virtually impossible. Microcomputers, on the other hand, are plentiful, easily accessible, and affordable. This is true not only at WSU, but in the Forest Service offices as well. One of the objectives was to take computer animation out of the exclusive research laboratories and demonstrate its potential as a design tool for even low-budget projects.

### Animation Software

In general, animation software can be divided into three major categories: electronic slide show, two-dimensional (2-D) animation, and 3-D animation (*9*). Unlike true animation, an electronic slide show creates the illusion of animation by providing smooth transitions from one image to the next (*8*) and is used primarily for presentations. The 2-D animation programs simulate traditional animation by combining sequences of images created with "paint" software. These animation systems are typically less expensive and easier to use than 3-D systems but are not as powerful. This project did not use 2-D animation because such systems create a flat "painting" that does not adequately capture the essence of moving through a site. Rather, 3-D animation software was used for the Weminuche Wilderness Overlook, because it provides a wide range of choices for designing precise, accurate models and creating photo-realistic simulations. Autodesk's 3D Studio was selected because of its combination of power, affordability, and ease of use.

### Specialized Peripherals

Although the main computer provides the primary computational and managerial functions, other hardware adapts the system to animation and actually eclipses the personal computer in terms of sophistication and price. This equipment typically includes a high-resolution color monitor and peripherals such as a color video camera, video camera recorder (VCR), VCR controller, sync generator, encoder, and mass-storage system (*7*). Specialized equipment is often needed because microcomputers typically do not have adequate memory or storage capacity for high-resolution, true-color animation sequences (*17*).

Most computer animation sequences are compiled and recorded directly to tape because of the tremendous storage space required to store the individual images that make up the sequence. For most animation software, the only way to render an animation sequence is directly to tape, one frame at a time. However, the slow rendering speed of microcomputers makes it difficult to render an animation directly to tape. Because of the expense involved, most video decks are shared among departments and individuals and it is not practical to tie up the video deck for days, weeks, or months at a time. For the Weminuche Wilderness project, preliminary animation sequences were rendered initially with low resolution and a limited color palette so they could be displayed on a standard computer screen. Final animation sequences were rendered one frame at a time directly to a hard drive, then compressed, stored on a removal tape cartridge, and recorded on ¾-in. or ½-in. video tape.

## DEVELOPING 3-D COMPUTER MODELS

Designs for the three proposed interpretive facility modules were developed by landscape architects with the San Juan National Forest before the decision was made to use computer animation. Before creating animation sequences, the basic design modules had to be converted from traditional hand-drawn plans to three-dimensional computer shapes using a process called "modeling" (*15*). Modeling is the step in which a designer describes to the computer the shape and dimensions of every object or character in the animation sequence. Most animation programs use a tool called "object editor" (*17*) for modeling the objects to be used in animation. Most object editors use the same functions and terminology as do computer-aided drafting (CAD) and solid-modeling systems.

There are two basic ways to create 3-D computer models (*15*). The first is to "extrude" or "loft" 2-D shapes to create 3-D objects. The second consists of creating simple geometric primitives, such as rectangles, cylinders, and cones, then combining them to create more complex objects. The first approach proved to be the most efficient because there were already detailed plan views of the interpretive facilities. Because the designs had not originally been generated on a computer system, the hand-drawn plans of the standard and enhanced modules had to be converted into a digital format that would serve as the foundation for developing computer animation sequences. These plans were digitized using a standard CAD program, AutoCAD Release 11, to create a digital 2-D line drawing. Although digitizing these plans was very quick and easy, the accuracy of the subsequent CAD images was not acceptable for use in 3-D modeling. The final images had to be very precise because 3-D modeling and animation is defined mathematically.

The only way to ensure that the final drawings would be accurate and precise enough for detailed computer modeling was to draw them from scratch. Although this took approximately twice as long as did digitizing, the results were free of even minor flaws or mistakes. The plans were exported out of AutoCAD as a standard data exchange file (DXF) file and imported into the 2-D Shaper module of 3D Studio where they were converted into 2-D polygons. The shapes were extruded using the 3D Studio's 3-D Lofter program (*18*) to add the "Z" dimension of height to the original images. Major design elements such as roads, curbs, steps, and ramps were modeled this way. Other site features, including rails, benches, light fixtures, signs, rocks, and automobiles, were created by combining simple geometric primitives to create more complex shapes.

