Automated timber stand delineation from aerial imagery

Making Timber Cruising more efficient

Cruising Timber is one of the primary jobs of a field forester, either in private industry or public natural resource agencies. The purposes of timber cruising are to estimate stocking levels and timber volumes, and to gauge overall forest health with regard to natural resource management. It is a necessary part of the commercial timber industry, and is also very time-consuming and expensive, especially when land holdings are large and dispersed.

Such is the concern of Plum Creek Timber Co. Inc. (Watkinsville, Ga.), the second largest private timberland owner in the United States, with eight million acres located in the northwestern, southern, and northeastern regions of the country. To address this concern, Sanborn is developing a method for mapping timber stands using aerial imagery. Plum Creek had already collected digital aerial imagery (Emerge, Andover, Mass.), over much of their landholdings in Mississippi at a 2-meter pixel resolution in a false color format (Near-Infrared, Red, Green) (Figure 1). The challenge is to come up with a method that is both accurate and cost-efficient.

Plum Creek cruises all plantations at age 12. To reduce inventory costs while maintaining survey precision, Plum Creek plans to do a type of stratified cruise based upon criteria such as site quality and stocking class. Estimated site quality information is available from other sources, but there is no reliable estimate of stocking of 12-year-old stands. If personnel travel to each stand to obtain an initial stocking estimate, they might as well go ahead and conduct the cruise since a significant portion of the total cost of a standard cruise is travel to the stand.

In addition, stand boundaries are often inaccurate due to various factors, such as:

- Intrusion of other species near the edges of a stand since the last map update
- Excessive hardwood competition or pine seedling failure. Inability to identify the actual stand boundary during the early years of a plantation
- Errors in mapping during the initial stand identification

Accurately identifying a stand boundary is important not only from a location standpoint, but also because it impacts the accuracy of the stand area estimate. Cruise information is scaled by the estimated area of the stand, making the quality of the area estimate as important as the quality of the cruise information.

Looking for a Solution

Several software packages for stand delineation and stocking identification were evaluated. The software package that showed the most promise for automating the process was Definiens eCognition with its capability to treat imagery both as a raster and vector dataset. Definiens eCognition is designed to

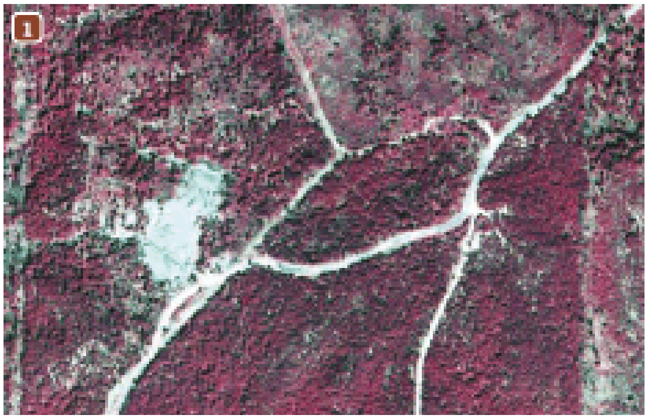


Figure: Portion of Emerge Aerial Imagery obtained over Plum Creek's ownership

segment the image into units of similar spectral and spatial patterns and to classify those segments according to a pre-defined rule base. Importing and segmenting the imagery at multiple resolutions, and exporting the resulting stand delineation as a shapefile can be automated, significantly reducing the amount of time and manpower devoted to the task, when compared to manual delineation.

The approach taken to identifying stands of pine consisted of two stages. In the first stage, the individual pines or pine clusters are classified using very small, or base-level segments. In the second stage, using higher-level segments, each with a much larger area, the relative area of pines is calculated. If the relative area of pine is high enough, the segment is classified as a pine stand. Those that are classified as pine stands can be subdivided, again using the relative area of pine, into different stocking levels. Implementing this approach in Definiens eCognition makes use of the multi-resolution capabilities of the software. In higher levels of segmentation, the polygons and their boundaries are based on those in lower levels, and the classification of high-level polygons can be based upon lower-level classifications.

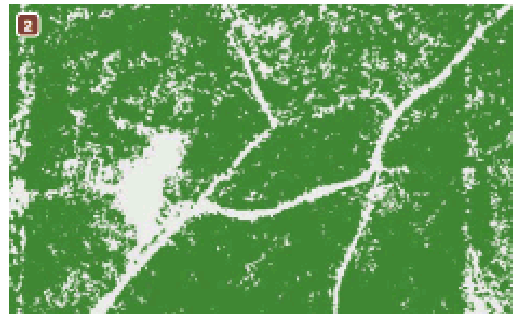
The sensor in the aerial camera sees the canopy of the tree, and once the pine trees are separated from the background (classified), stocking levels can be approximated if the canopy is not completely closed. If the canopy is completely closed, it can be difficult to distinguish individual trees from tree clusters. However, even when the canopy is closed, it may be possible to distinguish stocking levels based on other spectral properties. Therefore, during the development phase of the project, stocking levels are defined in general terms, such as low density, medium-low, up to high-density. Medium-high and high-density classes are further subdivided into young trees and old trees, based on other spectral properties (band 3/band 2 ratio). Seven classes are defined initially, with the goal of aggregating them into two to three meaningful classes to produce the final map.

