INITIAL RESULTS FROM A VIDEO–LASER RANGEFINDER DEVICE

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ABSTRACT

Three hundred and nine width measurements at various heights to 10 m on a metal light pole were calculated from video images captured with a prototype video-laser rangefinder instrument. Data were captured at distances from 6 to 15 m. The endpoints for the width measurements were manually selected to the nearest pixel from individual video frames.

Chi-square analysis shows that 95 percent of measurements can be expected to be within 13 mm of the actual. All errors lower than -13 mm were on nearly horizontal images. Poor contrast causing poor edge detection was the source of most of this error. All errors greater than 13 mm occurred between rows 280 and 390 on the image. Improper focus seemed to be the main contributor to positive errors. Improvements to the camera and lens system should improve these results considerably.

INTRODUCTION

Accurate individual tree stem measurements are critical for large-scale forest inventories, growth and yield estimation, and monitoring efforts. In addition, user demands on the quality, timeliness, specificity, and precision of information are increasing. Initial work (Clark 1998) demonstrated the feasibility of using a digital still camera for acquiring stem metrics. Digital range and inclination measurements were suggested to improve the existing system. These features were added, as well as increased magnification, with the development of the video-laser rangefinder device presented in this article.

Range measurement is a critical component of many optical dendrometers and hypsometers. Many of these instruments have traditionally relied on the calculation of ranges from a single distance measurement (sometimes of questionable accuracy) coupled with assumptions of stem lean. This physical distance measurement is often difficult to collect accurately and greatly increases the cost / time of measurement collection. While upper-stem diameters are often only ancillary to diameter at breast height (DBH) for many analyses where "sufficient" models exist, height measurements are critical and force the requirement of this extra effort. For decades this range problem has been elusive, with the only real success coming in the form of highly precise and expensive optical instruments (e.g., Barr & Stroud). This was true until the portability of electronic devices increased. Now there are a number of devices that use various forms of radiation, with or without retro-reflective targets, to measure distance.

In the early 1990's this technology was put to use in the creation of tree measuring instruments. One such instrument, which received much press, was the Criterion (Fairweather 1994, Liu et al. 1995, Williams et al. 1999). Results from varying developmental stages of this instrument have been promising, with the main problems being inclination and viewing. Given this, it seemed that the next logical step would be to combine the ranging and digital imaging technologies to create a completely digital system that would further decrease cost and subjectivity and head toward measurement automation. This was realized in 1999 with the creation of the instrument used in this study by Laser Atlanta, Inc.[1]

METHODS

Specifications for the instrument used in this study are shown in Table 1. The instrument is a modification of the Advantage® CIL Laser-rangefinder manufactured by Laser Atlanta, Inc. A standard format CCD camera was integrated into the system which outputs to a portable video cassette recorder via an RCA type video cable. The camera is directed through the display mechanism of the Advantage® so the crosshairs representing the pinpoint location of the laser pulse and the ranging information can be recorded to the video tape. On this display only one range, bearing, or inclination can be shown at a time, so the instrument was set to cycle these measurements to the display. The entirety of the ranging information can also be output to a memory card or to a separate data recorder via a serial port.

[1] Tradenames are used for informational purposes only and do not imply any endorsement by the US Department of Agriculture.

Field data were captured at distances from 6 to 15 m from a rectangular, metal lightpole. The unit was handheld and data were only captured from one azimuth. At each distance the lightpole was scanned from bottom to top, pausing periodically to allow the inclinometer to stabilize and the data display to cycle and be captured on video.

Video Frames of the paused locations were captured from tape and stored as uncompressed digital bitmaps. Measurements were taken from these images by heads-up digitization. A video frame was displayed on the computer monitor, and the left and right edges of the lightpole were visually interpreted and coordinates were recorded by manual input using a computer mouse.

Table 1. Technical Specifications for the prototype video – laser rangefinder device.

