HARVESTING TECHNICAL NOTE

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Hauler Vision System: Testing of Cutover Camera

Summary

Providing the yarder operator with a view of the breakout site has the potential to improve the productivity, efficiency and safety of hauler operations on steep terrain. This project, aimed at developing a vision system more advanced than the simple camera systems available on the market today, was split into two sub-tasks: a system developed by Scion comprising a combination of up to three cameras, for location at the hauler tower, at the mobile tail hold or on the cutover; and a rigging-based camera developed by Trinder Engineers of Nelson. This report describes the Scion-developed component of the FFR advanced hauler vision system, which comprised a combination of three cameras, a display and communications equipment. Software to control camera pan, tilt and zoom as well as image brightness was developed. The system was tested at a cable hauler operation at Tuhoe Forest in the Bay of Plenty. High variability in cable hauler cycle element times (especially outhaul and grapple times) and issues with sample size resulted in no significant difference being found in using the cutover-based camera system. The feedback from the contractor and hauler operator however was positive.

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Introduction

One of the projects in the FFR Harvesting Theme is to introduce new technology to improve the hauler operator’s view of the harvesting site to improve the productivity and efficiency of hauler operations on steep terrain. It was also expected that such technology could reduce the hazards involved in the hooking on and breaking out phases of cable logging.

In the earlier phase of this project an economic analysis showed that a camera system would be worthwhile if it resulted in a small reduction in average grapple time (Evanson and Parker, 2011).

The aim of this project was to develop and test a vision system to reduce grappling time. Two systems were developed in parallel:

- Part 1: a three-camera system with options for cameras positioned on the hauler, the mobile tail hold or the forest cutover was developed by Scion.
- Part 2: a rigging-based camera system, developed by Trinder Engineers of Nelson.

Both systems were developed because camera locations on and off the rigging each had advantages. This report describes the Scion-developed system.

Objective

The objective of the project was to improve the hauler operator's view of the grappling area through the use of a camera system.

Methods

1. Design and build a prototype camera system.
2. Field test the prototype system (alpha prototype).
3. Modify the system on the basis of the results of field testing (beta prototype).
4. Obtain support from a third party engineering firm to produce and market the hauler vision system on a commercial basis.

System Design

A three-camera system was considered to provide hauler contractors with options to “mix and match” whereby any combination of one, two or three cameras could be used to provide the best views of the operation. This three-camera system consisted of:

- a cutover-based camera,
- a hauler-mounted camera, and

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- a tail hold-mounted camera.

The locations of the three cameras were chosen to cover variations in terrain profile encountered during harvesting. For example the best view of the front face is provided by the tail hold camera and the back face by the hauler camera, while gullies and blind areas are covered by the cutover camera.

Digital Internet Protocol (IP) cameras manufactured by Axis were chosen, and communication was over a 5GHz 802.11n wireless LAN. The 5GHz frequency had the following advantages:

- The risk of interference with 2.4 GHz equipment such as the rigging camera system developed by Trinder was reduced.

- Higher frequencies enable high data rates.

The main disadvantage of a high frequency (5 GHz) is that line-of-sight was required because forest is relatively opaque to high-frequency communications (Hacker Friendly LLC, 2007[15]).

Video was streamed via RTSP using motion JPEG encoding. The main advantage of this choice of codec was minimal latency. Low latency was very important for a real-time application, as delays will impair the ability of the operator to work efficiently. The disadvantage of motion JPEG encoded video was lower compression than most other video codecs which limited the image resolution slightly.

Off-the-shelf software called Axis Camera Station was evaluated and found to be unsuitable due lack of configurability.

Instead, a user interface was developed on an Ubuntu Linux platform using Python, GTK and GStreamer. The software permitted digital pan, tilt and zoom, digital brightness adjustment and a mirror function. The brightness adjustment gave the operator an improved view of shaded gullies, and the mirror function facilitated grappling of logs when the camera was directed back towards the hauler.

Figure 1 shows the cutover camera system (with WiFi AP bridge and antenna at left).

Figure 1: The tripod-mounted camera in position in its protective housing.

A 14 Amp-hour 36 Volt Lithium Polymer battery was used for the cutover camera. The battery was located in a pelican case, together with the charger unit. All three cameras had DC/DC voltage regulators and fan-based cooling. One camera was tested for several hours in a Scion freezer and showed no evidence of condensation.

After smaller 15-inch and 17-inch screens were also tested, a 19-inch LCD screen was selected for the display. The display was mounted on an Ergotron wall-mounted LCD arm.

An Asus EEEBox PC running Ubuntu Linux was used to process and display the video images. Figure 2 shows the camera hardware prior to testing.

