

## **The Investigation of Classification Methods of High Resolution Imagery**

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**Abstract.** With the continuous advancement of remote sensing technology, high resolution imagery, such as Quickbird and photography from the National Agriculture Imagery Program (NAIP), is becoming more readily available for use in forestry applications. Quickbird imagery is currently the highest resolution imagery commercially available. It consists of 2.44 m (8 ft) resolution multi-spectral bands ranging from blue to near infrared and a panchromatic band acquired simultaneously at 0.61 m (2 ft) resolution. In the near future, NAIP will provide annually updated, orthorectified, natural color, aerial photography at 1 meter resolution across the continental U.S. Our objective was to investigate two classification methods, an Individual Tree Crown delineation and classification procedure and a technique using Feature Analyst software, for classifying high resolution Quickbird and NAIP photography. Both methods were found to be effective for discriminating different vegetation types using Quickbird and NAIP photography, although the Quickbird imagery proved to be superior to the NAIP photography according to visual and numerical assessments.

The numerical accuracy of the resulting maps ranged from 48 percent to 63 percent at the Level II classification, where a class was determined based on the plurality of the species within approximately a hectare of the point. At the Level III forest and nonforest classification, the numerical accuracies ranged from 89 percent to 94 percent. The visual assessments revealed good results, especially at Level III, forest and nonforest classifications. We believe that these assessments show strong potential for their use as ancillary products in IW-FIA's forest resource estimation procedures and should be further pursued

### **Introduction**

The U.S. Department of Agriculture Forest Inventory and Analysis Program (FIA) strives to produce better information with lower costs and increased frequency. The objective of FIA is to estimate broad-scale forest population totals and to track trends and detect changes in our nation's forests. In the past, inventories were

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conducted and estimates produced on a periodic basis (every 5 – 20 years). However, the 1998 Farm Bill requires a proportion of all field plots to be measured (1/10 in the western US, 1/5 in the east) *each* year on *all* lands in the United States, and forest population estimates must be updated. In an effort to become more efficient, the Interior West (IW) region of FIA is investigating high resolution remotely sensed products to assist in obtaining the information requirements of this legislation while reducing inventory costs.

With the technological advancement of satellite systems, high resolution satellite imagery, such as Quickbird, is becoming more readily available for use in forestry applications. Currently, Quickbird imagery has the highest resolution commercially available. It consists of 2.4 m (7.9 ft) resolution multi-spectral bands ranging from blue to near infrared and a panchromatic band acquired simultaneously at 0.6 m (2.0 ft) resolution. The Quickbird satellite was launched in October 2001 and is owned and operated by Digital Globe (<http://www.digitalglobe.com>).

Quickbird has a geolocational accuracy within 23 meters, a 16.5 km (10.2 miles) width imaging swath and 128 gbits image storage capacity on board, and an off-axis unobscured design telescope with an 11-bit dynamic range (Digital Globe 2005). These characteristics present an opportunity to identify individual crowns of vegetation.

In addition to Quickbird, another high resolution product we examined is aerial photography from the National Agricultural Imagery Program (NAIP), which is available for download from the Internet (<http://www.apfo.usda.gov>). The NAIP acquires digital ortho imagery during the agricultural growing season of the continental United States. The photography is ortho-rectified, natural color, 1-meter resolution photography with a

horizontal spatial accuracy matching within 3 meters of an ortho-rectified reference digital ortho quarter quad (DOQQ). With resolution, timely acquisitions, and availability, this product is very desirable as a modeling tool or for identifying/locating vegetative features on the ground.

There are numerous algorithms being developed for delineating individual tree crowns (Culvenor 2002, Definiens-Imaging 2003, Leckie et al. 2003, Pouliot et al. 2002). CLC-Camint Inc. (CLC-Camint, hereafter) uses Quickbird imagery and its own proprietary methodology for delineating and classifying tree crowns using Quickbird imagery. This methodology uses an automated Individual Tree Crown (ITC) classification and object-based segmentation procedure (Gougeon 1995, Gougeon 1997) to generate a digital map of tree crowns integrated into a Geographical Information System (GIS). The ITC algorithm uses a valley-following approach (Gougeon 1995) to delineate unique tree crowns. This approach searches for the shaded areas between crowns and removes (masks-out) these areas, leaving objects representing the crown of a tree. The method uses the Quickbird imagery to create a digital layer depicting each unique tree crown. These delineated crowns are further classified by species type based on identified training sites (or trees), along with multispectral, textural, structural, and contextual analysis tools. Signatures are developed for each individual tree crown, and a maximum likelihood decision rule assigns it to a species type class.

