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The Integration of Technology for Productivity Monitoring

Summary

The main research objective for the Future Forests Research (FFR) Harvesting Theme is to reduce harvesting costs by increasing productivity. To easily measure and monitor productivity in harvesting, improved systems must be made available to harvesting contractors. One of the initial projects in the FFR Harvesting Theme has been to research and in some cases develop new methods for monitoring productivity data and the factors that affect productivity. As part of this research effort over the past two years, six separate studies have been undertaken on different components of a productivity monitoring system. This paper investigates how these components could be integrated to form a cost-effective monitoring system for crew performance monitoring and research purposes. It also investigates the potential for modern satellite and cellular communication technologies for data transmission from remote logging sites.

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Introduction

The goal of the FFR Harvesting Theme's project "Real Time Productivity Data Collection" was to investigate and develop a suite of technologies to monitor logging productivity. As the well known quote, attributed to management guru Peter Drucker, goes: "If you can't measure it, you can't manage it." This quote indicates the importance, for both researchers and logging practitioners, of having the means to monitor accurately, and report on, productivity performance. The importance to the contractor of keeping good records for monitoring the performance of harvesting crews has been stressed over the years (Tombleson, 1988).

The key to developing a productivity monitoring system is integrating a number of existing measures to capture the major factors that affect productivity (Marshall 2009a). The key components for productivity are time (either measured in crew hours or man hours) and volume of wood extracted over that time (e.g., m^3/hour). Numerous productivity studies (Harper 1992a, Harper 1992b) and the FFR project in benchmarking cost and productivity (Visser 2009) have measured the key drivers for the productivity of logging systems. These include:

- piece size/payload;
- slope and other terrain factors;
- harvest system;
- average extraction/yarding distance;
- number of log sorts;
- operational crew configuration.

The requirement to measure and monitor logging productivity is shared by both harvesting researchers and logging practitioners, but the data resolution requirements differ significantly. Logging practitioners primarily need to monitor productivity on a daily or weekly basis. For logging practitioners it is important to understand changes and trends in productivity.

By understanding these trends, crew owners, managers and foremen should be able to better optimise crew performance. In rate-setting negotiations, logging contractors who understand the drivers that affect the productivity of their crews will be in a much stronger negotiating position than those who do not (Blackburne, 2009). Maxwell (1942) stated that the timing of operations is essential to all production and costs estimates. Researchers require higher resolution data allowing the determination of productivity changes due to changes in logging methods. Researchers are most often either trying to develop relationships to project productivity for future operations, or trying to determine whether work method is significantly better than another.

Historically productivity monitoring methodologies have suffered from being either too expensive or too inaccurate. Over the last two years of this programme a number of

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different elements and technologies have been investigated:

- Use of accelerometers to measure grapple openness as a way of measuring the payload of grapple skidders (Marshall & Evanson 2009);
- Magnet sensors for monitoring yarding distance on cable yarding/hauler systems (Evanson 2009a);
- Development of a Production Display Unit (PDU) for counting and displaying a piece count (Evanson & Tuthill 2009);
- A review of the Canadian built MultiDAT productivity data collection for use in New Zealand conditions (Evanson 2009b);
- Use a Sauer-Danfoss Controller in Haulers (Evanson and Henderson 2009);
- Use of tension monitors to estimate hauler payload (Evanson 2009c);
- Pre-installed machine monitoring system such as Komatsu Komtrax and Volvo Matris (Evanson 2010);
- Comparison of methods for estimating harvesting payload (Marshall 2009b).

The objective of this Technical Note is to discuss the possible integration of these technologies to enable both logging practitioners and researchers to collect accurate productivity data. There is also a discussion of the potential use of data communications technology for the transmission of information from remote logging sites.

Integration

There are numerous tools/sensors that could be integrated in a logging productivity monitoring system. If the information from different sensors is to be combined, it is important that data are time stamped, and that the timestamps from different sensors are synchronized. This programme has identified a number of systems that could be integrated to successfully monitor productivity for both business and research purposes.

Crew-Based Monitoring

The problem of measuring crew productivity is not new; the majority of New Zealand logging crews record productivity on paper, which can be unreliable and inconsistent. Canadian researchers at FERIC (The Forest Engineering Research Institute of Canada) developed the MultiDAT, a productivity data recorder for forestry machines. New Zealand-based trials, carried out as part of this programme (Evanson 2009b), showed that the MultiDAT is an effective tool for contractors to monitor machine utilisation. However, for more detailed analysis user input is required, which makes the collected data prone to entry errors. MultiDAT allows for extra external sensors to be added, such as GPS (Global Positioning System). The current cost in Canadian dollars (22/01/09) for the MultiDAT is upwards of $(CAN) 2,300-4,100 per unit. A major advantage of the MultiDAT is that it was developed specifically for the logging industry, hence it has been ruggedised to cope with the harsh working environment. The MultiDAT also comes with an analysis and reporting software package.

