

Chapter 7 Software Applications to Three-Dimensional Visualization of Forest Landscapes — A Case Study Demonstrating the Use of Visual Nature Studio (VNS) in Visualizing Fire Spread in Forest Landscapes

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Abstract

Three-dimensional (3D) visualization is a useful tool that depicts virtual forest landscapes on computer. Previous studies in visualization have required high end computer hardware and specialized technical skills. A virtual forest landscape can be used to show different effects of disturbances and management scenarios on a computer, which allows observation of forest landscapes without time limitations. This chapter lists updated methods and software used for 3D visualization of forest landscapes, and demonstrates a fire visualization using Visual Nature Studio and standard computer hardware. Elevation and vegetation data were used to create a representation of the New Jersey pine barrens environment. Photographic images were edited to use as image object models for forest vegetation. The FARSITE fire behavioral model was used to model a fire typical of that area. Output from FARSITE was used to visualize the fire with tree models edited to simulate burning and flame models. Both static and animated views of the fire spread and effects were visualized. The visualization method was evaluated for advantages and disadvantages. VNS visualization is realistic, including many effects such as ground textures, lighting, user-made models, and atmospheric effects. However VNS has additional hardware requirements in terms of

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memory or hard drive space and sometimes renders images slowly.

Keywords

Visualization software, FARSITE model, ArcGIS, VNS.

7.1 Introduction

Visualization is defined as any technique for creating images, diagrams, or animation in order to convey a message. Advances in computer hardware and software over the past 30 years have allowed researchers to simulate and visualize complex forms, phenomena, and dynamics, such as plant growth or changes in atmospheric conditions, in natural systems (Ervin and Hasbrouck, 1999). Visualization that previously required specialized computer systems and hardware can now be done on more affordable desktop/laptop systems. With this increased accessibility, visualization has become a tool available to even more researchers as a means of analyzing data.

In the field of landscape management and forestry, visualization can be used to demonstrate and analyze data from geographic information systems (GIS) or remotely sensed imagery such as aerial photographs or satellite images. Through the commercialization of hybrid 2D/3D visualization software such as Bryce 3D (DAZ Productions, 2009), World Construction Set and Visual Nature Studio (3D Nature Inc., 2009), and VistaPro (Virtual Reality Laboratories Inc., 1993), 3D modeling of landscapes possessing a high degree of realism, from different viewpoints, and having animation paths is now possible (McGaughey, 1998; Muhar, 2001). Due to the release of these programs, the use of visualization has become an important tool for analyzing existing forest landscape resources and for assessing the impact of proposed management practices (Lange, 1994; Orland, 1994b; McCarter, 1997; McGaughey, 1998). Furthermore, it can aid the understanding of successional dynamics and spatial patterns within a forest ecosystem. It may also be of aid to forest managers when selecting management practices to more efficiently utilize forest resources.

With the ability to produce realistic representation of data, visualization can play an important role in the land management decision making process. An important question that can be raised is what level of realism is necessary to draw meaningful conclusions from visualized images. Understanding how people observe and process visualization can assist in making them better present data and natural phenomena.

Oh (1994) studied the effects of representational image quality on perception. In scoring of representative images ranging from a simple wire frame view to fully digitized, color photographs, the wire frame and simple views were rated much lower. Likewise, these simpler views were also rated lower among observers having less knowledge of visualization and of the site.

Further studies by Bergen et al. (1995) compared scenic beauty ratings based on photographs to those obtained from computer-generated visualization of the same scene. Overall, the correlation between the rendered scenes and photographs were not significantly different, but the correlation with a smaller subset of five views had a greater significance where the rendered scenes played a more important role in the beauty rating. Computer-rendered visualization may have played a role in the preliminary assessment of the scene, but final quality decisions were found to be best done using photographs.

Daniel and Meitner (2001) compared different levels of realism/abstraction among visualized scenes. The most realistic scenes had full 16 bit color images with each successive scene having lower realistic qualities ranging from 4 bit color to black and white sketches. Visualized scenes with the highest realism had the highest correlation with perceived beauty. Likewise, it was also found that each reduction in realistic quality resulted in a corresponding reduction in correlation with perceived beauty.

The visualization methodologies identified in these studies play a crucial role in making useful visualized scenes. Moreover, software applications to visualization must take these processes into account in order to make them effective.

7.2 Forest landscape visualization

Landscape visualization requires a combination of several aspects such as software, geospatial data, and methods of representing data in order to be successful. A good visualization application will provide features that can accurately render landscape scenes in a realistic manner. Furthermore it should also include realistic models or the ability to import such models in order to represent features of the landscape being modeled. Geospatial data is necessary for modeling landscape features accurately. It can allow placement of features such as forests, lakes, roads, and buildings that can allow the user to identify and draw crucial information from the scene being presented. Visualization techniques can be simple things such as rendering features such as lakes or forest with accepted colors such as blue and green. More advanced methods can include using cloud models or the use of light and shadows. Techniques such as these acts to enhance the realism of the scene in order to allow the view to make a more personal connection to it, which in turn may help them draw more meaningful information.

7.2.1 Review of forest landscape visualization software

There are various different applications to landscape visualization (Table 7.1). However, each of these software packages is written with different goals in mind and each has different advantages and disadvantages. Table 7.1 lists the critical features for 3D visualization comparisons of various 3D visualization software packages.

In a comparative study, Karjalainen and Tyrväimen (2002) evaluated the three applications of MONSU (Pukkala, 1998), Smart Forest (Orland, 1994a), and FORSI (Plustech Ltd.) for their ease of use and suitability for producing landscape visualization.

MONSU (Fig. 7.1) produces automated computer line drawings based on site and tree parameters, rendering trees accurately in both size and shape as 2D or 3D images. However, understory elements are not present and ground elements are drawn with different colors. Landscape elements such as bushes, uniquely shaped trees, and buildings are not present either. The lack of these



Fig. 7.1 Long and near-distance views produced using MONSU (Karjalainen and Tyrväimen, 2002).

