HISTORICAL LANDSCAPE VISUALIZATION OF THE WILSON'S CREEK NATIONAL BATTLEFIELD BASED ON OBJECT ORIENTED TREE DETECTION METHOD FROM IKONOS IMAGERY

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ABSTRACT

The Battle of Wilson's Creek (called Oak Hills by the Confederates) was fought ten miles southwest of Springfield, Missouri on August 10, 1861. Presently the Wilson's Creek National Battlefield operated by the National Park Service marks the site. Mature, also called historical trees (trees that were present on the landscape at the time of the battle), have been identified by park managers as the park's primary resource. The trees are remnants of the post oak (*Quercus stellata)* savanna habitat that dominated the landscape over 150 years ago. The historic trees are often large oaks with open spreading branches that indicate the tree grew in a much more open environment, since then a new forest canopy has encroached on the historic trees. Tree location, degree of encroachment, relative health, and fuel accumulation information was necessary to guide management initiated selective cutting and prescribed burning essential for the survival of the historic trees and the restoration/perpetuation of the oak savanna habitat. To identify the crowns of the historical trees manual and object oriented image analysis of black and white 1941 aerial photography was used and validated in the filed. Information such as fuel accumulation and eastern red cedar (*Juniperus virginiana)* encroachment were extracted using object oriented methods from IKONOS imagery and validated using field data. The goal of this project was to produce realistic past and present landscape geovisualizations, based on the tree information extracted from the 1941 aerial photography and IKONOS imagery.

INTRODUCTION

Ten miles southwest of Springfield, Missouri lies an important national historic landmark. The hilly landscape is dissected by Wilson's Creek, the area was referred to as Oak Hills by the Confederates. The battle fought here on August 10, 1861, was the first major Civil War engagement west of the Mississippi River, involving about 5,400 Union troops and 12,000 Confederates. Although a Confederate victory, the Southerners failed to capitalize on their success. The battle led to greater federal military activity in Missouri, and set the stage for the Battle of Pea Ridge in March 1862. Wilson's Creek was also the scene of the death of Nathaniel Lyon, the first Union general to be killed in combat. With the exception of the vegetation, the 1,750 acre battlefield has changed little from its historic setting, enabling the visitor to experience the battlefield in near pristine condition. The National Park Service operates the Wilson's Creek National Battlefield designated on December 16th, 1970. The park management strategy is to provide the visitor with a landscape that resembles the 1861 conditions as closely as

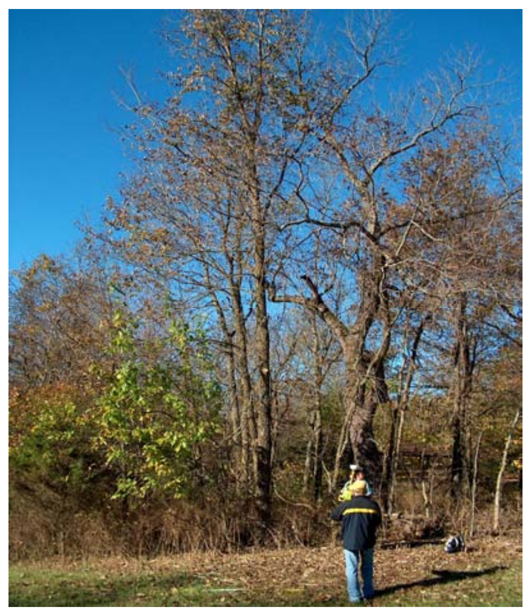

Figure 1. Remnants of the oak savanna landscape encroached by modern day forest.

possible. Thus, one of the critical tasks identified by the park mangers is the preservation of the mature post oak (*Quercus stellata)* savanna trees that were present at the location and dominated the landscape at the time of the battle over 150 years ago. These historic trees are often large oaks with open spreading branches that indicate the tree grew in an uncluttered environment, with little canopy competition from other trees. However, a new forest canopy has been encompassing the historical trees (Figure 1). In this modern forest eastern red cedars (*Juniperus virginiana)* are very common. The cedars compete for the same resources as the historic trees and the seedlings produced by the trees. Knowledge of historic tree location, degree of cedar encroachment, relative health, and fuel accumulation information is necessary to guide management initiated selective cutting and prescribed burning essential for the survival of the historic trees and the restoration/perpetuation of the oak savanna habitat.

