Forestry automation and robotics

Richard Parker, Peter Clinton, Karen Bayne and Brionny Hooper

Abstract

Automation and robotics have been introduced by industries as a way to increase productivity, reduce costs and increase the safety of the workforce. The mining industry in particular has become a leader in automation and robotics through trying to remove people from dangerous and often repetitive tasks. Operator jobs have been lost but new, often more technical, jobs have been created. Advances in automation and robotics in forestry will likely have a similar effect, and perhaps provide an opportunity to create harvesting machines and systems with a very light environmental footprint.

Forestry's challenges

The forest industry has particular safety and productivity challenges because a forest is a natural environment which cannot be easily controlled or standardised. Workers have to negotiate steep and slippery terrain, weather, hindrance from vegetation, noise and fumes and the danger of being hit by machines, falling trees and rolling logs. Much effort has gone into training workers to operate safely in such a hazardous environment and, where possible, machines have been introduced so that workers are safely enclosed within an armoured cab.

However, complex tasks like tree felling have always needed the cognitive and motor skills of a human to do the work. With sensing and processing power increasing, machines are becoming more able to do complex tasks. The application of sensor technologies and networks is revolutionising rural production through precision agriculture (Bayne et al., 2017) and mining (Parker et al., 2016).

The forest industry has already had some exposure to autonomous systems (Bray et al., 2016). When animals were used as beasts of burden forest workers could rely on the intelligence of the animal. It had some autonomy, as it could decide to walk fast or slow or not at all. A draught horse could follow a path in the forest, self-fuel (feed and water itself) and find its way home. With the internal combustion engine machines became dumb (and noisy) and needed to have human intervention to guide them.

Horse logging in New Zealand circa 1970. Source: http://tauranga.kete.net.nz

To date, much effort has been directed at developing automated and robotic machines to undertake apparently simple tasks like planting and pruning trees. However, the variable forest terrain and heterogeneous tree forms have defeated all attempts to make this work. To work in forests the machine must either be big and powerful to overcome the variable terrain, which means expensive, or if it is small and lightweight it must be very intelligent – again expensive. Successful pruning machines have been developed for tree species with straight stems and small uniform limbs, but not for the more variable radiata pine with nodal swellings and large limbs.

Forest harvesting is a task where workers can be seriously injured or die. Much effort in New Zealand and overseas has gone into removing people from dangerous positions by putting them in the cabs of machines. This keeps the worker safe from the impact of trees and debris, but because the machine is capable of handling trees very quickly it can expose the worker to insidious overuse injuries.

In an attempt to improve the work environment of machine operators, both John Deere and Komatsu have been developing systems that automate some of the boom control tasks of forestry machines. This is the beginning of a wave of automation technology which will appear in the future in the forest harvesting industry. Robots and automated machines are currently employed in mining, agriculture and manufacturing for conducting routine and repetitive tasks.

The mining industry

Sending people underground is fraught with risks. Mines are hot, can have poisonous gases, dust, high humidity, extreme noise and the potential for workers to be in close proximity to heavy machinery. The management of tasks underground has been simplified by the removal of people from the mine and the machines are driven remotely from the surface (teleoperation).

With no people in the mine, air cooling and ventilation is not so important and the mine can be operated at higher temperatures, higher humidity and lower air quality, therefore saving enormous costs in air conditioning. Surface mines have also benefited from automation. For example, driving a 400 tonne haul truck on the narrow roads of an open cast pit is repetitive and potentially risky. Automated GPS and sensor guided trucks can drive more accurately and remain in a convoy better than the best human operators and there is no loss of life if a truck goes over the side of the pit.

Mines are often remote and traditionally used fly in fly out (FIFO) staff who commute to the mine and go home at regular intervals. Using teleoperation the machines at the mine can be monitored, driven and in some cases maintained by operators thousands of kilometres distant at a location near their homes. For example, Rio Tinto's Remote Operations Centre based in Perth in Western Australia controls mining activities in the Pilbara region 1,000 km to the north. Operators can go home in the evening and participate in normal family activities.

Teleoperated harvesting machine operator station

New Zealand forestry teleoperation

The first steps in forestry teleoperation have already occurred in this country. The collaborative Steep Land Harvesting Primary Growth Partnership funded by the forest industry and the Ministry for Primary Industries sponsored work by Applied Teleoperation Ltd (ATL) to develop a successful teleoperation control system for a John Deere 909 harvester. The proof-of-concept machine was demonstrated in 2016. More recently, ATL created a teleoperation system for an excavator-based mobile tail hold where the hauler operator can control it from the hauler cab. Although there is a very steep teleoperation learning curve, these systems are likely to become more common in forest operations.

Employment issues

When automation and robotics become established over the coming decades it is expected that many jobs, as they are now, will no longer exist. If all tree planting, pruning and felling were replaced by machines our forests would be stripped of people, which is not good for the forest (e.g. no fit workforce with local knowledge to fight fires) or local communities. The Australian mining experience with automation is that operator jobs are lost, but many technical staff are needed to maintain the more sophisticated equipment, and there are a lot of jobs created in planning work and monitoring machines and processes. However, these are different skills from 'old-fashioned' conventional mining.

Possible future

Considerable effort is going into developing machines for forest operations. Lindroos et al. (2017) discuss recent innovations for mechanised timber harvesting. However, the ideal would be a utopian forest working environment where quiet, small forestry machines perform the tasks – planting, pruning, mensuration, felling and extraction. The machines work in swarms to do the bigger tasks like felling heavily leaning trees or log extraction.

There would be humans on-site, like shepherds, looking after the flock of forestry robots – repairing fallen machines, refuelling and sharpening cutting blades. All the machines would be small enough to be easily transported by light helicopter to the forest location. Because there are many, less expensive machines the economic risk for the contractor is less. If one machine is broken there are others that can continue to work.

The forest terrain is often steep and the ground covered in obstructions – debris, logs, rocks, holes and so on. Early work at Scion developed a tree-to-tree locomotion concept, based on the movement of animals that live in forests like gibbons, to move about the forest using the trees for support and not touching the ground at all. This concept was embraced by the Primary Growth Partnership Steep Land Harvesting programme, which sponsored Scion and the University of Canterbury to develop a prototype machine.

Tree-to-tree locomotion

Learnings

We have learnt the following from the mining industry that robotics and automation:

- Reduce the occurrence of injury
- Appear to be inevitable, but introduce new problems
- Open employment to a wider range of people
- Reduce operator jobs, but create new technical jobs
- Could allow the harvest of currently uneconomic forests
- Have made us aware that automation is a difficult technical problem.

Conclusion

The link between animals and forestry remains strong. We started with animals being used as beasts of burden and now we are learning how they have adapted to the arboreal environment from their millions of years of living in forests. Machines that work in the forest in the future could look like a tribe of gibbons – light, fast and agile – yet work like a colony of ants moving heavy weights by sharing the load, with forest workers tending these machines rather than driving them.

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Richard Parker is a Human Factors Scientist, Peter Clinton is a Science Leader, Karen Bayne is a Technologist and Brionny Hooper is a Human Factors Scientist at Scion based in Rotorua. Corresponding author: richard.parker@scionresearch.com