A Forest Landscape Visualization System

Tim McDonald and Bryce Stokes[1]

Abstract

A forest landscape visualization system was developed and used in creating realistic images depicting how an area might appear if harvested. The system uses a ray-tracing renderer to draw model trees on a virtual landscape. The system includes components to create landscape surfaces from digital elevation data, populate/cut trees within (polygonal) areas, and convert GIS output data into a form suitable for input to the renderer. The system provides a flexible design tool that, coupled with a GIS, allows a forest engineer to design harvest unit boundaries, set removal intensities, then render an image of the treated area. This provides the engineer with reliable feedback on visual impacts and facilitates an iterative design process to mitigate negative public reaction to harvesting. The system was used to create images of three areas in northern Alabama showing the effects of three different silvicultural treatments on each: no removai, clearcut, and strip clearcut. The images were shown to several groups of students on the Auburn University campus, who were then asked to rate the scenes for scenic beauty. Results indicated a significant difference in scenic beauty between the simulated images, indicating the potential of the system for assessing public reaction to design alternatives.

Keywords: simulation, visualization, forestry, aesthetics, forest harvest

Introduction

Forestry is the largest manufacturing industry in 9 of 13 Southern states. In Alabama, forestry accounts for $4.5 billion in value added manufacturing per year, and contributes nearly $2 billion in payroll for over 60,000 workers. Two-thirds of the land base in Alabama is forested, an area roughly the size of the state of Indiana. Every year, about 3 1 million cubic meters of wood are harvested from the state's forests.

Although forest industry is a major contributor to the economy of the state and region, forest management remains a controversial subject. The public's image of forest management is often shaped by the scenic quality of forest operations and controlling the aesthetic outcomes of these operations, especially timber

[1] Authors are: Tim McDonald, Research Engineer, USDA Forest Service, Southern Research Station. 520 DeVall Dr., Auburn, AL. tpm@usfs.auburn.edu; Bryce Stokes, National Program Leader for Forest Operations Research, Vegetation Management and Protection Research Staff, USDA Forest Service, PO Box 96090, Washington DC, bstokes/wo@fs.fed.us.

harvesting, is important in keeping public sentiment committed to the practice of sustainable forestry in the South.

In most instances, the aesthetics of timber harvesting are preserved best by careful adherence to logging best management practices. The public is generally willing to accept logging on private lands (95 percent of the land bass in Alabama) as long as water quality, wildlife habitat, and soil productivity are maintained. Opinions change; however, when dealing with public lands, and highly visible high scenic-value private ownerships. For those instances where stand intervention is required and aesthetic impacts are of great importance, careful harvest planning becomes a critical need.

One component of harvest planning that can affect scenic values to a great extent is the placement of unit boundaries, especially in hilly or mountainous terrain. The public has a great dislike for clearcuts that appear large or unnatural. Clever placement of boundaries can screen portions of a clearcut, and non-linear unit edges more closely resemble the effects of natural disturbance processes. It is difficult, however, for harvest planners to effectively lay out harvestable units that minimize aesthetic impacts. The layout process can be enhanced using computer planning tools that create visual simulations of forested landscapes showing the effects of unit boundary placement. A number of tools have been developed for forest landscape simulation, including *Vantage Point* by the University of Washington Cooperative for Forest-Systems Engineering, *Smart Forest* by the University of Illinois Landscape Architecture Department's Imaging Lab, and *UVIEW* produced by the US Forest Service. Each has particular strengths, and especially in the case of *Vantage Point*, the products are highly realistic, very powerful tools for simulating changes in forested landscapes. One drawback of each, however, is availability. A need existed for a universally-available, inexpensive software package for landscape rendering. This paper reports on one such system that has been applied in assessing alternative silvicultural approaches to upland hardwood management. Design considerations for the system are reviewed, followed by an outline of the development and use of the system as it exists. Results from using the system to assess public opinion on alternatives to clearcutting in upland hardwoods are presented.

Methods

System Development

A discussion of the design objectives and major system components was presented in McDonald (in press). Briefly, the main objectives for the system were that it be usable by forest engineers in assessing scenic impacts of variations in harvest unit boundaries, and that the visual simulations be realistic enough to accurately convey to the general public the results of the engineer's design decisions. Constraints on the system were that it be usable across a wide range of hardware/operating system combinations, that it would inter-operate with existing spatial data management systems, and that it be inexpensive.

