HARVESTING TECHNICAL NOTE

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Capturing decision making during log fleeting operations

Summary

Forestry excavator-based loaders are used to move and sort logs (fleet) onto log stacks in preparation for loading on to log trucks. The task is performed under time pressure to keep up with the production of logs on to the landing and to move them to the appropriate log stack. Decision making in these operations occurs at high speed under uncertain conditions. Operators must consider numerous cues from the environment and production pressures when decision making. All decisions have safety, productivity, and quality consequences. This report summarises initial measurement of the decision making of the operator of an excavator-based forestry log loader during log fleeting operations. This work has demonstrated that head mounted video recording and subsequent task analysis and retroreflective interview techniques give a detailed understanding of the machine operator's work under normal operational conditions.

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Introduction

Recent analyses conducted of forestry landing-related injury data from the Incident Recording Information System (IRIS) showed that the number of injury incidents (lost time, medical treatment and minor injury) has declined over the five year period to December 2018 – a trend likely due to the increase in industry mechanisation (Parker, *et al*. 2019).

Such advances have been a key driver for increasing productivity, safety, and sustainability across the forestry value chain. The Primary Growth Partnership (PGP) programme, *'Te Mahi Ngahere i te Ao Hurihuri – Forestry Work in the Modern Age'*, aims to scale and augment this evolution with pioneering automated systems (FGR, 2018).

As part of the PGP programme, Scion's Human Factors group has been exploring and extending research that will guide engineering design of new technology to improve the operator experience, productivity and safety thereby enhancing human-machine interactions (FGR, 2019).

There are many features of the forest environment that make technological advancement challenging. It is often difficult to collect useful data from real work situations because the presence of the researcher can disturb the normal flow of work. Furthermore, high risk workplaces can introduce unacceptable hazards to participants and researchers alike. An example is the log fleeting operation where logs are cleared from the log processing area, sorted and stacked using a knuckle boom excavator-based loader (Figure 1).

Figure 1: Excavator based loader fleeting logs

Knuckle boom excavator loaders are used to fleet (pick up, manipulate, rotate, sort, put down) logs because they have the power to lift logs weighing up to two tonnes each. The excavator boom has an extended reach of up to nine metres and can lift logs onto log stacks or onto truck or trailer units that are over four metres high. A grapple is attached to the boom with a hydraulic rotator allowing the operator to control its orientation. The body of the excavator is mounted on a rotating swing base attached to the track frame. Skilled operators can move all five degrees of freedom at once – swing base, lift boom, extend stick, rotate grapple and open/close grapple.

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In tasks like this, unobtrusive data collection methods are required. These methods must be relatively inexpensive, simple to administer and provide data in a form that is easily analysed.

Kirwan & Ainsworth (1992) identified three levels of intrusion by researchers on a participant. The lowest intrusion level, 'observer unobserved', is video analysis, where the researcher is completely removed from the workplace. The second level is 'observer observed' where the researcher is located at the operation and the personnel being observed are aware of their presence. At the greatest level of intrusion is 'observer participant' where the researcher takes part in the tasks alongside those being observed.

The aim of this study was to observe log handling activities to establish the work practices and decision making of experienced loader operators fleeting logs on the landing. This task may one day be automated and/or performed by robotic technology that will need to replicate the decision making of a human operator.

To gain a better view of forest workers' activities, a video camera was mounted on the loader operator's head (Figure 2).

Figure 2: Loader operator with head mounted video camera

This study technique corresponds to the second level of intrusion ('observer observed') using wearable technology. Video cameras are now small enough to be attached to the body or to clothing unobtrusively. Wearable video (body cameras) provide a new perspective on how work is done. The wearable video camera is a proxy for the researcher 'sitting on the shoulder' of the wearer - although the output is monocular with a field of view typically less than the human eye.

Head-mounted video cameras have been used to monitor the visual attention of forest workers (Hammond, Rischitelli & Wimer, 2011), rural fire fighters (Parker *et al.*, 2017), sports persons such as orienteers (Eccles, Walsh & Ingledow, 2006) and in the workplace, such as to study clinical reasoning of occupational therapists (Unsworth, 2001). There has also been extensive use of miniature body-mounted video cameras in animal behaviour studies over the last three decades (e.g. Parrish *et al.*, 2000).

Method

Data Collection using Wearable Cameras

The direction of gaze of the machine operator was recorded with a Garmin Virb XE compact, waterproof HD action video camera worn on his head. Video was recorded at a resolution of 1080p (high definition), a rate of 60 frames/second and with recorded sound. The purpose of the study was explained to the operator and the camera fitted to his head. The operator was then free to commence his normal activities. The researcher then left the immediate vicinity of the operation and retreated to a safe observation area approximately 100m from the machine. Recording continued for 30 minutes of normal operational activity.

Coding Analysis

In the laboratory, a coding scheme was set up using the behaviour observation package BORIS, a free, open-source and multi-platform standalone programme that allows a user-specific coding environment to be set for a computer-based review of previously recorded videos or live observations. The programme allows a project to be defined, such as a video of a loader operation that can then be shared with collaborators (such as the loader operator). Using a list of activities (or time elements), coding can be performed using previously assigned keys on the computer keyboard. BORIS allows definition of an unlimited number of events. Once the coding process is completed, the programme can extract a time-budget or single or grouped observations automatically and present an at-a-glance summary of the main behavioural features.

