FPInnovations' Forestry 4.0 Initiative

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Introduction

Supply chains have evolved significantly in recent decades, and yet are now on the edge of even more transformative changes driven by the digital revolution.

The world of information has progressed to the point where it is now common to exchange data in real-time from anywhere in the world. This has made it possible to generate enormous digital information flows, and the emergence of connected objects will amplify this phenomenon. In 2015 there were already 15 billion devices connected to the Internet (twice the global population). These new technological means are leading us to the 4th Industrial Revolution, where cyber-physical systems monitor physical processes and exchange data in real time in and out of organizations through the Internet of Things (IoT) and cloud computing. This revolution will allow much greater agility to react to the market and to produce custom-made products at an industrial scale. For the forest-to-market value chain, this would mean that all the links are inter-connected in real-time, allowing for greater agility and responsiveness.

Currently, Canada's resource sector is challenged to be part of this revolution. The biggest gap originates from the lack of adequate communication networks reaching into remote locations (Figure 1). In addition, timber supply chain production systems are rarely sufficiently technically developed to allow in-depth data collection and flow analysis. To close this gap, it is necessary to continue the development of technologies that will enable the generation and access to real-time process input/output data relevant to supply chain management and adapted to Canadian conditions. This foundational data can then be used to better understand the interaction among production variables, manage flows, and to analyze and propose real-time global solutions.

Figure 1 Mobile phone coverage for one major provider in Ontario and Quebec (2017)

To be successful with this initiative, several enabling technologies must be developed, implemented in the Canadian context and coordinated. These include elements such as enhanced forest inventories, the Internet of Things (IoT), Big Data management, real-time communication systems, automation, AI, etc.

FPInnovations' Forestry 4.0 Initiative

Given the needs expressed in the introduction, FPInnovations is launching the **Forestry 4.0** (https://youtu.be/r4vhLQ8OEP0) initiative aimed at bringing the upstream part of the forest value chain to fully leverage the agility and power of Industry 4.0 (Iasi *et al*, 2014). One of the key goals of the initiative is to help make the supply chain component of the forest sector value chain more reactive and more resilient by implementing connected solutions.

To fulfill the mandate, four research themes have been defined which, through their distinct functions, will help establish the upstream foundations of a new "connected" value chain for the forest sector. These themes are:

The Real Environment, a theme that is dedicated to developing technologies and the science necessary to feed the systems with foundational data on which monitoring, analysis and decisions can be taken along the supply chain (*assembler* function).The building blocks of the fourth industrial revolution is the generation of ubiquitous, reliable data describing the constantly changing "real environment" of production. This information is needed to dynamically adjust the supply chain processes based on user demand.

The Internet of Forest (IoF), in analogy to the IoT (Internet of Things), is the critical missing link in many remote and large areas of Canadian forests. The activities carried out under this theme will represent the key *enablers* in our ability to exchange real-time data between forest production nodes (i.e. forest contractors) and decision centers.

NextGen Fibre Supply Chain is a theme under which efforts will be made to develop, test and implement new production systems based on some of the latest technological developments. This theme is seen as the *accelerator* of the value chain, building on data from the Real Environment to leverage new technologies for more agility, connectivity and efficiency of the supply chain.

Data Analytics will focus on developing knowledge processing and decision tools to transform raw or semi-transformed data into intelligence capable of feeding management systems and supply chain processes based on powerful optimization and simulation models. In other words, this theme serves as an *integrator* of the complete upstream process in order to implement "smart harvesting" in the management of the Canadian forest sector value chain.

Figure 2 illustrates how the four components fit together along the value chain.

