HARVESTING TECHNICAL NOTE

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UNOBTRUSIVE WORK MEASUREMENT OF TREE FELLING

Summary

This project tested a new data collection system for measuring the productivity of tree fallers using chainsaws. Rather than use conventional time study work measurement methods, a novel data collection ensemble comprising two wearable video cameras was used to record tree faller activities. The results showed that multiple body-worn video cameras could provide a unique view of the activities of tree fallers without interrupting their work flow. In this short term study experienced tree fallers were twice as productive as inexperienced fallers. Both novice and experienced fallers looked up into the forest canopy for hazards frequently, but novice fallers looked up twice as frequently as experienced fallers. Further uses of video and other sensors for studies of harvesting tasks are discussed.

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INTRODUCTION

Tree felling operations were observed to determine the components of productivity of experienced and novice tree fallers. Traditionally, during work measurement studies of tree felling, the observer was required to follow the faller while they were working, recording the faller's activities and trying to remain in a safe position without getting hit by falling trees or debris, or the chainsaw. Often the observer, to be safe, retreated some distance away from the faller, which resulted in a poor viewing position and degraded research data. Also, it was often difficult to collect useful data from real work situations because the presence of the observer disturbed the normal work flow. This compromised results by introducing another hazard (the observer) of which the faller had to be aware.

Because motor-manual tree felling is a potentially hazardous activity, a new method of data collection comprising an ensemble of wearable video cameras has been developed by Scion.

The objective of the study was to gather baseline productivity data of manual tree felling as part of FFR's programme of steep country harvesting research.

METHODS

A short term production study was undertaken of eight full-time professional tree fallers working in seven different crews in various radiata pine forests in the central North Island of New Zealand. Of the eight workers in the study, three were experienced tree fallers with an average of 8.3 years' experience (SD = 1.5 years). The remaining five workers were novice tree fallers with 1.1 years' average experience (SD = 0.8 years).

Figure 1 - Tree faller wearing helmet and shoulder-mounted cameras

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The actions of each tree faller were recorded with two small (65mm by 20mm) colour PAL video cameras mounted on the tree faller's helmet and shoulder (Figure 1).

The video recorder and battery pack were carried in a pack worn on the tree faller's back. A microphone was attached to the right shoulder strap of the tree faller's backpack at the level of the collar bone.

All data collection was undertaken during the morning session (7am – 11am). The recorders were activated and the tree faller was then free to commence his normal activities and the researcher moved off site. Recording was continuous until the internal battery of the video recorder was exhausted (approximately two hours).

The work method involved tree felling with no delimbing at the felling face. Trees felled during each data-recording period were in both pruned and unpruned radiata pine stands. Detailed productivity-related information such as slope of ground, thickness of undergrowth, diameter of trees felled, direction of predominant tree lean and number and types of obstructions on the ground was not collected.

The researchers viewed the resulting video files four times: the first viewing coded task elements such as "top scarf", "bottom scarf" and so on; the second viewing coded the instantaneous work element "look up" which could be seen from the helmet camera image; the third viewing identified hazardous events (as defined in Table 1); and the fourth viewing was a check of coding accuracy at random points throughout the video file.

The type and frequency of hazards confronted by the tree faller was analysed from the video record. A situation was regarded as hazardous if an injury resulted or could have resulted had the faller been in a slightly different position relative to the hazard. This was a subjective assessment made at the time by the researcher experienced in tree felling.

The chainsaw sound recorded on the audio track was used as an additional cue to work element breakdown during the video analysis.

RESULTS

Ten tree fallers were selected for inclusion in the study. However the video results of two tree fallers could not be included in the analysis because of corruption to their video files due to an intermittent equipment fault.

The study was of a short duration (about 8 hours of useable video), approximately one hour of video per subject. The study did not capture a full day's work for each subject due to the limitations of battery power and video recorder memory.

Table 1 – Hazards of tree falling under normal operational conditions identified from previous studies (Ostberg,1980; Parker & Kirk, 1993)

Hazard	Description
Flying debris	Flying debris dislodged by falling tree and falling near logger
Comeback	Tree falling backward off stump
Drop start	Starting chainsaw by illegal drop starting method
Butt kick	Standing too close to butt of tree which kicks upward on falling
Wind / lean	Attempting to fell tree against a strong wind or severe lean
Eye	Dirt or wood chips in eye
Saw above	Using chainsaw above shoulder height
Into stand	Felling tree into standing trees
Over cut	Over cutting the back cut and tree falling sideways
Drive	Felling a tree by driving a second (or further) tree(s) on to it

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Table 2 – Productivity information for three experienced and five novice tree fallers

Faller	Experienced				Novice					
	1	2	3	Total	4	5	6	7	8	Total
Trees felled	30	23	33	86	11	8	12	18	12	61
Time[1](minutes)	52	28	45	125	33	52	29	48	33	195
Trees / hour	35	49	44	41.3	20	9	25	23	22	18.8

[1]Actual time engaged in tree falling excludes delays such as conversation with supervisor or walking to and from felling site.