Table 7.1 Comparison of commonly used 3D forest visualization software packages (updated from Song et al., 2006)

Software Pack- age Name	Visualization Technique	Scale	HW – OS	Cost	Additional Information Refer- ence	Comments
ArcGIS 3D Analyst/ ArcGlobe/ ArcScene	Image draping	All scales	PC-Windows, Macintosh	V 8.2 \$2,500	http://www.esri.com/software/arcgis/extensions/3danalyst/ Source: ESRI	Real time interaction, Easy link between visualization and data information
Blueberry3D	Image draping and geometric modeling	All scales	PC-Windows, Macintosh	V 2.0 \$2,490	http://www.blueberry3d.com/ Source: Sjoland & Thyselius Virtual Reality Systems AB	A procedural geometry engine, Allows rapid development and visualization of realtime 3D databases in high resolution for the Military Simulation Industry, Bridging the gap between high resolution 3D content and realtime display performance
Digital Land- scapes	Geometric mod- eling	landscape	Windows NT; Silicon Graph- ics IRIX	500,000 Japanese yen	http://www.jfp.co.jp/landscape_e/dland_top.htm JFP Morioka, Japan	Uses terrain data from Japan's National Geographical Institute
EnVision	Geometric mod- eling	Stand or land- scape	PC-Windows	Free	http://forsys.cfr.washington.edu/envision.html Source: Pacific Northwest Re- search Station, USDA Forest Service	Easy to use, Simple individual tree forms so low photorealism
Enviro (3D runtime envi- ronment)	Image draping and geometric modeling	Landscape	PC-Windows, Macintosh	Free	http://www.vterrain.org/ Source: Virtual Terrain Project (VTP)	Allows rapid construction of an interactive 3D visualization

Software Package Name	Visualization Technique	Scale	HW – OS	Cost	Additional Information Reference	Comments
FORSI	Image draping and geometric modeling	Landscape	PC-Windows	No longer available	Source: Finland company Plus-tech Oy, a subsidiary of the John Deere Company's <i>Timberjack</i> Division.	Achieves a high degree of fidelity in rendering forest scenery with texture-mapping techniques, Does not allow the viewer to move around in a forest setting or to interact with underlying data
GenesisIV	Image draping and geometric modeling	Landscape	PC-Windows	Educational: \$50 Enterprise: \$300	http://www.geomantics.com/genes4.htm Source: Geomantics	Fast rendering, Low price, Good teaching tool; Simple individual tree forms, Low photorealism
Google Earth	Image draping	Landscape	PC-Windows	Standard: Free Pro: \$ 400	http://earth.google.com/ Source: Google™	Displays satellite images of varying resolution of the Earth's surface, Allows users to visually see things like houses and cars from a bird's eye view
Landscape Explorer	Image draping	Landscape	PC-Windows	\$50; Educational: Free	http://www.geomantics.com/le2000.htm Source: Geomantics	Realtime 3D map/landscape renderer
Landscape management system (LMS)2	Geometric modeling	All scales	PC-Windows	Free	http://lms.cfr.washington.edu/ Source: University of Washington	Designed to aid in landscape level management, and linked to forest growth model, Simple individual tree forms, Low photorealism

Continued						
Software Pack- age Name	Visualization Technique	Scale	HW – OS	Cost	Additional Information Refer- ence	Comments
Light De- tection and Ranging (LI- DAR) based forest visual- ization (LI	Geometric mod- eling	Stand or land- scape	Specific equip- ment, such as CAVE	Expensive, Flight costs: \$100,000 + Soft- ware: \$1,500 to \$3,000	http://www.cfr.msstate.edu/forestry/sit1/sit1Likuko/vis.ikuko.htm Source: Visualization, Analy- sis, and Imaging Laboratory (VAIL) at Mississippi State University	Expensive, Real time interac- tion
LViz (LIDAR/ALSM 3D Visualiza- tion tool)	Image draping	All scales	PC-Windows	Free	http://lidar.asu.edu/LViz.html Source: Active Tectonics Re- search Group at Arizona State University	Designed for 3D visualization of LiDAR / ALSM point and interpolated data, Offers im- port of LiDAR point cloud data (delimited text file) or in- terpolated surfaces (in ASCII or Arc ASCII grid formats)
MapInfo	Image draping and geometric modeling	All scales	PC-Windows	Pro V8.0: \$1450	http://www.mapinfo.com/products/applications/mapping-and-analytical-applications/mapinfo-professional Source: MapInfo	Windows®-based mapping and geographic analysis ap- plication, Designed to easily visualize the relationships between data and geography
MONSU	Geometric mod- eling	Landscape	PC-Windows	Free	http://www.monsu.net Source:: University of Joensuu, Fenny	Software product for multiple- use forest planning by pro- ducing a set of management schedules on the basis of user- defined instructions

Software Package Name	Visualization Technique	Scale	HW – OS	Cost	Additional Information Reference	Comments
Natural Scene Designer	Geometric modeling	Stand or landscape	PC-Windows, Macintosh	V 4.0 \$139 Pro 4.0 \$329	http://www.naturalgfx.com/nsdwin.htm Source: Natural Graphics	Produces 360 degree panoramas from any location
PAVAN (Performing and Virtual Arts Northwest)	Image draping	Stand or landscape	PC-Windows		www.pavanw.com Source: DataView Solution	A Virtual Reality Modeling Language (VRML) compiler and project management toolkit for use in conjunction with MapInfo software
Persistence of vision raytracer (POV-Ray)	Geometric modeling	All scales	Many platforms	Free	www.povray.org Source: povray.org	A general purpose ray-tracing system, Capable of producing detailed, photorealistic images of geometric models
Rapid Terrain Visualization (RTV) LIDAR Toolkit	Geometric modeling	Stand or landscape	PC-Windows	Free	http://rockyweb.cr.usgs.gov/html/extract/ Source: SAIC	Extension of ESRI ArcView 3.2 requiring the Spatial Analyst extension, ArcView's 3D Analyst extension is required for exporting 3D Shape files
SmartForest II	Geometric modeling	Stand or landscape	UNIX (SGI or IBM-RS6000 with OpenGL) and PC-Windows	Free	http://www.imlab.psu.edu/smartforest/index.html Source: University of Illinois at Urbana-Champaign	3D ecosystem simulator, Requires detailed data, Visualization capacity is around 5,000 stems

