Original scientific paper

Development of a Sensorized Timber Processor Head Prototype – Part 1: Sensors Description and Hardware Integration

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Abstract

Forest operations are in constant development to provide increasingly higher standards of economic and environmental sustainability. The latest innovation trends are concentrated in the generation, storage and management of data related to the harvesting process, timber products and logistics operations. Current technologies provide productivity and position, but only physical parameters are made available for timber products. The possibility of providing a comprehensive quality evaluation of roundwood early in the supply chain and linking the information to each log provides a new tool for optimization of the whole forest-timber supply chain. Current in-field methods for grading logs are based on visual rating scales, which are subjective, operator-dependent and time-consuming. As an alternative, a sensorized processor head was developed, featuring the following sensors: near infrared (NIR) spectrometer and hyperspectral cameras to identify surface defects, stress wave and time of flight sensors to estimate timber density, hydraulic flow sensor to estimate cross-cutting resistance and delimbing sensors to estimate branches number and approximate position. The prototype also deployed an RFID UHF system, which allowed the identification of the incoming tree and individually marked each log, relating the quality parameters recorded to the physical item and tracing it along the supply chain. The tested sensors were installed and designed to be independent, nevertheless, their integrated use provides a comprehensive evaluation of timber quality. This paper presents the technical solutions adopted, the main hindrances found and some preliminary results of the operative prototype as tested in laboratory and in forest operational conditions.

Keywords: timber quality, processor head, sensors, NIR, cutting forces

1. Introduction

Forest operations and dedicated machinery are in constant development to provide increasingly higher standards of economic, environmental and social sustainability (Marchi et al. 2018). The latest innovation trends are concentrated in the generation, storage and management of data related to the harvesting process, timber products and logistics operations. Such data may be used for process optimization, product traceability and system control, among other purposes. Current technologies may easily provide parameters such as productivity and position of the machines, but when quality of timber products is considered, only physical parameters are available (e.g. taper, dimensions). The possibility to provide a comprehensive quality evaluation of roundwood early in the supply chain (at forest landing or roadside) and link the information to individual items (logs) provides a new tool for optimization of the whole forest-timber supply chain. Current in-field methods for grading logs are based on visual rating scales, which are subjective, operator-dependent and time-consuming. Assessment of commercial value of timber lots is a cumbersome activity. It implies the estimation of volume of log piles, segregated per different quality classes or assortments, where applicable. This practice is common in most countries and is essential for an effective value recovery of the produced round timber, being a possible alternative for the sale of the whole standing or harvested lot based on a rough expert-based estimate of its value. As a drawback, accurate volume and quality assessment has a high cost, which in the case of Italian Alps has been estimated at a value of 6–10 €/m^3 (Forest Service of Autonomous Province of Trento, personal information). This higher value is also due to the practice of commercial counterparts to compare the assessment of two or more expert evaluators (one for each party), repeating the same measures twice and occasionally with contrasting results. Most EU countries lack a third neutral party providing a unique and mutually accepted value estimation for timber and biomass assortments such as the Swedish VMF association. Timber volume estimation and geometrical characteristics are regulated by the standard EN 1309-2:2006, while timber quality is assessed according to standard EN 1927-1:2008 (for *Picea* and *Abies* species). Both standards are based on manual measurements and visual grading, thus leading to high costs per unitary volume and, to a certain degree, to the subjectivity of results.

The introduction of timber processor heads has provided an instrument for automatic measurement of several geometrical properties of roundwood and, most of all, its volume based on piece length, top and base end diameter. Commercial processors install sensors to measure these parameters while processing trees and store the resulting data using the StanForD format standard (Skogforsk 2018).

Processors have been studied as a possibility to provide reliable volume data as an alternative to manual measurements. If properly and frequently calibrated, timber processors proved to be sufficiently effective when dealing with larger assortments, while reliability decreased with pulpwood (Nieuwenhuis and Dooley 2006). A similar study on poplar plantations proved that processors may provide the same measuring precision as manual systems (Spinelli et al. 2011). Nevertheless, none of these experiences considered quality parameters of timber assortments.

Innovation in this sector has frequently focused in the introduction of sensors and automation, with different purposes (Lindroos et al. 2017). For instance, processor and forwarder booms have been equipped with sensors for precise recording of the head position (Lindroos et al. 2015), allowing detailed recording of the actions performed by the machine (e.g. each boom movement, including the position of the loads with respect to the machine), but also providing information useful for timber traceability. Miettinen et al. (2010) experimentally installed a stereo camera to test the feasibility of measuring the size and shape of processed logs, returning a digital model of logs even if irregular light conditions proved to be an important limiting factor for this technology. Dowding et al. (2014) tested with encouraging results the possibility of estimating timber quality with acoustic sensors, simulating the deployment on processor heads. This application had been successfully installed on commercial processors, proving their capacity to segregate timber assortments according to wood stiffness in the forest (Walsh et al. 2014). Acuna and Murphy (2006) found that NIR could be used to predict Douglas fir wood density from chainsaw chips, which indicated the potential of this technique to be used to segregate logs on the basis of their density.

Focusing timber processing activity on maximum value recovery is a possible approach to increase the overall benefit while addressing one of the key aspects of Sustainable Forest Operations (SFO) (Marchi et al. 2018). Nevertheless, this also increases the complexity of the operation and as a consequence increases costs by reducing productivity. This calls for a compromise between the number of assortment classes and productivity (Tolan and Visser 2015). The same authors suggested that significant value and productivity benefits could be found if other parts of the supply chain were considered. For instance, early detailed determination of log quality may provide a powerful tool to optimize the whole supply chain, by guaranteeing to end users the provision of the exact desired quality of timber. Based on this background and following the concept of supply-chain-level benefit of automated detection of quality parameters, a prototype of sensorized processor head had been developed in the framework of the EU project SLOPE (www.slopeproject.eu).

