HARVESTING TECHNOLOGY WATCH

HTW-015
July 2015

Summary

TECHNOLOGY WATCH is a biannual report outlining research and technology developments that are occurring outside the FFR Harvesting Theme, frequently from overseas. This report summarises the "Robotics in the Forest" workshop organised by FPInnovations in Montreal, Canada on 21–23 April, 2015. The workshop provided an opportunity to understand the issues facing the forestry sector, such as safety, increasing costs and a changing workforce. Mining technology experts at the workshop provided the forestry participants with valuable information on the introduction of advanced technology to the work environment. Presentations covered topics such as the mining industry's experience of automation, new developments in forestry technology, advances in sensing technology, automation in terrestrial and aquatic environments, and unmanned aircraft.

Richard Parker, Scion

ROBOTICS IN THE FOREST WORKSHOP

Jean-François Gingras, from FPInnovations, convened the Robotics in the Forest Workshop held in Montreal, Canada from 21–23 April, 2015. The aim was to explore the uses of advanced technology in forest operations and learn from the experiences of the mining industry, which has been using robotics and automation for several years now. The workshop was attended by approximately 70 experts, including machinery manufacturers and developers, and university researchers. The final goal of the workshop was to develop a plan for the next steps the industry should take to introduce automation and robotics into the forest.

Advanced technologies in mining mobile equipment

Robert Hall, University of British Columbia

Mine automation was introduced to reduce costs, improve safety and enable mining to continue in places where people do not want to live. Automation of haul trucks has allowed cost efficient planning methods (e.g. narrower mine roads because trucks can drive more accurately) and new concepts such as more, smaller trucks, rather than fewer larger trucks. The use of mine automation is going to increase as there are safety advantages with automation.

Robert Hall gave some advice from the mining industry's experience with automation:

- Automation and advanced technology is only "really important" when times are good.
- There is a trend for enthusiasts to oversell the benefits of automation.
- The industry in collaboration with providers needs a plan to develop and implement automation and advanced technology.
- We need to ensure human resources are available for the new equipment and the mine. People are needed to repair and recalibrate the machines.
- We need to look at step change technologies vs incremental change. Step changes can have the biggest gains.
- We need to convince companies to continue to invest through the highs and lows of commodity cycles.

Figure 1: Automated mining machines controlled remotely

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The Canadian Field Robotics Network

Greg Dudek, McGill University

Greg Dudek is the Director of the Canadian Field Robotics Network (NCFRN) which links academic, government, and industrial researchers in field robotics, to develop the science and technologies so teams of robots (on land, in the air, on the surface of or under water) work collaboratively.

The research programme of the NCFRN addresses issues along four themes, corresponding to different application domains: (i) Land, (ii) Air, (iii) Water and (iv) Human. Solutions developed in any of the themes may be applied to other themes. The Land theme is primarily investigating planetary and terrestrial robotics – visual navigation, autonomy, and human-robot interfaces, as well as robotics in terrestrial semi-structured environments, human-machine interaction and team coordination and control.

The NSERC is also involved in match-making, having an industry partner for each research effort linked to an academic expert, and importantly having intellectual property issues organised early in the project.

Opportunities for robotic systems in unstructured environments

Clément Gosselin, Laval University

Manual labour is still used widely in industry because so many tasks have difficult and complex manipulations which require dexterity and decision making. However, robots are becoming more capable in unstructured environments as evidenced by driverless cars and trucks.

The combination of human decision making with the strength and speed of robots provides the best combination for difficult unstructured environments. For example, a strong fast machine can work in the forest, controlled remotely by a human who can plan and has situational awareness and insight.

