



Application of Scanned High Resolution, GPS Controlled Large Scale Aerial Photography to a Forest Inventory

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Overview

The Remote Sensing Applications Center (RSAC), the Inventory and Monitoring Technology Development Committee and the Rocky Mountain Research Station studied a procedure for employing fine resolution scanned, large-scale aerial photography in a computer generated stereo mode. Emphasis was placed on developing techniques, which support forestry inventory information needed for monitoring inaccessible geographic areas. The techniques and methods in this project reveal that a photogrammetric assessment of tree height compares favorably to field based measurements. Possible limitations of this process include, handling large file sizes that exceed one gigabyte, additional hardware to view in stereo, incorporating a robust sampling strategy, and expert knowledge to perform some photo interpretation.

Background

Inventorying the forested lands of the United States of America, both inside and outside national forest boundaries, is the goal of the Forest Inventory and Analysis Program (FIA). Historically, field data has been captured on a ten-year

cycle. However, the 1998 Farm Bill requires that, a portion of all field plots, on all lands, be updated annually. Many of the field plots are easy to visit and plot tallies can be completed within a day. However, some plots are located deep within wilderness areas, contain hazardous conditions, or are geographically inaccessible, increasing the number of days for inventorying them. Advances in large-scale aerial photography offer an opportunity for exact locations to be captured (similar to FIA field plots), and measurements tallied through the use of scanned aerial photography, providing an alternative to visiting "difficult to get to" plots.

The Process

Aerial photos were acquired with natural color film, at a photo scale of approximately 1:3000. The negatives were scanned with a high-end photogrammetric scanner at 12.5 μ resolution. This high resolution scanning allows a 0.13 foot pixel size to be captured. This is an amazing digital resolution considering the terrain was initially photographed at one thousand meters away.

Key elements used to process the digital photos include:

- DEM and DOQ of the area
- ERDAS OrthoBASE Pro and Stereo Analyst
- A high-end graphics card (determined by system and viewing requirements)
- Shutter glasses (providing the ability to view in stereo)
- Aerial photos (scanned at a specified resolution)
- Camera information

When photo acquisition is well controlled, aerial photo stereo pairs allow interpreters to view the landscape in true relief. The hardware and software in combination with the high resolution scanning enabled photo interpreters to view the digital image in true stereo, and easily determine individual tree measurements (Figure 1).

The computer captures all the geometry required for measurements to be taken with little understanding of traditional aerial photography applications such as principle points and parallax values.

Photogrammetry

Photogrammetric techniques produce two types of information. Direct measurements can be obtained by using the geometry of the aligned stereo pair. Indirect measurements are derived or modeled from the direct

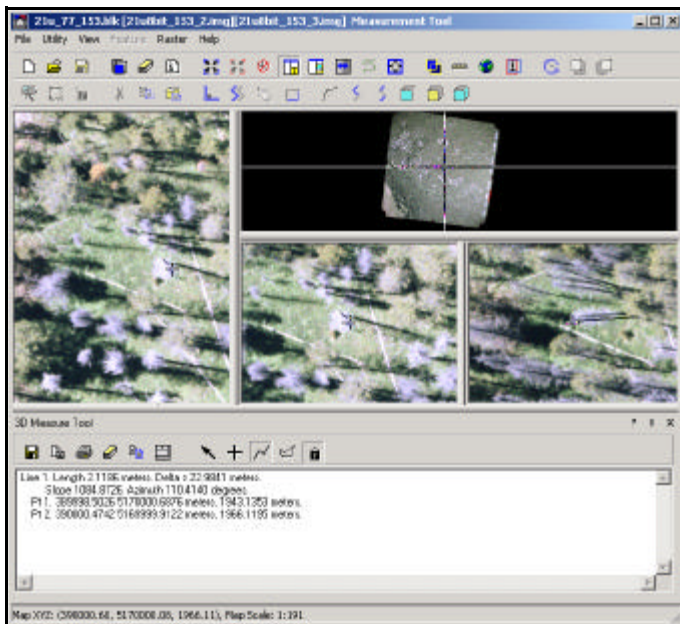


Figure 1. An example of a photoanalysts screen displaying a measurement tool. There are two photos in the upper right corner and a stereo view on the far left viewer. A measurement of tree height is depicted in the '3D Measure Tool' window. To take this measurement, an interpreter simply selects the location of the base of the chosen tree, and moves the cursor in the Z-plane to the tree top in the stereo photo.

measurements and other photo interpretation techniques. This study focused on the ability to compile some direct measurements from a field plot as defined by the FIA program. The following is a short list of the information directly available from aerial photos:

- Tree counts per area
- *Tree height
- Percent crown closure
- Visible crown diameter
- *Tree species
- Crown class
- *Tree Condition (living / dead)
- Ground layer structure (when visible)
- Patch sizes and shape
- *GPS coordinates (in UTM)
- Vegetation Type and Land Cover

*Measurements compiled for the current study.