An alternative automated procedure for extracting features is implemented in Feature Analyst, software developed by Visual Learning Systems, Inc. (<http://www.vls-inc.com>). Feature Analyst is a user-friendly, automated machine learning approach for extracting land cover features, or objects based on user-specified examples. Feature Analyst uses spectral and spatial pattern recognition techniques to extract features from high resolution digital imagery. Where traditional classifiers use color and tone to extract features, Feature Analyst uses characteristics such as size, shape, color, texture, shadow, association, and pattern to extract features of interest. Although Feature Analyst has the functionality of delineating individual tree crowns, only stand level classifications were generated for this study.

Our interest for this study was to investigate the capabilities of Feature Analyst and how it compares with CLC-Camint's ITC process for producing map products using high resolution Quickbird imagery as well as using high resolution NAIP photography. Three analyses were conducted in this study. First, we tested the accuracy of the ITC algorithm for delineating and classifying crowns in a diverse forest area in the southern Rocky Mountains of Utah,

USA using Quickbird imagery. Second, we tested the accuracy of Feature Analyst for classifying forest stands in the same area applied to Quickbird imagery. Third, we once again tested the accuracy for classifying forest stands using Feature Analyst, but this time applied to NAIP photography.

## **Methods**

### **Area of Interest (AOI)**

IW-FIA staff identified a 100 km<sup>2</sup> AOI within the southern Rocky Mountains of Utah, USA, that represented a diverse number of forest and species types. The AOI is east of Beaver, Utah, within the Fishlake National Forest (Figure 1). The area was selected for its diversity of species types and altitudinal range with the intent to examine the performance of the ITC and Feature Analyst methods across multiple ecosystems that occur in the western states. Within this area, elevation values range from 1920 m (6298 ft) to over 3000 m (9840 ft). The species types reflect this elevational gradient with pinyon pine and juniper species at the lower elevations, oak and mahogany hardwood species at mid ranges, and aspen, Douglas-fir, subalpine fir, and Engelmann spruce at higher elevations. The area also encompasses the Beaver River which typically includes riparian vegetation types.

### **ITC Delineation and Classification/Quickbird**

A map of individual tree crowns, with species identified, was produced using the ITC process over the AOI within the southern Rocky Mountains of Utah, USA. The process of producing this map involved multiple steps carried out by staff at IW-FIA and CLC-Camint, as outlined in table 1.

The Quickbird imagery for the area of interest was provided as courtesy of DigitalGlobe, Inc. CLC-Camint defined the specifications of the Quickbird scene and pre-processed the imagery. The acquired scene was approximately 300 km<sup>2</sup> in size, surrounding the AOI. This increased the range of altitudinal gradient to over 1630 m (5346 ft), from approximately 1815 m (5953 ft) to over 3450 (11316 ft) at Mount Baldy Peak. The scene was received from DigitalGlobe radiometrically calibrated and corrected for sensor and platform-induced distortions. CLC-Camint performed an orthorectification procedure based on a 1:24,000 map and mapped the scene.

At this stage, CLC-Camint applied an initial unsupervised classification technique to delineate sites with unique, homogenous signatures occurring on the image, with the help of aerial photographs. These areas were identified as potential training sites, which were delineated by a georeferenced point shapefile. A total of 170 training sites were identified. These sites were then located by IW-FIA on aerial photographs and labeled according to nine classes (table 2) of homogenous species or predominant mix of species based on the area around the sites. Each label was then given a number ranging from 0 to 100, indicating the percent confidence of the interpretation. The 170 labeled training sites were sent back to CLC-Camint for use in their ITC delineation and classification procedures.

CLC-Camint next performed the automated ITC delineation and classification procedure. The ITC valley-following algorithm does not work well in areas with sparse crowns (i.e., pinyon and juniper species types), where there are no shadows between the trees (Gougeon and Leckie 2001). Consequently, an eCognition (Definiens-Imaging 2003) procedure was applied to these areas prior to running the ITC algorithm. The ITC classification process involved two steps: a first run classification based on the 170 training sites, and a second run classification performed after reviewing the results of the first classification. For the second classification, there is an option to add ancillary information and/or new training information in areas having many misclassifications. The results for this paper include output from the first classification. Currently, we are running the second classification, after reviewing the results of the first classification, field-checking the original set of training sites, and identifying and labeling 130 additional training sites. The second classification will therefore use a total of 300 correctly identified training sites along with ancillary data from a 10-meter digital elevation model.

### **Feature Analyst/Quickbird**

A map of forest stands, with forest types identified, was produced using Feature Analyst over the same area of the Quickbird image. This process was carried out by IW-FIA staff. Although the same point training sites as the ITC procedure were used, we created polygons surrounding these points for use as training sites in the Feature Analyst classification since Feature Analyst uses characteristics such as shape, texture, association, and pattern. Additional training polygons, determined from our field visit, were also delineated and resulted in a total of 300 sites for classification. Labels were assigned at a stand level based on Level I class assignments representing the dominant species, the dominant species associations, or a nonforest type (table 3).