Development goals were met using a modular approach. The main harvest unit design system was a GIS, in our case the GRASS system. This allowed the engineer to use a spatial analysis package they were already comfortable with to create a series of potential unit boundaries. Topographic and polygonal data were then exported from the GIS and transformed using a sequence of purpose-built software tools to create input data for a computer rendering system, *POV-Ray*, which created the final scenes. *POV-Ray* is a public domain ray tracing/radiosity rendering system available for nearly every computer system that exists, including most versions of UNIX, as well as MS-DOS, MS-Windows, and MacOS. Table 1 details the components of the landscape simulation system, along with the data types passed among the components. McDonald (in press) is a comprehensive presentation of the details of system design and use.

System Evaluation Methods

Three locations were selected and each of three silvicultural treatments were simulated on them. One of the sites cot-responded to a study area on which we had installed an experiment to evaluate the effects of strip clearcutting on regeneration and harvest costs (Rummer and others 1997). The other two sites were chosen more or less randomly from a topographic map based on suitable surface relief and the presence of a nearby view point. Harvest treatments included strip clearcut, clearcut, and uncut control. Strip clearcuts were placed along surface contours and were spaced about 150 m on center. View points were chosen to be nearby hilltops. Table 2 is a summary of unit size, distance from view point to center of the unit, and stand characteristics of the simulated images. Figure 1 shows topography and unit boundaries for a typical strip clearcut (site 1). The view point is also marked.

The scenes were rendered using an image size of 1200x800 pixels. Camera characteristics were slightly different between sites, with site number 2 requiring a wide-angle view to capture the extent of the clearcut. Images for site number 3 incorporated atmospheric fog to add a little variety to the mix of scenes. Two other scenes were included in the mix of images: one was a deferment cut treatment on site number 1 (modified shelterwood with 25 residual stems per acre), and the second a modified clearcut with several small patches of trees left on the area to screen strategic locations. Total area removed in the patch cut was 78. I ha. These images were included to add a bit of variation in the sequence of scenes. Figure 2 shows three simulated images for site I, the uncut, clearcut, and stripcut scenes.

After rendering the images were exposed onto slides. Four groups of forestry students at Auburn University were asked to rate the slides for their scenic beauty on a scale of 1 to 5. A short introduction was presented before actually viewing the slides in which it was explained that these were computer simulations of silvicultural treatments that could not be implemented in practice, and that they were to rate the scenic beauty of the scene depicted, not the quality of the simulation. Responses of the students were normalized using the technique of Brown and others (1990), resulting in a numerical index called an SBE, or Scenic Beauty Estimator. Analysis of variance was used to determine the effect of treatment and site on SBE means.

Results and Discussion

System Performance

A full discussion of some of the problems with the system was presented in McDonald (in press). Most of the limitations were with the user interface and the steep learning curve required to effectively use *POV-Ray*. The power and flexibility of the renderer, however, was thought to compensate for lack of simplicity in its application. Another problem was the amount of data required to create an image. Data for each tree location was kept separately for each rendered scene. Although this was the simplest means of handling tree information, a better approach might have been to modify *POV-Ray* to directly place trees (or objects in general) on a given surface within a polygon. This would have eliminated the need to read long lists of tree locations, but perhaps have sacrificed some rendering speed. There were also some lingering inconsistencies in the rendered scenes that could not be resolved. For example, shadows under trees were not always rendered properly.

In general, the system was an acceptable, if somewhat impractical, solution to rendering images of forested landscapes. Flexibility was a key feature of the system in that it could be adapted to nearly any GIS for unit layout. The use of a general-purpose rendering system provided the capability to incorporate just about any type of object into images, but required a great deal of knowledge on the part of the user to deal effectively with *POV-Ray's* rather complicated scripting language. Application speed was acceptable, with large, complicated images rendered in a couple of hours on a RISC workstation. The ultimate test of the system, however, was in its capability for effectively conveying some idea of the visual impacts of silvicultural treatments.

Use for Public Opinion Assessment

Results of the public opinion survey indicated that the visualization system could potentially be used in evaluating response to proposed treatments. A single-factor model of response to cutting treatment was significant (R^2 = 0.28, n=531), and estimates of the mean response for each treatment are summarized in Fig. 3. All mean SBE values for the three treatments were significantly different from each other (a = 0.01), indicating that the viewers could visually distinguish the treatments when observing the rendered images. The order of the treatments, preferring uncut, stripcut, then clearcut, respectively, was as expected intuitively (Daniel and Boster 1976) and also was evidence that the images were accurate representations of real-life situations.