Many of the heavy equipment manufacturers that supply the New Zealand forestry industry with skidders, loaders and other heavy machinery offer some sort of onboard engine monitoring system. Evanson (2010) gives a brief overview of some of these systems, including the Volvo Matris, Komatsu Komtrax, Hitachi e-Service, Caterpillar Product Link and John Deere Link. Processors/Harvesters are also fitted with optimization computer systems such as the Waratah TimberRite, Dasa 4 system, Valmet Maxi Control System, Timbermatic 400, etc., which have the ability to monitor machine performance as well as production (Sondell *et al*. 2002). The main benefits of utilizing these systems are to maximize equipment utilization, monitor fuel consumption, improve maintenance and measure productivity (Evanson 2010). It is

the author's understanding that all of the Caterpillar hire fleet in New Zealand are fitted with the Caterpillar Product Link system. In fact the hours recorded by the onboard computers are used for billing as opposed to standard machine hours, which are recorded directly from the engine, as it is more accurate and less prone to tampering.

As part of this programme, researchers developed a low cost electronic piece counter (Evanson & Tuthill 2009) called the Production Display Unit (PDU) that can be used in both ground-based and hauler operations. The PDU is designed to record the number of pieces, categorized as either top or butts. It is currently being integrated with a magnet sensor system for measuring yarding distance (Evanson 2009a). The PDU does not currently store any data, but there are future plans to enable it to be connected to a data collection unit such as the MultiDAT. As the PDU was developed by SCION, additional development of functionality, such as the addition of a GPS unit, could be easily facilitated.

To identify trends and make effective management decisions it is important that the data collected by these measurement systems is stored and analysed. The FFR Harvesting Theme has developed a benchmarking system (Visser 2009) which comprises a website (www.foresteng.canterbury.ac.nz\survey) connected to a database. Currently the data analysis/benchmarking is carried out by Canterbury University at approximately 3-6 monthly intervals, but it is hoped that in the future "live" reports will be obtainable from the website. The system currently captures productivity at a harvest unit level; in the future this system, or a similar enterprise, could be adapted to allow productivity information to be entered at a daily level by contractors from a tool such as the MultiDAT or PDU.

Research

Recording logging operations by video (using multiple cameras), as described by Parker *et al*., (2010) provides researchers with the additional information required for research purposes that is not collected by tools such as GPS, MultiDAT and the PDU. Video allows researchers to carry out detailed time studies remotely. This allows them to quantify accurately the time taken to complete each task as well as the internal and external factors impacting on productivity.

Using video allows the collection of data from real work situations without disturbing normal work flow. In forestry, due to the *"dangerous conditions it can be impossible to collect such data because the presence of an observer introduces a hazard by dividing the attention of the worker, or the observer has to position themselves in hazardous locations to collect the data."* (Parker *et al*. 2010).

Parker *et al*. (2010) clearly demonstrated the effectiveness and practicality of using small video cameras to collect productivity data in forestry. Although videoing and then replaying the video at a later date has significant advantages over the traditional stopwatch style of forest production studies, this method has the disadvantage of requiring a researcher to watch hours of video. Parker *et al*. (2010) demonstrated how Noldus Observer XT[1], a software product designed for animal behavioural studies, can be utilized to extract manual tree felling productivity from multiple data sources, including video.

A small amount of research was carried out in this programme investigating the potential of using the readings from accelerometers placed on machinery (Marshall & Evanson, 2009). These readings can be used to divide the video into sections so the key tasks being studied could be extracted and studied without the analyst having to watch a whole video. GPS data could also be used to divide the video up into the key tasks. A useful software tool for increasing the cost effectiveness of research in this area would be one that could automatically segment video into logging tasks by using timestamp data from other sensors such as PDU, GPS, accelerometers or MultiDAT.

[1] http://www.noldus.com/

Data Communication

The "Holy Grail" in logging productivity monitoring would be the capability to continuously monitor productivity of a harvesting operation both remotely and from within the cab of any machine working in that operation. Historically, the major technical barrier to this was the lack of cell phone coverage at the majority of logging sites. The MultiDAT was originally designed for data transfer to occur via small PDA (Personal Digital Assistant), such as Palm[2], devices. FERIC have found this to be suitable for short-term improvement programmes, although over longer periods transmitting data using the above methodology becomes time consuming and costly. To overcome these issues FPInnovations-FERIC released the FPCom modem, which transmits MultiDAT recordings by satellite approximately every hour. Data are compressed so that communication costs are minimised (FPInnovations, 2008). In late 2008 at least one harvesting contractor had implemented the FPCom onto every vehicle in their fleet. To date this technology has not been available for companies outside Canada, but sources inside FERIC have indicated that this technology will be made available to organizations outside of the FERIC membership; hence it could available in New Zealand in the near future.

