FUTURE FORESTS RESEARCH

HARVESTING TECHNICAL NOTE

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PERFORMANCE DATA FROM WEARABLE DEVICES

Summary

Equipment and methods have been developed enabling performance data collection without disturbing or inhibiting individuals working in dangerous conditions. The results of the study have shown that through triangulation of novel combinations of recording instrumentation, rich interpretative insights can be gained into the working world of the tree faller and rural fire fighter. This in turn enables the development of practices designed to minimise or avoid physical risk to the worker. Furthermore, the annotated video collected in the forests and at fires can be utilised as an authentic resource for effective training of both workers and trainers.

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INTRODUCTION

This study investigated work activity in tree felling and rural fire fighting. The study had four aims: first, to record, measure and understand the work (including physiological workload) of people engaged in dangerous occupations; second, to understand how hazards were identified and dealt with by individuals working in extreme conditions; third, to gain insight into hazardous work environments for the purpose of enhancing training for personnel working in dangerous conditions; and fourth, to explore the use of new technologies in facilitating field study of people engaged in dangerous work situations without disrupting the work or adding to the danger.

Detailed results of the productivity and hazards confronted by tree fallers were presented in an earlier FFR Technical Note (Parker, *et al*. 2009a). Rural fire fighting was studied because it demonstrates how heart rate and location data (GPS) data can be integrated with video.

This current work was part of a PhD study to investigate work activity in tree felling and rural fire fighting. This Technical Note details how the performance data were collected and brought together in a useful integrated form studying both tree felling and rural fire fighting.

MEASUREMENT TECHNOLOGIES

Charles Babbage (1791 – 1871) was a pioneer in the observation and quantification of work (Lewis, 2007). In his book "*On the Economy of Machinery and Manufactures*" (Babbage, 1832) he provides the reader with a guide for conducting a meaningful 'plant tour' and "[his] guide comprised a set of structured questions" for the investigator (Lewis, 2007 p. 258). For example Babbage (1835 XII, p. 117) states that: "care should be taken: for instance, if the observer stands with his watch in his hand before a person heading a pin, the workman will almost certainly increase his speed, and the estimate will be too large." Thus, even in 1835 the presence of an investigator was seen as potentially biasing studies of work.

Timing

Initially, work was measured by observation and subjective judgment. Later, spring-powered clocks were used to time the duration of tasks. Next, ciné film was used to record work with a clock displaying seconds with a sweep hand in the field of view. Another innovation came about when a grid was placed behind the worker to allow easier measurement of the range of motions of the subject's body (Price, 1990).

Heart Rate

The technologies mentioned above were all related to timing and recording work movements. The reactions of the body to work could not be measured other than by manual palpation of the heart pulse.

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The Dutch physiologist Willem Einthoven developed the first electrocardiograph (ECG) in 1903 and subsequently was recognised with the Nobel Prize in Medicine in 1924 (Kligfield, 2002). Building on this development, a 'portable' version of the ECG, the Holter-monitor, was developed which could make a 24-hour recording of an individual's ECG on a tape (Holter, 1961). However, the device was large and heavy and could not be used easily when people were moving freely (Achten & Jeukendrup, 2003). The first self-contained, wearable recording heart rate monitor was developed in 1978 by the Polar Electro Company in Finland (Laukkanen & Virtanen, 1998). Over subsequent years, refinements in electronics and software have resulted in a vast range of wearable heart rate recording devices by numerous manufacturers.

Video
Ciné cameras and film for the study of work were superseded by video in the 1970s when video cameras and recorders became available to the consumer.

The greatest technical developments, which have been pivotal in field research, are the wearable miniature video camera (e.g., Mann, 1997) and the ability to record video to flash cards (e.g., Parker *et al.* 2009b). These developments have allowed people to wear a video camera and recorder during their normal work. A bullet camera is a small light weight video camera which is attached to a video recorder by a cable. The video recorder can record up to eight hours of video at 25 frames per second, and batteries power both the camera and recorder for up to eight hours of recording (e.g., *LawMate PV-500* device).

GPS
With the commercial development of Global Positioning System (GPS) receivers, the investigator has numerous options to select from to track and record the movements of people over terrain. Many software packages have been developed to decode and present GPS data in useful ways. The most recent has been the integration of GPS data into *Google Earth,* where the path of a subject can be viewed with a three-dimensionally rendered terrain model. It offers the capacity to overlay high resolution aerial photography over the *Google Earth* terrain model to create an almost photo-realistic image of the terrain which can be viewed from any angle.