Figure 2: The Hauler Vision System showing (from left): Display, Tailhold camera, Tripod-mounted cutover camera and hauler-mounted camera.

Results of Field Testing of Camera System

Figure 3: The tripod-camera system in the cutover at Tuhoe Forest.

The tripod-mounted cutover camera system was field-tested in a Madill 123 grapple yarding operation owned by Andrew Wood of Tama Rakau Logging Limited (Figure 3). The operation was working in Compartment 473 of Tuhoe Forest, managed by PF Olsen Ltd. Table 1 shows the stand details for the trial site. The area being extracted was largely visible to the hauler operator.

Table 1: Stand Details for the Test Site

Planting year	1984
Stocking	226 stems/ha
Extracted piece size (butt pieces)	2.57 m^3

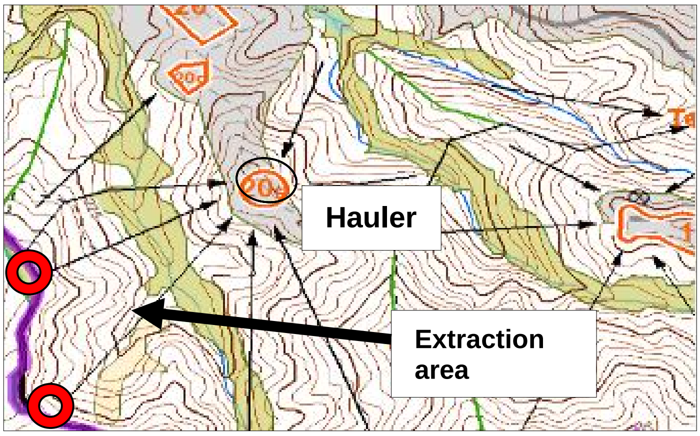

Figure 4: Map of testing site showing haul directions and camera locations (red circles).

Locations for the cutover camera are shown in Figure 4. The hauler was located on the pad in the centre, and haul directions are marked with arrows and camera positions are marked with red circles.

The LCD display was mounted in the operator's cab. The hauler camera was used in the initial stages of field testing but it was found to be less useful than the tripod-mounted cutover camera due to the direction of the hauler camera being fixed with respect to the cab of the swing-yarder. The tail hold camera was not used because the yarding system used stumps as tail holds which did not provide a suitable mounting position for the tail hold camera. Consequently, only the

tripod-mounted cutover camera was used for the evaluation.

The operator had about two hours to get familiar with the operation of the camera on the day prior to the evaluation.

Time study methods were used to evaluate differences in outhaul and grappling time. Video recordings were made of the grapple's operation, and times were measured directly from the recordings. Haul distance was measured using a laser rangefinder. The grapple time element started when the grapple tines first touched the stems to be extracted, and finished when the stem(s) started to move after being grappled. All grappling times recorded related to grappling from unbunched trees, lying as they were felled.

It was expected that the addition of a camera to the operation might have influenced both outhaul and grapple times. Accordingly, analysis of data collected focused on observed outhaul and grapple element times combined. Cycle times and haul distances were measured for 32 hauler cycles over the course of one day, 21 hauls using the camera and 11 hauls without the camera. Average haul distances were similar for these observations. A spotter was used in both situations, although there was little communication between the hauler-operator and the spotter when the camera was being used.

Results of combined Outhaul and Grapple element times are given in Table 2 and plotted against haul distance in Figure 5.

Table 2: Outhaul and Grapple Time Combined

	With camera	**Without camera**
Number of Observations	21	11
Average time (sec)	62.0	58.0
Average Haul distance (m)	201	202