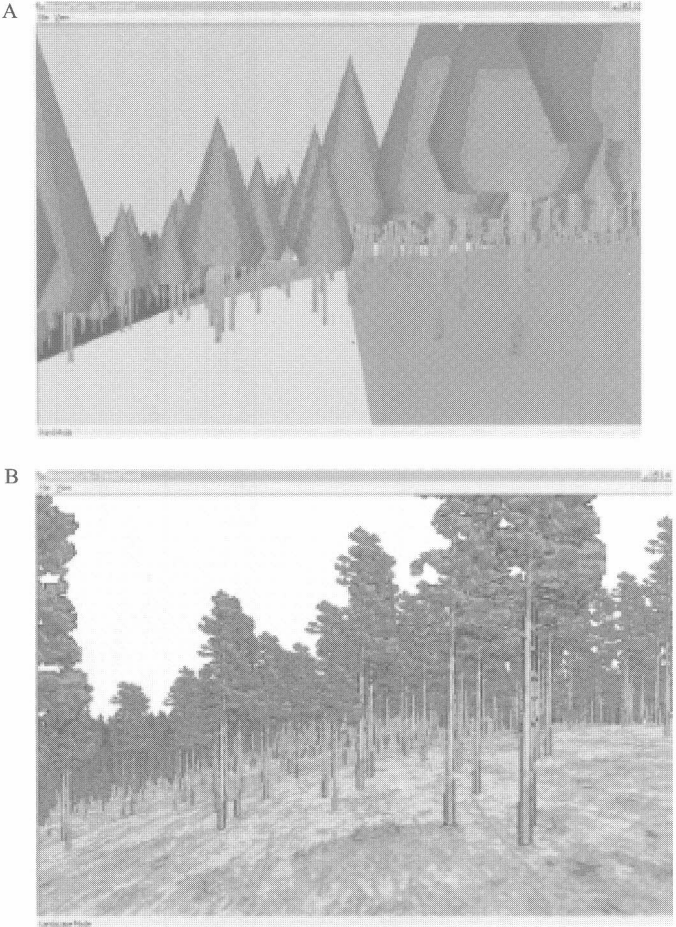
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Software Package Name	Visualization Technique	Scale	HW - OS	Cost	Additional Information Reference	Comments
UTOOLS and UVIEW	Geometric modeling	Stand or landscape	PC-DOS	Free	http://faculty.washington.edu/mcgoy/utools.html Source: Pacific Northwest Research Station, USDA Forest Service	Similar to Stand Visualization Simulator http://forsys.cfr.washington.edu/svs.html , Functions mainly at landscape scale
VirtualGIS	Image draping and geometric modeling	Stand or landscape	PC-Windows	£ 2,140	http://gi.leica-geosystems.com/LGISub1x39x0.aspx Source: ERDAS IMAGE	Visual analysis tool that offers GIS functions and capabilities in a 3D environments, Creates accurate 3D interpretations of your projects for interactive presentations
VirtualEarth	Image draping	Landscape	PC-Windows	Free	http://www.microsoft.com/virtualearth/platform/default.aspx Source: Microsoft®	Integrated set of services that provides quality geospatial data, Rich images, Dependable performance, Visualizes data to provide immersive end-user experiences
VistaPro	Geometric modeling; image draping	Landscape	PC-DOS, PC-Windows, and Macintosh	\$49	http://www.vendornation.com/*ws4d-db-query-QuickShow?vp001 Source: VendorNation	3D landscape rendering program

Software Package Name	Visualization Technique	Scale	HW – OS	Cost	Additional Information Reference	Comments
WCS and VNS, with add-on software of “Scenc Express”, “NatureView Express, a real-time 3D viewer”, and “Forestry Edition of VNS” for more efficient use of the powerful forestry features in VNS.	Image draping and geometric modeling	All scales	PC-Windows, Macintosh	WCS 6: \$500; VNS 2: \$2475; Scene Express: \$399 for WCS and \$699 for VNS; NatureView Express: Free; Discount for Education	http://www.3dnature.com Source: 3D Nature LLC	Photorealistic visualization, High compatibility with GIS data, Linkage to GIS data means that different vegetation or land use polygons will be rendered according to their attributes, Libraries of foliage objects and textures, pre-built components, and sample projects
World Builder	geometric modeling	All scales	PC-Windows	Standard: \$399 Pro: \$999	http://www.digi-element.com/wb/index.htm Source: Digital Element	Photorealistic visualization, Panorama rendering
World Perfect	Image draping and geometric modeling		PC-Windows	\$15,000	http://www.metavr.com/products/worldperfect/worldperfect.html Source: MetaVR	Terrain-and-content generation system for creating geographically large-scale detailed virtual worlds, Creates highly realistic 3D environments quickly and efficiently from imagery, elevation, and feature source data

features being rendered makes MONSU a poor choice for visualizing landscapes with special scenic beauty. The application's main strength comes from the ability to use forest inventory data very efficiently, being compatible with available forest inventory and satellite data. MONSU can simulate movement through a visualized forest by drawing scenes from points along a selected path; however, at the time of publication, real time movement was not possible due to hardware constraints.

Smart Forest (Fig. 7.2) is an interactive, 3D software package that has a management and landscape mode. Management mode provides a simplified view of the forest for quick queries of individual trees and forest stands in order to analyze the data. Landscape mode renders much more detailed and realistic scenes, with trees and water being presented as texture-mapped objects and ground details wrapped with 2D images generated from digitized photos. Smart Forest also allows user-defined heights to view scenes at dif-



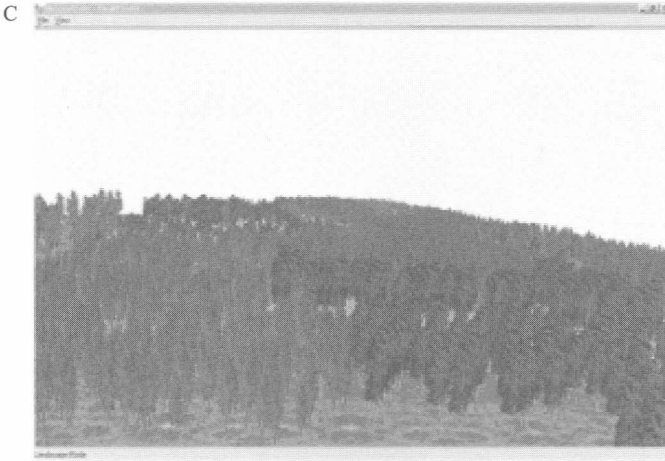


Fig. 7.2 Near-distance view in manager mode (A), long-distance view (B), and landscape mode view (C) produced using Smart Forest (Karjalainen and Tyrväimen, 2002).

ferent levels and movement within the scene for a real time walk-through of a virtual forest. However, the application optimizes graphic quality in order to produce smooth moving walk-through animation. Due to these optimizations, the ability to accurately represent local forest scenes when using Smart Forest's real time movement is greatly reduced.

FORSI (Fig. 7.3) is a smaller landscape visualization application designed mainly for Finnish organizations; however, it was written for realism and flexibility. Forest elements are represented by 2D objects generated from digitized photos.

Because these objects are digitized from photographs, high quality images can be produced that are only limited to the color depth and resolution of the original photograph. Likewise, new objects can easily be added to the standard library of tree and forest elements by simply digitizing them from a photograph. FORSI also has the ability to illustrate seasonal and atmospheric effects. This allows for more realistic scenes due to differing light and sky conditions. Movement simulation in FORSI is very similar to that in MONSU. Points are manually selected and scenes are drawn along that path in order to simulate movement throughout the forest.

Of these three software packages, Smart Forest and FORSI are commercial packages, whereas MONSU is free for use (Karjalainen and Tyrväimen, 2002). Currently only Smart Forest and MONSU have websites (<http://www.imlab.psu.edu/smartforest/> and <http://www.monsu.net/Englishmonsu.htm>); however, neither is available for download at this time. Due to their age, these software packages are no longer in use.