INTEGRATION OF DATA

Background
Occupational health investigators have embraced video technology since the mid-1980s. A prominent use of video technology is video exposure monitoring, which involves the combination of real-time monitoring instruments, usually for gases/vapours and dust, with video of the worker's activities (Rosén, *et al.* 2005).

When used for task analysis, video exposure monitoring allows the investigator to determine exactly what task the subject was engaged in and the associated exposure concentration. For example, a study of glass fibre reinforced plastic application in waste water tanks showed 46% of the total exposure to styrene was explained by activities undertaken in only 10% of the working time (Andersson & Rosén, 1995).

Visual exposure monitoring supplies solutions, and a way to test those solutions, to occupational exposure problems. Rosén (2002, p. 4) stated in his invited editorial in the *Annals of Occupational Hygiene* that "Visualisation acted as a catalyst for productive communication between process experts and occupational hygienists, and became the key to a systematic problem-solving process."

Non Intrusive Productivity and Performance Analysis

At Scion a method was developed to combine data from multiple video cameras and other sensors into a format that could be analysed and presented in a way to 'relive' the experience of the worker – NIPPA (non intrusive productivity and performance analysis).

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The NIPPA system was developed to record the work of tree fallers and rural fire fighters. Tree fallers generally work within a small area because they are felling all the trees in that area and work alone. Video was sufficient to collect rich data for quantitative analysis. In contrast rural fire fighters frequently change location, work with others and undertake a range of varied tasks, so video recording was supplemented with heart rate monitoring and GPS location monitoring.

The tree fallers were fitted with two small video cameras, one on the helmet which provided a view of what they looked, and another mounted on the shoulder which gave a view of the tree faller's hands and chainsaw.

Rural fire fighters were fitted with a helmet-mounted camera, a GPS logging device attached to their backpack shoulder strap and a hear rate monitor worn under the shirt.

Data Handling and Analysis

A coding scheme was set up in the observational data manipulation software *Observer XT* (Figure 1). Elements for the categories were derived from observation of logging operations and discussion with forest workers. Next, the video files recorded from the helmet- and shoulder-mounted video cameras (tree fallers) or single helmet-mounted video camera (fire fighters) were imported into *Observer XT.* For tree fallers the two video files were synchronised in *Observer XT*. For fire fighters, the corresponding heart rate data file from the heart rate monitor was imported and synchronised with the video data. Coding of the video files into an event log file was performed using the *Observer XT* software. Playback speed and direction of the video file could be controlled with the *Observer XT* interface enabling repeated views of an event to ensure accurate coding. Once the whole video file was coded, the codes were saved in a synchronised event log. Because video files took up a large amount of computer memory (1 Gb/hour) they were analysed in files one hour long. A log file containing a sequential list of tasks performed by the fire fighters and their time of occurrence was generated from *Observer XT* and converted to a comma-separated value (CSV) file. For fire fighter data, the CSV file was imported to *MicroSoft Excel* and the tasks were matched with the heart rate file and subsequently analysed in Minitab 13.1. Tree faller video data were analysed to determine, for example, the time taken to perform various tree felling tasks and the number of trees felled per hour.

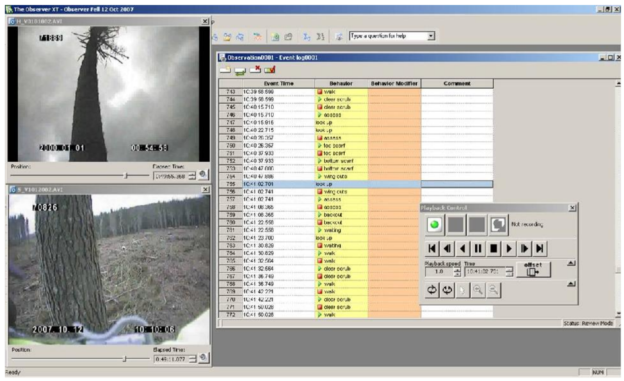

Figure 1 - Observer XT observation window used to code activities. The top image on the left side of the figure is from the helmet-mounted camera and the bottom image is from the shoulder-mounted camera.

RESULTS

To show how integrated performance data can be presented, results from both tree felling and rural fire are presented below.

Tree felling

Detailed productivity and hazard exposure results have been reported earlier (Parker, *et al*. 2009a).

The task elements from the video files were presented in a time line showing the order in which each task elements took place. When timelines for a novice tree faller (Figure 2) and an experienced tree faller (Figure 3) were compared, novice tree fallers tended to have to

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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. In contrast, the experienced fallers tended to get the cuts correct and did not have rework.