Most forest structure data is collected through field sampling methods. The practical and economic limitations of field-based inventories mean that the temporal and spatial dynamics of forest parameters must be inferred from sparse samples. Moreover, ground sampling does not allow the gathering of continuous measurements of specific variables over a landscape. Timely, cost effective, and easy to implement, forest characterization methodologies are crucial to sustainable-forest monitoring and management. Remote sensing, geographic information systems (GIS), global positioning systems (GPS), and other geospatial technologies are being used to gather, analyze, and organize information about forest ecosystems (Franklin 2001). Ecologists and forest managers need geospatial technologies not only for the decision support function, but also to enhance their understanding of landscape patterns and processes at multiple scales. More specific information on forest conditions over large areas can be extracted digitally than manually (Eldridge and Edwards 1993). Furthermore, remotely sensed satellite data can provide information on forest structure that is accurate and spatially continuous (Cohen and Spies 1992. Thus, a spatially continuous estimate of forest variables can be derived from the development of relationships between ground and remotely sensed data.

The spatial and temporal availability of remotely sensed data and the advancements in digital technologies are providing the tools that modern forest managers have been seeking. However, conventional methods of analyzing coarse resolution remotely sensed imagery, (such as Landsat TM) are not necessarily suitable for high-resolution imagery analysis (Townsend 2000). For example, maximum likelihood supervised classification or unsupervised classification are not suitable for the analysis of very high-resolution images, such as those captured by high-resolution aerial multispectral sensors, because these fail to incorporate the high spatial content and associated information in the classification scheme (Blaschke and Strobl 2001).

The high spatial content of new remote sensing platforms has fueled innovative methods of extracting forest inventory parameters from the data (Gerylo et al. 2000). For example, a volume of methodologies dealing with automated interpretation of high spatial resolution digital imagery for forestry has been presented in an 1998 international forum at the Pacific Forestry Center, Victoria, Canada (Hill and Leckie 1998). Methods addressed included the tree apex identification approach, image filtering and contouring and image segmentation. Image segmentation is of importance to forestry applications because discrete boundaries can be identified on high resolution imagery and directly related to tree crowns. This approach to high-resolution image classification, which uses image objects instead of pixels as the basic classification building blocks, was originally suggested decades ago (McKeown, 1988). One method increasingly being used for segmenting boundaries is *fractal net evolution approach* (Batz and Shape, 2000). This approach looks at pixel regions as objects or features, evaluating pixels within the context of reality. Consequently, an argument for the classification of homogeneous groups of pixels that reflect real-world objects is being strongly supported in recent literature (Hey et al. 2003; Blaschke and Strobol, 2001; Schiewe et al. 2001). Such method has been made easily available to the image analysis community through the eCognition software by Definiens Imaging GmbH (Definiens 2004) and by Feature Analyst by Visual Learning Systems (VLS 2004).

It is well established in statistics that graphics, specifically data visualizations, are usually the simplest and most powerful means for communicating results (Tukey 1977, Tufte 1983). This important concept has been expanded to include the use of visualizations for representing natural landscapes. Campbell and Egbert (1990) summarize 30 years of animated cartography and point that only at the end of the 20th century has geographic visualization begun to be applied in scientific studies. Computer visualization is increasingly used as a delivery tool for the results of environmental change studies and management plans, especially concerning forested environments (Tang and Bishop 2002). To determine the appropriate visualization technique, one must consider the size of the project area, overall goal of the visualization project, the amount of detail that must be present in the final visualization, and the amount and types of data available describing the project area (McGaughey 1997). With recent increases in computer speed and software availability, forest visualization techniques are beginning to include the communication of change analysis studies using animation (Stoltman et al. 2002) and geovisualizations (Dunbar et al. 2004). Thus, geospatial information is used in the visualizations to produce geovisualizations where locations in the visualization represent authentic forests based on accurate forest inventories.

The goal of this project was to produce geovisualizations that showed the 150 year landscape change that has occurred at Wilson's Creek National Battlefield. To meet this goal the following objectives were identified:

- Determine the geospatial location of historical trees on remotely sanded imagery and in the field;
- Map out the extent of the cedar encroachment , and;
- Integration of all data into geovisualizations using Visual Nature Studio and Scene Express (2004).

METHODOLOGY AND RESULTS

Black and white rectified aerial photographs of the area from 1941 were used in conjunction with a February 6th, 2002 IKONOS multispectral imagery resample to 1 m per pixel resolution. The IKONOS image is shown in Figure 2, the cedar encroachment in the park can be readily observed as the conifers appear red, the preset park boundary is delineated in yellow.