Song et al. (2006) investigated general approaches to landscape visualization and presented some information on software applications, finding that

A



B



Fig. 7.3 Near-distance (A) and long-distance (B) views produced using FORSI (Karjalainen and Tyrväinen, 2002).

one of the key challenges facing software applications for use in visualization is real time interaction. However, many software packages are improving on

this. Commercial software packages such as Ecomodeler/Ecoviewer (Viewscape 3D Graphics Ltd) can display visualization with point of view and fly-over capabilities in real time, with options to include management activities and the ability to navigate freely (Song et al., 2006). Another problematic aspect of many visualization applications is the lack of photorealism. However, some freeware applications, such as Persistence of Vision Raytracer (POV-Ray, Povray.org), are capable of producing detailed, photorealistic models. Development of software with real time user interaction and photorealistic modeling helps to provide better tools for the use of visualization in landscape management.

7.2.2 Case study: Forest landscape visualization of fire spread

Wang et al. (2006) created a visualization of the landscape of the Chequamegon National Forest in northern Wisconsin using publicly available data sources such as forest inventory analysis (FIA, USDA Forest Service) and GIS data. The visualization was done using Visual Nature Studio (VNS, 3D Nature Inc.), a relatively new visualization software package. Mathematical models were then applied to the forest data to determine changes in future succession and growth. The resulting data were applied to the initial forest visualization to show changes in forest stand structure and composition that may occur due to harvesting or some other disturbance events. Resulting visualizations that came from these data were time lapsed images showing the changes in the forest over extended periods of time.

We adopted the Wang et al. (2006) approach to develop visualization for a wildfire event in the pine barrens of New Jersey. An initial forest environment was constructed using public topographic, vegetation, and GIS data for the study area. Data output from the FARSITE model (Miles et al., 2001) was then applied to the visualization in order to show the spread and effects of the fire. FARSITE is a fire behavior and growth simulator program used in the prediction of fires based on initial fuel, weather, and topographic conditions. It is widely accepted and used by fire behavior analysts from a wide variety of agencies, including the USDA Forest Service, USDA National Park Service, and the USDI Bureau of Land Management. The program accepts vegetation, fuel load, weather, and topological data in the form of text files and raster images. Output from the program consists of ArcGIS raster images with data pertaining to fire line intensity, flame length, and other fire characteristics. Using FARSITE, managers can predict the occurrence of both surface and canopy fires along with fire behavior based on factors such as firebreaks and the influence of weather.

7.2.3 Visualization using visual nature studio

The computer used for working with VNS was a custom built system with an AMD Athlon X2 4200+ dual core CPU, 2 gigabytes of RAM, and an nVidia GeForce 7600 GS graphics card. An updated version of VNS version 2.7 was used for the study. Add-on tools such as Scene Express or the Forestry Edition were not installed or used.

A 2,590 hectare (10 square miles) section of the Cedar Bridge area in the New Jersey pine barrens was selected as our study site. This area consisted primarily of a mature pitch pine canopy with a small number of hardwood species and high shrub loads present in the understory. Most of the area is forested; however, there are some small areas with buildings and several highways. There is also one large lake and several smaller water bodies within the area (Fig. 7.4).

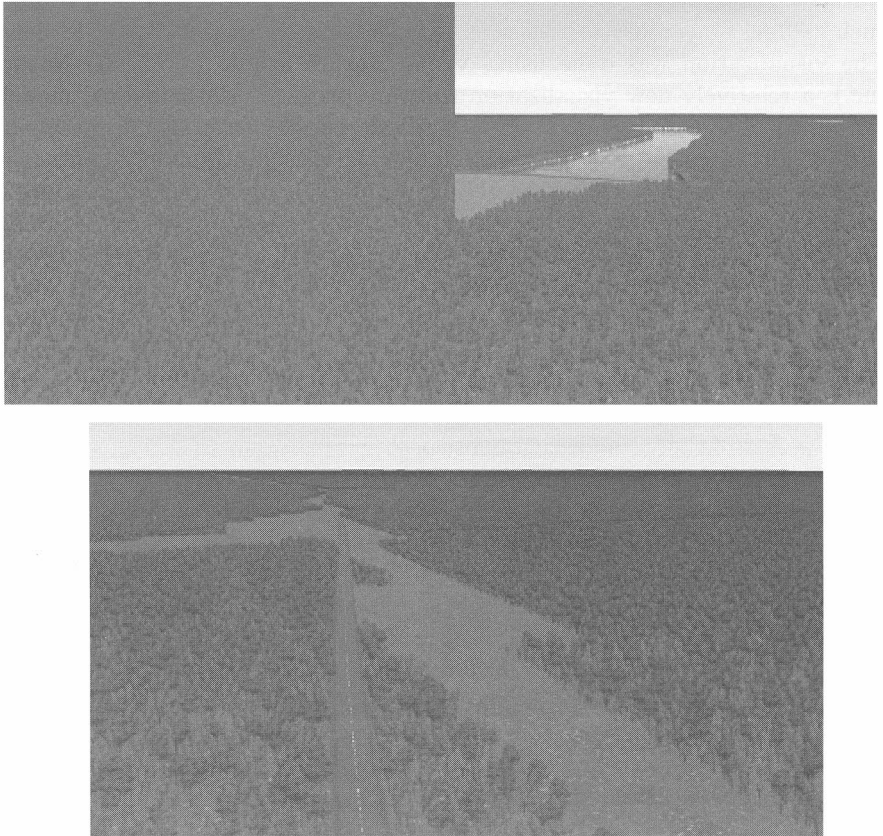


Fig. 7.4 Visualization of New Jersey pine barrens before fire showing surface features such as roads and lakes.

One of the first steps in this visualization was to recreate the forest environment in the pine barrens. Elevation and base heights for the landforms were obtained from a 10 meter digital elevation map (DEM) that was imported into VNS. A georeferenced aerial photograph was then used to digitize surface features such as roads, urban areas, and bodies of water. Surface features were digitized from the photograph into shapefiles using ArcMap. The shapefiles were imported into VNS in order to visualize the surface features. Road and water features were visualized using the included models in VNS, which looked similar to the features observed in the photograph. Urban areas were similarly visualized with a model comparable to asphalt, but with few or no buildings. This was done to reduce the total number of models in the visualization and to increase rendering speed.

To visualize the forest vegetation, user-made tree models were used instead of the models included with VNS. These tree models were made from photographs of local pine barrens tree species taken with a Nikon D70 digital camera during a visit in the summer of 2006. The photographs were loaded into Adobe Photoshop, where surrounding vegetation was removed to leave the tree of interest alone in the foreground, and the background was painted black. They were saved as JPG (JPEG, Joint Photographic Experts Group, compressed image) files and imported into the VNS graphics library to use as models.

