The internet of things for forestry: new concepts, new opportunities

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Abstract

The concept of an 'internet of things' (IoT) has been around for a while, and this review presents the current picture of the IoT and also its potential application to the forestry industry. Value from the IoT is being generated among businesses in many industries by establishing inexpensive sensor networks that efficiently collect large quantities of data and integrating these with data-analysis capability to provide improved inputs for more precise decision-making.

The IoT is also being used for asset optimisation such as plant, machines and vehicles supporting proactive maintenance, capacity planning and safer operating environments. Many applications in other sectors are immediately transferable to the forest sector, with sensors and networks being used to optimise agricultural land uses and generate supply-chain efficiencies.

A view of the future

The world is increasingly connected through the internet and other communication technologies that are improving the availability of information on demand, and are creating an increasingly complex and competitive business environment. One of these technologies, the IoT, is currently receiving a lot of media coverage and is a hot topic for discussion at conferences and events. However it is not always clear what this new technology actually is, what its benefits are and, specifically, what value this technology adds to the forestry sector.

What is the internet of things?

The IoT is simply the integration of three technologies: smart and very cheap sensors; autonomous networks that record and manage data; and analytical capabilities in storage and data mining that develop actionable information for decision-making.

Basically, the IoT involves autonomous collecting and processing of real-time data utilising the internet and other sensing technologies without human intervention or interaction. Sensing technology is becoming more sophisticated and less expensive while connectivity is rising, leading to a massive growth in interconnected sensors (Woodgate et al, 2014). Monitoring of humans, equipment and the environment is increasing, and data are being collected at a higher spatial and temporal resolution than has been previously possible.

The ability to collect, process and analyse data in real-time as an event unfolds means decision-making can be transformed. Remote monitoring and control, as well as automation and optimisation, become possible and subsequent decisions are based on actual real-time information rather than using estimates based on limited data. However collecting all this information leads to new problems – where to store it and how to use/protect it.

Data storage has become cheaper and more accessible as data-processing capabilities have increased. Cloud-based storage systems are the latest development in response to increasing amounts of data. The challenges of data security and privacy have not been completely resolved, but there are already workable solutions in almost every sector. Larger amounts of more complex data mean increasingly complex and high-intensity computers are required, and this is also being addressed through cloud computing.

Increasingly, data sets are being merged and cross-referenced to provide a more balanced 'complex systems' view of the world that, in turn, is leading to new ways of solving problems using data-mining techniques such as pattern detection or machine learning. These types of technologies are already being used in the fast-moving consumer goods sector to analyse customer data, in the horticulture sector for automated pruning, and in forestry for steepland harvesting.