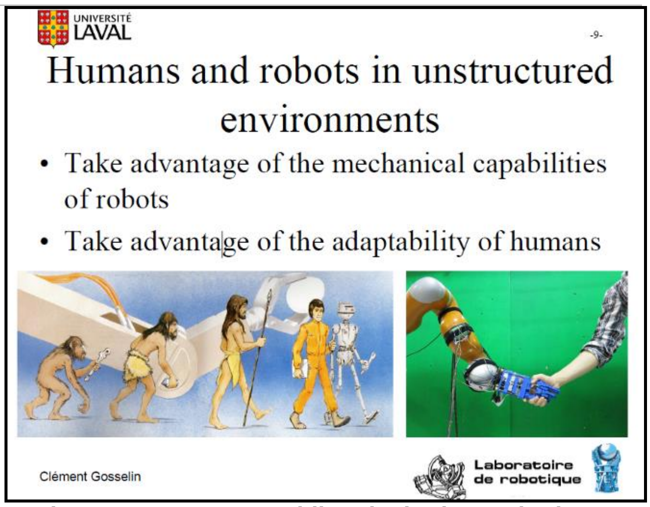

Figure 2: Humans providing the brains and robots providing the muscle

A key challenge for robots in unstructured environments is the ability to manipulate objects. The human hand has many sensors and great dexterity. Robotic grippers (hands) are not yet as dextrous.

Mining robotics

Greg Baiden, Penguin Automated Systems Inc.

Penguin Automated Systems Inc. is a private company whose mission is to formulate existing and new technologies that enable teleoperation to allow people to go where they should not or cannot go.

Penguin build specialist telerobotic machines primarily for the mining industry. They also develop software to give remote operators greater situational awareness. One example of a specialist mining machine the company developed was for the removal of "draw bell blockages" where explosives have to be placed precisely on hung up rocks balanced precariously in an underground mine. Conventionally a worker must place the explosive which is extremely hazardous, due to risk of collapse and explosion. Penguin ASI developed a telerobotic electrically powered 6-tonne machine which can place the explosives precisely while controlled remotely. Many of the problems that have been confronted by the

mining industry will be found in forestry. We can learn from the solutions developed in mining.

Figure 3: Teleoperated mining machines and remote operators

Human-machine interaction programme

Martin Englund, SkogForsk

Martin Englund described the work SkogForsk in Sweden is doing investigating the human/machine interaction when operating a forwarder. Few machine operators are able to use the full capacity of the machine – they become the bottleneck in the system. However, with automation the machine operator can keep up with the machine. Intelligent boom tip control allows the operator to concentrate on moving the grapple on the boom to the correct location with a computer controlling all the individual hydraulic rams on the boom and stick.

There is also auto-boom control where the forwarder boom automatically reaches for the next log and awaits the grapple command from the operator. These developments are being driven by human factors studies on the effect of repetitive work on machine operators.

Overview of MDA robotics & space technologies

Cameron Ower, MDA

MDA make robots for space, medicine, and the nuclear industry. Their most well-known robot is the "Canadarm" which is a robotic arm with grippers on each end which can do useful tasks on the outside of the International Space Station. A more recent development is the "Dextre" which has its own arms and fits on the end of the Canadarm. Cameron described how MDA do considerable prototyping and simulation before they finalise a robot design. Getting reliable robotic systems is a real challenge. Their robots have been on the last four missions to Mars.

Figure 4:Canadarm on the International Space station

Environment & self-learning systems

Philippe Giguère, Laval University

Philippe Giguère discussed the challenges for automation in forestry. The forest environment is complex with varying soil type, slope, lighting and weather conditions and difficulty receiving radio signals (e.g. GPS) through the forest canopy. He identified three important areas where robots in forestry will be challenged:

- **3D localisation and mapping**

Best to combine information from multiple sensors (GPS, stereo cameras, LiDAR, inertial measurement and odometry). In this way robots in the forest can build up detailed maps which are more accurate. This requires considerable computing power which is now available.

- **Terrain identification**

Vibration sensors on the robot can provide valuable information on road or track conditions so pre-emptive road maintenance can be done. Also vibration sensors give the operator a sense of how smoothly they are controlling the robot and an indication of wear on robot components.

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- **Detection of logs on the ground**

LiDAR and 3D cameras to identify the location of logs and automatically guide the grapple to pick up the logs.