The prototype featured the following sensors: near infrared (NIR) spectrometer and VIS-NIR hyperspectral cameras to identify surface defects (e.g. resin pockets, rotten areas, etc.), stress wave and time of flight sensors to estimate timber density, hydraulic flow and pressure sensors to estimate cross-cutting resistance and delimbing sensors (on stroke piston and below delimbing knives) to estimate branch number and approximate position on the log. The sensors were installed and designed in order to be independent, thus leaving the option to install one or more of them, according to the specific requirements of the market, owner and end-users. Nevertheless, the whole set of sensors was designed to provide a comprehensive evaluation of timber quality, returning a »Quality Index« for each log as an alternative to visual grading performed according to the current standard.

The prototype also deployed an RFID UHF auto-ID system, which integrates a reader with a mechanical automatic tagger. The former allows identification of the incoming tree, gathering information from the digital forest inventory (Pichler et al. 2017) and, where available, cutting instructions to provide maximum value recovery (Picchi et al. 2015). The automatic tagger marks each log, relating the quality parameters recorded to the physical it. Finally, a Wi-Fi communication system enables the machine to exchange data in real-time with logistic operators and end-users for online purchase. By relating to each log quality and quantity parameters automatically collected (thus impartially measured), an alternative service could be offered to manual measurement, reducing overall costs. Furthermore, geographical and time data can be included, allowing for an effective traceability of timber products from the forest to the industry.

This paper presents the technical solutions adopted, the main hindrances found and some preliminary results of the operative prototype as tested in laboratory and in forest operational conditions.

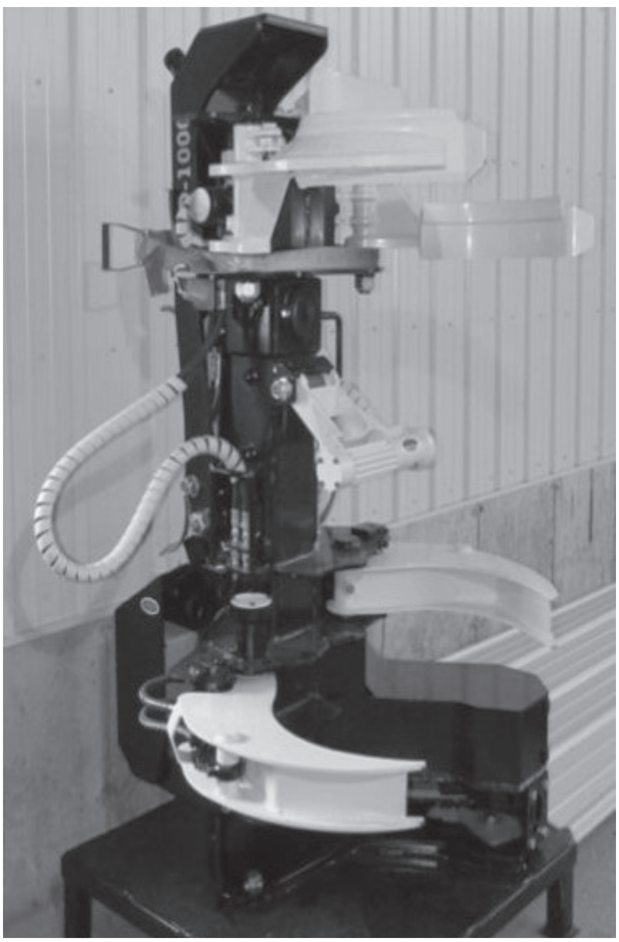

Fig. 1 The base machine for the prototype: ARBRO 1000 S processor head

2. Material and Methods

For the development of the prototype, a suitable base machine was identified through a comprehensive analysis among commercial timber processor heads. Creating a sensorized processor head is a considerable challenge, thus one of the desired features was an inherent construction simplicity, simplifying the tasks of reverse engineering and installation of new sensors and motors. Stroke processors were preferred since the peculiar delimbing and measurement system could provide a series of benefits that will be described in the following paragraphs (2.4). Given these constraints, the model ARBRO 1000 S was chosen as the best suited base machine to develop the prototype (Fig. 1, for more details refer to www.powerforest.fi). To host the sensors, the base processor head was modified by extending the height of the chainsaw holding frame by 25 cm. This created an enclosed area, where a number of sensors and functions could be hosted and protected while benefiting from an optimal position to gather data from the cross section of processed logs.

The prototype was conceived as a system to test the most suitable technologies for timber quality sensing under real conditions. As such, in some cases, more than one system was installed to measure the same parameter, in order to assess the best performing sensors considering the quality of the results, robustness and reliability of the adaptation to the forest environment.

As previously mentioned, even if the sensors had been designed to be independent, the whole set was designed to provide a comprehensive evaluation of timber quality, returning a »Quality Index« *QI* for each log resembling the overall visual evaluation. The *QI* is a numerical indicator ranging from 0 to 1, indicating superior quality or resource suitability for a specific application with values close to 1. The complete evaluation was conceived as an automatic routine, starting with the incoming tree and finalized after processing the last log and dropping the top of the tree on the slash pile (Fig. 2). Sensors will be described following the order programmed in the routine.

Each of the installed sensors consisted of a hardware component (sensor, case and supports, actuators or motors), controlling software to deploy the sensor, and an algorithm to interpret the raw data provided. The complete description of the system is too extensive to be included in this paper. Therefore, the paper will focus on hardware composition and technical solutions adopted.