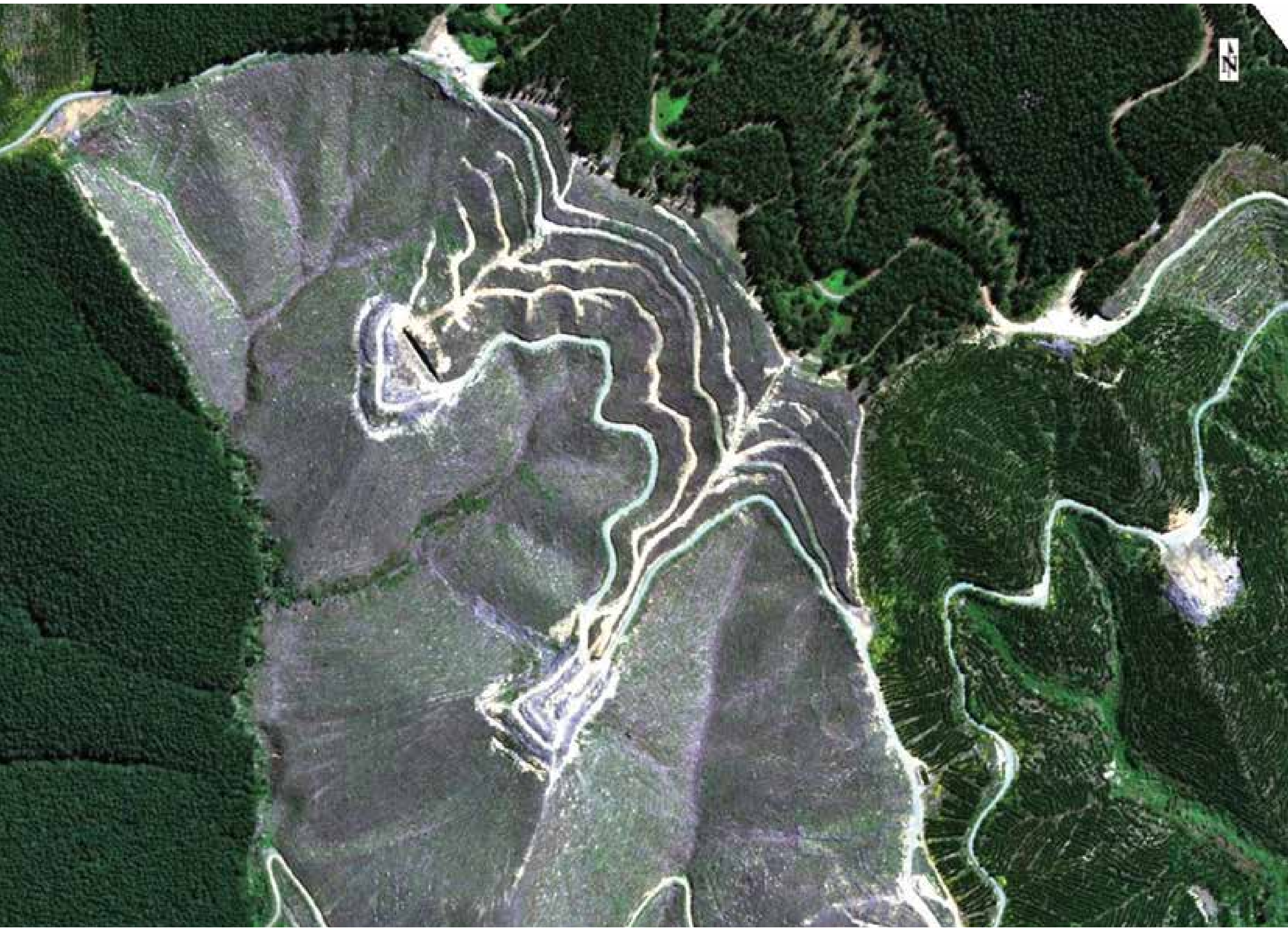
What are the benefits of this new technology?

There have already been significant examples of the IoT adding value to other sectors. Within industrial plants, transportation, health and urban monitoring decisions are required on a temporal range from instantaneous to daily. For example, shipping companies can track in real-time not only where their boats (and cargo) currently are, but also whether the engine and hull are operating at peak performance or in need of maintenance. Also, technologies originally applied in Formula 1 racing cars are being applied by major truck manufacturing companies to produce a connected truck network that goes beyond knowing where a particular truck is located. Additional information can be collected that enables transport routes to be autonomously optimised, or the number of gear changes to be monitored based on current load sensing and the type of terrain.

A different example from the New Zealand horticulture sector is one that has been developed as a result of market research into consumer preferences for apples of certain colours. By utilising the IoT, a machine can detect the side of an apple with the best colour, then orientate and place it in a tray with that side facing upwards.

Technology using the IoT is advancing rapidly in the agriculture and horticulture sectors in New Zealand. Applications include precision application of fertilisers, robotic milking, electronic stock identification, smart irrigation and wearable fitness monitors 'fitbits' for cows. Mapping of agricultural and pastoral land provides owners with an accurate understanding of inventory and crop health leading to early intervention and cost savings. Smart irrigation using fully computerised central-pivot irrigators has revolutionised water management on large crop farms by increasing water use efficiency while reducing environmental impacts from run-off. The performance of each irrigator is managed by using results from electro-magnetic mapping and sensor networks that provide localised soil moisture content data so that individual nozzles can be switched on and off remotely (Agri-optics, 2015).