Further analysis also added support to the claim that the images were potentially suitable for assessing public opinion. Adding site to the analysis as a second factor improved the model fit ($R^2 = 0.36$), with both site and site- by-treatment factors being significant. Results showed a difference in mean SBE response among the sites by treatment, with sites having greater topographic relief (mainly site 1) eliciting a higher negative response with increasing harvest removal intensity. This result is in agreement with other empirical data that indicates a negative correlation between exposed soil surface and scenic beauty (Willhite and Sise 1974). Not evaluated In this study was how close the response to the simulated scenes was to that from actual photographs of the treatments. That experiment is impractical to conduct at this time because of the lack of sites where strip clearcutting has actually been implemented. Given the net positive response to strip clearcutting in this study, however, it may be possible to convince land managers to try strip clearcutting in those situations where visual quality is important, and to conduct a true comparison of responses to simulated and real images of the same scene.

Availability of Software

All software used in the landscape visualization system was in the public domain, or developed specifically for this study and available through our web site. The *GRASS* GIS is available from the US Army Construction Engineering Research Lab at

http://www.cecer.army.mil/facts/sheets/LL12.html.

scape was developed by Paul Heckbert and Michael Garland of Carnegie Mellon University and is available at

http://www.cs.cmu.edu/afs/cs.cmu.edu/Web/People/garland/scape/.

POV-Ray can be found at

http://www.povray.org.

Software and documentation developed for this particular application is available at our web site:

http://srs4703.usfs.auburn.edu/research/prob4/vis_sys.html

All programs were compiled with the GNU *gcc* compiler, and the programs to read and write **polygon** information require the GNU *flex* and *bison* lexical analysis and parser generator software.

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Tables

Step	Software	Input Requirements	output
I. Data assembly	GIS (GRASS[1])		DEM, view points, stand polygons, tree species and age charactersitics
2.Create TIN	*scape*[2]	raster DEM	list of triangle vertices
3.Add vertex normals	*normcalc*		TIN with vertex normals, in intermediate format
4. Add trees to scene	*lt* *cutpoly*	TIN, stand polygons, # of trees	List of x,y,z coordinates of tree locations
5. Convert TIN to *POV-Ray*	*gs2pov*	TIN, ground surface textures, stand polygons	*POV-Ray* object with textures assigned to ground surface polygons
6. Assign tree attributes, convert to *POV-Ray*	*trees2pov*	Tree types and sizes, stand polygons	List of 'tree' objects for inclusion in *POV-Ray*
7. Render	*POV-Ray*	Control script, tree definitions	24-bit color image of landscape

Table 1. Components of the visualization system.

Site Number	Treatment	Total Area (ha)	Stand Density (stems ha^{-1})	View Point Distance (m)
1	clearcut	29.1	1000	961
	stripcut	17.4		
2	clearcut	85.4	250	1234
	stripcut	45.7		
3	clearcut	15.0	500	892
	stripcut	9.3		

Table 2. Harvest unit characteristics for the three test sites.

Figures

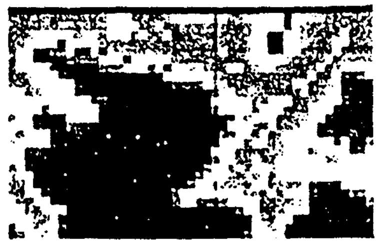

Figure 1. Harvest unit boundaries for site 1. View point is marked with a white box.

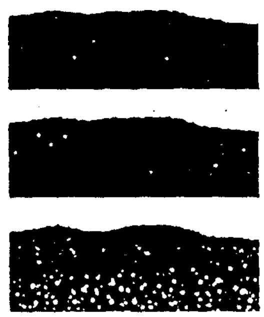

Figure 2. Example images for sire number 1: uncut (top), stripcut, clearcut (bottom).

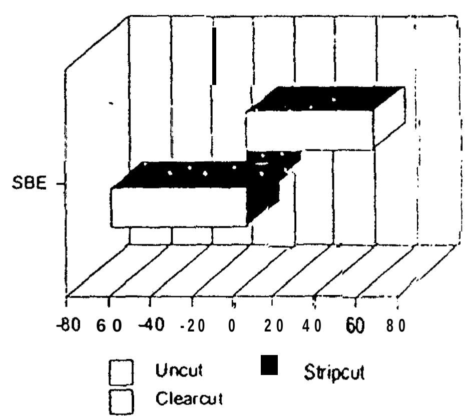

Figure 3. Scenic beauty estimates for (he single factor (harvest treatment) analysis model.