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TECHNIQUES FOR VISUALIZING THE APPEARANCE OF TIMBER HARVEST OPERATIONS

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ABSTRACT: The appearance of landscapes and individual stands after harvest operations is critical to public acceptance of timber harvest practices. This paper reviews four visualization techniques suitable for visualizing the appearance of timber harvest operations: geometric modeling, video imaging, a hybrid technique combining geometric modeling and video imaging, and image draping. Data requirements and output image characteristics for the techniques are reviewed and compared for application to plot-, stand-, and landscape-scale projects.

The appearance of landscapes and individual stands after harvest operations is critical to public acceptance of timber harvest practices. Thorough planning, detailed site-specific analysis, and careful monitoring of harvest activities will not result in truly successful operations if the public views the resulting landscape as an eyesore. Activities intended to mitigate the visual impact of harvests include modifying unit boundaries to conform to topography and other natural stand openings, prescribing silvicultural treatments that retain higher numbers of standing trees or groups of trees, and attempting to "hide" or "screen" harvest units from sight. These mitigation efforts can be successful. However, foresters charged with designing harvest unit shapes and silvicultural treatments often find it difficult to develop visually acceptable solutions by working in the field or with planimetric maps and aerial photographs. Visualizations depicting the appearance of treatments or harvest operations provide important feedback during the design process and help communicate management intentions to specialists and public stakeholders.

OVERVIEW OF VISUALIZATION TECHNIQUES

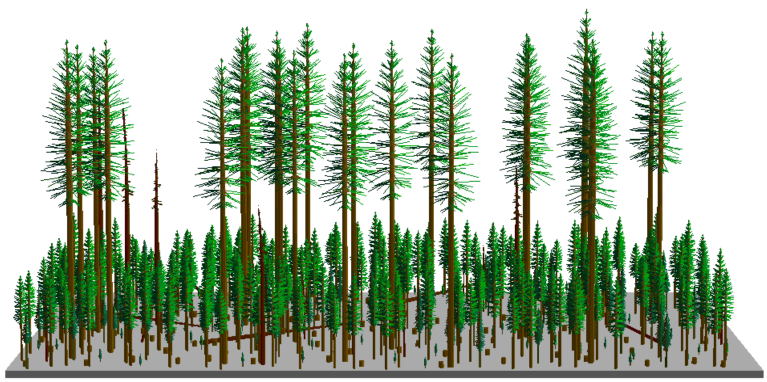
Forestry professionals have used visualization techniques to address a variety of forest management problems. Prior to the advent of computerized methods, they used "artists' renditions" to communicate the effects of land management activities. Perspective sketches and scale models continue to help communicate the spatial arrangement and extent of management activities to the lay public. However, current forest management practices involve more detailed harvest designs with small treatment areas scattered over larger landscapes and the removal or modification of specific stand components. Alternative treatments vary the mechanical methods, spatial arrangement of treatment units, and levels of modification within individual treatment units. With such treatments, the traditional "artists' rendition" cannot be made specific enough to represent the subtle differences between alternative treatments.

Computerized visualization methods range from simple diagrams to complete virtual realities. Four methods are commonly used to produce visual representations of forest operations:

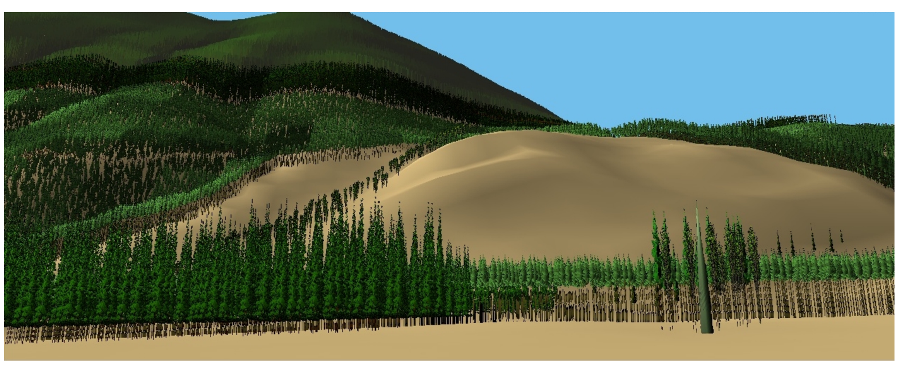
- geometric modeling,
- video imaging,
- geometric video imaging,
- image draping.