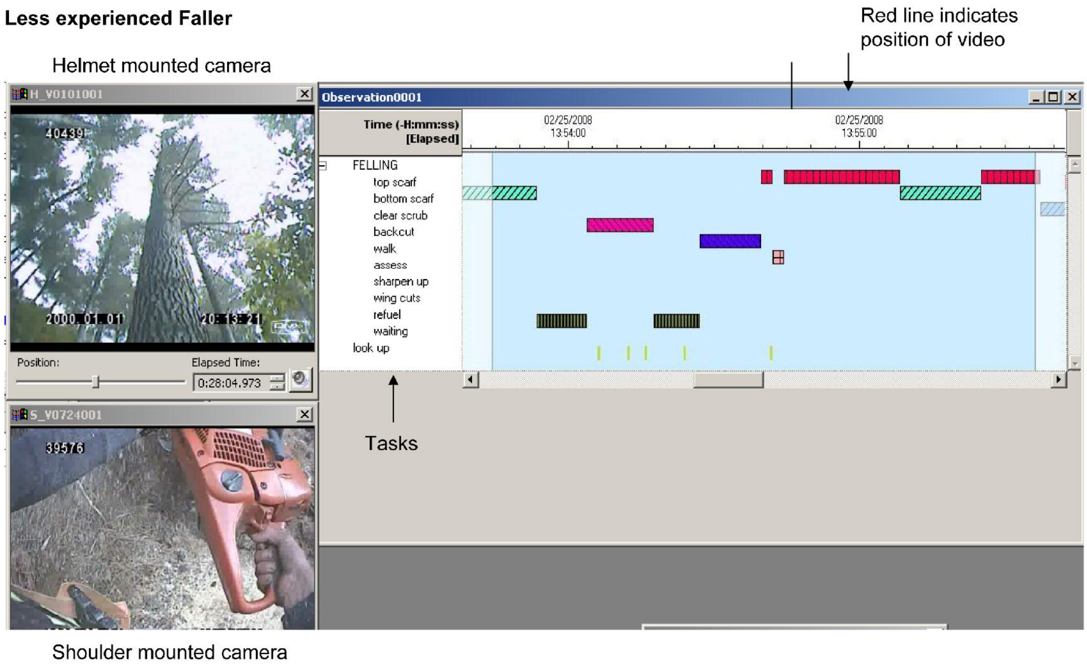

Figure 2 - Time line of task elements for a novice tree faller. Note the recutting of the scarf – red bar at the top of the Figure.

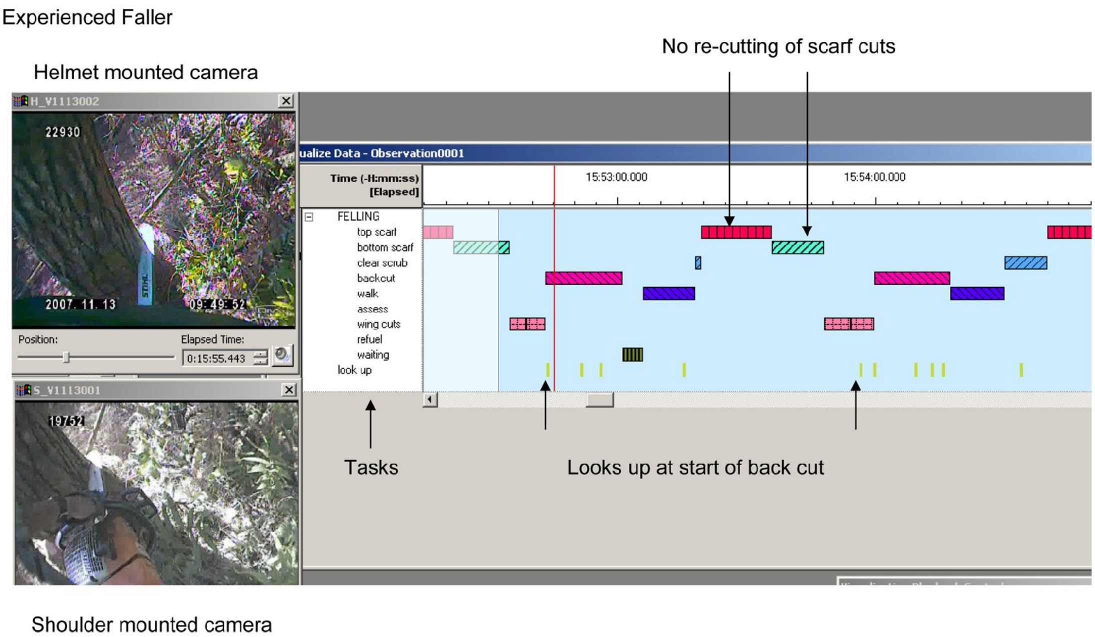

Figure 3 - Time line of task elements for an experienced tree faller.