One of the most time-consuming tasks in 3-D computer animation can be building the models that form the foundation of the sequences. Modeling the proposed interpretive overlook for the Weminuche Wilderness was not very difficult, primarily because the original design was fairly simple and very geometric. Creating a model of the proposed site along the Weminuche Wilderness was a much greater task. Trying to model intricate shapes typically is a laborious and repetitive task (*9*) and can create special problems. Traditional modeling methods do not adapt well to objects with the complicated shapes, such as trees, water, and topography, necessary for landscape architects. The first step in creating a computer-based landform model of the site was to digitize contours from a topographic map. Each line was defined with a Z coordinate to represent its respective elevation, an algorithm generated spot elevations at intersecting points on a grid, and the points were combined to create a rectilinear wire mesh formed by polygons. The most accurate representation of the actual site was obtained by a 5- × 5-ft mesh, but the resulting CAD file was too large (4.7 Mb) to work with efficiently. Larger meshes, 20 × 20 ft and 30 × 30 ft, were unacceptable because the interpolation process eliminated too many points in the landscape. A 10 x 10 ft mesh provided an acceptable level of detail to model the site faithfully and was not beyond the capabilities of current hardware and software.

Generating 3-D vegetation for the final computer model was also a challenge. In many ways, the difficulties in creating a 3-D model of a tree epitomize—more than any other elements—the problems inherent in modeling a site (*7*). Trees take on a bewildering variety of forms under the influence of their environment, and those forms change as the plant grows, ages, and adapts to its environment. Each species has its own habit of growth and its own way in which branches and leaves are arranged. The problems of modeling and rendering a single tree in a foreground are quite different from those of a forest seen in a background. When seen from a distance, trees are large elements defined by their shape. On closer inspection they break down into a connected system of branches, twigs, leaves, buds, and flowers (*7*). Because of the complexities involved, it is little wonder many people avoid trying to develop detailed 3-D trees.

The first attempts focused on creating 3-D trees with a high number of polygons to achieve a high level of realism. Although these trees surpassed expectations of visual quality, each consisted of more than 100,000 polygons and was approximately 1.2 Mb in size. They looked great, but required so much computing power to render that it was difficult to put more than a few in an animation sequence. The next tree was a more simplistic version, created with a series of overlapping "shingles" draped over a simple geometric cone. To create the final 3-D trees, two panels were combined to create a "plus," then texture-mapped with scanned photographs of the original trees, and combined with transparency maps to allow a viewer to "see" through the branches of a tree. Tree panels were created as self-illuminating to minimize problems with shadows and to create the illusion of being irradiated by the sun. The benefit of these "panel" trees is that they provide the realism of a photograph while maintaining the benefits of a 3-D object.

After models of the proposed interpretive facilities were modeled, a "scene editor" (*17*) was used to render the individual 3-D objects created with the object editor. The final rendering step is the equivalent of adding ink and paint in the traditional animation process. Colors are added to each object, and the surfaces were enhanced with textures, shading, reflections, and motion blur. Surfaces of the objects were enhanced with bump maps, surface properties, and texture maps (*19*) (Figure 2). Bump-mapping creates the appearance of roughness on a surface. Surface properties refer to the degree of transparency of an object and the way its surface reflects light and objects around it. In texture mapping, an image of a texture, material, or photograph is overlaid on a 3-D computer model of an object.

To provide an acceptable level of realism for this project, background images were created by texture-mapping a sequential series of images onto large panels, which functioned much like billboards. The same basic technique was used to create the trees described earlier. The graphic images were actual photographs taken of the Weminuche Wilderness Overlook site. Eight different photographs were taken from the same spot, with the photographer turning slightly to create a panoramic view while ensuring that each image overlapped, to eliminate any gaps. Truevision TIPS (*7*), an image process program, was used to combine the images so they would appear as one.