Geometric Modeling

Geometric modeling methods (figure 1) build geometric models of individual components (ground surface, trees, other plants, and structures) and then assemble the component models to create an image of a forest stand or landscape. Scenes depicting the complete model are then rendered from a variety of viewpoints. In its simplest form, this technique can be used to generate perspective drawings showing typical GIS data coverages such as roads, streams, and polygon data overlaid onto the ground surface. More complex applications build detailed models of individual trees that include small branches and leaves for use in rendering. Geometric modeling systems specifically aimed at producing visualizations of forestry activities have been presented by several authors (Burk and Nguyen, 1992; Fridley and others, 1991; Hanus, 1995; Larson, 1994; McGaughey, 1997; McGaughey and Ager, 1996; McGaughey and Twito, 1988; Myklestad and Wager, 1976; Orland, 1997). These systems use perspective or orthographic drawing techniques to render stand and landscape images for land areas ranging in size from less than one acre to several thousand acres. Some systems have been interfaced to stand projection models to help users understand the capabilities of the projection model and to depict stand conditions that result from silvicultural treatments and modeled stand growth.



(A)



(B)

Figure 1. Geometric imaging systems such as the Stand Visualization System (A) (McGaughey 1997) and the Vantage Point landscape visualization prototype (B) (Fridley and others, 1991) provide a direct relationship between data describing forest and landscape conditions and elements in a scene.

Video Imaging

Video imaging (figure 2) uses computer programs to modify scanned full-color video or photographic images to represent changes to stand and landscape conditions. Video imaging produces television-quality (or better), full-color visual representations that depict current and future conditions. Orland (1988, 1993) reports the use of images created using video imaging techniques for both internal and public reviews of proposed management activities.

(A)

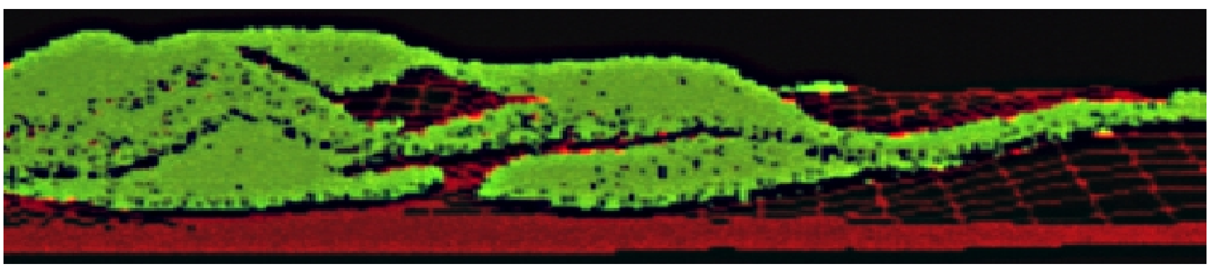
(B)

Figure 2. Video imaging begins with a scanned image of the project area (A). Operators then manipulate the photograph to show the effects of management activities (in this case the addition of a harvest unit) (B).

Video imaging typically requires a library of images representing different forest conditions to replace portions of an original image, however, direct manipulation of images is also possible. Orland and others (1990) used image processing techniques to analyze the color changes associated with insect damage in forests. Then they applied similar color changes to new landscape images to simulate new damage. Larson and others (1988) report using similar techniques to simulate the effects of atmospheric pollution on the quality of photographic images and scenic views.

Geometric Video Imaging

A hybrid approach, called geometric video imaging by the author, combines geometric modeling and video imaging techniques to produce very realistic images that accurately represent data describing the effects of forest management activities (figure 3). Operators use geometric modeling to produce scenes that specify the location, arrangement, and scale of proposed landscape changes. Video imaging is then used to modify a digitized image to reflect these changes. The technique can be extended to use geometric modeling to determine the locations for digitized images, or icons, of single trees. Hybrid approaches result in images that accurately reflect the data describing proposed changes. However, to produce photo-like images, hybrid techniques require extensive libraries of tree and stand images that represent an appropriate range of species, tree sizes, growth forms, and landscape positions. Orland (1997) describes the use of the SmartForest-II geometric modeling system to guide video imaging efforts on a series of photo images used in public preference studies.