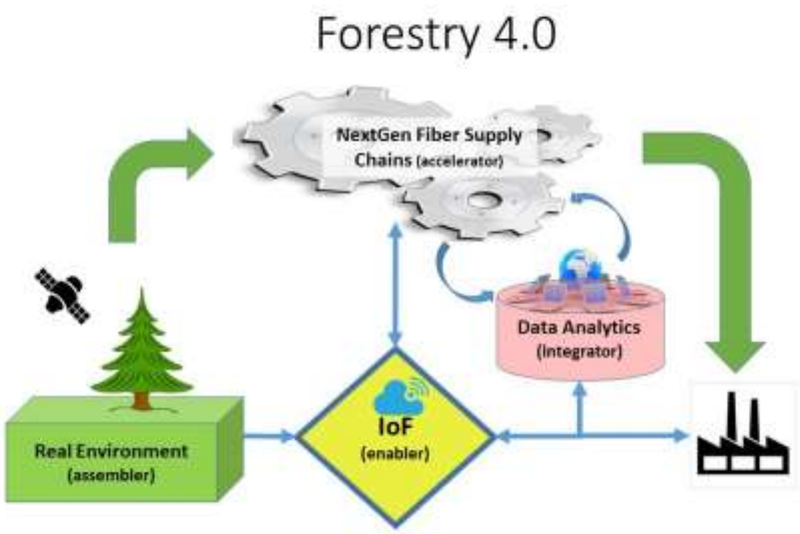

Figure 2 The four theme blocks of Forestry 4.0

1. The real environment

Current situation

Cyber-physical production systems of the Industry 4.0 can continuously share information about the production environment, stock levels, production unit problems or faults, and changes in orders. In forest supply chains, accurate information is needed on the amount and quality of fibre available, the physical environment in which operations will need to be deployed and the transformational outcomes of the various phases of harvesting systems.

Currently, remote sensing technologies provide a rich source of data to characterize forest resources. While this technology is not fully leveraged yet in the forest industry, the use of imagery and LiDAR 3D point clouds for example is widespread across Canada (Figure 3).

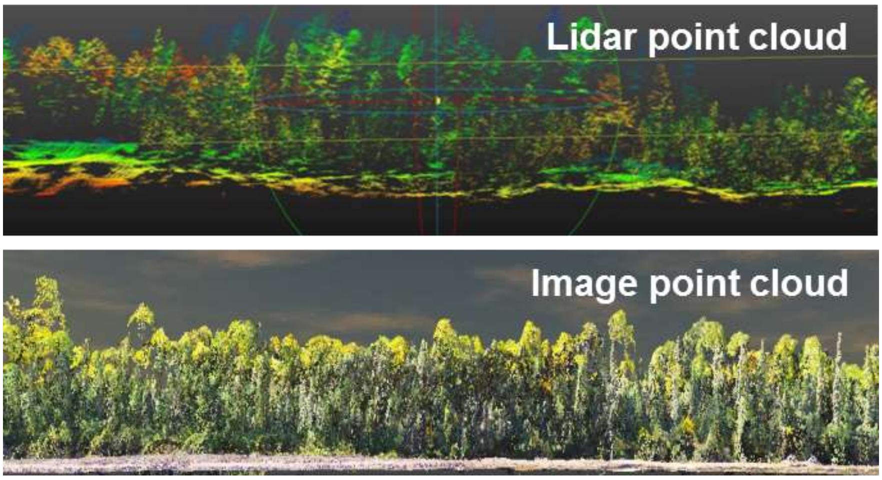

Figure 3 Lidar and image point clouds for enhanced forest inventories

The use of drones in forestry application has also increased exponentially and opened the door to less manually-intensive approaches to monitor forest operations. To monitor forest machines, production data capture from on-board computers and telematics information is increasingly available but accessibility is governed by the OEMs. Machine-generated data is more available for the cut-to-length machines and much less so for the tree-length systems (feller-bunchers, skidders).

Objective

The objectives pursued in this theme are to develop tools aimed at maximizing the collection of fundamental, spatially-explicit data about the operational environment. This will involve leveraging available data sources and developing new sensor systems. Another objective is also to make this data accessible as soon as they are captured to provide constant feedback of the real environment.

For example, the new WorldView-3 satellite system, which can provide daily updated data for a given area with a 31-cm resolution, will help us to detect any short-term changes about the forest environment over large areas.