The choice of the imagery bands, or imagery derivatives to use in the software, is also very important. Definiens eCognition internally calculates many different statistics for each segment on each level, only a few of which are useful for differentiating Loblolly Pine from the surrounding land cover. To winnow these choices down to a statistically significant few, the segment statistics (independent variables) were input to a statistical modeling software along with a training sample (Pine and Non-Pine, the dependent variable). The software chose image ratio bands, band 3/band 1, and band 3/(band 1 + band 2 + band 3), as the most likely to discriminate Lodgepole Pine from its surroundings. This result made intuitive sense for two reasons: band 3, or the near-infrared band, is more sensitive to chlorophyll content than the visible-light bands, and therefore better for discriminating different types of vegetation. Also it makes sense because band ratios, for example band3/band1, tend to normalize the imagery for lighting and terrain effects. An added virtue of using band ratios is that the values are more consistent from image to image, making a rule-base more 'portable', and making automation much simpler.

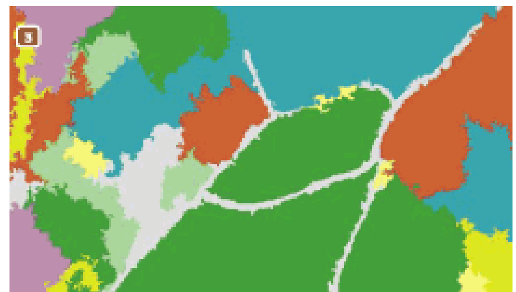
Once the higher-level image classification is complete, showing the desired stocking classes and stand boundaries, it is exported as a shapefile, which may be viewed in many different software packages. At this point, the stand boundaries appear convoluted, with too many extraneous bends and crenulations. This is because the lines were generated from the raster image. To make the boundaries more readable to the forester, the lines can be generalized, or straightened to a degree, while removing unnecessary bends. The degree of generalization may be adjusted to provide optimum readability and area estimates. In this representation, the forester is observing a minimum mapping unit of approximately 5 acres. (No stands less than 5 acres were delineated.) Errors in the boundaries are evident; these will lead to errors in volume and density estimates.

The protocols developed in this project will be transferable to other imagery types, such as scanned aerial photographs, with appropriate modifications to the classification algorithm. The use of near-infrared (NIR, red, green) imagery is recommended due to the utility of the NIR band for discriminating target species. Once the algorithm is calibrated, creation of the stand boundary/stocking layer from raw image to smoothed polygons requires approximately 10-12 minutes for a 2000 x 3600 pixel image on a workstation with a 2.4Ghz processor with 2Gb RAM.

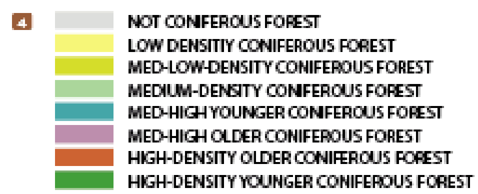
Results of the project will be visually evaluated by Plum Creek GIS Analysts and foresters. Stocking classes will additionally be evaluated with respect to the cruise data currently in Plum Creek's databases, and to further refine the class definitions. It is likely that some manual processing of the maps will be necessary to optimize the stand boundaries, but preliminary results indicate that automated processing of aerial imagery could provide significant savings in time and resources for Plum Creek.



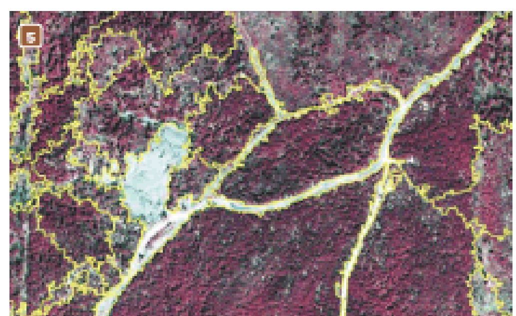
LEVEL 1 CLASSIFICATION OF PINES USING SMALL SEGMENTS. PINES ARE GREEN, NON-PINE IS GRAY



LEVEL 2 CLASSIFICATION OF STOCKING LEVELS BASED ON REELATIVE AREA OF PINES IN EACH IMAGE SEGMENT



Legend for stocking level classification



UNSMOOTHED STAND BOUNDARIES DERIVED FROM THE STOCKING LEVEL CLASSIFICATION

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