(A)

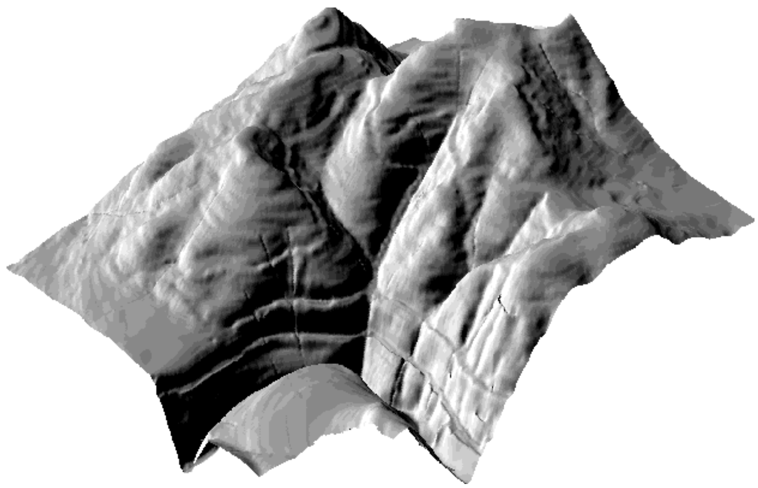
(B)

(C)

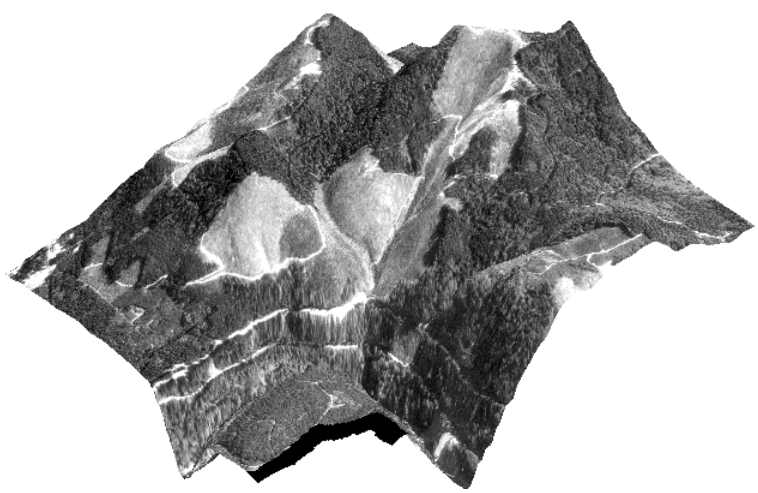
Figure 3. Geometric video imaging uses geometric modeling techniques to determine the location and size of proposed harvest units (A). Then video imaging techniques are used to modify an original image (B) to show the appearance of the proposed harvest unit (C).

Image Draping

Image draping (figure 4) mathematically "drapes" an image over a digital terrain model and then renders the resulting scene from a variety of viewpoints. Operators usually obtain the image from a satellite scene, aerial photograph, orthophoto, or map sheet and use techniques common to video imaging to modify the original image to reflect management activities. Several GIS and image processing applications provide draping capabilities. Most include rectification procedures to properly orient and align a digital image to the ground surface. Simple applications utilize orthophoto images that have already been registered to the ground surface and corrected for elevation, or relief, displacement. Bishop and Flaherty (1991) report the development of an image draping technique that relies on a library of images and textures to provide image content needed to create realistic representations of GIS databases.



(A)



(B)

Figure 4. Image draping mathematically drapes a photographic image onto a digital terrain model (shown in plate A as a shaded relief model) to show the appearance of the landscape (B). This technique can be used to show the effect of proposed treatments by making suitable modifications to the original photograph. (Images courtesy of Phil Hurvitz, GIS Specialist, College of Forest Resources, University of Washington)

Comparison of Visualization Techniques

Direct comparison of visualization techniques is difficult. All of the techniques mentioned are suitable for forestry visualization. However, inherent limitations in the techniques, data requirements or quality of the final image products make some techniques better suited to particular applications. Table 1 compares the data requirements, level of realism, operational complexity, and data integrity of visualization techniques. If a technique has high data requirements, this means that either large amounts of data or detailed data are needed to apply the technique. Realism ratings refer to the image quality relative to a photograph of a similar scene. Operational complexity represents a combination of general software system complexity, data manipulation required to use the technique, and general artistic abilities required of the operator. Data integrity refers to the technique's ability to represent changes in the source data describing a particular treatment in the final image. High data integrity means that the technique can be used to portray small changes in the input data.

Table 1. Characteristics of visualization techniques suitable for depicting the effects of forest harvesting operations.

Visualization technique	**Data requirements**	**Level of realism in final scene**	**Operational complexity**	**Data integrity**
Geometric modeling	High	Low to moderate[1]	Moderate to high	High
Video imaging	Low	High	Moderate	Low to moderate[2]
Geometric video imaging	Moderate to high	High	Moderate to high	Moderate to high
Image draping	Low to moderate	Moderate	Moderate to high	Moderate

[1] Commercial rendering applications, commonly used for motion picture special effects, produce very realistic scenes. However, their high cost, computer system requirements, and the complexity of the data needed to build the required models limits their usefulness in forestry applications.