To visualize the forest environment in a realistic manner, it was necessary to link the tree models with the actual forest structure in terms of characteristics such as tree height and density. This was accomplished using forest inventory data and a georeferenced Canopy Bulk Density (CBD) map. The forestry inventory data from test plots included tree height, species, diameter at breast height (DBH), basal area, and density. The data were analyzed to determine the averages and standard deviations for tree height and DBH in each plot. Test plot density was compared to values from the CBD map based on the equation for deriving Canopy Bulk Density in mixed conifer environments developed by Cruz et al. (2003):

$$\ln(\text{CBD}) = (0.319 * \ln(\text{basalarea})) + ((0.859 * \ln(\text{treedensity})) - 8.445$$

When solved for density using the values from inventory data and the CBD map, the numbers obtained were highly correlated with measured density in the test plots. Therefore, the CBD map proved to be a suitable link between the visualization and physical inventory data. It was imported into ArcMap where each map symbology value was given a significantly different RGB (red, green, blue) color code and then exported as a GeoTIFF file (a Tagged Image File Format image retaining its spatial coordinates). When imported into VNS, this GeoTIFF acted as a color map to visualize various forest ecosystems of different structure based upon the CBD value.

Various forest “ecosystems” were constructed using the ecosystem function in VNS. An ecosystem is defined in VNS as an association of plant species all

sharing common characteristics such as height, density, and relative frequency. Appropriate tree models were placed in the canopy and understory layers based on species from the inventory data. Average height was used for the main tree height while the standard deviation was used as an offset factor to vary tree heights. An included ground texture representing a forest floor with leaf litter was assigned to represent the ground. Due to the uniform nature of the site, most of these ecosystems were essentially the same in terms of species type, tree heights, and DBH classes. The most noticeable differences were in tree numbers and density, which was reflected in the CBD values used for color mapping.

Wildfire data were obtained from FARSITE simulations performed by Matthew Duveneck of Southern Maine Community College. The simulation was performed based on the conditions in the area on April 4, 2005 to recreate a fire that had occurred within the area previously. Temperature ranged from 4.8 to 18.9°C (40 to 66°F) with a humidity range of 16 to 61%. Wind speed ranged from 14.5 to 20.3 kilometers per hour (9 to 13 miles per hour) for the day. The wildfire was simulated over a series of 30 minute increments from 12:30 to 6:30 PM EST. Results from the simulation included a shapefile outlining the spread of the wildfire over each 30 minute increment and several raster files with data pertaining to flame length, fireline intensity, and crown activity (Fig. 7.5).

The custom tree models for tree visualization were recolored using Photoshop to represent burned trees. Models representing slightly burned trees remained mostly green, but had a small amount of brownish hue in the lower foliage and trunk. Additional yellow and red hues were added to the foliage to represent trees receiving more moderate damage. For more severe damage a larger amount of red hue was added to foliage along with a darker brown color or black marks to the trunk. Completely burned tree models had all foliage removed with very dark brown or black trunks and branches. A collection of flame models was also used to show fire occurrence (Fig. 7.6 and Fig. 7.7). A few models were drawn with Photoshop for the purpose of representing ground and understory fires. Another group of flame models came from a collection of Photoshop brushes created by Shimerlida (2007). These flame models were combined with the burned tree models to represent fire burning through the various layers of the canopy. Each tree model of different burn severity was merged with a corresponding flame model to represent fires occurring in the lower, middle, and upper canopies of the trees. To represent fire moving through the canopies of a group of trees, the larger flame models were merged with groups of three or four of the tree models.

Visualization of the wildfire was performed in a similar manner to ecosystem placement through the use of the CBD map. Examining the fireline intensity and flame length output in ArcMap showed a strong relationship between the two; areas of intense fire typically had flames of greater length. Therefore, the flame length output was chosen to serve as a color map to guide proper

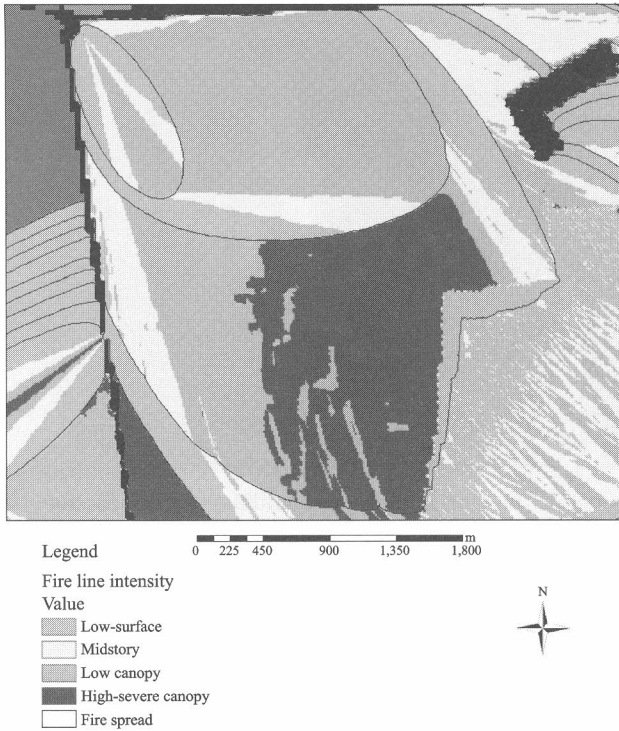


Fig. 7.5 An example of FARSITE output showing fire line intensity within the pine barrens study area.

fire visualization. Four different fire severity environments were constructed based on flame length: (i) flame lengths of 0 to 3 meters (0 to 9.84 feet) represented ground and understory fires; (ii) flame lengths of 3.01 to 6 meters (9.875 to 19.69 feet) were mid-canopy fires; (iii) flame lengths of 6.01 to 10 meters (19.72 to 32.81 feet) were overstory fires; and (iv) flame lengths of 10.01 to 16 meters (32.84 to 52.93 feet) represented fire extending over the top of the canopy. Three different burned environments were also constructed to show the effects of a fire passing through the forest: one for areas in which the flame front had just moved through it, one for areas with low intensity and flame length, and one for areas with high intensity fires.

