Application of carriage-mounted agricultural cameras to improve safety in cable logging operations

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Abstract

A large number of logging safety accidents in cable operations occur as a result of poor visibility between yarder operators and individuals in the brush. Industrial safety campaigns, such as Weyerhaeuser Corporation's 'in-the-clear' messaging, help to improve safety. However, reliance on audio communication with audio signals as the primary method for communications to ensure safety when the yarding of logs commences has some safety shortcomings that could potentially be improved upon. For example, if the yarder operator receives a signal to commence yarding when a choker setter has not yet moved fully into the clear, there is no back-up safety system to confirm the audio command.

Recently, carriage-mounted agricultural cameras have been used to guide the acquisition of sawlogs by remote grapple carriages, such as the Eagle Yoder Claw Grapple and Eagle Mega Claw Line. A small agricultural camera is mounted on these carriage models. The grapple is operated remotely from the cab by the operator, who has a bird's eye view of the area below the carriage on a 9 inch screen that is mounted in the cab. In this study, we are evaluating the potential use of inexpensive agricultural cameras and screens as a back-up, secondary safety measure in cable logging communications. We affixed an agricultural camera to a carriage on a Koller 300 series yarder used on the University of Idaho Experimental Forest, and also on a small, trailer-mounted mini-yarder. A designed experiment was conducted to evaluate the effects of image filtering methods, harvest type, and camera field of view on image contrast and visibility. Our objective was to determine whether a combination of remote sensing image filtering techniques could be used to clearly identify choker setters with very high contrast under a range of light and background conditions. Results of the preliminary experiment are reported and a larger operational pilot study is described.

Introduction

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A number of inexpensive video cameras marketed alternatively as agricultural, security, trailer, and vehicle backup cameras have recently become available. These cameras are popular in various agricultural applications because of the high quality video they provide at limited cost (typically <$400). Increasingly, agricultural cameras are also showing up on logging equipment, where they provide increased visibility in blindspots for loaders, feller-bunchers, and other equipment. Depending on the desired application, inexpensive video cameras are available in closed circuit and wireless models. Some models exist that transmit directly to a screen, requiring a separate battery connection both for the camera and screen. Various, small battery-powered video cameras with field mounts designed for extreme sports (e.g. GoPro, Contour) are also readily available, and several of these have the capacity to transmit via cell signal when cellular coverage is available.

At least two models of grapple carriages, the Eagle Yoder Claw Grapple and Eagle Mega Claw Line, now make use of agricultural cameras for operation. With these carriages, a yoder operator is able to watch a screen in an enclosed cab that feeds directly from a camera mounted vertically below the carriage. This perspective facilitates rotating and positioning the grapple correctly to collect logs down the hillside, independently of whether the operator has a direct line of site.

Many cable yarding injuries and fatalities occur in the brush, when choker setters are struck by rolling are swinging logs during yarding. The Washington FACE program reported seven fatalities associated with loggers being struck by logs over the five year period between 1998 and 2003 (Washington FACE, 2004). Technological advancements such as use of remote-controlled chokers, synthetic rope (Pilkerton et al. 2001) and increased safety campaigns have the potential to reduce cable logging accidents. However, the use of agricultural cameras coupled with carriages as a supplemental safety precaution has not previously been investigated.

In this preliminary study, which will guide a larger field trial in 2013-2014, I conducted a preliminary experiment to evaluate methods for creating high contrast imagery of the area below the skyline carriage. My hope was to develop a method by which a high level of contrast could be created on an onboard screen, in order to increase visibility of a ground worker below the skyline being viewed through a carriage-mounted video camera.

Methods

Several factors potentially affect the ability of agricultural cameras to provide clear, high contrast images for yarder operators to utilize for safety purposes. To begin the process of determining the relative importance of these factors prior to an operational study with full size yarders, a factorial experiment was conducted with small machines to evaluate the relative importance of image filtering methods, stand density, and worker position on visibility and detection in video capture images.

For the preliminary study, two small yarders were used to collect carriage videography. The first was a Koller 300 series yarder mounted on the 3 Point Hitch of a 70 HP Valtra 700 farm tractor modified for woods use. The second was a small, 8 HP custom built trailer-mounted mini-yarder used primarily for research and teaching purposes. The skyline for the Koller was extended approximately 900 feet across a stream and secondary forest road on the University of Idaho Blodgett Outdoor Classroom. The mini-yarder skyline was extended 600 feet across a draw on the West Hatter Creek Unit of the University of Idaho Experimental Forest. Average slope was 43%. Height of the skyline at the measurement point for the Koller 300 was 35 ft. Height for the mini-yarder was 20 feet.

The factor treatment levels for the experiment were as follows:

Worker position	**Image filter**	**Harvest type**
Below skyline	Red band only	Partial
25 % from center	Red, green, blue	Clearcut w/ reserves

All images were captured using digital video as a camera passed over a worker stationed either directly beneath the skyline corridor centerline or at a 25% angle from the center, measured from the camera in a horizontal direction perpendicular (lateral) to the corridor. Three separate video passes, treated as replicates, were recorded for each treatment combination. Image contrast was quantified using the histogram spread (HS) metric proposed by Tripathi et al. (2011):

$$HS = \frac{Interquartile\ range\ (IQR)}{Potential\ range}$$

Where the interquartile range is based on the actual image histogram pixel values observed (75 % - 25 %), and the potential range is the minimum minus the maximum values that any pixel can take on. Image filtering was carried out with Multispec software. Histogram measurements were conducted with the Gnu Image Manipulation Program.

