Development of a Digital Camera Tree Evaluation System

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Abstract

Within the Strategic Plan for Forest Inventory and Monitoring (USDA Forest Service 1998), there is a call to "conduct applied research in the use of [advanced technology] towards the end of increasing the operational efficiency and effectiveness of our program". This tool is a part of that research, aimed at decreasing field time and increasing the informational value and reliability of field data. Our approach started with the use of a commercially available, non-metric digital camera for obtaining diameter and height measurements from individual stems. The lessons learned from these original attempts have shown that this concept is feasible, and helped to indicate specific methodological, instrument, and processing areas needing improvement. The ways these areas are currently being addressed are described in this poster.

Introduction

To date, forest inventory has consisted of measuring a few easily obtainable indicator variables and making predictions based on a relatively small number of intensively measured trees that may or may not accurately represent the population being measured. For instance, the merchantable volume or biomass of a 500 acre, 130 year-old mixed bottomland hardwood stand, in Virginia, that has been thinned from below cannot be determined with very good precision (or possibly even accuracy) from 2000 DBH measurements, heights, etc. referenced to a multiple-entry volume table created from a sample of 20000 mixed hardwoods spread throughout the southeast United States. Also, there is great difficulty and subjectivity of quantifying stem quality information using conventional means. This is important to some users who desire information on merchantable value. In order to improve on current methods, a tool is needed to rapidly measure, directly if possible, the variable of interest or at least a sufficient number and type of predictor variables to give the best possible estimate without incurring a great cost. A digital imaging device can capture large amounts of data very rapidly with predictable geometric fidelity. Automated image processing procedures using digitally recorded ancillary data can provide such a tool that can be used to virtually reconstruct the stem and algorithms can be developed to extract customized measurements.

Previous Results

Up to this point diameter has been the only measurement that has been analyzed explicitly.

In leaf-on tests in the fall of 1998 (Clark et al. 1998) a 6.9 percent inacurracy was reported for 54 diameter measurements at heights from 1.4 to 21 meters.

After some methodological modifications, a leaf-off test on 241 diameter measurements at heights to 20 meters produced a maximum anticipated error of ±4 cm (95% chi-square).

Methodological Improvements

Some issues involving the methodology of collecting data with the camera are presented in the aforementioned studies. Ultimately, the methods can be customized to fit the needs of the data user. In further field studies, however, certain improvements will be made in regards to the methods used for experimental control. Direction was the only source of variation that was controlled in each of the studies of diameter measurement by Clark et al.. Some have suggested (e.g., Bruce 1975) that these small, uncontrolled tests are of less value than tests that attempt to evaluate every source of variation. Although this is impossible, in future tests heights will be marked to allow explicit evaluation of height in addition to diameter as well as controlling for taper and bark roughness variation (to some extent).

Problem - Tree Lean

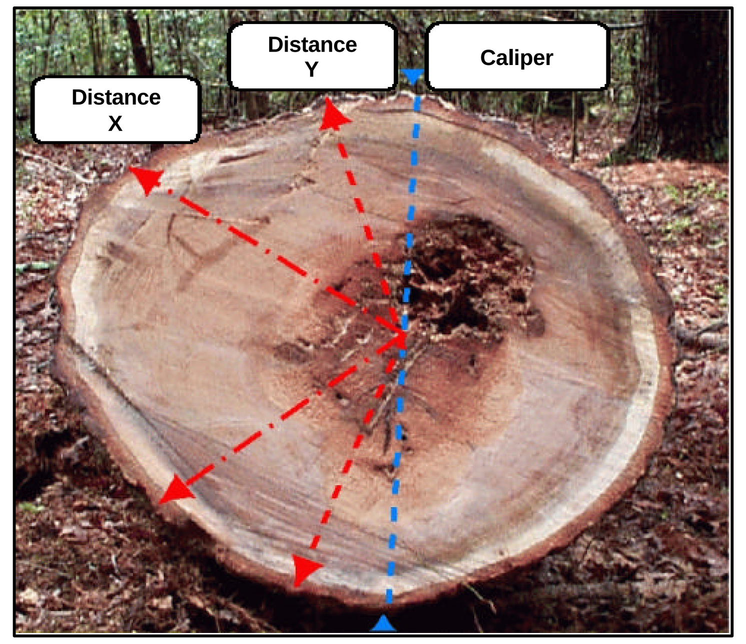
The most obvious, and presumably greatest, source of variation using the methods employed up to this time is omission of the effect of tree lean. This is especially important when dealing with hardwoods as the diametrical images here indicate. The blue regions represent the area containing the desired diameter, and the red lines indicate the diameters that were arithmetically averaged and compared to calipered diameter measurements taken at heights measured with a tape. In addition to the faulty vertical location on the stem, the problem is magnified further by a false range assumption.