The quality of these measurements is scale dependent, and the ability to “zoom” into a stereo pair allows for more accurate measurements. It is also important to understand that bias may affect the direct measurements. Photo interpreters have long been known to incur measurement biases when measuring different variables, and these biases are unique to individual interpreters. While it is best for a sampling design be in place prior to photogrammetric measurements to correct the bias, this study did not include this kind of compensation.

Modeled or inferred information is just as important as direct measurements. The relationships between the direct measurements and the indirect variables need to be fully developed. For example, relationships between tree height and tree volume, or visible crown diameter together with percent crown closure and stand volume. The relationships need to be well understood for regression models to be of any use. Models using tree height alone may not be very useful for understanding wildlife habitat, but if tree species and percent crown closure are added, these models may be able to explain a great deal about habitat probability. This list includes some indirect attributes that are of interest to the FIA:

- Volume (wood fiber, crown carbon sequestering)
- Diameter at Breast height (basal area)
- Wildlife habitat suitability
- Forest growth
- Canopy structure

Tips for Using LSP in a Scanned High Resolution Format

- Capturing 12.5u data from aerial photo requires large computer files. File sizes exceeding 1.2 gigabytes are common in TIFF and IMG formats. The system at RSAC was developed specifically to handle large image files. In time, the computer systems available to federal service employees should easily accommodate these large file sizes. Many file compression programs are available. Initial work with compressed images is

promising because height measurements are similar to those obtained with uncompressed images. Compression rates of 1 to 20 allow forest service contract workstation PCs to be capable of this process.

- Finding preexisting plots can be problematic. This study focused on basal plots, otherwise known as a point sample. In this type of sample an individual tree is tallied only if it exceeds a function of tree size and distance relationship from the plot center. This type of sample will not capture all the trees, as one would visually interpret from an aerial photo. Using radial plots (a fixed radius sample) and determining plot locations by a field visit on the photos prior to photo interpretation can increase the ability of aerial photos to be useful for capturing plot data as future samples occur.
- Using an expert for the tree species identification phase of this study significantly decreased the amount of time required. An expert in tree species identification helped assure an unbiased judgment. It would have undoubtedly taken more time to recognize tree species and there would have been many more errors if the interpreters had been unfamiliar with the types of trees in the study area (Figure 2).
- This study focused on a relatively new way to use of aerial photos: capturing precise GPS locations, and taking only a small number (two or three) of photos per plot with large distances between the plots. This aspect of the project is unique. Historically, a broadcast aerial photo collection, including overlap and flight lines, has been necessary to accommodate

sample points. While this type of broadcast survey still has value, capturing exact GPS locations with relatively large distances between them optimizes aerial photo acquisition (Figure 3).

- Known GPS locations were very important for project success. While the benefit of knowing the exact location of the plot is vital as a reference for the flight path and aerial photo capture, the use of this value in a referenced stereo image usually does not relate to the desired location. In most cases the

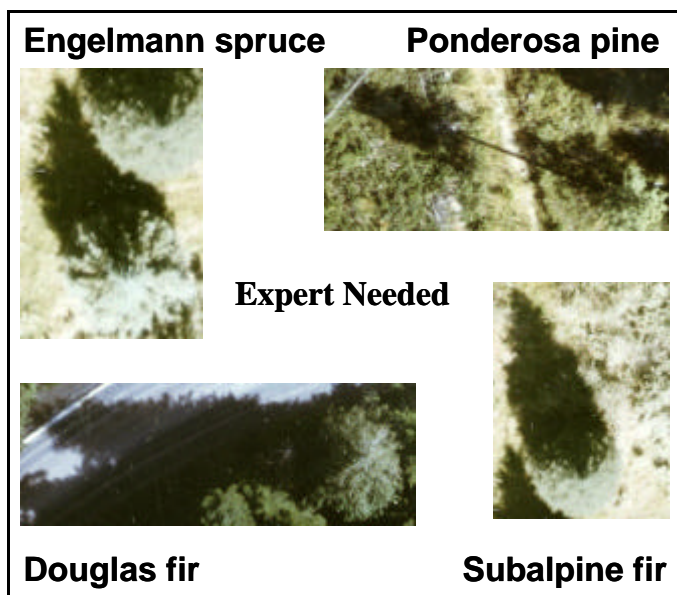


Figure 2. An example of some species identified on FIA plots. In most cases, an interpreter needs other information such as altitude, plot location and look in the general area captured by the photo for hints to identify a tree species. The current study relied on an expert for tree species identification.