These environments were constructed similarly to the regular forest environments in which the appropriate burned tree models were selected for each one. Ground textures were made using Visual Nature Studio's texture editor. The basic ground texture was edited to show increasing amounts of damage with increasing fire intensity. These different environments were then assigned to each of the different forest ecosystems as a material. Materials in VNS act much like an ecosystem with each possessing tree heights, density, ground models, etc. However, materials inherit all their characteristics

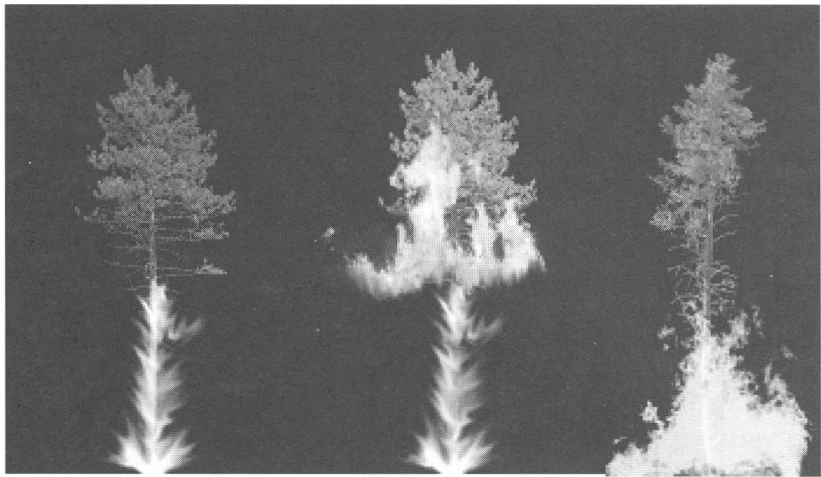


Fig. 7.6 Example of custom models used to illustrate fire damage. Individual tree models were edited to show varying degrees of damage based on severity. Different flame models were used to show movement of fire through the canopy.

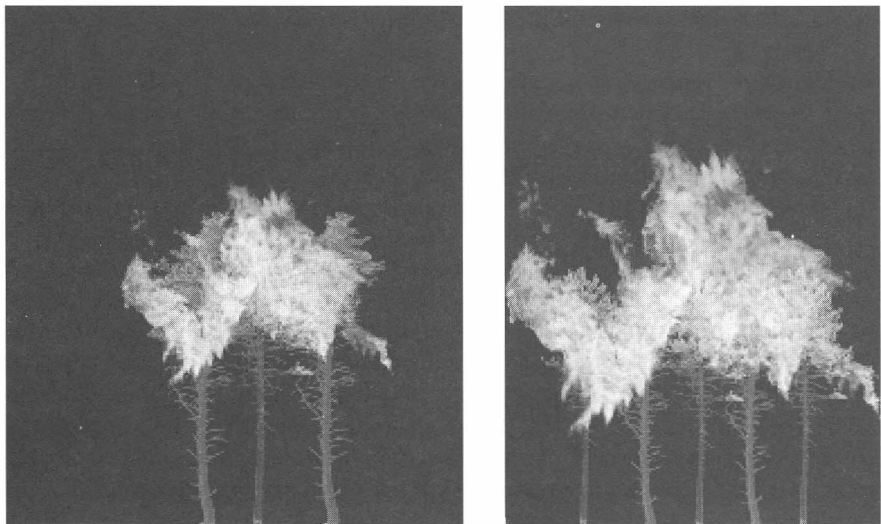


Fig. 7.7 Additional custom models for illustrating fire damage. Several tree models were used together with a larger flame in order to show movement of fire across the canopy.

from their parent ecosystems. As for the CBD map, the flame length raster and fire shapefiles were imported into ArcMap for editing to make a color map. Within each 30 minute increment of the fire as defined by the shape file, the map symbology of the flame length raster was changed to a varying grayscale RGB value for each type of fire ecosystem. As the fire progressed,

it was necessary to change the type of ecosystem present in already burned areas to reflect the behavior and effects of the fire. Based on consultation with Matthew Duveneck (personal communication, 2007), it was estimated that a lowering of fire intensity would usually occur sometime during 30 minutes of the flame front moving, with a complete burn-out occurring after about an hour. Each of these edited images was saved as a GeoTiff and imported into VNS as a color map. The individual images were placed as a second color map overlying the original CBD color map. The use of both color maps was needed so that the proper forest ecosystem type was selected first and then the proper fire/burn materials within that ecosystem were visualized.

Animation was produced using the included animating editor. VNS' animation editor functions as a sequence moving through key frame images. Each key frame image is rendered in sequence as a still frame, with VNS adding a transition between frames. When combined, it produces a seamless animation through the entire sequence. By default, VNS saves animation in Windows .WMV format, but other formats such as QuickTime or .AVI can be made if the proper codec (a set of instructions for playing a specific computer media format) is present.

7.3 Results and discussion

As demonstrated by this study, Visual Nature Studio is capable of producing visualization for wildfires, with both still and animated images being produced (Fig. 7.8 and Fig. 7.9). Furthermore, it shows that such visualization is capable of being produced on a computer system running standard equipment. Despite being custom-built, the system used for this study possessed hardware easily purchased at most computer specialty stores. Likewise, the software applications used were standard for their given use: Photoshop for graphics and Arc Desktop for GIS analysis. Some specialized skills were needed for the graphics work to produce the custom models or for using VNS; however, no real programming knowledge was needed to construct the visualization. Unlike some past studies that needed custom programming to extend the capability of the visualization program, all the features needed for this study were included as part of VNS.

The still frame images and animation produced effectively showed the spread of the wildfire and its effects on the environment (Fig. 7.8 and Fig. 7.9). By combining the burned tree models with different flame models, the fire's movement through the canopy could be shown. The different models used illustrated the movement from the forest floor to the upper canopy of the forest and beyond. The different burn environments also showed the effects of the fire on the forest.

Tree models in each of the environments reflected fire severity and intensity, with high areas having almost total burned trees and low areas having

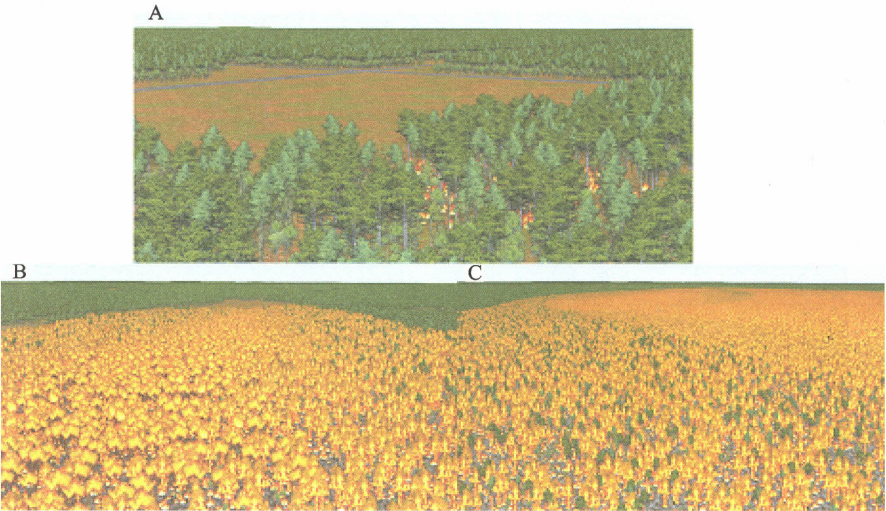


Fig. 7.8 Example of VNS visualization with fire in different canopies of the forest. A, surface fire; B, upper canopy; C, mid canopy. The position of the fire within the forest canopy relates back to the flame length output of FARSITE.