Dimensions	21.5 x 11.5 x 19 cm		
Weight	2.1 kg		
Distance (no reflector)	Range 2 – 610 m	Accuracy	±15.3 cm
Azimuth	Range 0.0º – 359.0º	Accuracy	±1.5º RMS
Inclination	Range ±50º *	Accuracy	±0.4º
CCD Camera	480 x 720 RGB color		

* Mounted at a 30º incline to cover a range from -20º to +80º respective to horizontal

Before actual measurements could be obtained with the instrument, the focal length had to be determined. A pinhole camera model was assumed. An elementary scale equation, shown by

$$\frac{d}{D} = \frac{f}{L_o}$$

(where d is the image space measurement representing the real world length D, f is the focal length of the camera, and L_o is the horizontal distance between the lens and the object), was applied to images captured perpendicularly to the lightpole. d was measured manually to the nearest pixel from captured video frames using heads-up digitization software. D was measured to ±1.6 mm using a steel tape. And, L_o was measured by the rangefinder to within 300 mm rather than within it's 150 mm capability because the digital output was not accessible. 18 d measurements were taken from 4 frames, each at a different L_o, and averaged to obtain the f used in subsequent calculations.

Three hundred and nine measurements were captured from 41 captured frames. The data were captured without regard to any experimental design so the number of observations per frame ranged from 3 to 11. D values were determined according to the calculations set forth in Appendix A of Clark 1998, which is just a simple perspective projection without any corrections for lens distortions.

RESULTS AND DISCUSSION

Mean error for all observations was +1.9 mm with standard deviation of ±6.7 mm. Maximum anticipated error from a 95% chi-square analysis (Bell & Groman 1971) is 13 mm. Figures 1 and 2 show errors by distance and angle, respectively.

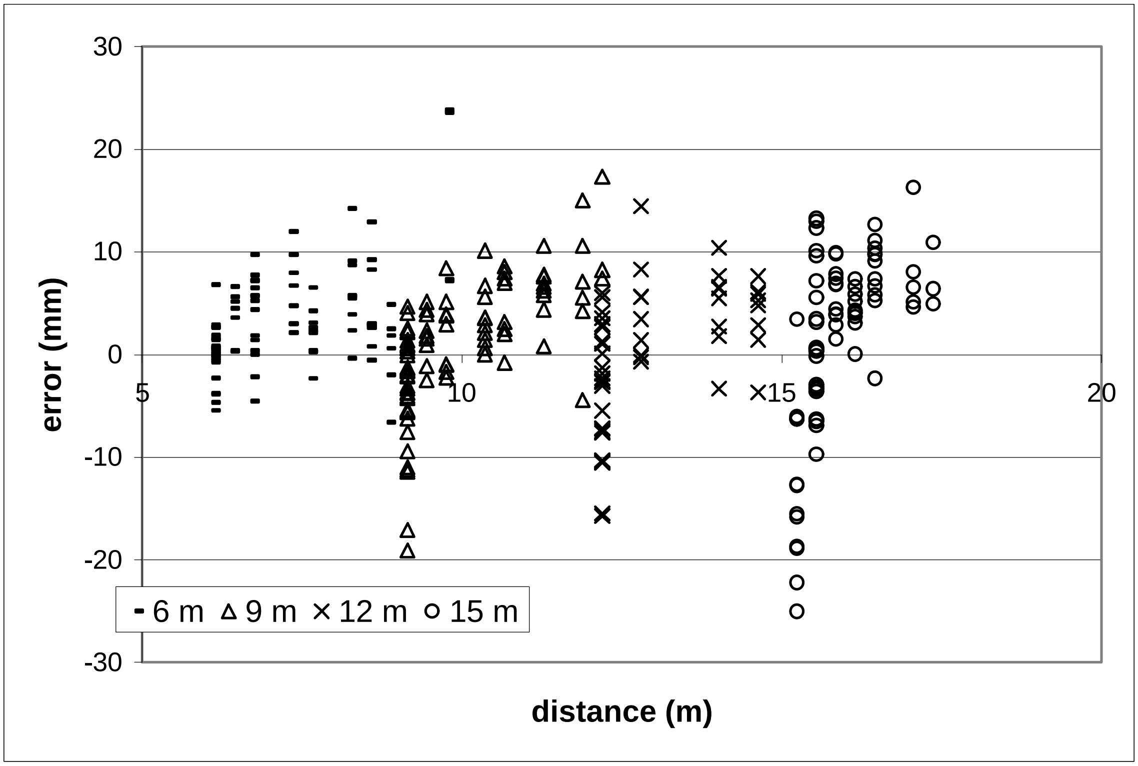

Figure 1. Measurement errors by range for 6, 9, 12, and 15 meter horizontal distances.