Most of the heavy equipment onboard monitoring systems such as Komatsu Komtrax, Caterpillars Product Link and Volvo Matris facilitate wireless communication. According to Robertson (200X) Matris and Komtrax are at the forefront of satellite-based monitoring. Local equipment suppliers will have more information on setting up these systems and whether remote communication is viable in a specific area. These systems offer users a wide range of information including vehicle tracking, performance and productivity.

There are number of companies that offer general GPS vehicle tracking system. A company called Vehicle Tracking Systems[3] offers a product that utilises GPRS mobile communication network or the Satellite Communication System. This provider's system can even be connected into the CAN-Bus (vehicle's internal communication system) allowing information such as vehicle weight, water and oil temperatures, engine revolutions and a number of other critical conditions to be transmitted from the vehicle back to a monitoring location (Vehicle Tracking Systems, 2009).

There are numerous satellite broad band providers in New Zealand that claim to have national broad band coverage. In late 2009 the monthly charge for satellite broad band was around $60. It is unlikely that transmitting productivity data would get close to the 1 Gb data limit of these plans, so the connection could be used for other purposes. The installation of satellite broad band would require a satellite dish to be installed. Having internet access on a logging site could have numerous advantages beyond the transmission of productivity data, such as improved crew communication via email, access to safety and technical manuals, etc. Nearly all modern Scandinavian harvesters have the ability to connect to the internet and access email remotely (Sondell *et al*. 2002). Although remote communication back to the office is important, the communication of the productivity of individual units/machines between members of the crew is advantageous. Individual crew members having the capability to monitor their own productivity would be a useful feature of the system. This could be achieved as simply as in the PDU example, where the number of butts and tops hauled per day is displayed.

Challenges

Payload or volume harvested remains the most difficult parameter to measure. When utilising a Waratah-like processing machine, crew productivity can be monitored using the onboard computer. However in most New Zealand

[2] http://www.palm.com

[3] http://www.vehicletrackingsystems.co.nz/

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harvesting situations the cycle or hourly volume extracted can be estimated only by counting the number of pieces. This is often done using pen and paper (Evanson & Tuthill 2009), but studies indicate (Marshall 2009b) that estimating productivity (m^3/hr) by multiplying the piece count per hour by the average pieces size is barely accurate enough to monitor crew productivity, and does not provide sufficiently detailed data for research purposes. A recent study (Marshall & Evanson 2009) explored the potential use of accelerometers to determine the payload of the grapple skidders. Although results were promising, the study concluded the method had limited use outside grapple skidders. A research paper (Evanson, 2009c) suggested that tension monitors could be used to determine payload, but these are rarely used in New Zealand despite their availability.

An additional challenge for the New Zealand forestry industry, particularly in steep terrain, is that much of the hauler fleet is old. Most of these machines do not have electronic control systems, making automatic monitoring of productivity difficult. Some hauler owners are now opting to refit old air-over-hydraulic controls systems with more reliable and responsive electric-over-hydraulic controls, thus providing the ability to capture electronic data on hauler productivity. An example of one such electric-over-hydraulic system being retrofitted on to haulers is the Sauer-Danfoss Controller (Evanson & Henderson 2009).

Finally, educating the logging industry on the importance of using productivity information to optimize harvesting efficiency remains a major challenge. The widespread acceptance of the use of productivity monitoring tools through the industry will represent a major advance, with the additional training required to use the tools a relatively simple process.

Conclusion

To increase productivity and reduce harvesting costs, the New Zealand forest industry needs methods which monitor productivity. The historical solutions of detail and shift level time studies are too inaccurate and costly. This FFR Harvesting Theme research programme has discovered that for logging practitioners aiming to monitor productivity there are a number of cost effective solutions available on the market, including the MultiDAT and PDU. The use of video in combination with data collected from other sensors such as GPS, on-board computers, MultiDAT, etc., offers a good solution for productivity monitoring for research projects. Small high resolution cameras with large storage capacity make the use of video an increasingly attractive tool for studying logging operations. Work is still required to develop software tools which integrate time stamped data from other sensors with the video to make video analysis less labour intensive. There are a range of options on the market for the transmission of productivity data from remote logging sites; the biggest challenge is finding a data collection tool with the ability to collate and transmit all available data.

A number of technological and educational challenges remain. The major technological challenge is to measure accurately payload or extracted volume. For those operating mechanical harvester/processors, the challenge of measuring extracted volume is overcome by using the volume calculated from the processing head. Crews that process logs manually are still limited to measuring the volume extracted using load-out dockets and stock estimation, or through using a piece count method.

The major educational challenge is to spread an understanding of the importance and potential benefits of performance monitoring throughout the forestry sector. Staff motivation is an important driver of productivity; as such an interesting future study in this area would be to understand how to best use productivity information to motivate both individual staff and harvesting crews to maximize efficiency. Despite these challenges, the potential gains from monitoring harvesting productivity are significant, and the continued development of improved cost and productivity monitoring systems is justified.

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