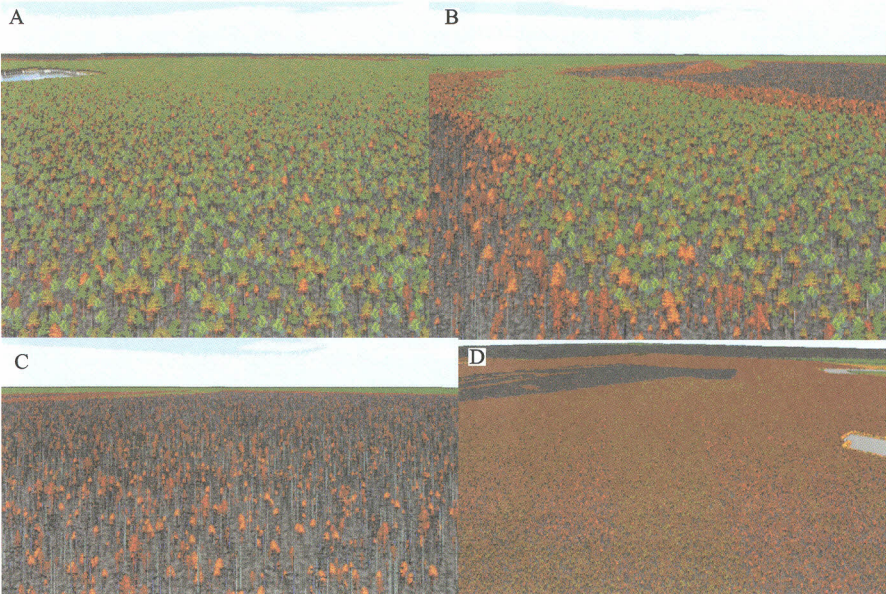


Fig. 7.9 Example of VNS visualization illustrating different levels of burn severity. A, surface fire; B, mid canopy; C, upper canopy; D, landscape level. The varying levels of severity can be linked back from the fire line intensity output of FARSITE.

trees with little or no damage. The edited ground textures served to show fire effects on ground and understory layers. With increasing severity, the textures grow darker with more and more understory material being burned out. Through the use of VNS' more advanced features, the scene realism is enhanced with effects such as clouds, lights and shadows, and reflections on water. As suggested by past visualization research, such realism allows observers to more readily identify with a scene. With such easy identification, observers are able to perceive it more easily and draw more meaningful conclusions.

There were several aspects that were detrimental to the realism of the visualized wildfire. One is the occurrence of a solid wall of flame for each fire type. Ordinarily, there should be an active fire front with varying levels of fire intensity behind it based on fuel types and amounts. Something similar was planned for the visualization but the mechanics of the shapefile prevented it from being implemented. The area for each 30 minute increment within the shapefile extended outward from the initial point of ignition. Using the outline of that area for a flame front would have yielded an unrealistic image of a flame front occurring all the way back to the original ignition point, which may have already burned out. Likewise, the raster images for flame length had to be reclassified into smaller groups more easily managed for visualization, so variation was limited. Therefore, areas of fire are best thought of as representations of the fire severity occurring over the area at the time, other than the fire actually occurring. Another problem for realism was the large extent of the study area. The large size made showing events over the whole area difficult to illustrate. Just to show the first three hours of the fire required the camera to be at height of nearly 150 meters. Such a height made showing areas further away difficult because many of the details were lost or they were almost indistinguishable. To show the entire wildfire in one scene would be extremely difficult and result in nearly all the details of faraway viewpoints being lost.

7.3.1 Data compatibility

Various data formats showed great compatibility with VNS. Shapefiles, raster images, and DEMs were easily imported and used with no conversion. Once imported, they could easily be used to visualize ground heights or other features based on the table attributes. Image files, such as JPEGs and bitmaps, could be imported easily to be used as custom models, but sometimes required some modification using Photoshop to paint the background black for a transparency mask. Georeferenced maps could be imported as color maps. However, some work was needed to change the RGB values in the map symbology due to VNS having difficulty to distinguish similar colors.

Data formats also showed a high degree of compatibility between VNS

and ArcGIS. Features in shapefiles could be used in a similar manner in both programs. In fact, the shapefiles from ArcGIS could be easily imported into VNS and used with almost no modification. DEMs and raster files could also be used by both applications with no modifications.

7.3.2 Visual nature studio: Strengths and weaknesses

Visual Nature Studio has several advantages for producing realistic visualization of a scene. One is the ability to import user-made images as custom models. This feature is extremely useful for constructing more realistic tree models. Many of the other visualization applications such as VistaPro, Bryce 3D, and even ArcScene have tree models that are either very simplistic or composed of geometric shapes. While functional, these models may not look quite realistic or be recognizable by observers. By using photographs of the actual tree as models they look much more real and recognizable. In addition, there are options to vary the height and direction for the custom tree models. Custom models help recreate the variation among trees that is found in a natural forest. The custom model feature also allows the user to utilize models that are not normally part of VNS' graphics library, such as the flame models used in this study. It extends the function of VNS so that aspects not originally part of the application can be modeled and visualized.

Another advantage of VNS is its ability to use georeferenced images as color maps. Using each unique color as a guide, ecosystem matching can be done on the visualized landscape. Through this matching, forest ecosystems can be visualized more accurately as to how they appear in nature. They can be shown in the correct locations within the environment. Furthermore, two or more different color maps can be used for the same set of ecosystems. This allows for uses before and after visualization of a disturbance event or showing how a forest landscape changes over time. Another feature of the ecosystem mapping is the option to blend the edges of two different groups together. Raster images usually used for color maps have divisions with blocky shapes due to the information stored in each pixel. The blending of the edges allows ecosystems to appear more like they would in nature, merging in with the one next to it instead of instantly stopping after an imaginary line.

While the included tree models in VNS are rather poor, many of the other included models are of high quality and more realistic. Most of these models are part of the built-in tools used to simulate the general environment. These models include different types of clouds, water types, roads, ground textures, and sky models. The collection of high quality environmental models plays an important role in enhancing the realism of the scenes. Such high quality, realistic scenes have been found to be more effective for visualizations because the observer can identify with them better. This collection of models is an advantage for the user as well because it reduces the number of custom

models needed. The user is able to quickly construct the base of the environments using the included models and then spend more time constructing custom models more crucial to the visualization. If every single model needed to be constructed by the user, creating visualization would be a long and cumbersome process.

