HARVESTING TECHNICAL NOTE

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Safety benefits of growing forestry technology

Summary

Tragically, accidents resulting in death and serious harm continue to plague New Zealand forestry workplaces, inflicting a huge financial cost on the economy and a devastating emotional toll on everyone affected. In forestry, the workplace is characterised by high operational demands and unpredictable conditions. The current solution is to integrate workers with machines to mechanise and/or automate hazardous, labour-intensive tasks. As our mastery of technological innovation evolves, such solutions have also expanded in complexity and simplicity. Now digital automation and robotics are being incorporated into forestry systems, driving more efficient operational processes and better outcomes spanning safety, accuracy and economy. This transformation is going to gain momentum as it produces viable responses to industry challenges.

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Introduction

Our ancestors harnessed early inventions, such as stone tools and machinery like the wheel, to simplify activities and broaden their physical capability to optimise survival. Throughout history, innovations augmenting human abilities have yielded fundamental shifts in industry. Take, for instance, the plough – a device that enabled man to exploit the strength of animals to increase agricultural output, allowing perpetually nomadic communities to settle. Nowadays, the speed of innovation development totally eclipses the experience of previous generations. To put this in perspective, consider the difference between the cell phones of today compared to those of merely twenty years ago.

Within the forest industry, we only need to consider the progression in tree felling technology over the last 50 years from axe to chainsaw to feller buncher (Figure 1) and grapple harvester to appreciate how fast this rate of change has occurred. Such technological advancement has not only been a key driver for increasing productivity, quality and sustainability across the entire forestry value chain, but also improved worker safety.

Recent analysis indicates there were a total of 185 landing-related injury incidents reported to the New Zealand forest industry Incident Recording Information System (IRIS) in the five years to December 2018 (Parker, *et al*. 2019).

The number of injury incidents (lost time, medical treatment and minor injury) has declined over this period, and is likely to be due to the increase in mechanisation on landings.

The new Primary Growth Partnership (PGP) programme, 'Te Mahi Ngahere i te Ao Hurihuri – Forestry Work in the Modern Age', is set to create a revolutionary automated forestry value chain to address the growth constraints and sustainability issues we face as an industry (FGR, 2018).

Figure 1: Feller buncher on steep terrain

Technology is currently being used to bridge the gaps between market demands, labour shortages and productivity requirements, while reducing environmental and safety impacts.

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As part of its mandate in this programme, Scion's Human Factors group has been exploring and extending research that will guide and enhance new human-machine interactions as part of this challenging work. A new project, entitled Cognitive and Physical Human-Machine Interaction has commenced to provide input to engineering design of new technology to improve the operator experience, effectiveness, productivity and safety (FGR, 2019).

This report explores how technological innovations, such as automation, robotics, virtual and augmented reality could improve the human-machine interaction in mechanised harvesting to reduce operator workload and fatigue, and increase safety and productivity.

People and Machines

One way to leverage today's rapid advances in technology is by amplifying the communication loop between the operator and the machine – an approach encapsulated in the Japanese phrase *Jinba Ittai*, describing the 'oneness between horse and rider'.

Figure 2: Mazda's cab becomes an extension of the driver

Automotive company, Mazda, capture this engineering ideology and put it into practice – most noticeably in their famously responsive sports cars, like the Mazda MX-5 (Mazda, 2020). Mazda's design philosophy is that just like the symbiotic relationship developed over time between a horse and rider—*Jinba Ittai*—driving the MX-5 feels like a natural extension of the driver (Figure 2).

In the context of forestry mechanisation, we are referring to 'human-machine interaction'. Forestry machines are not designed for style, they fulfil functions of power and tempo. More effective interaction between operator and machine, such as improved visibility and easy to read instrumentation, makes the work easier, faster, more enjoyable, and safer (Figure 3).

Figure 3: Operator cab with improved visibility and easy-to-read instrumentation

As an example, Liebherr have developed INTUSI, or intuitive user interface, a new piece of control technology that combines an intelligent user interface with sophisticated machine intelligence for construction and earthmoving machines (Figure 4).

Figure 4: The new Liebherr intuitive user interface INTUSI

The goal of the new technology was to create a future-orientated interface for machine operators

that would be easy to use (Liebherr, 2018). Such performance outcomes not only improve the operational landscape, but indirectly influence larger workforce issues, such as motivation, ease of recruitment, worker retention, and reduced labour turnover.