Data collected from machines can also represent foundational data on which to establish connections with biophysical data (stand, terrain, weather, etc.). They can be acquired from production monitoring systems (onboard data loggers, onboard computers) or from external sensors. This data can be used “live” for artificial intelligence systems or connected later and linked to decision support systems to manage the supply chain. For example, detailed roadside inventory information on volumes and quality can be a vital piece for transportation planning and optimal dispatching of trucks to minimize waiting times and wasted travel time. Similarly, additional information about the road infrastructure can become helpful building blocks around planning the whole transportation system.

2. The internet of forest

Current situation

Unlike most developed countries, Canada’s cellular telephone network does not cover a wide area, being concentrated along the southern border where the majority of the population lives. However, forest operations typically take place in more northerly locations or at significant distances from urban centers and thus have no connectivity to these networks. For this reason, many of the commercially-available connectivity solutions are not applicable in these conditions.

Some platforms, such as FPInnovations' FPSuite comprising the FPDat datalogger (Figure 4) and the FPTrak data hosting web site, use satellite communication, such as the Iridium or Globalstar constellations, to move data from remote locations back to mills or decision centers in urban locations (Castonguay & Gingras, 2014). However, these systems typically feature limited bandwidth and high data transfer costs. Typical IoT solutions become inapplicable in these situations.

Figure 4 FPInnovations' FPDat datalogger for forest machines

Objectives

The objectives of this theme are to help foster the development and implemention of communications systems in resource operations that will enable the implementation of the Industry 4.0 standard. These communications' systems will cover a range of needs: Vehicle-to-vehicle and machine-to- machine (V2V/M2M), vehicle and machine-to-infrastructure (V2I/M2I), operations-to-cellular and internet networks, real time communications in remote operations, etc.

The overall approach is to find, test and/or develop communication systems to determine whether they meet the requirements for V2V/M2M, V2I/M2I and data flow of remote forest operations. Furthermore, the terminal part of a forest-wide communication network is the fleet of equipment operating in the forest. These machines must be able to act as nodes for the efficient transmission of data among them, or from them to the office/network and vice-versa.

The work will involve partnerships with telecom companies, communication technology suppliers and university partners for testing out different combinations of systems.

3. Next-Generation Fibre Supply Chains

Current situation

Advanced technologies will be required in harvesting systems to truly enable full Forestry 4.0 functionalities around connectivity and agility to upstream and downstream changes in the supply chain. In addition to the 4.0 standard, the forest sector is interest in automation and robotics because of the growing difficulty to find and attract workers and machine operators, because also of safety concerns when operating in hazardous conditions (e.g. steep slopes) and finally because of the need for increasing productivity and competitiveness (Bayne & Parker, 2012).

Unlike agricultural fields or mines, the forest presents some significant challenges to automation and robotics because of the highly variable terrain conditions (from flat, soft ground to steep slopes to boulder fields) and the ever-changing forest stand structures, even in managed natural forests (with the exception of plantations).

Already, some early automation is starting to appear, such as John Deere's IBC system (Intelligent Boom Control) which replaces the traditional joystick geometry with intuitive simplified controls where the operator directs the boom tip to the desired location instead of having to control individual boom articulations (https://www.deere.com/en_US/corporate/our_company/news_and_media/press_releases/2017/forestry/2017feb7-intelligent-boom-control.page) . The Swedish Cluster of Forest Technology (Skogstekniska Klustret) is one of the world leaders in developing automation systems for forest machines (http://www.skogstekniskaklustret.se/english/).

Remote control or teleoperation systems are also starting to appear, with prototypes being developed and tested by several OEMs, although these are still mainly line-of-sight systems, because sophisticated sensor & feedback loops still need to be improved.

Virtual or augmented reality technologies will likely provide additional opportunities for displaying decision-support or training-related information to workers in remote locations, or even while operating forest machines. These new data streams may be implemented through wearable systems like Microsoft's Hololens (https://www.microsoft.com/en-ca/hololens) for example or through heads-up displays on windshields, for example with the Optea system (http://optea.com/products/).