[2] Video imaging techniques rely heavily on the operator's skill to manually make changes in the image to represent changes in stand or landscape conditions. A skilled operator can produce visualizations that accurately represent data describing proposed conditions.

Geometric modeling and geometric video imaging generally rely on detailed data describing terrain and stand conditions to create an image. When data are available, these techniques should be used to provide the most data-driven visualizations. Geometric modeling does not generally produce realistic images when compared to photographs. The image products tend to be somewhat abstract using simple wireframe objects, shaded polygons, and lighting models.

Video imaging starts with a photographic image representing pre-treatment conditions and modifies the image to represent proposed changes. Video imaging can be used for any forestry project and requires very little data describing terrain and vegetation characteristics. However, for stand- and plot-scale projects, it may be difficult to accurately reflect changes to individual trees and small groups of trees needed to show the effects of silvicultural treatments. Users of video imaging techniques must understand the effect of harvesting operations and proposed treatments and make the necessary changes to an image to accurately reflect the treatment. In addition, operators must be able to transfer planimetric data such as treatment unit locations and roads from planimetric maps or other sources onto the perspective scene represented in the original photograph. If operators are unable to accurately represent treatment effects, the images they produce become "artists' renditions" and may contain operator introduced biases that severely limit their usefulness. Video imaging is especially vulnerable to operator introduced bias because there is no one-to-one relationship between data describing a proposed treatment and elements in the final image.

By combining geometric modeling with video imaging, geometric video imaging can produce data-driven images that exhibit a high degree of realism. A skilled operator is still needed to modify digital images and large libraries of images are needed to provide the rich palette of vegetation types, sizes, orientations, and colors needed to make final image modifications realistic. Nonetheless, this is the only visualization techniques currently available that can produce photographic quality images that reflect small changes to stand and landscape data.

Image draping, like video imaging, starts with an image that represents pre-treatment conditions and modifies the image to show proposed changes. Image draping should be reserved for projects designed to show an overview of a large project area with few details regarding the treatment or treatment effects. Image draping does not show treatment effects on individual stands or trees well because it cannot represent tree height information. For example, the edge of a clearcut usually provides a sharp contrast between the height of an adjacent stand and the bare ground of the clearcut area. This height difference cannot be displayed using image draping since textures are applied only to the ground surface.

All four methods presented in this paper can use databases describing stand conditions before and after proposed changes to provide a data-driven solution. The degree to which changes in the database are visible in the final image depends on the technique and the operator's skill at applying the technique. Systems should have well-designed databases and linkages between the database and the visualization technique. Such linkages allow users to respond quickly to design changes and shifts in management strategies and to provide consistent results for a variety of treatment alternatives. In general, geometric modeling and geometric video imaging can be considered the most "data-driven". They provide for a one-to-one relationship between data describing a treatment and objects in the final scene. Video imaging and image draping techniques do not provide such a relationship but instead rely on the skill of the operator to accurately reflect database elements in the final scene.

VISUALIZATION PROJECT CONSIDERATIONS

Significant criteria to be considered when selecting an appropriate visualization technique for a project are the:

- size of the project area,

- overall goal of the visualization products,
- amount of detail that must be present in the final visualizations,
- amount of data available describing the project area.

Table 2 summarizes these criteria for three project scales: landscape, stand, and plot. The land areas covered by these scales are loosely defined. Projects can span more than one scale and the same data can be used to generate images representing different scales. For example, many projects include landscape-scale images to show the overall vegetation patterns and harvest unit locations and stand- or plot-scale images to show harvest unit layout information and specific stand treatments.

Table 2. Characteristics of potential visualization projects.

Project scale	**Land area**	**Overall goal**	**Tree/plant detail**	**Typical data requirements**
Landscape	> 200 ha > 494 acres	Represent vegetation texture, spatial arrangement of stand types, location of specific treatment areas, visual quality, insect or other stand damage effects	Species, height, color, density	Topography; ground surface characteristics; stand polygons; average tree sizes, predominant species, and stem density for each stand
Stand	2-200 ha 5-494 acres	Represent harvest area layout, patch clearcut or group selection treatments	Species, height, color, density, general crown characteristics	Topography; ground surface characteristics; stand polygons; tree size and species distributions for each stand, general understory conditions
Plot	< 2 ha < 5 acres	Represent stand structure, habitat quality, silvicultural prescriptions	Species, dbh, height, specific crown and foliage characteristics	Individual tree characteristics, individual or aggregated understory plant characteristics, spatial arrangement of understory and overstory plants