Through the Looking Glass

Recent improvements in sensor technologies and machine vision allow for the seamless transfer of sensory experiences between an operator and the machine. Biofeedback and haptic technologies provide the platforms to proactively manage safety and performance risks, such as fatigue and vehicle/pedestrian interactions, with novel approaches.

Harvester simulators already provide operators with a realistic way of learning machine functions In Scandinavia, forest machine operators are trained on simulators for a minimum of two years to a professional standard based on forest industry standards objectively monitored and measured through data driven metrics (Broadley, 2019). The John Deere TimberSkills software / cloud based training programme provides an independent training mechanism to train operators professionally to a consistently high standard (Figure 5).

Figure 5: User training on the John Deere TimberSkills simulator

Operators use information to accomplish daily tasks using machines. While much of this information can be found in manufacturer references and databases, on a fast-paced harvesting production site it is not helpful for the operator to know the as-designed parameters, they need to know the functionality immediately to accurately use or maintain their machine.

Augmented Reality (AR) and Virtual Reality (VR) systems provide a new way to enhance how machines and humans work together. AR is an extension of the real world, which adds something to the environment we see and interact with, while VR creates a brand new environment, which has no connection to the real one.

AR systems can be employed to communicate information in situ by superimposing data in the field of view for operators and mechanics. Head-up displays provide operators with information directly in the cab of the machine (Figure 6).

Figure 6: Harvester operator using a head-up display to access information

Research has shown this can reduce learning times, decrease errors and free up cognitive processing space for reacting to unexpected, safety-critical events.

It is becoming increasingly evident that we are moving towards in-moment visual learning using AR tools. The highly visual and interactive format is proving to be more effective for training than traditional text and video approaches. This aligns well with the forest industry's on-the-job apprenticeship format. The literature largely supports the view that expertise is implicitly learned over time.

As we move forward in the seven-year PGP programme in Automation and Robotics, we aim to identify, fabricate and test 'AR products' that allow for the implicit acquisition of knowledge and improvement of skills in parallel with machine development.

Another potential application for this technology is machine maintenance. Maintenance carried out in forestry currently requires transportation of the machine to a workshop, or a specialist mechanic to travel to an isolated site, a process that incurs additional costs. AR guided maintenance and instructional overlays have the potential to circumvent this problem, and assist in the further development of operator skills (Figure 7).

Figure 7: AR provides step by step instructions for repair and maintenance training

In alignment with the *Jinba Ittai* concept, AR can be used to make up for perceptual limitations and/or augment human abilities. An example might be to use AR vision to enhance precision-critical tasks, such as a loader operator configuring a truck load of logs. AR is fundamentally about allowing humans and machines to team together to achieve results neither could alone; a relationship that is becoming more and more critical to operational success.

Mind Control

Control mechanisms have evolved markedly over recent years. From simple levers and steering wheels to gaming-style joy-stick remote controls to voice-activated control systems to control by gestures and gaze (in current VR and AR systems), available technology has shaped these developments. Machines designed with greater human interdependence and a new era of transformative neurotechnologies will guide future innovations.

Advances in brain-computer interface (BCI) technology have given rise to applications including thought-controlled prosthetic limbs. While currently in early clinical trials, one such device 'BrainGate', based on pioneering research from a number of universities, has demonstrated that the neural signals associated with movement intent can be 'decoded' in real-time by a computer and used to control external devices, such as wheelchairs and prosthetic limbs (Murray, 2018).

Elon Musk's neurotechnology company, Neuralink, is developing implantable brain-machine interfaces to enable an operator to control computers with their mind. The goal is to eventually begin implanting devices in paralyzed humans, allowing them to control phones or computers (Lopatto, 2019).

The proposed future technology is a module that sits outside the head and wirelessly receives information from threads embedded in the brain. These flexible "threads," which are 4 to 6 μm in width (much thinner than a human hair), are less likely to damage the brain than the materials currently used in brain-machine interfaces, and also create the possibility of transferring a higher volume of data.

Putting aside any ethical considerations for the moment, regarding merging human and artificial intelligence, the potential applications of such human-machine/robot integration in complex, high risk operations are staggering.

With safety in mind, the reduction in reaction time alone due to machines operated at the speed of

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human thought compared to the latency of current mechanical, hydraulic and electronic controls is set to eliminate many risks.

Moving Forward

Ultimately, one of the goals of the FGR Human Factors programme is to scientifically propel human-machine interaction towards a symbiotic future where technology empowers and protects, rather than enslaves, machine operators.

This 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. This collaboration is a key element of the PGP programme and one sure to guide the effective use and adoption of new technology across the New Zealand forest industry and with huge potential for export overseas.

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