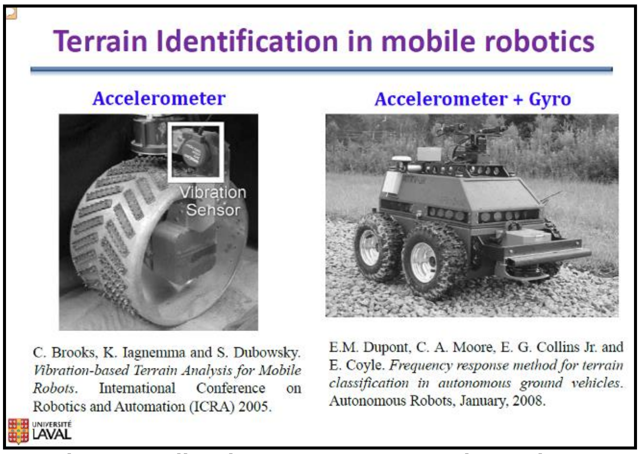

Figure 5: Vibration sensors mounted on robots

John Deere intelligent boom tip control system

Marko Paakunainen & Timo Kappi, John Deere Forestry Oy

John Deere has developed a boom control system which automatically adjusts the hydraulic rams to move the boom tip to where ever the operator wants it. Therefore the operator is not controlling individual rams, which reduces workload.

Marko Paakunainen & Timo Kappi explained how the new intelligent boom control system shortened the learning curve of operators, resulted in faster cycle times, and improved fuel economy. With automatic boom control, the life of the boom structure and cylinders is extended because motion is smoother than if under human control.

They detailed the five step development process which could be used for developing any advanced machines for forestry:

1. Kinematic algorithm development utilising the training simulator
2. Hardware in-the-loop boom test bench
3. Mule machine with engineering control module
4. Mule machine with embedded software
5. Lead customer fleet for feedback, validation and durability testing.

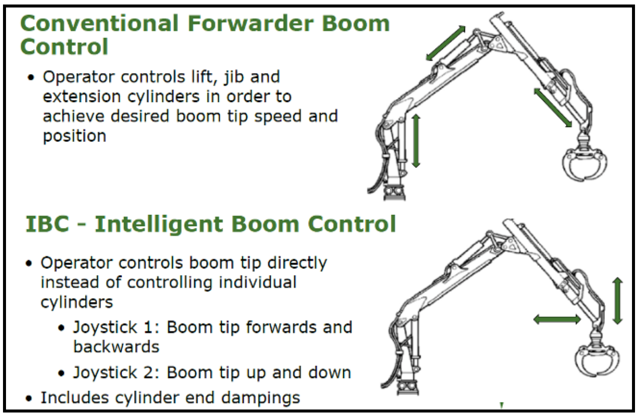

Figure 6: John Deere intelligent boom control

Advanced technologies from Motion Metrics

Shahram Tafazoli, Motion Metrics

Very large mining machines are at risk of catastrophically damaging other (expensive) machines working nearby. Shahram Tafazoli's company, Motion Metrics, develops sensor systems to give the machine operators (and the machines) situational awareness of the surrounding environment.

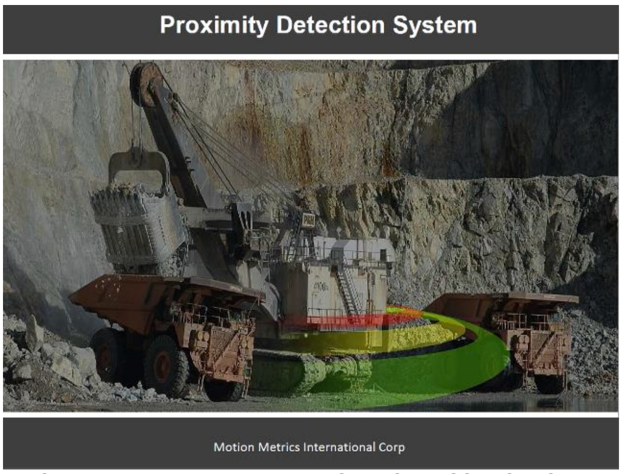

Figure 7: 1400 tonne rope shovel working in close proximity to haul trucks

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For example, 1400 tonne rope shovels have radar sensors fitted for proximity detection of other machines and video cameras to provide the operator view of blind spots.