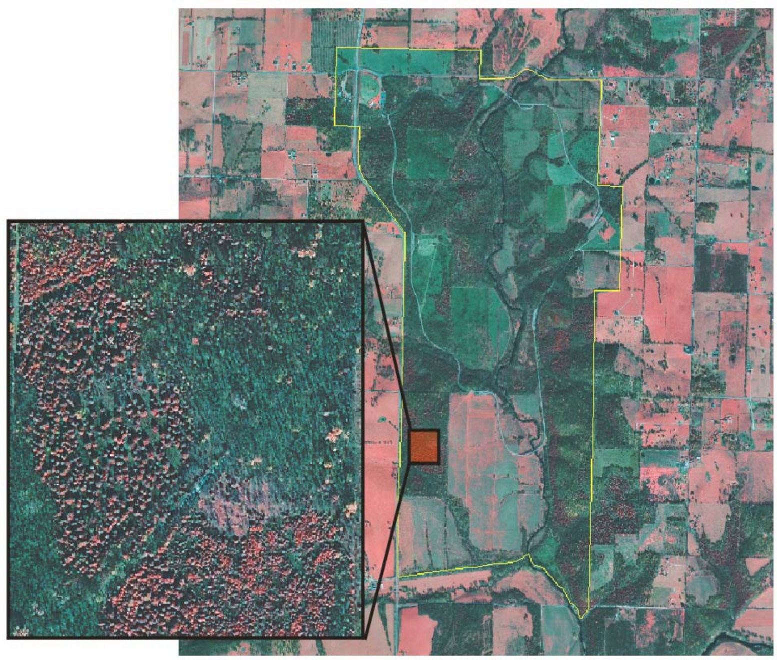

Figure 2. IKONOS imagery of the study area, inset shows the cedar encroachment.

The crowns of possible historic trees were extracted from the aerial photographs using feature extraction methods shown in Figure 3. Aerial photography from 1941 was used to train the feature extraction (light green polygons on image A; Figure 3). Post classification refinements were made to remove any clusters not associated with tree crowns (red polygon in image A; Figure 3) and a second feature extraction classification was performed. Final features were used to produce point files of trees that existed in the study area in 1941 (points on image B; Figure 3). The points associated with large polygons, of more then 3 m in diameter were used to produce a final possible historic tree point coverage. The 1941 extracted point coverage was compared to field data acquired during the fall of 2003. Historic trees were located in the field using previous field data from the park as well as a diameter at breast height (dbh) that was greater then 40 cm. Global Positioning System (GPS) was used to collect the spatial coordinates for each tree location. Tree height, dbh, health and cedar encroachment were also estimated in the field and recorded in a GPS data dictionary. The data was imported into a Geographic Information System (GIS) and differentiatial corrections were performed on the GPS coordinates.

The IKONOS image was classified for cedar and fuels using feature methods (Figure 4). Similar refinement methods were used as the methods for the 1941 black and white aerial photography imagery. Filed GPS locations of cedar trees were used to asses the accuracy of the feature extraction. A visual interpretation of the GPS points