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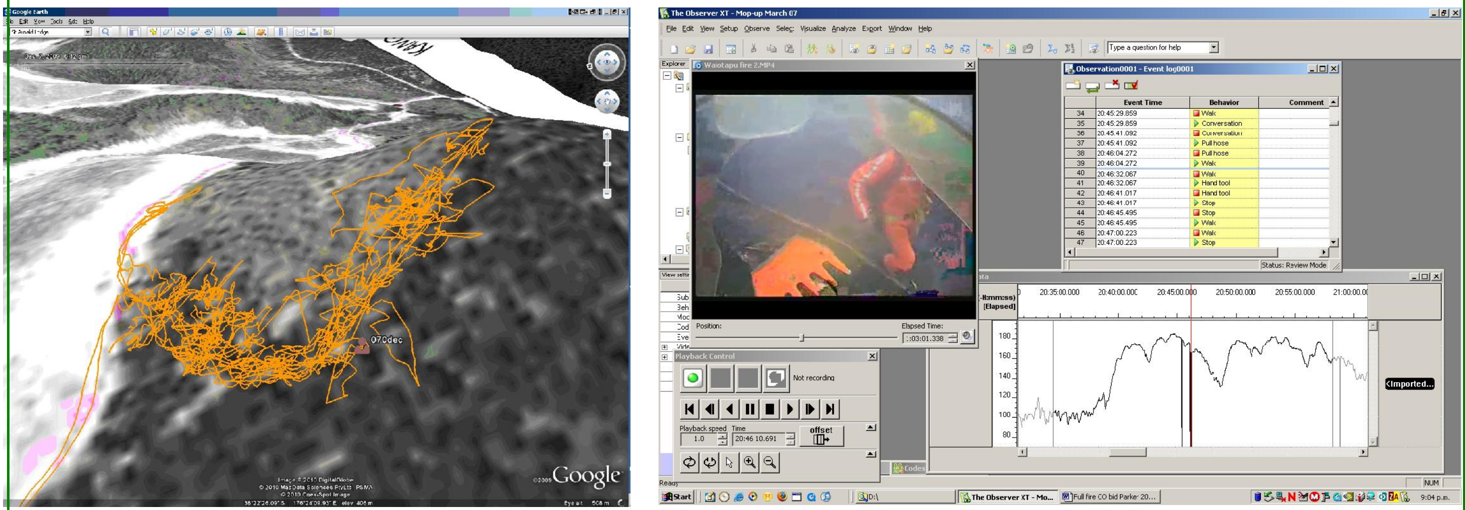

Figure 4 –View seen on two computer screens of the synchronised and animated integration of data from a rural fire. On the left screen is the moving position (icon) of the fire fighter's path using Google Earth. On the right screen is his helmet video image, audio, his heart rate and task analysis displayed on Observer XT. The icon on the left screen moves across the terrain in synchrony with the video and heart rate on the right screen.

Rural Fire Fighting

Using the integrated data collection system, a high level of understanding of the fire fighter's work environment and responses to that environment have been developed. From the video images (Figure 4) it has been possible to determine that the fire-fighter is walking while carrying a McCloud hand tool, he has been talking to another fire fighter about hoses, the air is thick with smoke, the terrain is loose dirt and burnt vegetation and the noise from helicopters flying overhead can be heard. The other sensors determine that his heart rate is 170 beats/minute, and he is walking uphill on a slope of approximately 30° at a speed of approximately 2 km/hour. In the past 5 minutes he has traversed 60m of ground.

The rural fire fighting example above shows how the activity of the fire fighter can be 'relived' on the computer. Harvesting operations could be analysed with multiple data sources and presented in a similar way. For example, the butt-rigging on a hauler could be fitted with a GPS logger, and similarly the breaker outs could wear GPS loggers and video cameras, and their movements in relation to the rigging could be investigated and presented in a visual form. A study is currently under way to record the activities of breaker outs.

CONCLUSIONS

This research study of the performance of people working in dangerous environments was enabled by the development of a novel ensemble of technologies and methods. The ergonomists were able to measure work unobtrusively in conditions which were too dangerous for the presence of a researcher. In the study of people at work it is important that normal working conditions and practices are not disrupted in order to get a true measure of how work is conducted. This working ensemble of technologies and methods was used to collect comprehensive data without interfering with the normal activity of the worker, and has been able to provide insights into the work practices of fire fighters and tree fallers.

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