Solution: Use convergent images, preferably perpendicular to quantify lean.

Problem - Out-of-Roundness

Cross-sectional deviation from a regular geometric shape (circle, ellipse) is experimentally accounted for by directional control. However, for instruments that do not measure parallel tangents (as does the caliper which is the basis of comparison), this still does not remove all of the variation due to the observation of different tangents about the circumference. For example, for the cross section shown in the image, the radius being estimated at distance X would be different from the radius estimated from the same direction at distance Y, as well as different from the radius estimated from the caliper measurement, unless the cross-section was a perfect circle.

Solution: There is no solution if using a paired statistic considering the conventional caliper measurement to be "true". A more suitable test would be to compare the modeled cross-sections derived from both camera and caliper diameter measurements to the actual measured cross-sectional area.



Instrument Improvements

The Need for Modification

Digital Camera

Limitations
- Not rugged enough for field conditions
- Requires manual measures of angle and distance in the field
- Requires manual data entry prior to image processing

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Laser Rangefinder

Limitations
- Requires manual entry of scale reading to calculate diameter
- Small obstructions can produce anomalous results
- Single diameter or height measurement

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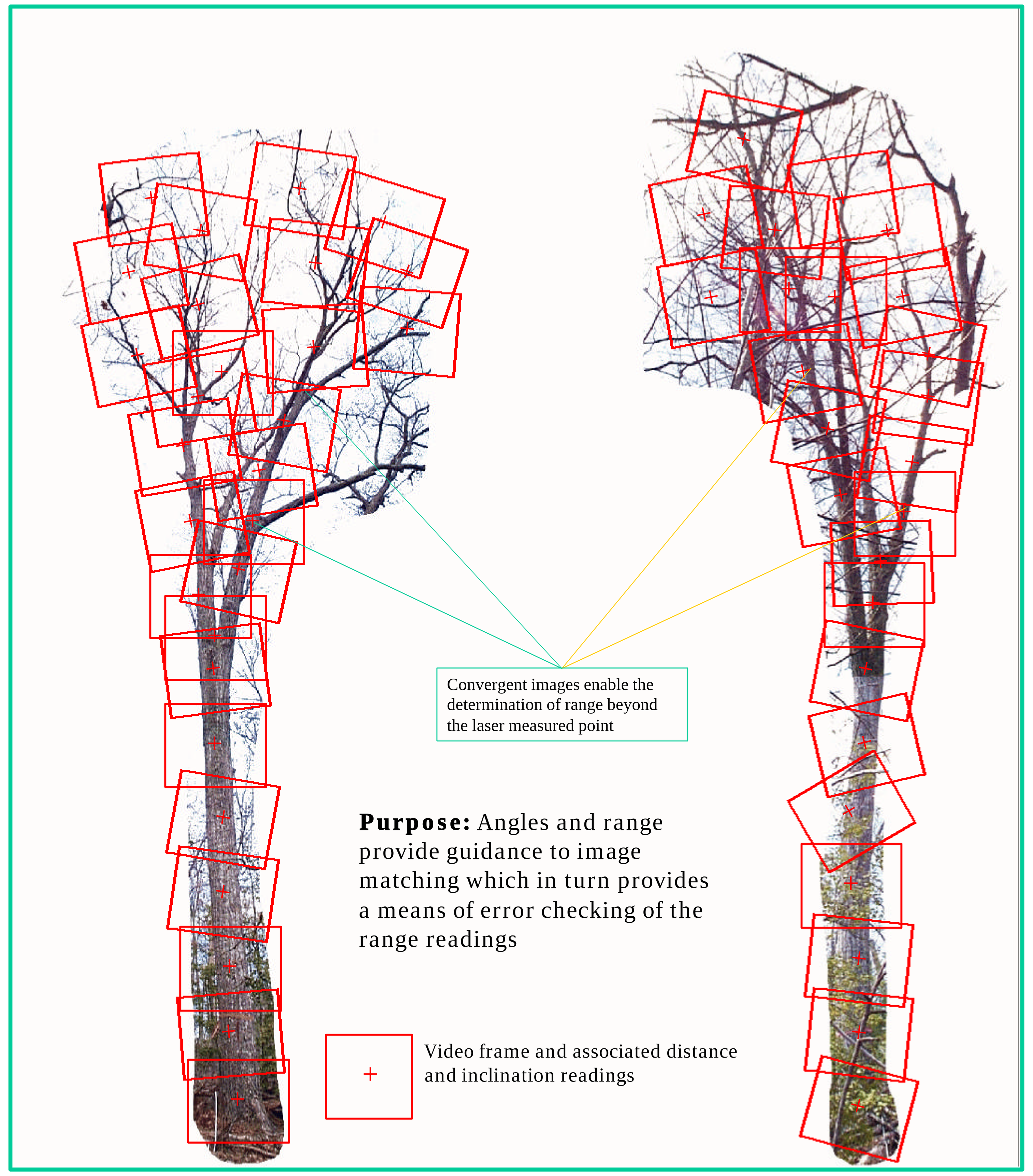
Tree Measuring System Instrument

