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Identifying tree crown delineation shapes and need for remediation on high resolution imagery using an evidence based approach

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ABSTRACT

In order to fully realize the benefits of automated individual tree mapping for tree species, health, forest inventory attribution and forest management decision making, the tree delineations should be as good as possible. The concept of identifying poorly delineated tree crowns and suggesting likely types of remediation was investigated. Delineations (isolations or isols) were classified into shape types reflecting whether they were realistic tree shapes and the likely kind of remediation needed. Shape type was classified by an evidence based rules approach using primitives based on isol size, shape indices, morphology, the presence of local maxima, and matches with template models representing trees of different sizes.

A test set containing 50,000 isols based on an automated tree delineation of 40 cm multispectral airborne imagery of a diverse temperate-boreal forest site was used. Isolations representing single trees or several trees were the focus, as opposed to cases where a tree is split into several isols. For eight shape classes from regular through to convolute, shape classification accuracy was in the order of 62%; simplifying to six classes accuracy was 83%. Shape type did give an indication of the type of remediation and there were 6% false alarms (i.e., isols classed as needing remediation but did not). Alternately, there were 5% omissions (i.e., isols of regular shape and not earmarked for remediation that did need remediation).

The usefulness of the concept of identifying poor delineations in need of remediation was demonstrated and one suite of methods developed and shown to be effective.

1. Introduction

Individual tree analysis of high resolution imagery is a maturing approach to forest analysis. In its ultimate form the objective is to delineate each photo visible tree and establish its species and health condition. With such information, if accurate, traditional stand based forest inventory may be extracted to more precision, and new types of stand information such as stem and gap distribution, location of snags, and crown size can be created. Alternately, individual tree analysis presents an opportunity for a new forest management paradigm based on dynamically created forest units (stands) tailored to the management decisions being made, as well as, actual individual tree management. Individual tree analysis can also be done with systems that only identify the location of trees and do not outline the tree crowns themselves, but these do not provide as rich an information suite. Individual tree analysis also affords data for niche applications such as planning thinning operations, growth and yield plot assessment, free to grow surveys, and damage assessments. Key to the effectiveness of the individual tree approach and soundness of management decisions based on it, is the accuracy and reliability of the individual tree data. At the core of this accuracy is the tree detection and location, and for the full approach using tree crown outlines, it depends on the crown delineation accuracy itself.

Several main approaches have been explored and developed for the location or delineation of trees for individual tree crown analysis. Some concentrate solely on determining tree location and counts and do not attempt to portray the tree crown at all (e.g., local maxima methods). Others find the location and approximate the crown boundary or make an estimate of crown diameter (e.g., template matching). Several approaches attempt to delineate the crowns themselves creating automated delineations also referred to as isolations or isols (e.g., Gougeon, 1995; Brandtberg and Walter, 1998; Walsworth and King, 1999; Culvenor, 2002; Pouliot et al., 2002; Erikson, 2003; Wang et al., 2004). Few address the issue of recognizing and improving poorly delineated trees. Zhang et al. (2012) used spectral values to determine poor delineations and showed that forest inventory estimations were better when only well delineated trees were used. Pixel based species

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classification was used by Heinzel and Koch (2012) to identify possible cases of two trees of different species within a delineation. As part of a crown delineation procedure, Bunting and Lucas (2006) incorporated segmentation and local maxima and an iterative process to cluster, split, recognize oversegmented crowns and merge them. Pouliot and King (2005) examined the spectral values between touching tree delineations and merged them if the value was high relative to the maxima spectral value within the delineations. Katoh and Gougeon (2012) combined evidence from local maxima and valley following techniques to improve tree counts.

Poor delineation can result from a variety of sources, for example: (a) poor quality sensors and imagery, (b) illumination and view angle effects such as excess tree shadow, obscuration of trees by adjacent taller trees and radiometric saturation of data on sunlit crowns, (c) openings in the forest stand exposing sunlit understory or ground vegetation that may appear like a tree, (d) internal branching structures that can look similar to separate trees (e.g., clumped branching in some hardwoods or large single branches on some conifer trees), (e) odd branching structures caused by individual branches extending long distances into openings between tree crowns, (f) densely packed tree crowns, (g) varying health condition within and between trees (e.g., dead crowns or large branches), (h) mixed and variable crown sizes, and (i) row structures (e.g., sun azimuths perpendicular to local alignment of tree crowns such that there is no shade between the trees). In addition, the delineation algorithms and parameters used to adjust the algorithms can cause artifacts or have tendencies to create wrong shapes in certain conditions.