Productivity

The average tree diameter for the total study was 41.0cm, and there was no significant difference between the diameter of trees felled by experienced fallers and those of novice fallers.

As expected, the experienced tree fallers were considerably more productive than the novice tree fallers (Table 2). The three experienced tree fallers were significantly more productive, felling an average of 41 trees / hour compared with the five novices who felled an average of 19 trees / hour ($t_6 = 4.46$, $p = 0.003$). The actual time engaged in tree falling excluded normal delays not associated with the tree falling task, such as refuelling, conversation with other workers or walking to and from felling site.

The task elements from the video files were presented in a time line showing the order in which each task elements took place (Figure 2).

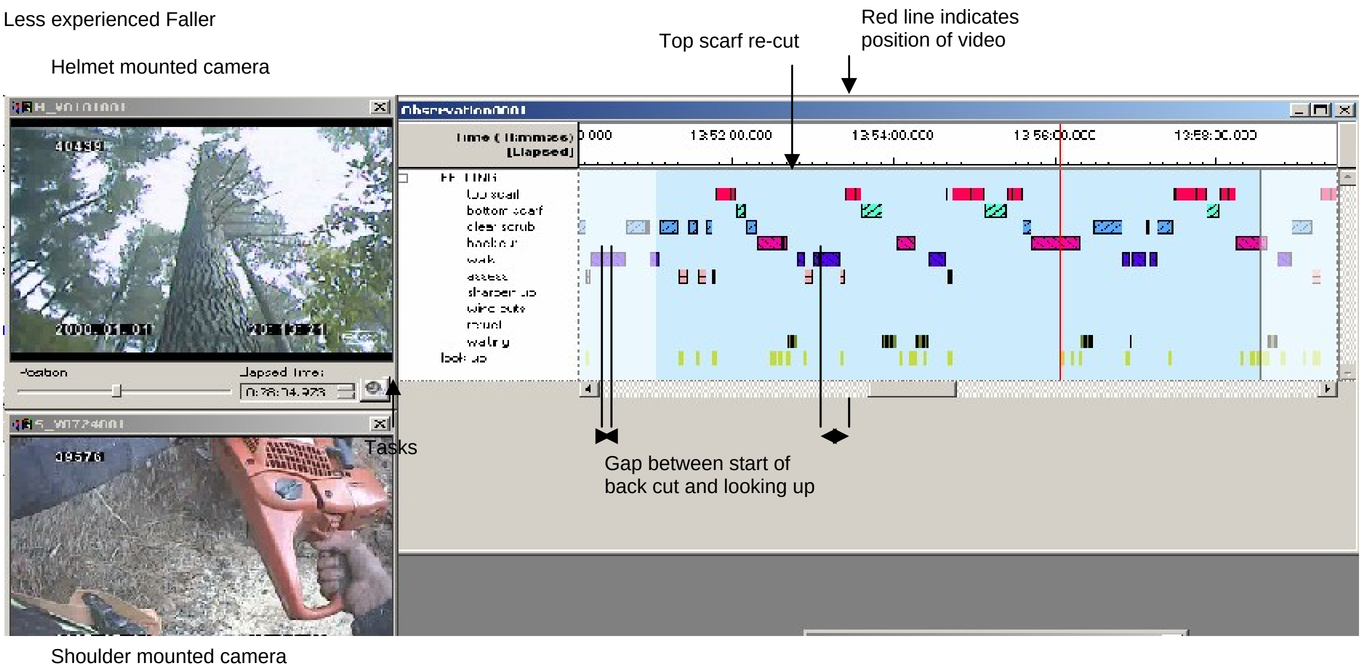

Figure 2 – Example time line of work elements for one novice tree faller

When timelines for novice tree fallers and experienced tree fallers were compared, novice tree fallers tended to have to do more rework of their felling cuts in order to match up the top and bottom scarf cuts and create a hinge for the tree to fall. It is important that the felling cuts are accurate for the tree to fall in the intended direction. In contrast, the experienced fallers tended to make the cuts correctly and did not have to rework.