There is a sensor system which detects the loss of teeth on the shovel and loader buckets. If a tooth (which can weigh 200 kg) breaks off and gets into the rock payload it can cause very expensive damage at the rock crusher.

Feller buncher teleoperation

Matthew Fordham, ARA

Matthew Fordham reported on the work ARA are doing in developing a teleoperated feller buncher. They have developed a "Modular Robotic Applique Kit" (MRAK) which can be quickly attached to a suitable base machine. It provides full teleoperation control with a 2-km range. The system has eight video cameras and an audio channel for operator situational awareness.

The MRAK system was developed to cut down trees on land littered with unexploded ordinance (UXO). In the United States there is 170,000 square kilometres of land contaminated with dangerous UXO. The teleoperated feller buncher is working on flat land and is clearing 500 ha of forest land at Fort Bragg. ARA are integrating the MRAK onto a CAT 521B Feller Buncher.

Figure 8: MRAK system for felling machines

Tree-to-tree robot

Richard Parker, Scion

Richard reported that the inspiration for the robot came from observing animals moving through the trees – quickly as in apes, or slowly as in stick insects.

Figure 9: Tree to tree robotic platform "Stick Insect"

There was considerable interest at the workshop in the tree-to-tree locomotion concept. Having a machine that is independent of the ground also makes automation easier because the variability of ground conditions does not have to be accommodated in the sensing and control of the machine.

The Umeå Forest Technology Cluster

Maria Hedblom, Skogstekniskaklustret

Maria Hedblom is CEO of the Umeå Forest Technology Cluster which consists of 11 companies and research organisations. Funding comes from the EU's structural funds and the Swedish Innovation Agency, VINNOVA. County councils and municipalities are also involved in financing. In-house funding of projects is possible through a significant financial commitment from the Swedish state forestry company Sveaskog. In addition, the companies contribute their own time, personnel and resources.

Students from the Umeå Institute of Design, in consultation with the forest industry, develop innovative new concepts for forestry machines. The Institute is very highly regarded internationally.

Figure 10: Autonomous harvester concept machine

Unmanned aircraft and unmanned ground vehicles … why they might find a way into the forest

Stewart Baillie, Unmanned Systems Canada

Stewart Baillie is Chairman of Unmanned Systems Canada, a not-for-profit association with 700 members, representing the interests of the Canadian unmanned vehicle systems community. Stewart detailed the activities the organisation undertakes to promote research, develop regulation, educate and network.

Stewart provided examples of current commercial uses of unmanned vehicles:

- Policing – aerial vehicle to document a crime scene for use as evidence in court
- Agriculture – aerial vehicle to measure soil properties for accurate irrigation/fertilising
- Fruit – small ground vehicle to spray fungicide under banana plants

Potential unmanned vehicle uses in forestry were presented and included forest monitoring for disease and fires, harvest planning, precision harvesting, transport convoys and remote equipment operation.

Promising future pathways for advanced technologies in forest machines

Luc Lebel, Laval University

In the final discussion session of the Workshop, Luc Lebel pointed out that forestry has a more positive public image than mining. Forestry is not seen as an extractive industry but as an industry that harvests a renewable crop. However, forestry has difficulty attracting skilled workers. Most forestry sites are remote and isolated and safety is still a large problem. If harnessed successfully, robotics and automation will provide many solutions to forestry's problems. People will be able to work near their home, remote from the forest, and safety will be improved. Automation will shorten the expensive learning curve and improve productivity and reduce wear and tear on machines. The Swedish Forest Technology Cluster has demonstrated the rapid gains that can be achieved when organisations can work collaboratively.

ACKNOWLEDGEMENTS

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