The color IR Quickbird imagery was used, including green, red, and near infrared bands as well as a 10 meter, USGS digital elevation model (DEM) obtained from the Automated Geographic Reference Center website (<http://agrc.its.state.ut.us/>). All bands were resampled to a pixel size of 4.8 m, the smallest pixel size. For feature recognition, we set the pixel search pattern to a “Manhattan” style with a width of five pixels (fig. 2). Feature Analyst was set to run a wall-to-wall classification of the Level I classes resulting in a map with a minimum map unit size of 24 pixels (~1 hectare).

### **Feature Analyst/NAIP**

A map of forest stands, with forest types identified, was produced with Feature Analyst using NAIP photography, within the study area. This process was also carried out by IW-FIA staff. The same 300 polygon training sites as the Feature Analyst/Quickbird process were used, but because of the misregistration between the NAIP photography and the Quickbird imagery, all polygon training sites were individually shifted to match the corresponding area.

The natural color NAIP photography was utilized, including blue, green, and red bands as well as the 10 meter, USGS DEM. All bands were resampled to a pixel size of 1.0 m, the smallest pixel size. We set the pixel search pattern to a “Manhattan” style with a width of five pixels (fig. 2) for feature selection. Feature Analyst was set to run a wall-to-wall classification resulting in a map with a minimum map unit of 24 pixels (~1 hectare).

### **Accuracy Assessment**

Map accuracy and map comparisons were based on visual and numerical assessments at a stand level. A visual assessment was performed for each map to determine the reliability of the results of the ITC crown delineation and classification and the Feature Analyst results using Quickbird imagery and NAIP photography. For the ITC procedure, the visual assessment was based on the accuracy of the crown delineation and the classification of each crown. For the results of the Feature Analyst stand classifications using Quickbird and NAIP products, visual assessments were examined at three class levels: Level I - all 26 classes that were used for training (table 3); Level II - nine classes based on the plurality of species including one class with all nonforest classes (table 4); Level III - two classes representing forest and nonforest.

For a more objective, numerical assessment and comparison of the three maps, an independent test set of 100 points was randomly selected within the extent of the Quickbird image and applied to each map. The points were assigned classes based on interpretation of 1:16,000 stereo aerial photographs and expert knowledge. These classes were compared to the maps based on the three class levels mentioned above for the visual assessment of the Feature Analyst classifications. For the maps generated using Feature Analyst, the test points were compared directly to the intercepted pixel class of the map. The ITC map involved two steps. First, the individual tree crowns were evaluated at each point and a stand level class was assigned based on approximately a hectare or more area surrounding the point. Then, these class assignments were compared to the class assignment of the test set.

Error matrices were generated for each map and a percent correctly classified accuracy and a Kappa statistic were calculated to provide a numerical statistic of accuracy. The accuracy and comparisons were evaluated at the three different class levels (Level I, II, and III).

## **Results**

### **ITC Delineation and Classification/Quickbird**

Based on a visual evaluation of the ITC product compared to the panchromatic Quickbird image, the ITC procedure performed fairly well delineating individual tree crowns. In areas of low crown densities with pinyon and juniper species, the delineation process generally picked up most of the tree crowns (fig. 3). In some of these areas, though, it seemed like larger pinyons and junipers were split into more than one crown and smaller trees were not captured at all (e.g., the gray circles in fig. 3). These conditions were a result of the eCognition procedure completed on the lower density areas prior to the ITC valley-following approach. The ITC valley-following algorithm performed adequately in depicting changes in stand densities, such as the different aspen stands shown in figure 4. This process did not perform well in areas having steep terrain, where tree shadows were long and narrow and/or there were many downed trees. For both of these conditions, the ITC algorithm placed trees incorrectly (fig. 5).

Although the ITC classification performed well in some areas, overall it needs improvement. Most of the classification difficulties were related to changes in elevation and aspect. For example, pinyon and juniper species on northern slopes were typically misclassified as spruce/fir and white fir species. Also, in the higher elevations, spruce/fir and aspen species tended to be misclassified as pinyon, juniper, and mahogany species.

The results of the numerical assessment for each class level is shown in table 5. When comparing the Level I class values interpreted from the first iteration ITC product to the 100 randomly selected test point values, 32 percent of the points were correctly classified with a Kappa value of 0.25. For the Level II class values, 48 percent of the points were correctly classified with a Kappa of 0.37. For the Level III forest/nonforest classes, 90 percent of the points were correctly classified and a Kappa of 0.56.

#### **Feature Analyst/Quickbird**

The visual evaluation of the Feature Analyst classification of the Quickbird image compared to the color IR Quickbird image indicated fairly good results. Figure 6 shows an area with aspen and mixed white fir/aspen stands. In this example, the classification performed relatively well in distinguishing aspen and white fir/aspen stands but confused mahogany with some of the more dense white fir areas (fig. 6b, 6c). At the Level III, forest and nonforest classification (fig. 6d), Feature Analyst performed very well.