While VNS has several advantages, there are also several limitations of the application. One disadvantage is that some computers need additional resources to optimally run VNS. Originally we had intended to do visualization on an older laptop system, but later had to use the AMD X2 instead. While many of the laptop's hardware components were near or above minimum requirements, more system resources would be needed for better usability. VNS should be run on a computer having at least 1 gigabyte of RAM, a 128 megabyte OpenGL video card (nVidia Geforce 5xxx family or above), and at least an 80 gigabyte hard drive. Many consumer computers sold currently can be purchased with this level of hardware or higher. However, users operating laptops or older computer systems may not have the necessary hardware to run VNS. Upgrading the system to high spec hardware in these cases may be expensive or not possible at all. These higher system requirements may be an important consideration for using VNS and may cost additional money to ensure that they are met.

Another feature of VNS that can be seen as a weakness is its rendering speed. Rendering in VNS occurs from the camera point out to edge of the horizon along the DEM of the landscape. In cases where a landscape covers a large area, the DEM is broken up into several smaller portions for rendering. VNS attempts to optimize rendering speeds by drawing only the portions of the scene that are immediately visible; however in many instances this is not what actually occurs. In many cases, VNS processes other partial DEMs and image objects that are not present in the immediate scene. The processing of these unnecessary items can slow rendering due to the application waiting to process the actual information needing to be rendered. Increased time for rendering can slow work if many previews of a visualization are needed while components are being edited. Increased time can complicate the production of animated images as well. With each additional individual key frame scene added to the animation, even more information is accumulated for processing. Time necessary for rendering these sequences can increase dramatically with the addition of more key frames. Even short sequences running up to a minute at 30 frames per second can take up to 72 hours to render.

VNS is a very powerful application capable of performing many different functions. However, many of these functions are quite complex, requiring many steps to carry out. There is a tutorial that explains the basic functions of the application, but many of the more advanced functions and settings are not explained. In addition, the explanations in the manual are not very detailed. This lack of sufficient explanation can be a potential problem for new users not familiar with VNS. Users may require additional time to learn the

features and experiment with settings to determine their function. Extra time taken to obtain this familiarity can be added to the time needed to complete a visualization. An improvement in both the tutorials and documentation included with VNS could help to provide users with more information and better understanding of the application.

7.4 Conclusion

As demonstrated in this study, wildfire visualization is possible using Visual Nature Studio. Functions in the application allowed for high quality tree models and flame models to be used to create a realistic scene. Editing the tree models and ground textures allowed the effects of the fire to be illustrated both in the tree canopy and on the ground. The result was a realistic visualization of the New Jersey pine barrens showing the spread of fire and its effects within the environment. Still frame images were easily created during any point of the fire along with animated views by piecing together a series of key frame images. The large area in which the event took place presented challenges for visualizing the total extent of the wildfire. High aerial views often had to be used which reduced the graphical quality of the visualization to some extent.

This study also helped establish a protocol for visualizing fire using VNS. Such a protocol provides users with appropriate visualization methods without the need for all the original methodological research and investigation. Lab technicians with adequate computer operating skills can use the protocol for creating visualization of fires not only in New Jersey, but in any other area. These technicians would not necessarily need to understand the fundamental theories and mechanics of visualization as long as they possessed the necessary skills to use the various graphic and visualization applications. Having these methods established beforehand could potentially allow visualization to be constructed more quickly, saving both time and money.

Identifying the advantages and disadvantages of different applications can help users to choose the proper application for use based on available resources such as computer hardware, money, and operating ability. In our case study, Visual Nature Studio was found to be very good at creating realistic, high quality scenes. There is ample support for natural environments such as forests, mountains, and deserts. However, there is also support for more urban environments such as towns. Using the right application for a project can help to construct a visualization in a timely manner. Less time is spent on exploring features that are unnecessary, saving more time for aspects crucial to creating a meaningful visualization.

7.5 Future wildfire visualization research

3D visualization could be very useful for building and evaluating forest scenarios that do not currently exist, such as historic forests, alternative management scenarios, and possible future disturbances, allowing the public and scientists to better comprehend the dynamics of actual and potential forest and landscape patterns. 3D visualization provides managers and scientists with an opportunity to foresee forest landscape changes before a management plan is executed.

Fire visualization efforts for the immediate future should focus on improving the realism of rendered scenes based on the constraints of the application. For VNS, this could include features such as animated smoke and flames, ground textures from actual fire events, and tree models made from burnt trees in the field. VNS supports the NTSC video format so it may be possible to include video footage of a wildfire as part of the visualization. Likewise, observer rating studies would be valuable for determining how closely observers are able to identify with a visualization. While rating studies have been done for other types of visualization, there have been no studies to determine how observers relate to those done using VNS or other 3D visualization software. Working within the constraints of the current applications allows for effective visualization methods to be developed without modifying the application. As the applications are improved, these methods can then be applied using the newer technology.

With the recent introduction of multi core CPUs, faster RAM, and more powerful video cards, computing systems have grown even more powerful. With most software, visualization applications can be improved by taking advantage of this increased power. With more computing potential and faster graphic power, a goal of visualization programs should be the real time rendering of landscapes with animated fire and smoke. The program would be able to use high quality graphics to show real time movement of the fire through the environment.

While there is no software application that does everything described, an application that shows great promise is VRFire (Sherman et al., 2007). VRFire is a visualization application being developed at the University of Nevada that uses the FARSITE model to control fire visualization. Analysis is performed to determine the location of the flame front. When combined with landscape and vegetation data, the application is able to determine vegetation within the flame front zones and render appropriate tree models, flames, and smoke if necessary. When areas of flame front are combined for the intervals over the entire fire, the visualization is able to display burned areas in real time. VRFire has the advantage of running on an open source platform of Suse Linux and using open source graphical software. The application runs on a current Opteron CPU-based system with an nVidia Geforce 6800 GT graphics card. Output can be displayed to a wide variety of display outputs, from standard

computer monitors to a display screen that interacts with a virtual reality head and wand tracking unit. Currently, VRFire suffers from problems such as limited graphical details and a simplified view of the flame front. However, these problems are being improved so that they accurately represent features that exist in nature.

Improving applications such as VRFire allows the software to take advantage of more powerful computer hardware. With increased technological capability, more features such as real time rendering and higher quality images can be made part of the application. As visualization incorporates more realistic and higher quality images in real time, they can begin to more effectively represent events that occur in nature. With a higher accuracy of representation, observers are more able to identify with the scene and draw conclusions from it, making visualized scenes more useful and important tools for exploring data or natural processes.

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