Current research into IoT applications for hill-country pasture management relates hyperspectral imaging to crop production, where the analysis of images obtained at different wavelengths is used to determine fertiliser requirements. This information is relayed to an aerial topdressing pilot who then accurately targets under-productive pastures. This selective approach reduces adverse effects on the environment by limiting fertiliser waste and consequent nutrient run-off (Grafton and Yule, 2015). These are not science fiction examples, but rather current business applications where real value is being added. So the question really is not if this technology can add value to forestry, but rather how?



Worldview-3 pan-sharpened imagery at 30 cm resolution of New Zealand plantation forest

How will the IoT benefit forestry?

The implicit and underlying premise for using the IoT within forestry is to cost-effectively obtain and utilise more data about New Zealand's forests and their environment. Many of the decisions that forest managers need to make are not as time critical as in other industries, but there are still numerous benefits from using the IoT.

Optimising physical assets

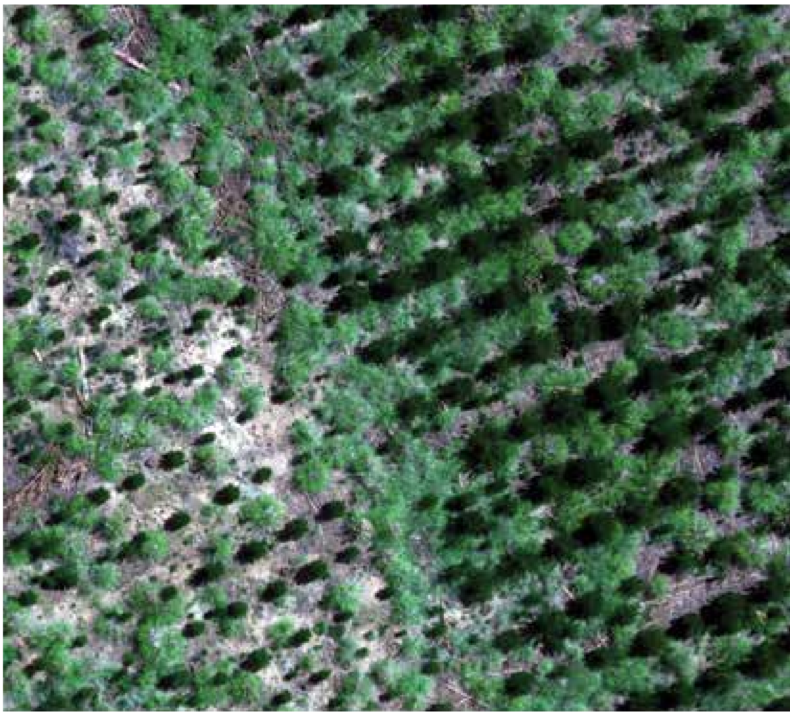
A key benefit of the IoT would be in connecting and integrating different aspects of the forestry value chain, e.g. harvesting, processing, manufacturing, transportation and the operation of machinery. By optimising log-product merchandising on the skid site or at the harvester head, scheduling and managing fleets, performing chain-of-custody tracking and tree data management (tree/log data goes with each log) there is the potential to reduce the need for rescaling, providing more detailed information to forest managers and processors. The IoT can also be used for performance assessment, compliance monitoring and enforcement, maintenance monitoring and scheduling, as well as integrating safety systems in plant and other physical assets.

The benefits from implementing IoT systems arise from forest owners and contractors being able to minimise downtime and reduce asset loss/damage through being informed more frequently about when maintenance is required (pre-emptive maintenance). Automatic start-up/shut-down, minimising redundancy, and efficient compliance processes could all be integrated within the actual assets being worked on.

Optimising biological assets

A further potential use of IoT technologies is in the biological monitoring of forests and the environment, typically weather and response variables such as soil temperature or water availability. Within the agriculture sector, sensor-based monitoring systems are already in place that optimise planting, irrigation, fertiliser application and harvest in order to improve asset utilisation, productivity and profitability. One potential application involves monitoring waterways to assess changes in quality over time in order to demonstrate where water degradation occurs and understand the role of forests in that change.