Results

In preliminary image processing, filtering images to show only the red color band appeared to create a high level of contrast for conventional high-visibility orange safety vests used commonly in forest operations (Figure 1).

Figure 1: High visibility safety vest with no filtering (left), and with a red band filter applied (right).

However, in the replicated field experiment, the amount of vegetation present (harvest type) also affected contrast, in addition to filtering method. Imagery collected in partial harvests had higher contrast than imagery collected in clearcut with reserve treatments. Both factors significantly affected image contrast (Table 1).

	DF	SS	MS	F	Pr(>F)
Treatment	1	0.0076	0.0076	6.2472	0.0213
Angle	1	0.0005	0.0005	0.4422	0.5136
Filter	1	0.0073	0.0073	6.0201	0.0234
Residuals	20	0.0244	0.0012		

Table 1: ANOVA table indicating the factors affecting image contrast.

In all analysis, field of view had no significant effect on the level of image contrast observed; contrast was equal when the worker was directly below the center of the skyline corridor, or positioned laterally at 25% of cable height.

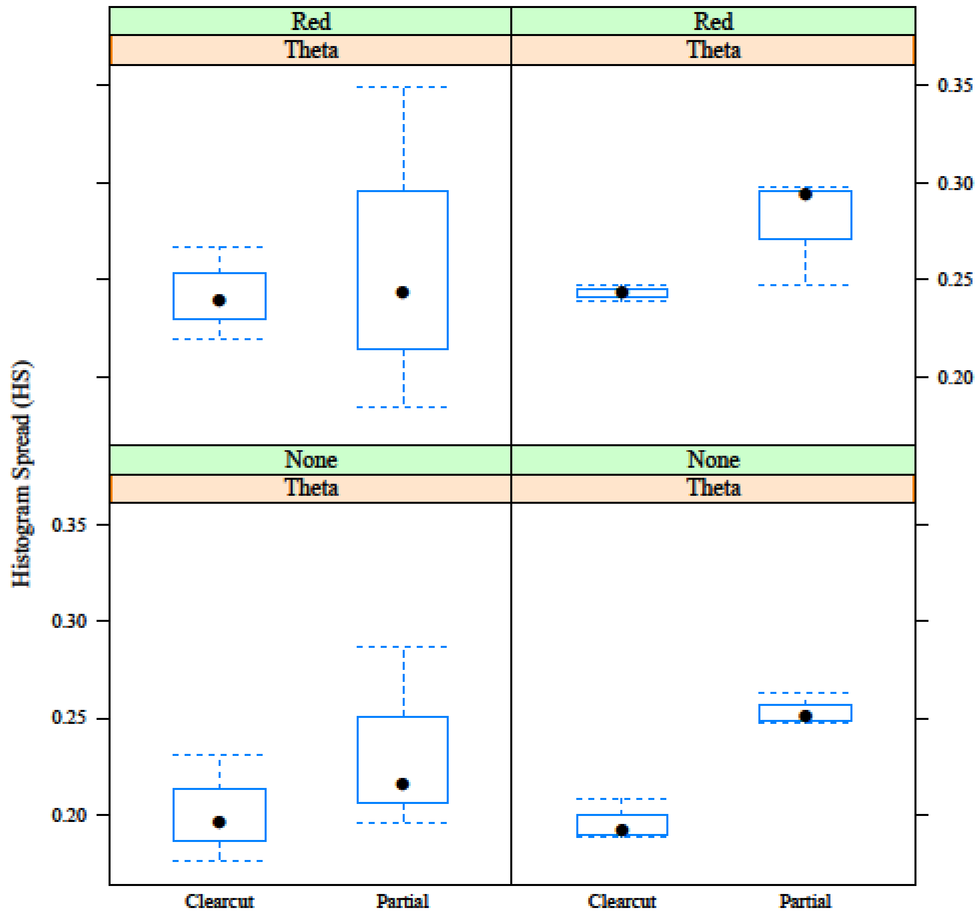

Figure 2: Level of image contrast, measured as histogram spread (HS) for all treatment combinations.

Discussion

Our assumption in designing this preliminary study was that deploying methods to maximize image contrast, quantitatively, would produce the most highly visible screen viewing environment for detection of individuals working unsafely below the skyline. However, practical analysis of the imagery collected showed that non-filtered imagery including all R,G,B bands was more useful than red band filter imagery in partial harvests. Although filtering only the red band produced greater image contrast based on histogram spread, the resulting whitening of orange safety vests made it difficult to distinguish the worker from residual overstory vegetation. In partial harvests, full color imagery showing the hi-visibility orange safety vests and yellow safety hard hat worn in the trials made it easier to quickly identify workers within the field of view of the carriage.

Further research to evaluate the potential use of agricultural cameras to improve safety in cable operations is needed before any operational use should be considered. In 2013-2014, a field study is being conducted that will evaluate use of wireless cameras mounted on carriages in active operations, including collecting perceptions from loggers. This preliminary image analysis study suggests that factors to be considered in the larger, operational study should focus primarily on high visibility safety helmets and vests coupled with color cameras and viewing screens, rather than partial color image filtering to increase contrast.

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