## QUESTION OF REALISM AND VALIDITY

An important question when considering computer animation for the Weminuche Wilderness Overlook was what level of realism and accuracy was needed. During the planning stage of this project, one of the first assumptions was that the final images needed to be both "valid" and "realistic" (*1*) because the final computer models had to illustrate that the interpretive facilities would visually "fit" the existing site (*12*). It was assumed that crude models would not have given the degree of detail necessary for members of the public to develop a level of understanding and confidence that would enable them to make informed decisions. But as work progressed, a number of questions needed to be answered. Are wire-frame images sufficient to convey a design concept? Do hidden-line algorithms need to be implemented to remove "visual noise?" Do textures and colors play an important role in the visualization process? Is the search for "realism" appropriate and necessary? Is it acceptable to create images that simply "look" real or should the complexities of a site be duplicated?

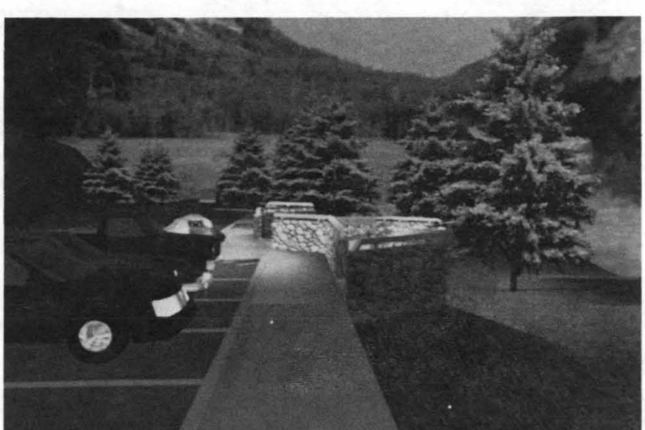

**FIGURE 2 Photorealistic 3-D computer model of standard interpretive facility at Weminuche Wilderness Overlook.**

In the past, these questions were mostly rhetorical because hardware and software limitations made it virtually impossible to achieve a high level of detail or realism (*15*), especially for landscape architects with limited budgets and little or no computer training. Even with advances in computer technology, providing a high level of realism is difficult. It is neither practical nor appropriate to attempt to include every site element in infinite detail (*7*). Not only are resources unavailable to generate such a computer model, but the rendering and seen-area algorithms available today do not naturally accommodate the complexities of the entire visual field (*7*).

Foley and Van Dam (*20*) see the quest for realism as the production of "images which are so realistic that the observer believes the image to be that of a real object rather than that of a synthetic object existing only in the computer's memory." Appleyard (*21*) has suggested that "simulations should be realistic and accurate; that is, they should convey how a project will be experienced." Kaplan and Kaplan (*4*), on the other hand, advocated the use of "a highly simplified physical model of the physical environment." The limited evidence (*22*) suggests that the most realistic simulations, those that have the greatest similitude with the landscapes they represent, provide the most valid and reliable responses (*23*). Early computer-generated simulations (*24*) were found to be inaccurate in comparison with photographs of the actual completed projects. Research by Sheppard (*5*) showed that design professionals and planners placed the greatest confidence in models and photographs and the least in line renderings and computer graphics because of their limited realism.

## DEVELOPING ANIMATION SEQUENCES

After 3-D models of the site elements were completed and surface materials defined, light sources, atmospheric conditions, and camera positions were added to the scene. Lighting is one of the most important aspects of the final rendering. In 3D Studio, three types of lighting can be added—ambient, omnidirectional, or spot lighting (*25*). Ambient light (*25*) provides a minimum level of illumination throughout a defined scene but has no direction or definable color. Omnidirectional lighting (*25*) is a consistent light source much like the sun, except that it does not cast shadows. A spotlight is used to highlight a specific part of a scene and is the only light source which casts shadows (*25*). Shadows can be important in the final rendering, especially when the objective is to add a touch of realism (26). Each rendering of the final animation sequences for the Weminuche Wilderness Overlook uses a combination of the three different light sources, but spot lights have the greatest impact. The lighting was arranged in attempt to create the illusion of the sun peeking through a dense ceiling of clouds.

Different shading techniques were used at various stages of the design process. The three most common shading techniques are Flat, Gouraud, and Phong (25) shading. For initial massing studies where a high degree of detail is not necessary, models were rendered using flat shading. Flat shading provides the fastest rendering but offers the least amount of surface detail. To create a more realistic-looking image, computer models were rendered using Gouraud or Phong shading options. Gouraud shading provides smooth rendering, but Phong shading provides a more realistic representation and must be used to render shadows and highlights. Although Phong shading takes a considerable amount of processing time, the final Weminuche Wilderness Overlook animation sequences were all rendered with Phong shading.