Base image from: http://www.eclipse.net/~essco/survey/lalaser.htm, subsequently edited

Strengths
- Field-ready, Durable, Self- Contained
- Digital Image Capture
- 3 Axis Magnetometer
- Laser Rangefinding
- Output Formatted For Automation Software

It was shown in the cited studies, that the camera did have the capability to capture stem diameters at a somewhat reduced precision compared to other types of optical dendrometers. This is somewhat do to the method of collection (the least amount of magnification was chosen to increase areal coverage). At the same time the camera had captured about 2000 diameter measurements per stem (counting each pixel as a discrete unit) in about 20 seconds. The need to manually collect and transfer angle and distance data was the main drawback using the camera. Conversely, with previous laser rangefinder instruments, angle and distance were no problem, however the diameter had to be manually read and entered into the system. The creation of a hybrid of these two tools has the potential to revolutionize single stem (and maybe even plot) level data collection. The current system under development contains a CCD array incorporated into the laser instrument capable of streaming video, distance, and orientation data simultaneously. This way the view can be magnified to increase the precision. The digital capture and transfer of angle, distance, and imagery will allow the field forester to shoot the tree and the computer will output the desired information, whether it be height, diameter, biomass, volume, value of product, live crown ratio, etc.



Instrument Improvements (cont.)