Sensors provide raw data to the CompactRio NI-cRIO-9014 controller, connected to the industrial PC installed on the excavator. The latter also installs the algorithms to interpret raw data into quality indexes, which are presented to the operator for decision making and stored on a portable hard disk (so called »black

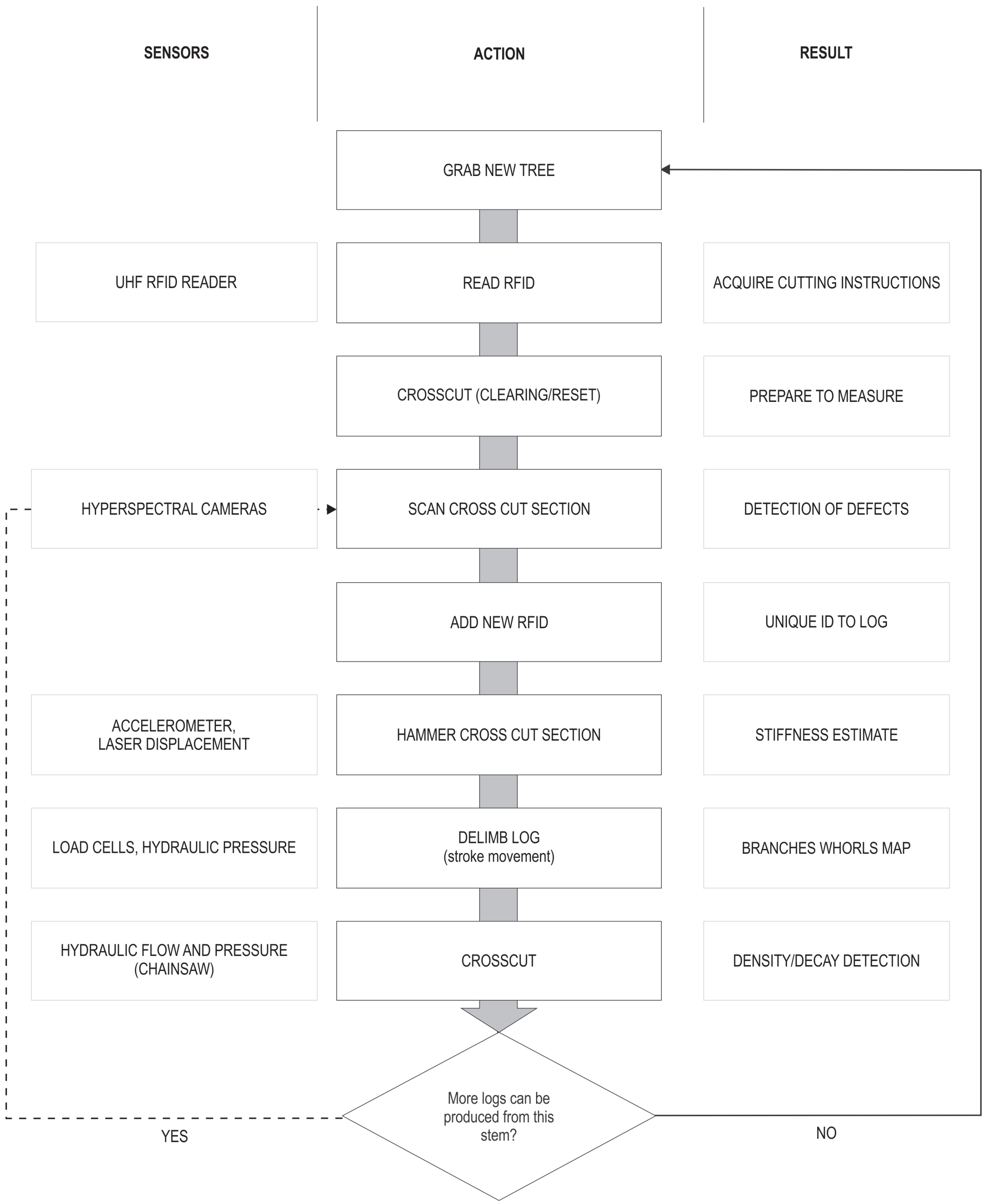

Fig. 2 Simplified routing for log processing and quality assessment

box«). Optionally, all the data can be transmitted in real time via a GPRS connection, if available in the working location. The black box is a solution to provide a backup of the acquired data, necessary when bad or no GPRS coverage is available in the area. In that case, the operator uploads the daily data to the central server by connecting the black box to the internet at his rest location.

2.1 RFID reader

The processor was designed to work coupled with a cable yarder. In the work flow described by Picchi et al. (2015), felled trees are related to the digital forest inventory by manually applying a UHF RFID tag at the butt end of the trunk. This position provides a higher survival rate for the tags and the best conditions for automatic reading. For this purpose, an UHF RFID system was installed on the prototype, composed of a CAEN A528D Muon Compact embedded UHF RFID reader coupled with a X004 linearly polarized antenna (3 db gain) assembled in a protective PVC box (150x150x150 mm). The box was fixed on the frame wall opposite to the position of the incoming log (Fig. 3). This solution allowed for minimum dimensions and maximum reading capacity even if deployed with lower power limits (500 mW), generally imposed for handheld devices. The antenna has an angle of 32° downwards with respect to the main axle of the processor in order to effectively irradiate the whole crosscut section of the log.

The system is completed by an automatic tagger, that inserts a new UHF RFID tag after each crosscut (new log). The tagger is located to the side during processing, and is moved in front of the log when activated to mark the logs on the freshly cut surface.