The final step in the process was to script motion from the beginning to the end of the animation sequence (Figure 3). This motion scripting allows a designer to define the movements of the objects, characters, lights, and cameras and is often the most difficult task in advanced animation. Our objective was to give the viewer a feeling of what it would be like to drive down a road to the proposed interpretive center overlooking the Weminuche Wilderness.

## SUMMARY

Landscape architects at both WSU and the Forest Service were interested in using this project to help determine the potential use of computer animation as a design, visualization, and analytical tool. Animation sequences of the proposed Weminuche Wilderness Overlook were developed to understand the spatial experiences and dynamic interrelationships of the landscape. But beyond this overall goal, the two participating groups had different perspectives on what would make this project a success or failure.

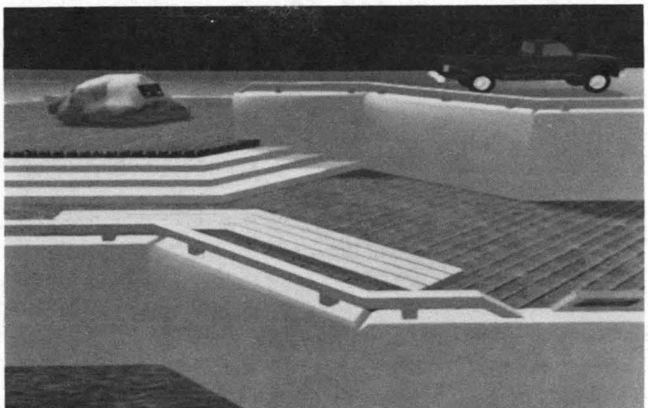

**FIGURE 3 Sequential images of animation sequence that shows use of different materials for proposed interpretive facility.**

### Forest Service Perspective

The original goal of the Forest Service was for the computer animation to aid the designers in making decisions on proposed design concepts for interpretive facilities and how these concepts would fit into a selected site. It was hoped that there would also be some adaptation of these animation sequences in approaching possible sponsors of sites along the Skyway. The technology would open other opportunities for adaptation of other projects throughout the Forest Service system.

The actual benefits of this project are varied, and some benefits may not be fully discernible at this time. From the standpoint of the Forest Service landscape architects, the previously mentioned goals and expectations generally were met and, in some areas, exceeded. The two major benefits to them were as a design and analytical tool and as a marketing tool. Being able to visualize a proposed facility on the landscape in a 3-D depiction has helped the Forest Service designers in refining the scale, function, form, and choice of materials that would successfully harmonize with the setting. It also helps meet the agency's planning goals and guidelines as suggested in the Recreation Opportunity Spectrum and Landscape Management programs.

As a marketing tool, computer animation has aided the Forest Service in developing partnerships with parties who may be interested in participating in the development of interpretive sites along the scenic byway. The use of these animation sequences, or others done for specific sites, will give a convincing simulation of what the finished facility will look like.

The use of this computer animation technology for the San Juan Skyway project has also opened up other applications possible for other projects throughout the Forest Service system. There have been a number of inquiries from other field units considering the applications that computer animation has for some of their projects.

### WSU Perspective

One of the major reasons WSU landscape architects participated in this project was to develop a series of animation sequences to be used for further studies addressing issues such as the effectiveness of microcomputer animation, the benefits of animation over traditional graphic media, and perceptions concerning animation sequences and still images. Although a detailed analysis of the Weminuche Wilderness Overlook animation project has not been completed, preliminary observations have yielded some interesting results.

- For the designers involved with this project, the use of computer animation did not result in a greater level of creativity. Although basic design decisions had been made before any attempts to develop computer animation sequences, the physical separation between WSU and the San Juan National Forest, the lack of computer knowledge by Forest Service employees, and the tremendous time required to render the final images would have presented major problems in trying to use computer animation as a design tool.
- Creating 3-D computer models of the various design proposals for the interpretive centers were a fairly simple,

straightforward task. Even the most complex design alternatives could be modeled in days, with modifications being made in hours. Although time and effort were devoted to modeling the proposed interpretive facilities, most of this time focused on trying new techniques or procedures.