The results of the numerical assessment are shown in table 5. For the Level I class, the percent correctly classified (PCC) of the Feature Analyst map using Quickbird imagery was 41 percent with a Kappa value of 0.37. The Level II class had a PCC of 63 percent and a Kappa of 0.57 while the Level III class had a PCC of 94 percent and a Kappa of 0.69.

#### **Feature Analyst/NAIP**

Figure 7 shows an example of the Feature Analyst classification of the NAIP photograph compared to the color IR Quickbird image for the same area in Figure 6. Although the visual assessment of the results of the classification looks very different than that of the Feature Analyst classification of the Quickbird image, the results from the numerical assessment are fairly good. At the Level I classification, the PCC was only 23 percent with a Kappa at

0.19 (table 5). For the Level II classification, the PCC was much higher at 51 percent with a 0.43 Kappa value. The Level III forest and nonforest classification had a PCC of 89 percent with a Kappa of 0.50 (table 5). This increasing accuracy is noticeable visually as well.

The PCC and Kappa values of the Feature Analyst map using NAIP photography were generally lower than the map using Quickbird imagery. With many classes (Level I) the PCC and Kappa of the NAIP map were much lower (18 percent, 0.18, respectively) than the Quickbird map. With fewer classes (Level II), however, the PCC and Kappa of the NAIP map were only 12 percent and 0.14 lower, respectively, than the Quickbird map.

### **Discussion**

Our investigation of high resolution products was an initial test of the usefulness of the resulting map products in providing ancillary information to IW-FIA's forest resource estimation process. We based this investigation on both visual observations and numerical accuracy of the resulting map products as well as the time and costs devoted to the methods used to generate the products.

The visual evaluation of the map products revealed the conformity of the maps to expert knowledge and highlighted specific areas of concern. For the ITC delineation and classification product, most of the concerns were related to the species classification. As mentioned previously, the assessments were based on the first iteration of the classification effort. The final classification will most likely improve with the addition of the new training sites and ancillary information, such as elevation and aspect. Another issue discovered through the visual assessment was the consequences of long shadows in the areas of steep terrain and where there were many downed trees. These issues will need resolution within the valley-following algorithm.

Feature Analyst performed successfully as an alternative automated procedure for classification at a stand level, using both Quickbird imagery and NAIP photography. Most of the issues involved sensitivity of the classes defined, the number of classes, and the training samples used for classification. We created a fairly comprehensive list of classes based on the species occurring in the area and common associations that occurred in a stand. Common types

with many training sites, such as aspen and pinyon and juniper, were well-classified, but less common types, such as cottonwood and water, were over-estimated. One characteristic of Feature Analyst that was not explored in this study was its learning ability. Classifications can be refined by delineating areas that were misclassified or classified correctly and re-running the algorithm. This process is more time-consuming but may be worth pursuing, especially for classes that are less common.

The numerical assessment showed that the Feature Analyst classification using Quickbird imagery had the highest percentage of correctly classified points and the highest Kappa at all class levels. Again, these were preliminary comparisons to the first iteration classification of the ITC process including fewer training sites and no ancillary data. Also, the stand level comparisons were based on visual interpretations of classes defined by individual crown delineations, not the automated stand delineation process included with the ITC product. Still, Feature Analyst proved to be competitive with the ITC process at a stand level. Further investigations at a crown level are necessary.

The Quickbird imagery proved to be superior to the NAIP photography both visually and numerically. This is most likely because of its availability at a higher resolution, as color infrared, and at a higher bit size. Notably, the characteristics of NAIP including accessibility, resolution, and acquisition frequency make NAIP more appealing than Quickbird imagery for future analyses.

Although the ITC process and Feature Analyst are automated procedures, the generation of training sites is not yet automated. Defining the classes and delineating training sites is a tedious and time-consuming step that is essential for high quality classifications. The level of detail and number of classes needed should be considered when defining the classes. Time allocated to photo interpretation and field visitation should be considered when delineating the training sites. The accuracy and experience of the photo interpreters should also be considered when delineating the training sites.

## **Conclusion**

The objective of this study was to evaluate CLC-Camint's automated ITC delineation and classification approach and to investigate and compare two alternative automated methods for classifying stands within a diverse forested area near Beaver, Utah, USA. The numerical accuracy of the resulting maps ranged from 48 percent to 63 percent at the Level II classification, where a class was determined based on the plurality of the species within approximately a hectare of the point. At the Level III forest and nonforest classification, the numerical accuracies ranged from 89 percent to 94 percent. The visual assessments revealed good results, especially at Level III, forest and nonforest classifications. We believe that these assessments show strong potential for their use as ancillary products in IW-FIA's forest resource estimation procedures and should be further pursued.

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