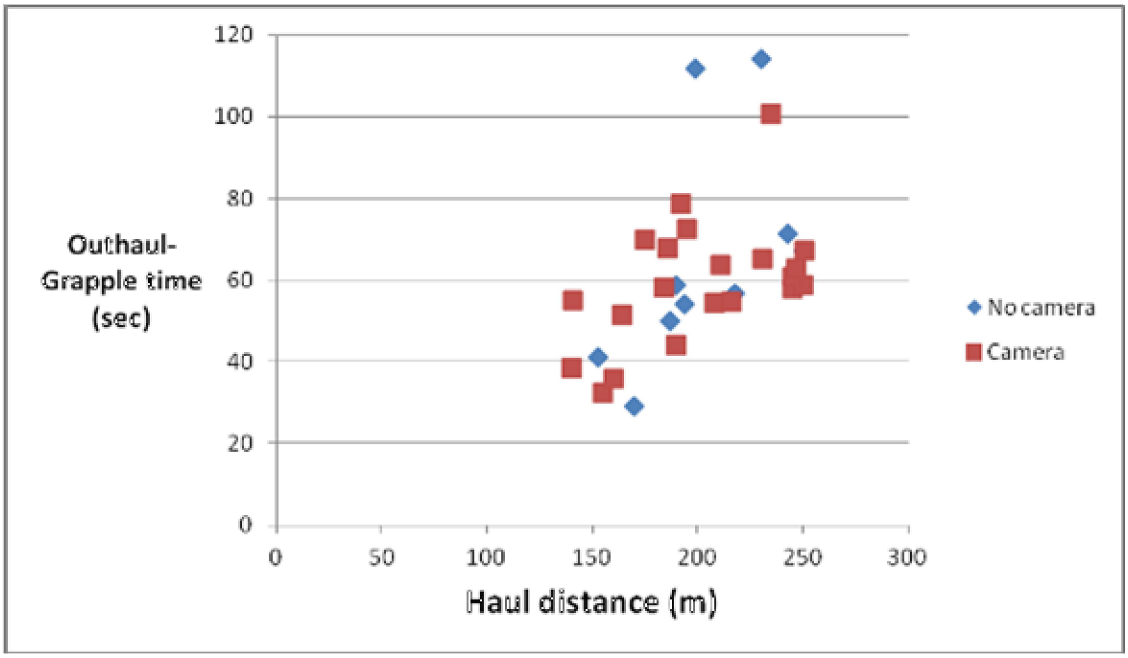

Figure 5: Plot of Outhaul-Grapple Times versus Distance

No significant difference was found in combined Outhaul-Grapple times between the use of the camera and without the camera. Figure 5 shows a lot of variation in the Outhaul-Grapple times, and also the sample size was too small to detect any significant differences using the camera.

The analysis was done using grapple times only. A total of 50 observations of the grapple time were made, 32 using the camera and 18 without (Table 3).

Average grapple times with and without using the camera were found to be not significantly different at the p>0.05 level.

Grapple times for different categories of grappling attempt (i.e. first attempt, second attempt) were also compared (Table 4).

Differences between average grapple times for first and second grapple attempts for camera, and no camera use were not significantly different at the p>0.05 level. There are indications that there may have been less variation in average grapple time (both first and second attempts) with camera use.

Table 3: Analysis of Grapple Time Only

	With camera	Without camera	Total
Number of Observations	32	18	50
Average time (sec)	27.1	30.2	28.2
Average Haul distance (m)	201	202	201.3

Table 4: Grapple Time by Attempt Category

	With Camera System			Without camera System			Total
	First attempt	Second attempt	Total with Camera	First attempt	Second attempt	Total without Camera	
No. of Observations	27	5	32	13	5	18	50
Percentage Attempt	84%	16%	100%	72%	28%	100%	
Average time (s)	27.5	24.9	27.1	30.0	30.9	30.2	28.2
Standard Deviation (s)	12.1	7.1	11.4	18.7	28.0	20.8	

Although the average grapple time showed no significant improvement with the use of the camera, the proportion of times the log was loaded at the first attempt was higher and the time taken to load the stem at the second attempt was on average faster using the camera system. The sample size of the study was too small to draw more definite conclusions.

Despite the measured grapple times the system was received favourably by both the hauler operator and the contractor; the operator said he found the hauler vision system to be useful and the contractor expressed a willingness to purchase a cutover camera system.

Table 5: Capital cost of Camera System

Item	Cost ($NZ incl. GST)
Screen	$ 559
Computer (incl. box)	$1,000
Wall Mount	$ 260
Antenna/Receiver	$ 254
Sub-total Display	**$2,073**
Camera	$1,250
Batteries/Charger	$2,400
Tripod/Backpack/Wiring	$1,556
Antenna/Transmitter	$ 263
Sub-total Camera	**$5,469**
Total Cutover Camera	**$7,542**

The capital cost for the tripod-mounted cutover camera system is shown in Table 5. Each additional camera would add approximately $2,500 (incl. GST) to the total cost.

Conclusions

A hauler vision system was developed that is an advance on the grapple-based cameras currently on the market.

The system consisted of a combination of up to three IP cameras, an LCD display and wireless communications hardware. A computer program was developed as a user interface.

The system was tested in an operational harvesting site at a cable logging operation at Tuhoe Forest. Results indicated:

- The small sample size of the study and large variation in the outhaul and grapple time failed to show conclusively the effect of the camera system
- Feedback from the contractor and hauler operator was positive.
- There was sufficient interest in the system to proceed to the commercialisation stage and to engage in continuous improvement of the product.

Reference

Evanson, T and Parker, R. 2011. “Advanced Hauler Vision System – A Feasibility Study”. FFR Report No. FFR-H006, 30 June 2011. Future Forests Research Limited, Rotorua, New Zealand.

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