• The general feeling of movement and motion created by the animation sequences did a lot to make up for the overall quality of an individual image (*27*). Reviewers of the animation sequences appeared to have difficulty distinguishing between 8-bit (256 colors), 16-bit (32,000 colors), and 24-bit (16,700,000 colors) images when they were part of an animation sequence. In contrast, they quickly noticed a difference in the overall quality of images when comparing individual frames from a sequence. This was in contrast to our original belief that high-resolution, high-color images were necessary to convey the aesthetic concerns of the site and validates past research (*28*) that concluded that, although greater color and pixel resolution give more accurate simulations and more reliable impact measures for development proposals, video editing based on 8-bit graphics systems is viable.

• Rendering time was the greatest limitation in using computer animation to explore different design alternatives or modifications. With current microcomputer technology, it is not cost effective to create 24-bit (16,700,000 colors), photo-realistic animation sequences in an acceptable amount of time. After modifications were made, it would take several days to render an animation sequence before the results could be analyzed. This effectively eliminated any interactiveness or spontaneity. An acceptable substitute appears to be 8-bit (256 colors) animation sequences, which provide a good representation (*28*) of a proposed alternative, yet enable most sequences to be rendered overnight.

• In general, computer animation sequences were viewed very favorably by viewers. There is concern, however, that this had more to do with the media itself and not how effectively the proposed interpretive overlooks were illustrated.

• There needs to be a greater understanding of the numerous visual cues, identified by psychologists (*27*), by which our minds interpret 3-D space. These visual cues include motion parallax, size, linear perspective, angle of regard, interposition, aerial perspective, light and shade, texture, disparity, convergence, and accommodation. Motion parallax, disparity, and convergence (*27*) are not easily addressed by current computer technology, but an understanding of the other visual cues is critical if computer animation is truly going to become a useful analytical, design, or visualization tool.

• Shading appeared to play an important role in making an image or sequence more understandable or more realistic, but the addition of shadows had very little positive impact. This information appeared to contrast with past research (*27*), which indicates that the full use of a number of visual cues requires both shade and shadows.

• The patterns in the mind appear to be as important as the objects of sight. Most students believed they saw objects in animation sequences that were not really there. When asked, several viewers said shadows were helpful in making an animation sequence more believable even though there were no shadows in the sequences they observed. They "saw" shadows because they expected to see shadows, not because they were actually present in the scene. These results agree with Land's retinex theory (*26*), which states that we do not determine the color of an object in isolation; instead, we are always comparing the object with its surrounding.

• The perception of realism (*27*) seemed important to viewers, yet the question of how valid or accurate the final scenes were did not seem to be a concern. None of the viewers, even those familiar with the area, questioned whether these scenes faithfully depicted the Weminuche Wilderness area.

## FIGURE OF ANIMATION IN LANDSCAPE ARCHITECTURE

Computer animation has had limited implementation outside the entertainment industry. Design professionals have been especially slow in embracing computer animation for a number of reasons. There are still a number of technical limitations that make animation very laborious and time-consuming. Most firms or organizations do not have anyone with the necessary skills or training to be proficient at creating computer animation sequences. In addition, a new computer tool, such as computer animation, typically generates an abundance of enthusiasm, making it difficult to determine its long-term value as a design tool. It is easy to get caught up in using a new toy like computer animation without having a clear objective of why and how it should be used.

Zube et al. (*1*) reviewed available simulation techniques and believed that the potential of computer graphics and animation in landscape architecture was very high and that, given some cost reduction, "a major transformation in graphic communications is likely to occur in all of the environmental design fields." The communications effectiveness of computer animation, however, is not very well understood and there are still a number of problems and questions that need to be addressed. As computer animation is used more frequently for public communications, the need to address these problems becomes more urgent.

Perhaps the key to using computer animation efficiently lies in the ability to be flexible, to match technique with the situation at hand in a way that will best reveal the essence of what design professionals are trying to communicate or study (*7*). During the early stages of a design or a large-scale project, massing studies consisting of wire-frame models, simple geometric shapes, and minimal detail may be appropriate. For a final design solution and projects involving sensitive aesthetic considerations, photo-realistic images, accurate shadow casting, and complex three-dimensional animation sequences with a high degree of detail may be required.

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