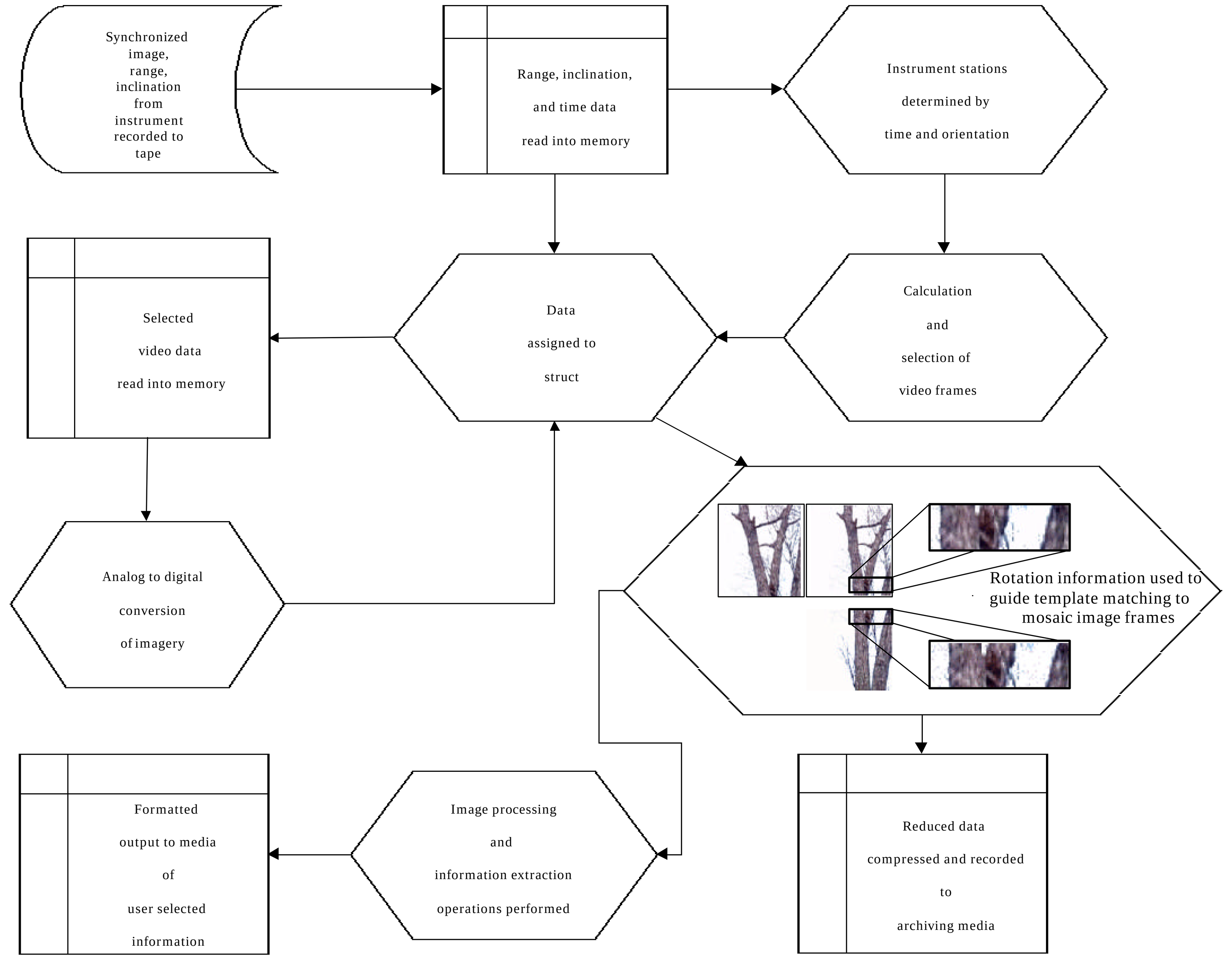
Problem - Interior Orientation / Lens Distortion

Once the tree measuring system instrument has been produced, all of it's component sensors have to be calibrated, including the imaging surface (in this case CCD array). The orientation of this component to the lens as well as the lens system alignment itself may cause image distortion from the theoretical perspective projection of a pinhole camera. A set of parameters for radial lens distortion can be determined from the analytical plumb line method (Brown 71), or any set of straight lines (Prescott and McLean 1997). A target range can also be used to verify the results obtained using line methods and to locate the perspective center.

Solution: Use a variation of the analytical plumb line calibration technique to determine interior orientation parameters.

Processing Improvements

At this stage we have utilized technology to collect a large amount of raw data. This is no advantage to us if we still have to manually extract all of the desired information. The fields of close range photogrammetry and machine vision are making great strides in automated information extraction from digital images. Though most practical applications are industrial in nature under controlled lighting conditions, this technology is proceeding out-of-doors and into the forest. Work by Byrne and Singh (1998), Vehtari et al. (1998), and Juujärvi et al. (1998) all deal with extracting tree information from digital images. This is being done at various scales and with various data collection protocols. Our goal is to bring together and improve on these methods to process the raw data to the stage needed by the end user.



Future plans involve onboard processing and output of the compressed still image and select information

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