Examination of the errors by distance indicates some periodicity in the data. While there is good evidence to suggest that the model may be flawed on the basis of the periodicity there is some indication from analysis of the individual images that spectral contrast may have been the causal factor of both positive and negative extreme errors. The periodicity was evident even when ignoring the perspective projection and simply multiplying the measurements by a constant scale factor. Figure 2 shows that no real trend is observed between the angles of 5 and 50 degrees implying that the model is not the causal factor of the periodicity. Only the extremes, which happen to be correlated with confounding spectral characteristics, indicate any significance.

Two likely explanations are lighting and range. The data were collected in an outdoor setting and thus the amount of incident radiation varies with the inclination of the instrument. The CCD camera automatically adjusts to the changing amount of radiation and this adjustment may affect the measurement.

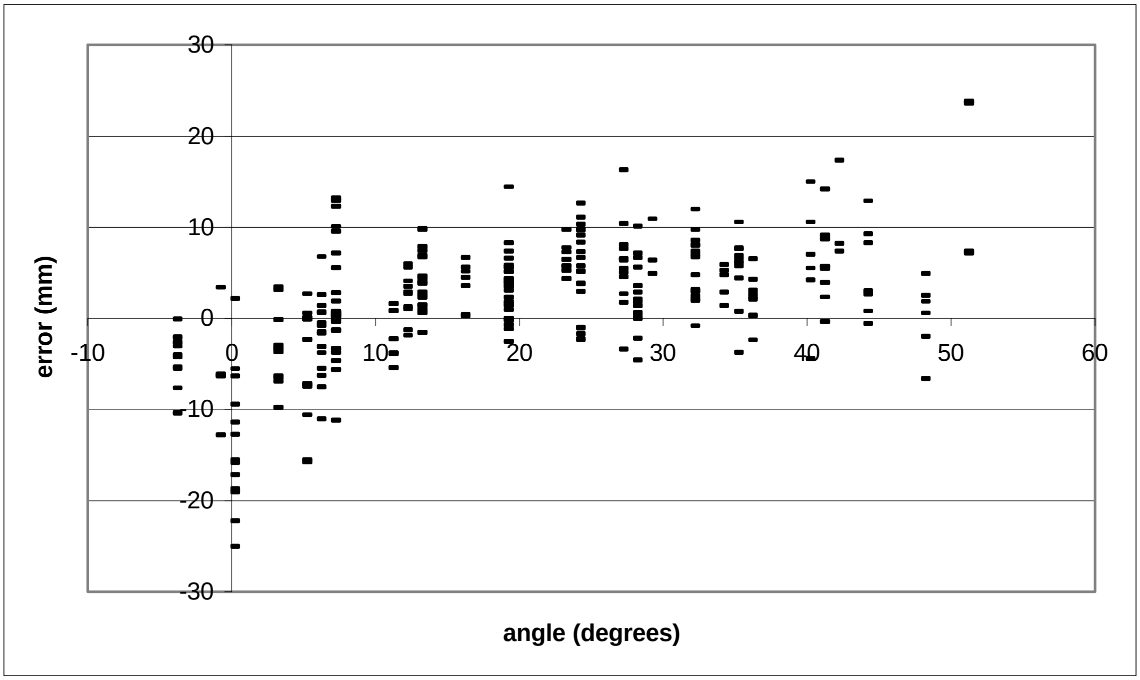

Figure 2. Measurement errors by inclination angle.

If the range was being recorded of a point higher than that point indicated on the display, an exponential effect would result with increasing inclination angles. Errors on the same height on the pole at the 6 m distance would be much greater than the same height from the 15 m distance. In addition, the precision limitation of ±30 cm could cause errors as great as 7 mm at the 6 m distance. While this may explain the shift of an entire group of measurements, multiple measurements on each frame commonly varied by 10 mm or more.

All of the measurements that were less than 10 mm below the actual were taken from frame captures of the bottom of the pole. All other frame captures, except those of the top of the pole, have a uniform background of the sky. The frames of the bottom of the pole are characterized by varying dark tones, which reduce the contrast between the lightpole and background. This inability to distinguish on a spectral basis added to improper focus and biased edge selection of more than one measurement per frame result in the large amount of extreme errors.

CONCLUSIONS

The results presented by this prototype device show that there is much room for improvement. Adjustment of the lens focus should greatly reduce measurement variation within each frame. The ability to access the actual range data to will also be a stabilizing factor. Work needs to be done to eliminate the spectral confusion between the object and background. With these improvements and increased automation within the system, this system has the potential to be a great aid for forest inventory.

LITERATURE CITED

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