The United States Department of Agriculture Forest Service has already developed a digital environmental sensor and telecommunications programme that captures information about the state of the air, water and forests (Smart Forests, 2015). Wired sensor networks are not new in New Zealand forestry, but the challenge going forward will be to create affordable wireless networks for forest monitoring that provide remote upload of data capability to either the cloud, an unmanned aerial vehicle (UAV) or a satellite.



Pinus radiata inventory and evidence of weed competition with *Cordateria selloana* (Pampus grass)

Key research questions for biological IoT systems are how to assess productivity and generate an accurate, consistent and accessible inventory of productivity data. Having an in-depth knowledge of the health and quality of each individual tree throughout a rotation would give forest owners more certainty around their product and allow market demands to be addressed more responsively. Starting with accurate aerial mapping of forest stands post-planting, trees can be monitored on an annual basis to identify gaps, monitor tree health, assess weed competition, and to provide relevant information on the need for silvicultural practices such as thinning and pruning (see first photo).

Accurate inventory assessments pre-harvest will contribute to more accurate financial forecasts. Detailed mapping of sites post-harvest will provide more accurate cut-over assessments by reaching difficult-to-access sites and reducing labour units on the ground. Aerial imagery captured by planes or UAVs is currently being used by forest owners. However satellite imagery is also becoming increasingly more accurate, with a ground resolution of 30 cm now feasible (see second photo).

As costs reduce, this capability will be available to more forest owners. On the ground, specialised tree sensors could monitor the health and growth of individual trees and contribute to the 'forest as a warehouse' theory, which promotes individual tree harvesting to meet market demand.

Health and safety

Some work sites are dangerous locations as they involve the interaction of people, machines, trees and log movements within a very physically demanding environment. The use of the IoT for improving health and safety is in its infancy, but other industries use proximity sensors on people to shut-down equipment or warn them and others about the location of dangerous hazards.

Challenges

All three technologies that comprise IoT need to be operational before good decision-making can take place. Predictive analytics and advanced data management systems are required in order to gain meaning from the data. Data obtained using IoT systems need to be collated, analysed, coalesced and integrated with other sources of information, for example, matching real-time tree growth information with weather data over a full rotation. This is a challenge for all industries, including forestry, as the skills required to build such systems are rare and expensive. Attracting skilled and experienced systems developers and data analysts will therefore become even more competitive and challenging.

Other critical barriers include agreement on what to measure and how, and what sensors to use to provide the building blocks for good information. Currently available outdoor-monitoring sensors typically assess a localised environment. While the technology exists for forming broader sensor networks, the ability to scale up IoT applications to encompass an entire forest still needs to be addressed. Other barriers include the lack of standards in the marketplace for sensors and nodes.

The future of the IoT in forestry

Manyika et al. (2015) reported that global IoT 'business-2-business' applications will generate 70% of the expected $US11.1 trillion economic benefits arising from IoT by 2025. Within factories, asset optimisation is expected to generate up to US$3.7 trillion. In 'outside' application areas, including logistics, benefits of up to US$850 billion have been predicted and 'worksite application areas' will have benefits of up to US$930 billion.

As outlined above, the benefits of IoT technologies in forestry applications are immense. However IoT systems must be practical, dependable, affordable and proven to increase returns for forest owners before uptake is widespread. Future research should focus on inventory accuracy and detailed understanding of the health and quality of individual trees, all of which will assist foresters to become more competitive in the market place. Such research has already started, with Scion and others in the forestry industry capturing image data using sensors mounted on UAVs. Early results are promising and should encourage industry to get involved in other projects such as long-term multi-sensor forests, tracing logs from nursery to manufacturer, and informing the supply chain.

Conclusion

The IoT enables companies to gather data from every aspect of their business, from environmental monitoring to how many lightbulbs are switched on across their business. Forestry has historically relied on empirical information from a small numbers of samples, as well as gut feeling, tacit knowledge and/or other data gathered at a low temporal scale. The IoT has the potential to revolutionise what forestry considers to be good information, as well as what it means to have all the information required to make the right decision at the right time.

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