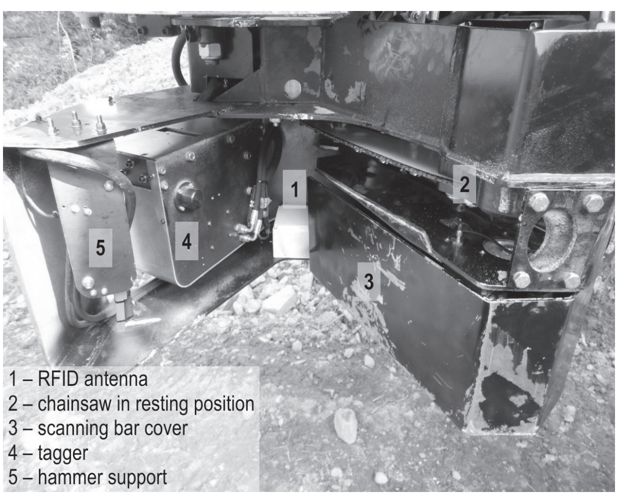

Fig. 3 Sensors installed on processor head

2.2 Hyperspectral imaging camera and NIRS spectrometer

Hyperspectral and particularly Near Infra-Red spectroscopy have proved to have a high potential to identify timber characteristics (Sandak et al. 2016). Deploying these tools on a processor would allow quality determination of resources (logs) early in the processing chain, even before cross cutting of each log to the desired length. Measuring timber cross section with hyperspectral imaging provides a unique possibility to avoid production of low-quality logs (for example cutting out log sections containing rotten wood) and to determine the optimal path for use of the resource. Coupled with chemometrics tools for raw data interpretation, hyperspectral imaging is regarded as capable of detecting several wood characteristics, such as presence of decayed wood, reaction wood, knots, resin pockets, as well as discriminating bark, sap and normal wood. Moreover, hyperspectral imaging technology can be used for detailed determination of log diameter without bark.

This type of sensors was particularly challenging to install on a processor head due to their relative fragility, which has so far relegated them to laboratory use. Furthermore, it was necessary to identify sensors sensitive to the spectral characteristics of light reflected from the rough surface of the section cross cut by the chainsaw. Also the selection and installation of optimal illumination for spectroscopic application was crucial, since illumination may vary greatly on a moving machine in forest conditions. Finally, the development of chemometric models suitable to determine quality indexes was another crucial point for the success of the system.

The objective of hyperspectral imaging is to create a picture as detailed as possible of the cross cut section. For this purpose, due to the limited focus distance of most cameras (few mm), it was decided to install the sensors on a scanning arm featuring a rotational movement similar to that of the chainsaw of the processor. Consequently, it becomes possible to produce lines of pixels representing different portions of the cross surface of the log, from bark to bark by installing one or more sensors on the scanning bar (Fig. 4).

For testing the prototype, two models of detectors were selected, featuring different characteristics.

2.2.1 Near infrared portable spectrometer MicroNIR PAT-U

This is a compact spectrometer designed by the manufacturer Viavi for process control and suitable for implementation in harsh environments. In spite of its compact size (45 mm diameter and 69 mm height),

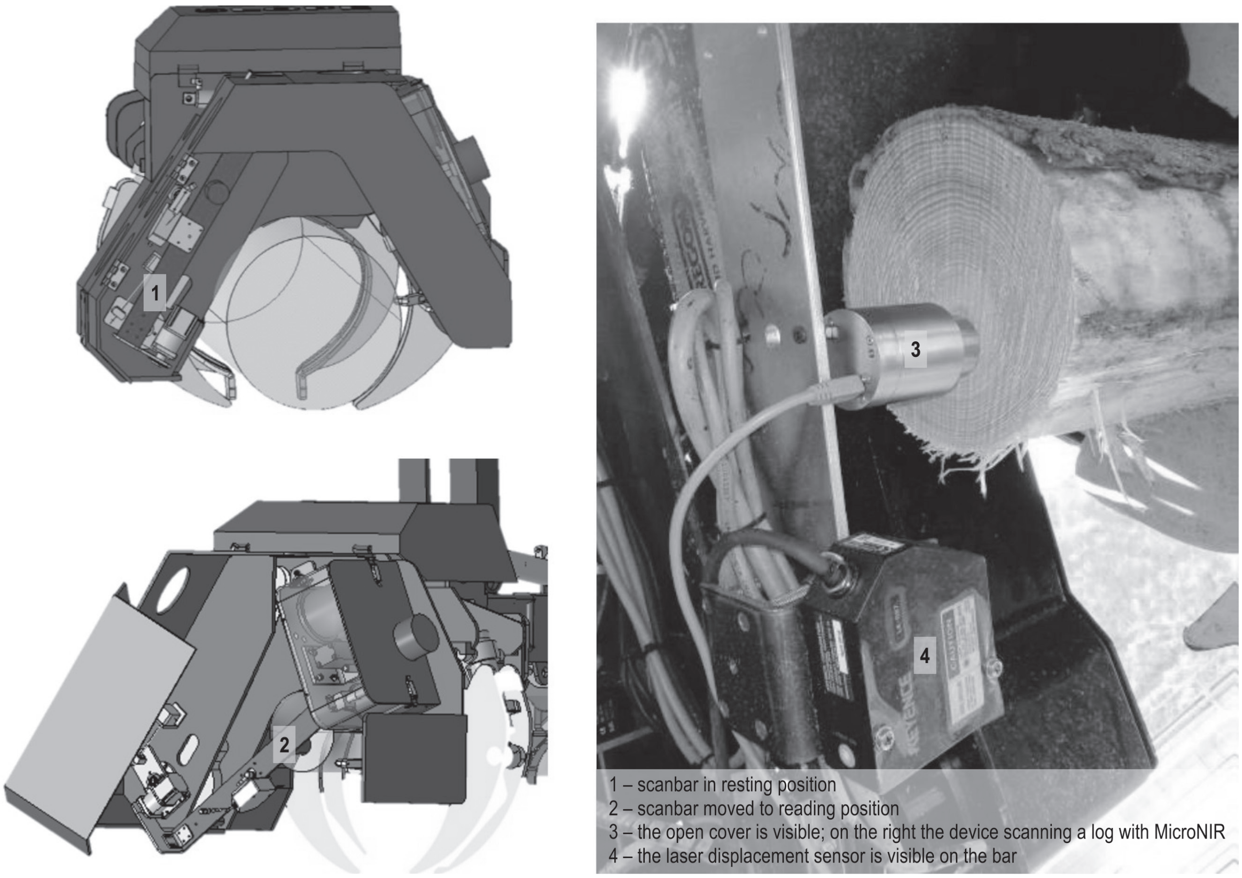

Fig. 4 Schematic representation of the scanbar

this is a complete solution including spectrometer, illumination and base electronic in a single IP67 bundle. The sensor operates in a wavelength range of 950–1650 nm, with a focus distance of 0–15 mm, providing very high performance. Due to its present high unitary cost, just a single device was installed on the processor head prototype.