There were no statistically significant differences in the proportion of time experienced or novice tree fallers engaged in each tree felling task. However experienced fallers tended to take a greater proportion of their time preparing the top scarf which is the first felling cut from which all other cuts follow (t_6 = 2.08, p = 0.08). Experienced fallers also tended to use a smaller proportion of their time waiting for the tree to fall or walking between trees.

Hazards

Vision is the primary sense used by tree fallers to locate hazards in the felling environment. Many of the hazards fallers are exposed to come from the forest canopy above, so the faller is frequently looking upwards. They also look up to judge the direction of tree fall. Tree fallers look at the lean of the tree, the distribution of branches, the direction of the wind and the presence of broken branches which may fall when the tree starts moving. The number of times the faller looked up at the tree being felled and the canopy of the surrounding forest was measured by viewing the video file from the helmet-mounted video camera.

Experienced fallers looked up 6 times per tree, which was significantly less frequently than novice fallers who looked up 15 times per tree (t_6 = -2.5, p = 0.04). This study did not identify exactly what the faller looked at or looked for in the overhead environment, but it is possible that because of their greater skill and experience the experienced fallers had a more efficient visual scanning process and were better able to identify potential hazards quickly.

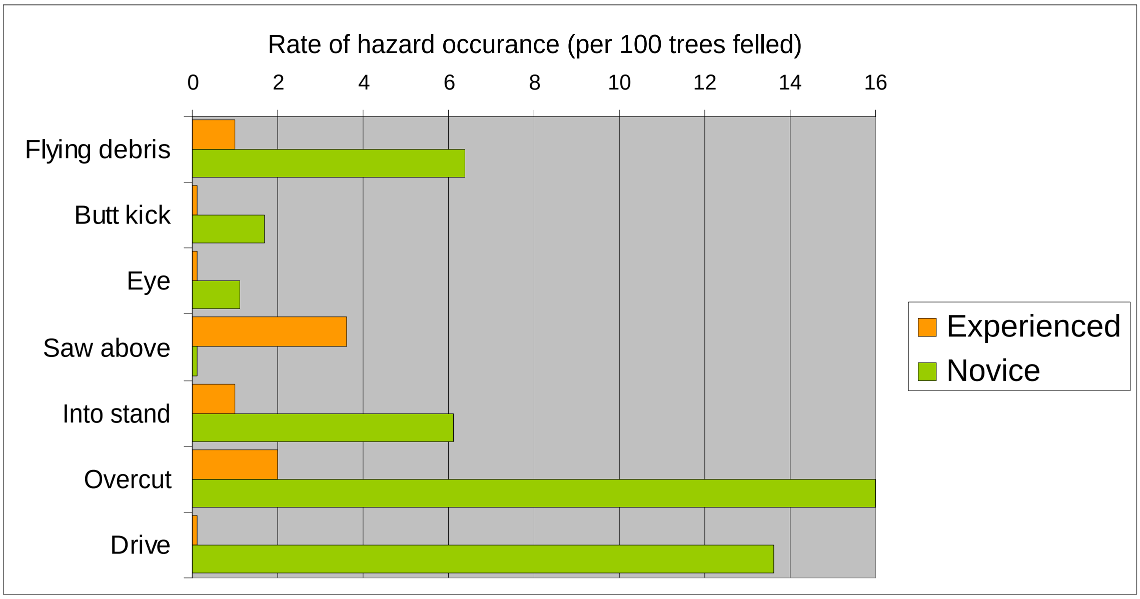

Figure 3 – Frequency of felling hazards (per 100 trees felled) for novice and experienced tree fallers

Figure 3 shows that the greatest difference in hazards between experienced and novice fallers was in "over-cutting the back cut – 16 trees per 100 felled by novices compared with only 2 trees per 100 felled by experienced fallers. Also, experienced fallers did not drive trees at all, while novice fallers drove 14 trees per 100 felled. Novices also felled trees into other standing trees more frequently than did experienced fallers.

DISCUSSION

Productivity

Tree felling is a highly skilled occupation. To reach a high level of productivity requires experience and the gaining of considerable skills as can be seen by the high productivity of the experienced fallers in this study. The experienced tree fallers were considerably more

productive than the novice tree fallers, felling 41 trees per productive hour compared with 19 trees per productive hour for novice fallers.