Fully automated or autonomous machines in forest operations are still some years away. This represents the end-goal of a step-wise progression in the automation of repetitive tasks and the integration of several technologies such as machine learning, path planning, machine grasping, artificial intelligence and advanced vision systems. Westerberg (2014) provides an excellent overview of approaches to semi-automate various forestry functions.
The first manifestation of autonomy in the forestry context will likely be around autonomous trucks in controlled operating environments (e.g. mill or log yards, private roads). The mining sector has already started implementing autonomous trucks in large open-pit mines and around 200 such trucks are currently operating in mines around the world.

In virtually all cases of advanced technologies implementation in forest operations, the need for real-time connectivity everywhere is and will remain critical, currently a major stumbling block in Canada.

Objectives

From the context provided in the previous chapter, the objective of the work under this theme is to accelerate development and implementation of next-generation equipment, hardware, software and models that will allow the supply chain actors to run to an Industry 4.0 standard by being automated, connected and accessed in real-time.

This project will be pursued along two main fronts: (1) evaluation of enabling technology around automation, sensors, machine learning, robotics and augmented reality, and (2) development of autonomous vehicles specific to the forest sector. On the latter, the Society of Automotive Engineers (SAE) has summarized driving automation technology into six levels, starting at 0 which is no automation to level 5 which is full automation. Technologies of SAE level 1 (driver assistance) and level 2 (partial automation) are on the market now or soon will be and need to be tested for their applicability to rural/resource roads. As well, there are opportunities to take advantage of the remote and controlled environment of forest operations by developing niche vehicles at level 4 (high automation) and 5 (full automation) which can be implemented without the restrictions that apply to highway transportation. Along these lines, FPInnovations will continue to work on the development of a fully automated yard truck.

4. Data Analytics

Current situation

While an increasing amount of data is being generated in all components of the timber supply chain, surprisingly little is actually captured, stored and utilized in value chain decisions. As such, there is little data analytics being done in forest operations in the true sense of the term .The main data streams being generated in forest operation are related to the forest inventory, the machine data (from on-board computers) and the transported volume of wood (from scale or manual measurement). Most of the time, these data sets are not centralized nor widely accessible. Because of this, big data analysis is not applied to transform these raw data into actionable information.

Whereas many commercial or in-house decision-support systems (DSS) exist, few actually manage and optimize the forest value chain because of the complexity and burden of providing all of the necessary base data in order to generate the optimal decisions. Most forest companies do not monitor or track the data needed to feed a value chain DSS, or they are not in a compatible format. For these reasons, many companies do not use these decision-support tools for operational purposes, but use them only at a tactical or strategic level because it takes so long to gather the data and run the models.

Objectives

The main objective of this theme is therefore to help develop solutions to more easily centralize and standardize data coming from various streams (e.g. the real environment) in order to have a more complete set of raw data that can be analyzed from various angles and needs in order to take better decisions. Another objective is also to develop new predictive and prescriptive models to automatically generate corrective action when deviations from the original plan are identified.

Recent and rapid developments in the field of artificial intelligence (AI) open up opportunities to build more robust model based on large datasets. Of course, this will reinforce the need for real time access to the data generated during operations. This will also be key, from a decision-support system point of view, to constantly update the modeled scenarios based on actual production information, and thus enable their use at the operational level. One challenge with big data is the need for management tools that can make sense of large sets of often imperfect or incomplete information, typical of forest operations. The data pool is getting larger, more complex and faster moving, to the point where traditional analysis and management tools are now ineffective. Gradually, the objective is to shift from passive data used to monitor operations to active data used for managing processes and predicting behaviors through artificial intelligence and deep learning systems.

Conclusion

FPInnovations' Forestry 4.0 Initiative aims to bring the Canadian forest value chain to operate within the parameters of the Industry 4.0 standard of cyber-system connectivity and on-demand production. Several challenges remain before reaching this goal, the main one being around the availability of wireless networks in the remote locations where forest operations take place. Other challenges around the variability of the operating environment in contrast to other industries also will hamper the implementation of advanced automation, autonomous and robotic technologies.

Through this initiative, FPInnovations hopes to leverage the knowledge developed from a network of industrial and academic partners to achieve its goals. Ultimately, FPInnovations aims to be a key facilitator of forest industry 4.0 by facilitating the integration of the new technologies and approaches in the business processes and infrastructure of the timber supply chain.

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