2.2.2 Hyperspectral imaging camera Hamamatsu C11708MA

This is an ultra-compact mini-spectrometer operating in the spectral range from 640 to 1050 nm with a spectral resolution of 20 nm. The detector itself is compact (27.6×16.8×13 mm) and lightweight (9 g). However, it does not include any focusing optics or built-in illumination, which must be added to the hardware configuration. Proper focus was achieved by installing a 60x Zoom Mini Phone Camera Lens Microscope Magnifier in front of each detector. The solution was cost effective and allowed an optimal distance between lenses and measured surface (D=3 mm). The selection of the optimal illumination was more challenging, and finally two complementary light sources were adopted: a low-cost standard bulb with focusing lenses and a Visible-IR spectroscopic focused micro lamp T-3/4 as a supplementary source. This solution was optimal not only from the economic point of view, but also allowed finest cover of the whole spectral range for the sensor. Given the relatively low unitary cost of these sensors, it was possible to build an array of 16 mini-spectrometers, each with individual lenses and illumination, capable of spanning over the whole surface of the crosscut section.

The scanning bar was protected by a metal cover, which closes it completely when in idle (parking) position. The cover is opened automatically when the scan bar is activated and starts rotating to gain the starting scanning position. Once it has reached the optimal reading distance, the scan is executed all along the surface of the freshly cut log section. Finally, the scan bar returns to the idle position and the cover is closed. Inside the cover, the cameras were exposed to white and dark reference spectra, crucial to ensure proper sensor calibration and compensation for the temperature variation effect.

2.3 Sensors for timber stiffness assessment

Although measurement of stress wave propagation is not completely new in forest processors, it is foreseen to be a valuable source of information for the overall assessment of timber quality and grading of commercial assortments. The prototype tested two measuring systems, which assessed timber stiffness by measuring different parameters.

2.3.1 Stress wave propagation velocity measurement system

The physical basis for measurement of stress wave velocity is its close correlation with the modulus of elasticity of material. It is, therefore, possible to link high quality resources of superior mechanical characteristics with high velocity values. The usual sensor used for timber assessment is based on ultrasonic transducers. Such a solution was tested but it was finally rejected due to high attenuation of the ultrasound by moist freshly cut wood. An important limitation was also the poor coupling between the ultrasonic sensor and the log, especially considering the presence of bark. Therefore, several pin shapes were tested in order to determine the optimal geometry to ensure the best contact between the accelerometer and the wood (Fig. 5). It was finally decided that the best coupling was achieved with sharp pins nailed directly to the wood through the bark layer.

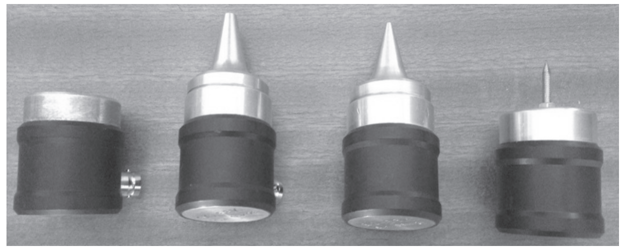

Fig. 5 Accelerometers shapes tested (on the right side the best performing model)