Considering the potential sources of error and how they vary among data sets and forest conditions, automated methods cannot be expected to achieve perfection. All show errors and need for improvement, except in the simplest and most ideal forest conditions for the algorithms. Good crown counts and delineations are critical to bring the benefits of individual tree analysis to forestry and other applications. Thus it is useful to develop techniques to correct the tree crown delineations. This paper is part of an overall initiative to examine strategies, create a possible framework for tree isolation improvement, and develop and test some specific algorithms and methods. Concentration is on optical imagery, but the approaches may also have application to lidar data or individual tree analysis using combinations of both optical and lidar data. Key steps to improving tree isolations are:

(1) Identification of potentially bad crown delineations.
(2) Characterizing the nature of the suspected bad delineations in terms of: common mis-shapes, causes of the poor shape, and potential solutions to correcting the shapes.
(3) Correction of the shapes (remediation).
(4) Assessment of the effectiveness of the corrections and identification of those crowns still not well delineated.

The goal is to create crown delineations that represent the crown as portrayed on the imagery as well as possible. Overall success will be to correct a worthwhile percentage of poor delineations relative to the effort to do so, while introducing few additional poor outlines through applying the procedures. Important in this is the identification of remaining poor delineations.

There are three general categories of bad delineations (Leckie et al., 2005): (a) delineations that represent one tree but are a poor shape, (b) those that combine several true tree crowns or parts of several crowns into one delineation (grouped case), and (c) larger single crowns that are broken into several or even many automated delineations (split case). The work presented here addresses isols representing one tree but with a poor shape, plus grouped cases. It does not consider split cases; a companion paper (Leckie et al., in preparation-a) addresses these situations.

This paper deals with identification of poor automated crown delineations and characterizing the nature of the poor delineations (steps 1 and 2 above). The basic concept adopted was to define and identify a suite of tree isolation shape types relevant to identifying isols that might not represent the true shape of a tree and that are useful for indicating what kind of remediation might be needed to correct the shape. Various methods to classify these shape types were explored and developed. The methods use a set of primitives or elemental building blocks related to specific tree or image characteristics based on factors such as size, shape, morphology, presence of local image intensity maxima, or image patterns similar to that expected from trees. These primitives are generated and then applied in an evidence based approach that tries to mimic the decisions or logic a human would make in manually delineating tree crowns and identifying shapes. The approach allows for some knowledge of expected tree size, crown shape and shadowing. The expectation is that trees will have a generally regular and circular or oblong crown outline. Alternately in the case of low view angle and conifers, an elongated triangular outline on the image might be expected. However, unexpected shapes will not always be poor delineations. There can be exceptions where convoluted and odd shapes represent true tree crown boundaries, for example trees that extend a branch well out from the main crown into a canopy gap or between two other trees. Thus an issue is not only to recognize anomalous shapes but try to determine if the poor shapes are poor delineations or indeed do represent reality. The work is exploratory and although limitations in terms of processing time, complexity and data volumes are considered, they are not overriding design factors. At this stage it is of more interest to determine if the general strategy of a evidence and rule based approach is useful rather than develop optimum operational tools.

This paper also examines the usefulness of shape types to direct the type of remediation needed (step 3). Further research is developing remediation procedures to correct the tree isolations identified as poor and produce a better representation of the trees associated with the original delineations (Leckie et al., in preparation-a, in preparation-b). In this process some of the tools and primitives developed here are also used to help decide on the new delineation.

In the fourth step, remediated isols will again be checked for having a poor shape. Remaining poor delineations will be identified and marked as "likely poor". These poor isols can be discounted appropriately when using the isols to make forest inventory estimates such as species composition, volume and stem count. It is anticipated that the procedures developed in this paper can be reapplied to remediated delineations to help determine if they remain poor.

The development and testing of methods here is based on a standard automated tree crown isolation procedure (Gougeon and Leckie, 2003) applied to a mosaicked optical image data set over a test site near Petawawa, Ontario, Canada. The effectiveness of the primitives developed for identifying the tree or image features they are supposed to represent was tested. Also tested were the accuracy of the shape type classification and the use of the shape types to predict poor delineations and the likely type of remediation needed. This testing was done with a set of test isols for which isol shape was visually assigned, true tree outline determined, and needed remediation type estimated.

2. Development of test data set

2.1. Image and automated tree isolation data

The input data for this study was example tree isolations. Desired is a range of typical tree isolations: good, bad and