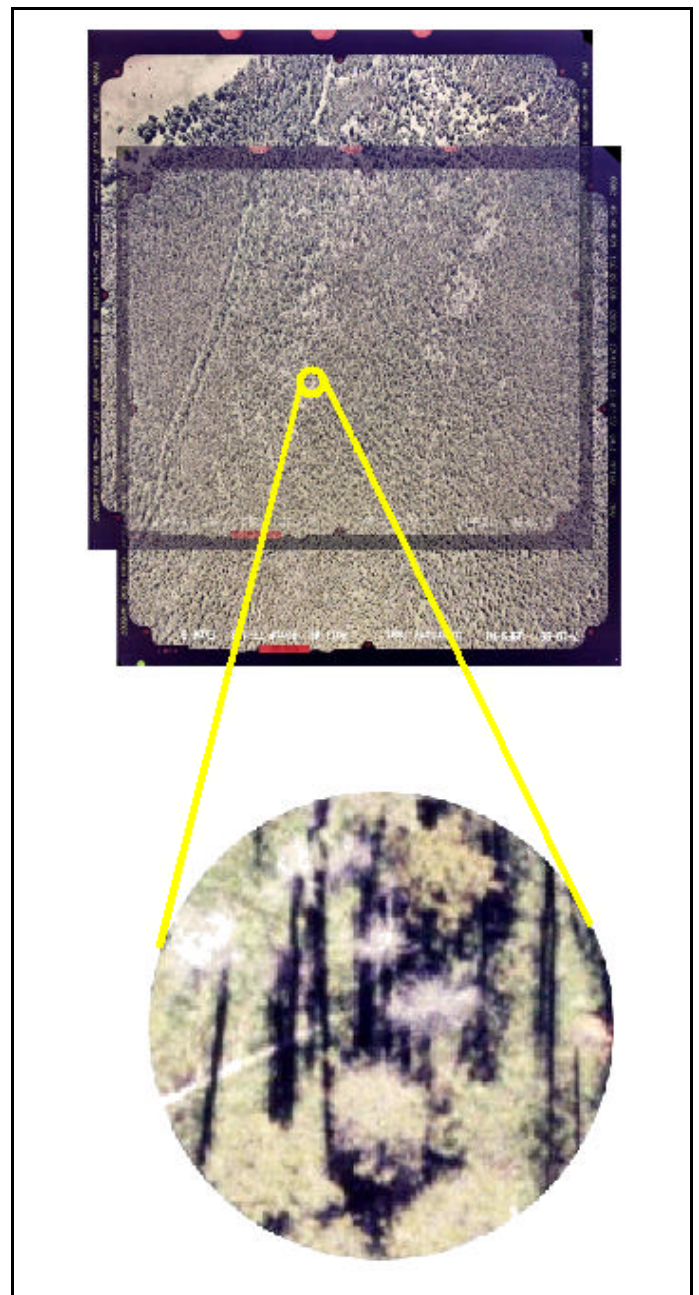


Figure 3. A stereo pair with overlap captured by using forward motion compensation and real time GPS control. Only two aerial photos, taken at 1000 m above ground, are needed to locate the plot and accurately measure individual trees by zooming in from a 1:3000 scale photo to a 1:100 scale.

use of available GPS coordinates did not allow us to pin point the plot center on a stereo image; the use of the GPS coordinates used on the stereo photos allowed an interpreter to be in the area.

- In the past, a zooming power of 2X to 10X was used on diapositive or paper copies of the negatives. Today's technology allows for a zooming power of hundreds of times, yet retains the quality necessary for precise measurements. A photo interpreter can easily do the job of many field crews, compiling forest measurements within a relatively large continuous area. Techniques in this project can add tremendous value to a broadcast aerial photo collection (Figure 4).

The software and hardware to accommodate the ability of viewing high resolution scanned aerial photographs in stereo is available on the Forest Service contract.

Conclusion

The technology described in this paper allows specific GPS ground coordinate locations to be captured by aerial photography, and individual tree measurements tallied, within tolerance, from a digital stereo pair. To take advantage of this technology, future studies should focus on developing techniques provide more opportunities to use aerial photography. Some aspects of this project need further development; including assessment of aerial photo interpreters by ground crews, statistical design implications related to using measurements from aerial photography (development of inferred and modeled variables), and organizational acceptance of aerial photography as a source of data.



Figure 4. A photo interpreter viewing in stereo with the aid of glasses that mimic the screen flicker. Combining real time GPS control and forward motion aerial photography, with software and hardware capable of orthorectifying, zooming into a photo and viewing in stereo, provides the key for precisely and accurately measuring individual trees and deriving other pertinent information.

Suggested Readings

- Avery T.E. 1978. Forester's Guide to Aerial Photography. Agriculture Handbook No. 308. U.S. Department of Agriculture Forest Service. Stock Number 001-000-03914-8. 45 pp.
- Avery T. E., G.L. Berlin. 1992. Fundamentals of Remote Sensing and Airphoto Interpretation. Fifth Edition. MacMillan Publishing Company, New York. 472 pp.
- Caylor, J. A. 1988. How to Use Aerial Photographs For Natural Resource Applications: Course Workbook and Manual. USDA Forest Service. 222 pp.
- Paine, D.P. 1981. Aerial Photography, and Image Interpretation for Resource Management. John Wiley and Sons, New York. 571 pp.

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