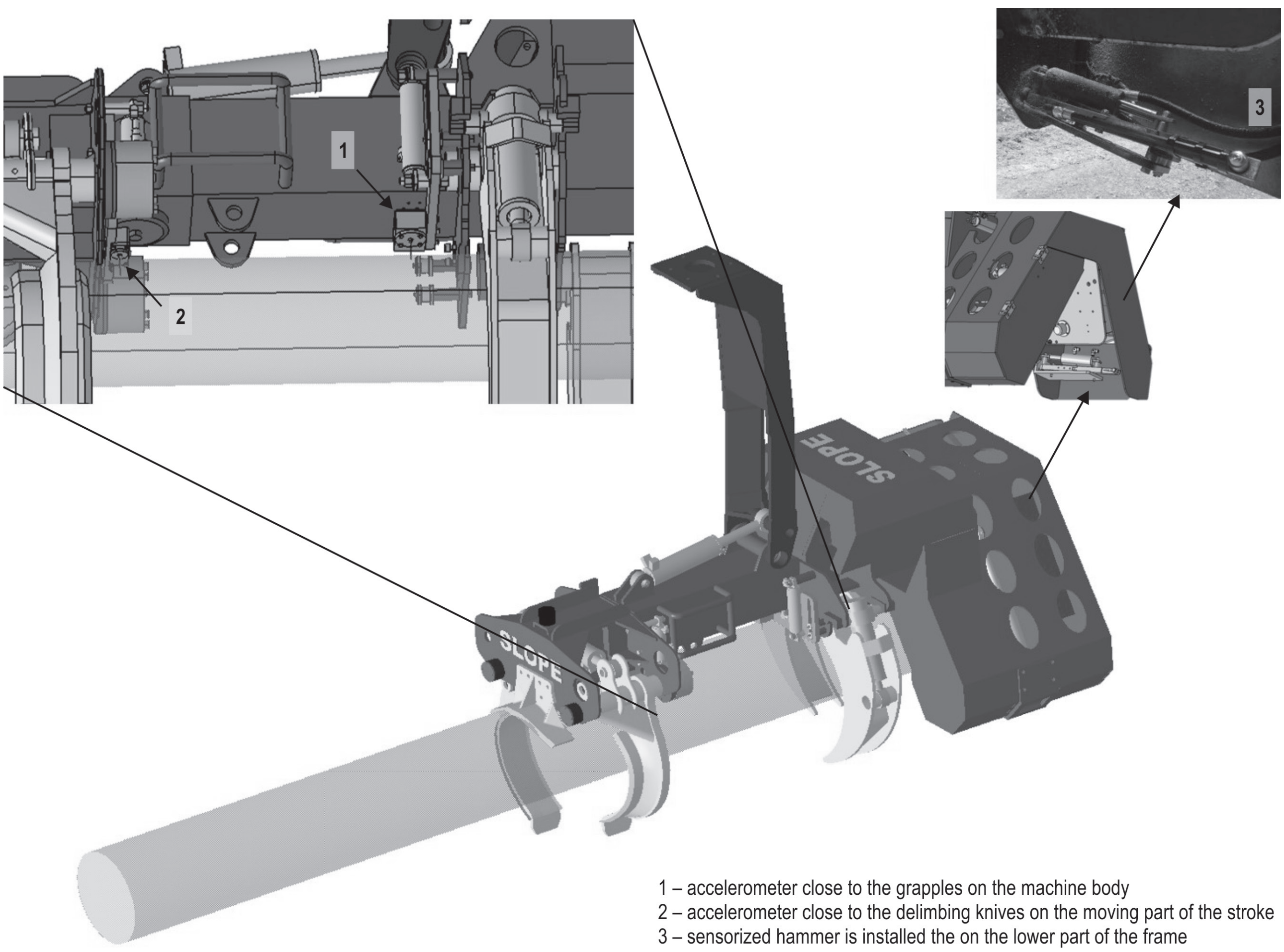

Fig. 6 Schematic representation of the stress wave measurement system

The system implemented on the processor head was composed of a hammer fitted with a dynamic load cell. The hammer generated the impulse (or trigger) by hitting the crosscut section of the log freshly cut by the chain saw. Two accelerometers installed at the stroke (knives zone) and main body (grapples zone) of the processor allowed detection of the Time of Flight between the hammer and each accelerometer. The distance between both sensors varied depending on the stroke position and was between 1270 mm (stroke closed) and 1895 (stroke open). It is schematically presented in Fig. 6. A prototype hydraulic system was developed to ensure proper coupling with the wood. This was achieved by pushing both accelerometers with a sharp pin toward the log side using hydraulic actuators.

Measuring the stress wave is a separate technical operation, which requires the processor to idle for a short time while suspending the tree and tightening it to the machine body in order to minimize movements during measurement. The measurement sequence was implemented as a routine requiring the operator only to initiate the procedure by pushing a predefined button. Once both accelerometer sensors were in contact with the wood, the hammer provided the impulse signal, which was detected by the sensors located in the zone of grapples and close to the knives. By knowing the detailed position of the stroke during measurement, it is possible to compute the stress wave velocity as a ratio of the distance (hammer to accelerometer) and time of flight.

2.3.2 Free vibrations measurement system

An alternative to the stress wave velocity estimation by time-of-flight is to measure free vibration of the trunk. In that case the stress wave propagates from the bottom of the log to its top and then part of the reflected energy turns back. It results in both acoustic effect and mechanical vibrations of the log. It can be measured by means of an interferometer or laser displacement sensor. The second option was selected for implementation on the prototype processor due to the relatively low cost of the hardware but most of all due to its compact size and light weight. The laser displacement sensor (Keyence LK-G87) was installed on the scan bar along with the hyperspectral camera and near infrared spectrometer. An additional accelerometer sensing vibrations of the scan bar itself was mounted in order to compensate for signals not related to the free vibrations of the tree.

The system deployed the same hammer (with dynamic load cell) to provide the excitation to the tree grabbed by the processor. Prior to excitation, the scan bar moves from the idle/protected position to the front of the freshly cross cut section (Fig. 3). Mechanical impact of the hammer causes audible effect and mechanical vibrations of the log. The laser displacement sensor records these vibrations together with compensation of the scan bar vibrations. The Fast Fourier Transforn is performed to determine the frequency spectrum and then to identify frequencies for diverse vibration modes. As a rule of thumb, highly stiff wood of high Modulus of Elasticity possesses high frequency of natural vibrations.

Similarly to the stress wave propagation velocity measurement system, the free vibrations procedure required a short interruption in the processing operation. In this time the protective cover of the scan bar opened, the scan bar moved to the optimal scanning position, and the hammer impacted the log.

2.4 Load cells on knives, hydraulic pressure of stroke

The use of a stroke processor as base machine allowed for the implementation of a complete system of measurement of cutting forces while delimbing. This can be regarded as an important quality aspect, not yet implemented in any other machine (Fig. 7). This is possible by means of two different sensors, acting in synergy:

⇒ load cells installed on the two moving delimbing knives

⇒ hydraulic pressure of the stroke and log length with the overall external quality of the processed log.

For such purpose, the supports of the delimbing knives had been modified to host a load cell each, returning the longitudinal strain due to friction with the bark (base value) and to the impact with branches (goal value). Delimbing knives cover most of the circumference of the trunk and nevertheless the branch-