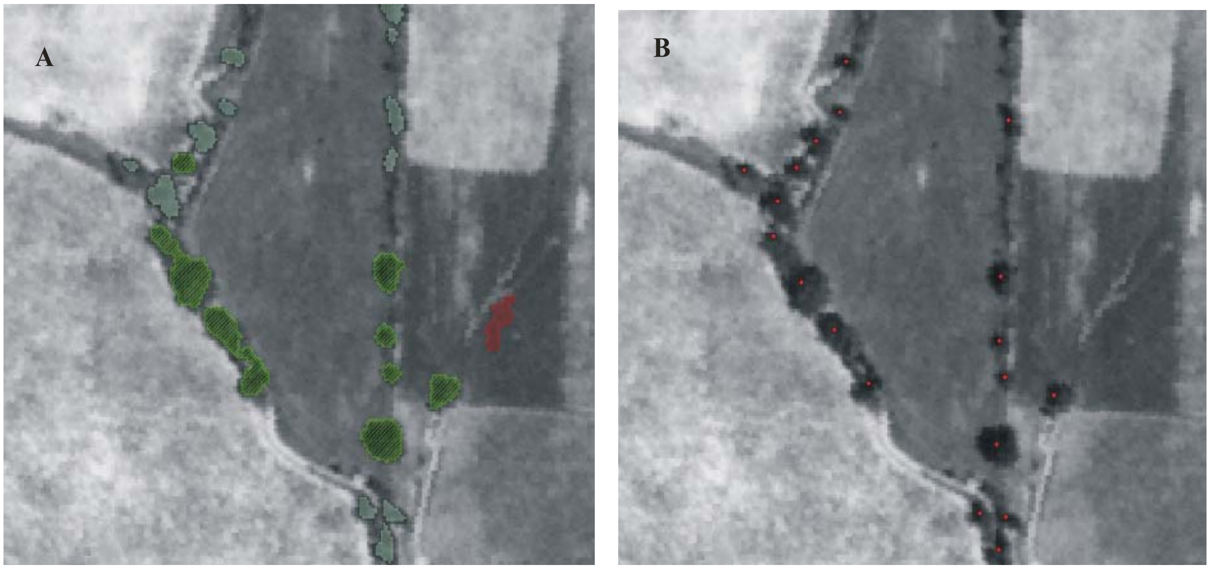

Figure 3. Aerial photography from 1941 used to train the feature extraction.

over the IKONOS image showed over 95% agreement in areas where cedars were recorded in the field. GPS data for all cedars encountered during the field data acquisition was not collected due to time constraints.

Encroachment was interpolated for the IKONOS imagery based on point distance to historic trees. Higher encroachment values (1 through 9) were assigned to cedar polygons closer to the historic trees. Agreements between the encroachment potential based on IKONOS image as compared to the field methods were assess and are shown in Figure 5. IKONOS methodology showed overestimation of encroachment as compared to the field methods. However, rather then interpreting this over estimation as an error it is likely that the cedars were underestimated in the field due to issues of visibility through the forest.

Figure 4. IKONOS image of the same location as in Figure 3. Blue polygons were used for the cedar classification; red polygons were used to refine the classification. Yellow polygons show the spatial extent of the cedars.

Numerous geovisualizations were produced based on the geospatial datasets extracted from the aerial photography and IKONOS imagery. The simplest geovisualization showed the topographic characteristics of the battlefield landscape. Another geovisualization showed the various satellite and aerial imagery useful for landscape change studies. Simple stills of present and past landscape views similar to the one show in Figure 6 were also generated. Two three dimensional virtual reality models (VRML) of the study area, based on the historical aerial photography and IKONOS imagery were developed. All geovisualizations were meant to be used as an educational tool for the public. The geovisualizations can be obtained by contacting the author.

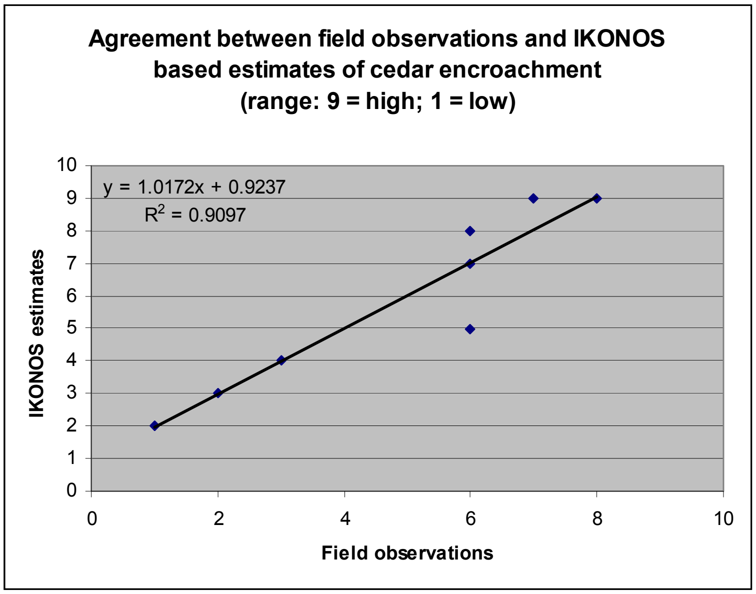

Figure 5. Agreement between field observation of cedar encroachment and IKONOS based estimates.

Figure 6. Historical oak savanna landscape visualization.

CONCLUSIONS

Feature extraction from high resolution multispectral imagery is a new approach to forest inventory characterization. The semi-automated approach utilizes the photo interpretation skills of the user, but due to the automation it greatly cut down on processing time compared to traditional manual methods. The method performed well in quantifying historical trees and cedar encroachment. The visualizations objective of this project was completed successfully. Any remote-sensing-based research results in forest compositional or structural classification, forest modeling, or forest management plans could benefit from the ability to more clearly relay results to intended audiences using visualizations. Virtual forests based on real data such as the VRML landscapes can be displayed from any perspective under by the user providing the individual with a greater understanding of the environment understudy.

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