As a general rule, the larger the project area, the less detail required in the input data and the final visualizations. Landscape-scale projects usually show the spatial arrangement, scheduling, and cutting intensity of treatment areas. Such projects can be accomplished using geometric modeling techniques based on digital terrain data, stand polygons, and stand descriptions consisting of average tree size and stem density. The same project could be accomplished with little or no descriptive data using video imaging techniques. The operator would simply modify photographs of the project area to show the location of harvest units and to reflect the effect of the treatments. Additional photographs showing treatments similar to those being considered provide the image content used to edit the original photographs. Stand-scale projects, on the other hand, require more detailed descriptions of stand conditions. Tree size, general crown characteristics, species composition, and possibly spatial arrangement are needed to represent the overall effects of harvest activities on stand structure. Projects designed to show detailed changes to stand structure, for example, small areas to be thinned adjacent to large, highly desirable crop trees, require more detailed data describing stand and tree characteristics and the spatial arrangement of the treatments.

To a large extent, the intended use of images produced by a visualization project dictates the technique used to produce the images. Geometric modeling techniques are sufficient to communicate the overall intent and some details of harvest operations and silvicultural treatments. Such images work well for internal reviews involving resource specialists and others familiar with forest practices. However, different types of images may be needed for public presentation and review. Such uses may require images that are more realistic to engage the viewers and provide them with enough information to evaluate management alternatives. Non-foresters may have difficulty relating the somewhat abstract images produced using geometric modeling techniques to their own, in-woods, experiences.

VISUALIZATION SOFTWARE

Many software packages are available to produce forestry visualizations. Commercial computer aided design, rendering, and animation systems produce and render geometric models to create images and animation sequences. Unfortunately, commercial systems can be expensive, often require a specialized operator to produce satisfactory results, and require extensive data manipulation to convert typical forestry data into a suitable form. Public domain visualization systems that provide visualization and image editing capabilities suitable to forestry visualization are available for little or no cost.

Adobe Photoshop® is the most common software used for image editing and manipulation associated with video imaging and image draping. Additional programs suitable for video imaging such as Adobe PhotoDeluxe®, Corel PhotoPaint®, Softkey Photofinish®, and the Gnu® image manipulation program (GIMP) for UNIX platforms are available from a variety of sources but none provide the full range of editing capabilities found in Photoshop®.

Many GIS and image processing applications provide visualization capabilities. Geographic information systems such as ARC-INFO® can create perspective views using geometric modeling to show the ground surface and vector or raster data layers. Image processing systems such as

ERDAS® and IDRISI® provide image rectification and draping capabilities. Unfortunately, GIS and image processing systems typically cannot render objects such as trees on the ground surface limiting their usefulness for stand- and plot-scale project visualizations.

Summary and contact information for several visualization tools is maintained by the author on the World Wide Web at http://forsys.cfr.washington.edu/viztools.html.

CONCLUSIONS

This paper has reviewed four techniques suitable for producing visualizations that depict harvest operations and other forest management activities. Computer visualization techniques can be an extremely powerful tool to communicate and educate critics of forest operations. However, they can just as easily be used to mislead people into believing a harvest operation will have little or no detrimental impact on the appearance of a forested landscape. Practitioners must ensure that visualizations present accurate representations of reality. This does not necessarily mean that visualizations must exhibit a high degree of realism to be effective. Images must, however, accurately represent stand and landscape conditions and the effect of a harvest operation on these conditions. While most people readily understand images that closely resemble photographs, the use of highly realistic images can lead to misconceptions about the amount of control foresters have over the future condition of stands and landscapes. Observers may find it difficult to separate the reality of a photograph from the uncertainty associated with forest management activities. It can be difficult to communicate that the project area will not look exactly like a photographic image created using video imaging techniques. As a result, their expectations may far exceed what is physically and biologically possible for the project area.

Visualization techniques and software systems are rapidly evolving as personal computers become more powerful. Recent developments such as three-dimensional rendering and image processing functions included in PC operating systems are making previously impossible levels of realism and rendering speed commonplace. Even with the most sophisticated visualization systems, the amount of agreement between projected conditions, represented by stand development models and visualizations, and attainable conditions can vary dramatically. Once a desired visual condition has been identified, achieving that condition can be difficult given the operational constraints imposed by forestry equipment, vegetation response to the treatment, topography, and operator proficiency. Harvesting systems must be applied correctly to ensure safe, efficient operations. If the desired visual condition requires restrictive harvest activities and patterns, operations can become unprofitable or, in the worst case, dangerous for logging crews.

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