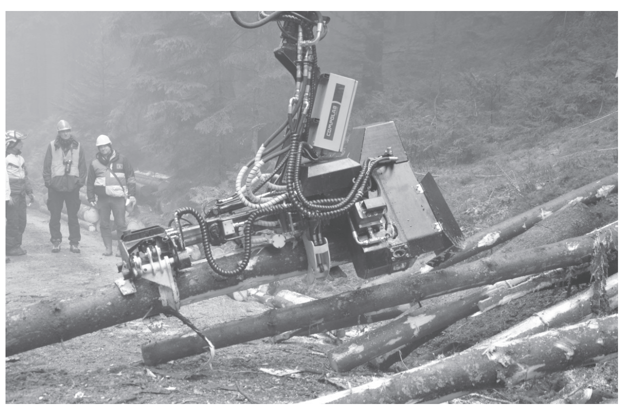

Fig. 7 Prototype processing a tree, with the stroke moving forward

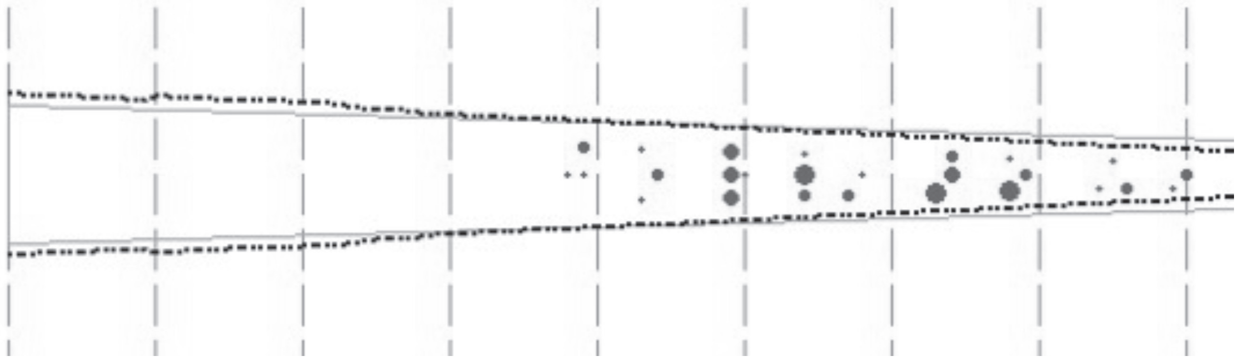

Fig. 8 Example of the knots map representation, potentially to be used by the operator for deciding optimal crosscut position and selection of the produced assortment

es removed by the fixed knives would not be recorded. This is the function of the second sensor, and hydraulic pressure meter, which allows to calculate the hydraulic force required by the main piston to move the delimbing knives forward with the stroke movement. The returned value could be per se an index of »branchiness«, but it can be used to determine the delimbing effort on the fixed knife according to the following formula (Eq. 1):

force_central =
force_stroke – (force_left + force_right) *(1)*

Given the peculiar stroke system used by the processor head, it is also possible to determine the position of the branches on the length of the log by using a linear encoder integrated with the stroke, creating a map of location and size of branches or whorls on the trunk (Fig. 8).

This analysis does not require additional working time, as it is performed during the normal actions of delimbing, providing valuable information without hindering the productivity of the processor.

2.5 Cutting forces by chainsaw crosscutting

The last action performed on each log is crosscutting. Even with this operation, it is possible to gather valuable quality information. In fact, by relating chain saw cutting forces, oil flow velocity, hydraulic pressure and log diameter, it is possible to estimate the quality (density) of the processed log. The hydraulic power is computed in [N*m/s = W] according to the following formula (Eq. 2):

hydraulic_power =
hydraulic_flow * (pressure_inlet – pressure_outlet)
$[m^3/s * N/m^2]$ (2)

where data is provided by a hydraulic flow sensor, and the hydraulic motor inlet and outlet pressure. For a precise estimate, the algorithm requires to be integrated with further data, such as the position of the saw bar, the log diameter at the position corresponding to cross cut location and the number of cross cuts done by the saw so far without tool re-sharpening. The hydraulic power is normalized according to the cutting length, defined here as the length of the chain saw contact with the log at any moment of cutting, computed according to the following formulas (Eq. 3):

Saw_position =

$$\theta = 123° - \arccos\left(\frac{a^2 + c^2 - (b-x)^2}{2ac}\right) \quad (3)$$

Where:

a, b, c dimensions of the mechanical parts of the chain saw system as shown in Fig. 9
x extension of the hydraulic cylinder
θ chain saw angle (0° rest position).

3. Results and Discussion

The prototype was tested both in laboratory and in forest conditions within the framework of the demonstration pilots of the SLOPE project, proving the general validity of the solutions adopted. However, the

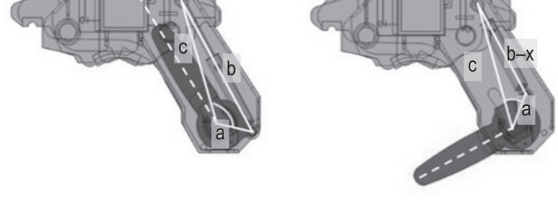

Fig. 9 Schematic representation of the saw position geometry

Fig. 10 Identification of the new RFID tag applied by the tagger

tests were not balanced for all sensors, since not all of them could be installed on all occasions. Furthermore, for most analysis, no reference data could be gathered to validate the system (e.g. stiffness of logs measured with an official system to be compared with the output of the prototype). For the same reason, the algorithms designed for the interpretation of raw data, still require some calibration based on validation tests. Tests are ongoing for the validation of some of the promising sensors, and the results, as well as the software of data interpretation, will be the subject of a future publication. The main remarks and lessons learnt regarding each sensor system deployed are reported below.

3.1 RFID reader

Forest tests of the RFID system resulted in an effective capacity to detect incoming trees. Nevertheless, reading rate was about 80%, while the target is to detect all active RFID tags. Further studies are ongoing on installing a circularly polarized antenna, which delivers less energy but is more suitable for operation with unpredictable reading angles, such as those of a tree landed by a cable yarder. The RFID tagger proved to have satisfactory reliability for a prototype designed