The coding scheme used the elements described in Table 1 (Friard & Gamba, 2016). The elements were derived from observation of log fleeting operations and discussion with operators.

Table 1: Elements used to describe log fleeting activities.

Element	Event Type*	Description
Swing Empty	State	Swing boom with empty grapple
Grab Logs	Point	Pick up log(s) with grapple
Swing Loaded	State	Swing boom with log(s) in grapple
Release Logs	Point	Release log(s) with grapple
Travel	State	Machine moves to a new location
Tamping	Point	Lining up the ends of the logs in the stack with the grapple

**A state event exists for a period and a point event is instantaneous.*

The video file recorded from the head-mounted camera was imported into BORIS. Coding of the video file into an event log file was performed using the BORIS observation window (Figure 3).

The play speed and direction of the video file could be controlled with the BORIS interface enabling repeated views of an event. The playback controls of the BORIS observation window were used to start, stop, rewind, and play the video multiple times to ensure coding of tasks was accurate. The whole video file was coded, and the codes saved in a synchronous event log.

Figure 3: Video view from head-mounted camera

Results

Task Element Analysis

Experienced loader operators can manipulate logs with a high level of dexterity. The multiple movement functions of the loader (such as rotating the machine base, extending the stick, rotating, and opening the grapple) can be performed simultaneously by the operator creating synchronised smooth and productive movements (Table 2).

Table 2: Example of 8 task elements performed in 34 seconds

Events for "1" observation

	time	subject	code	type
1	00:00:10.498		release logs	
2	00:00:10.650		release logs	
3	00:00:14.678		grab logs	
4	00:00:14.680		grab logs	
5	00:00:19.652		release logs	
6	00:00:19.655		release logs	
7	00:00:21.905		swing empty	START
8	00:00:22.402		swing empty	STOP
9	00:00:27.967		travel	START
10	00:00:28.179		travel	STOP
11	00:00:30.905		grab logs	
12	00:00:31.962		grab logs	
13	00:00:35.416		swing loaded	START
14	00:00:35.417		swing loaded	STOP
15	00:00:44.400		release logs	

The task elements from the video file were presented in a timeline demonstrating the order tasks were undertaken. An additional task of extending and retracting the loader stick was difficult to determine from the video and therefore excluded from the analysis.

Loader Operator Reflection to Increase Research Understanding

Reflecting on the loader operation allowed increased understanding by the researcher of the operator's point of view. A few days after field data were collected the loader operator viewed the video data on a computer monitor at his home, in the presence of the researcher. The loader operator controlled the viewing (start, stop and rewind) allowing him to comment on features of interest and point to them with the mouse cursor. A microphone was used so that the explanation of what was happening in the video clip could be accurately captured on audiotape.

Discussion

Knuckle boom loader operation is a high-speed operation. Greater experience results in greater levels of dexterity and consequently, greater productivity. This study attempted to characterise the tasks involved in fleeting logs with a knuckle boom excavator-based loader. Simple observation or time study of machine operators does not result in an understanding of why operators use the machine the way they do.

The presence of an observer in the cab would have compromised data integrity by disrupting the normal flow of work of the operator. The presence of the observer would have also resulted in the operator feeling 'watched' and therefore pressured to perform either at a higher rate of work or at a higher level of skill than normal.

For this study, a video camera was mounted on the head of the operator to monitor direction of gaze. The observer then retreated from the immediate work area but could observe the operation from 100 metres distance. The machine operator stated that he soon forgot about the presence of the camera and observer and worked at a normal pace using standard practices. Another advantage of the camera was its ability to enable analysis of an event on the video file repeatedly until it was fully understood.

The BORIS behaviour observation software used to create a task analysis of the machine operator's actions worked well. The task analysis quantified the fast rate of operation of the controls, but without further enquiry it was difficult to determine why certain tasks were being performed. For example, tapping the ends of logs in a stack to get them lined up neatly for loadout. The retrospective reflective interview of the operator provided a greater level of understanding of the work. The operator could watch a video recording of his work and, with prompting from the researcher, comment on the reason for the activities occurring. These audio comments were overlaid on the video file.

The wearable video camera, retrospective reflective interview and subsequent task analysis proved to be a reliable method to collect detailed information on the work method and decision making of the operator of a log loading machine engaged in the task of fleeting. A similar method was used by Parker *et al*. (2017) to understand the work of rural fire fighters fighting fires in real, hazardous situations where it would be difficult (and dangerous) to collect data as an observer.

Conclusions

Use of wearable video cameras offers researchers a unique perspective on the work pattern of a loader operator in a harvesting operation. The ensemble did not interfere with the operator's normal methods, providing a safe way to observe hazardous work. The video material produced can be viewed repeatedly, edited to ensure anonymity of the operator, and further developed (with voice-over) subsequently for use in training materials.

This study is part of a long-term programme, with much more to be done in collaboration and partnership with sector stakeholders, researchers and innovators, and technology developers and

manufacturers. Such collaboration is a key element of the PGP programme and will continue to guide the effective use and adoption of new technology across the New Zealand forest industry.

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