Using video analysis to create detailed timelines of the fallers' work elements enabled examination of their work flow. Experienced fallers in this study were faster at felling trees because they did not have to redo felling cuts. In contrast, novice fallers, who have less developed skills, used more time to place their chainsaw cuts and had to repeat some cuts.

Work Methods

The presence of an observer compromises the results of felling studies by introducing another hazard for the faller, who had to be always aware of the location of the observer before felling the tree. The presence of the observer also resulted in the faller's perception of "being watched" and also of pressure to perform either at a higher rate of work or at a higher level of skill than normal. For this study, miniature video cameras were mounted on the helmet and shoulder of each faller to monitor direction of gaze and use of the chainsaw respectively. Fallers stated that they soon forgot about the presence of the cameras and worked at a normal pace using normal practices. They also did not have to be aware of the location of the observer because they knew the observer had moved off site.

Hazards

Experienced fallers created fewer hazards than novice fallers by fewer over cuts, less frequent felling into standing trees and no occurrences of tree driving. In an earlier felling hazards study the most frequently occurring hazard during the felling phase was "driving" (Parker and Kirk, 1993). In that study both experienced and inexperienced loggers on average drove eight trees per 100 felled. In the current study, driving trees during felling was observed with novice fallers only (13 trees per 100 felled).

In terms of accident statistics over a twenty-year period (1968 to 1987) tree driving was the third greatest cause of felling fatalities (Gaskin, 1988). Based on this study (of eight randomly selected fallers), driving still appears to be a practice in common use, at least among novice tree fallers.

Detailed investigation of the tree fallers' direction of glance was achieved by examining the video record from the helmet-mounted camera. In addition to looking up to identify hazards, the faller will look up to watch the movement of the tree while inserting the back cut to evaluate whether the tree moves backward and wedges are required to keep the back cut open and to ensure the tree falls in the required direction.

The tree faller relies predominantly on vision to locate and manage hazards, and must therefore have a well developed visual situational awareness. In this study, both novice and experienced fallers looked up frequently into the forest canopy for overhead hazards and to determine tree movement.

Novice fallers looked up more than twice as frequently per tree felled as experienced fallers. The conclusion is that experienced fallers appear to be more efficient in their visual scanning than novice fallers. While it is not clear exactly what the experienced fallers looked at when they glanced up at the canopy, it is probable they were looking for potential hazards such as broken branches ("sailers") identified by changes in the normal pattern of tree branching. Use of a portable eye scanner would enable researchers to better determine what fallers look at when glancing up at the canopy.

Equipment

While the earliest known use of cameras for the study of work dates back to Frank and Lillian Gilbreth's ground-breaking micro-motion studies in the early 1900s (Price 1990), this is the first recorded use of multiple body mounted video cameras to undertake researcher-independent studies of the behaviour of tree fallers in such detail.

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The current study has resulted in an archive of 20 hours (28 GB) of raw felling video data. Of that, 8 hours of video is indexed second by second to work elements to enable detailed analysis of each tree faller's behaviour.

Unobtrusive video technology can be used successfully to improve accuracy and precision of tree felling time studies. One advantage of the cameras was the ability to analyse an event on the video file repeatedly until it was understood, and to get a better view much closer to the faller.

This study was of short duration due to limitations in battery power and video recorder memory size. Video results of two tree fallers could not be included in the analysis because of corruption to their video files due to an intermittent equipment fault. Work is currently under way to develop a system which will successfully record for eight hours.

Other Applications

By combining video records with other sensors, such as heart rate monitors, GPS receivers or on-board machine monitoring systems, new training methods and materials could be developed. For example, skidder operator technique could be investigated – to demonstrate best practice techniques – by mounting a GPS receiver on the machine to record location and a video camera on the operator's helmet to record direction of gaze. Both data streams could be synchronised and presented as highly visual training material with reference to the terrain being traversed by the skidder. Similar methods could be used for improving breaking out techniques by demonstrating how two or more breaker outs could work more productively together.

CONCLUSION

Unobtrusive video technology has been shown to be used successfully to undertake accurate time studies of harvesting operations. Wearable video cameras offer researchers a unique perspective on the work pattern of a tree faller. The ensemble does not interfere with the faller's normal methods, and offers a safe way to observe hazardous work. The video material produced can be edited to ensure anonymity of the worker, and can be subsequently used in undertaking hazard analysis or developing video training materials.

On-going developments of the video system involve correction of equipment faults and increasing battery life and memory size, which will enable 8 hours of continuous recording.

Further studies of other harvesting operations using the unobtrusive work measurement equipment are planned.

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