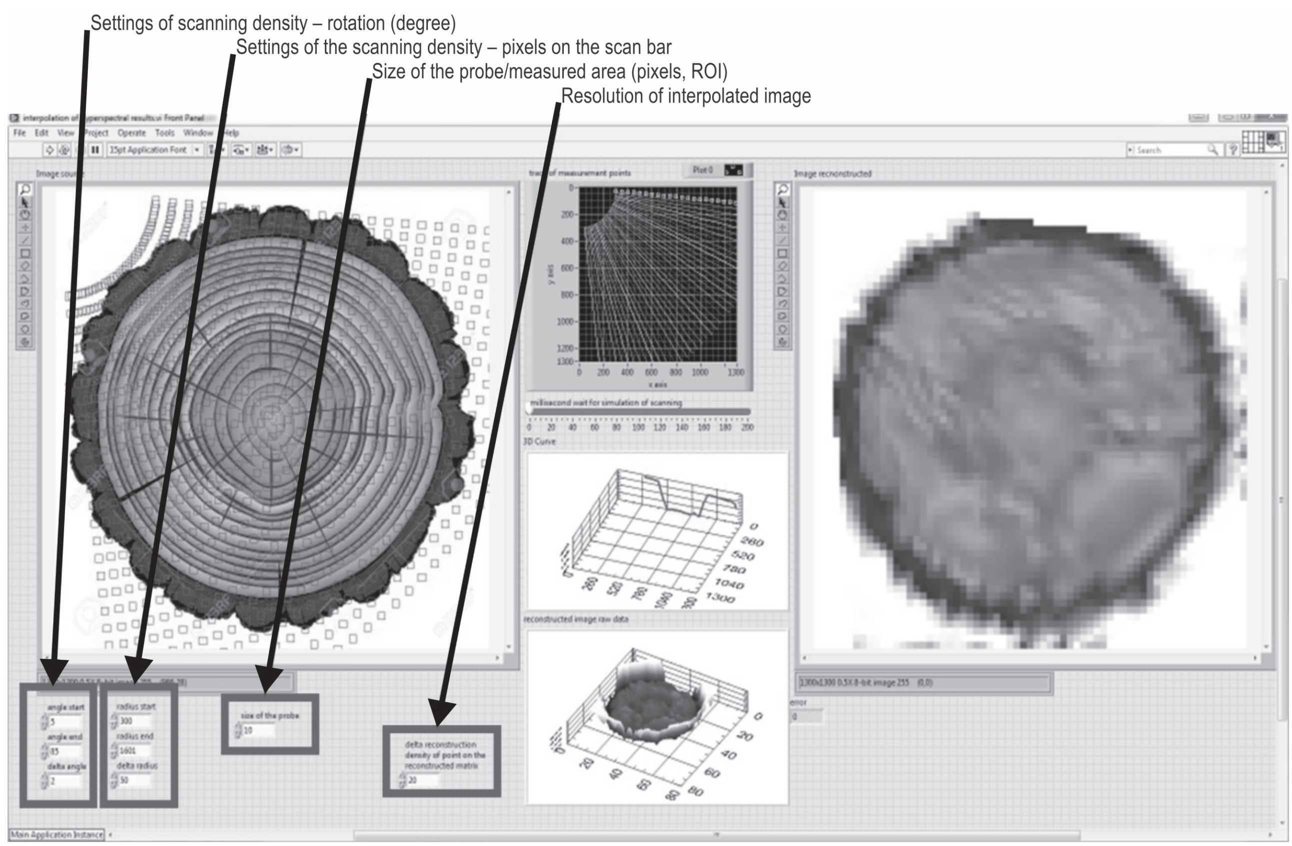

Fig. 11 Simulation of the crosscut surface hyperspectral imaging (top left) – red squares represent the readings (pixels), following the movement of the scanbar; on the right side the interpolated representation of the log surface

from scratch. Further commercial development would greatly benefit from the experience gained from this first device.

3.2 Hyperspectral imaging camera and NIRS spectrometer

The hyperspectral system has not been fully installed on the prototype for extensive testing in the forest. Manual simulations of the scanbar proved the validity of the concept, capable of discriminating several quality aspects, visible or not to human eye, such as detecting first stages of wood decay (Fig. 11). Nevertheless, some of the main challenges, such as environmental light variations, vibrations and resistance to shocks require further investigation.

3.3 Sensors for timber stiffness assessment

Stress wave measurements proved to be effective, returning consistent data regarding stiffness of the logs produced. The operation required 7–8 seconds, reducing the productivity of the processor. The geometry of the pins and the relative actuators require revision since, by running the sensor in operational conditions, the spikes were frequently twisted. Raw data results have not been compared with reference methods for assessing timber stiffness of the samples, but studies are ongoing to validate the system.

3.4 Load cells on knives, hydraulic pressure of stroke

Cutting forces as measured during debranching proved to be a valuable quality parameter. The related sensors are relatively easy to install and maintain, while representing a limited cost compared with other systems tested. Further research is ongoing to validate the system and provide an optimal interpretation of the raw data, filtering out the base resistance given by the friction of the knives with the tree bark. The robust structure of this sensor, coupled with the absence of delays in the processing activity, makes this system one of the most promising among those tested.

3.5 Cutting forces by chainsaw crosscutting

Wood density measured by the cutting resistance of the chain saw during cross cutting benefits from the same advantages as delimbing forces: a robust sensoring structure and absence of delays in the timber processing activity. However, more refined estimate will require careful testing of the cutting edge dulling and other possible parameters affecting cutting forces (such as variations in wood moisture content, presence of reaction wood, temperature and viscosity of hydraulic oil, among others).

4. Conclusions

Project SLOPE had the scope to develop intelligent machines to work in mountain forests. The resulting prototype of a sensorized timber processor is a demonstrative study of the potential of automated timber quality assessment early in the supply chain. The implementation of this pioneering concept could greatly optimize the forest-timber production process, with important cost reductions for the whole system and providing a tool to deliver to end users exactly the assortments of the required quality (and quantity) rather than woodlots to be further classified in the sawmill. The first stage demonstrated the practical feasibility of installing several sensors on a processor head and retrieving raw quality data related to each produced log. Tests identified the best performing, or most reliable solutions for each of the parameters to be measured. The following steps of this research will be the validation of each quality index generated by interpreting the raw data with a dedicated algorithm, and the creation of a weighted evaluation matrix. By interpolating all the quality indexes recorded by the sensorized processor, the matrix will return a unique quality index, which may be a possible alternative to the visual quality grading systems for roundwood currently in use.

Acknowledgements

This work has been conducted within the framework of the project SLOPE receiving funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under the NMP.2013.3.0-2 (Grant number 604129). The authors also gratefully acknowledge the European Commission for funding the InnoRenew CoE project (GA #739574) under the H2020 Widespread-Teaming program and the Republic of Slovenia (investment funding of the Republic of Slovenia and the European Union of the European Regional Development Fund).

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Received: April 30, 2018
Accepted: July 02, 2018