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TRACEABILITY AND ADAPTIVE PRODUCTION IN THE DIGITAL SAWMILL

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Abstract:

The paper describes the development and the evaluation under industrial conditions of a fingerprint traceability system for Scots pine (Pinus sylvestris L.) and Norway spruce (Picea abies L.). It was found that 99% correct matches could be obtained while tracing 89% of all pine boards and 87% of all spruce boards.

This method can be used to connected production data along the whole production chain and will provide new information on the relationship between raw material properties and final product properties. The paper also elaborates on how such information will form the basis of the adaptive production control in the digital sawmills of the future.

Key words: *boards; digitalization; fingerprint; logs; sawmill; traceability.*

INTRODUCTION

Over the past decades, the sawmill industry has become more and more digitized. Nowadays, a wide range of sophisticated measurement systems are used for scanning logs and boards in different stages of the production chain. For example, many sawmills use X-ray-based log scanners to predict the grade of sawn goods before actual sawing takes place, thereby optimizing production by using the right logs for the right products. Sawn goods are scanned with optical systems or X-rays in order to determine dimensions and grade and to make decisions for the further processing.

The data collected by such instruments is however still used only to a limited extent. The scanning systems are primarily being used for making production decisions in the current production stage, for example an edging, cross-cutting, grading or sorting decision. Some information is also being logged into databases which enables follow-up of the production on batch level.

Data about individual logs or boards are however rarely being saved and reused later on in the process. The main reason for this is the difficulty of keeping track of the identity of logs and boards throughout the production chain. Literature suggest many different methods for keeping track of individuals between different stages of the production using additional ID marking equipment such as RFID transponders, ablation lasers or color markers (*eg.* Uusijärvi 2010).

Another approach involves using the biological diversity of the wooden raw material to calculate unique fingerprints of each individual. These fingerprints can be identified in a later stage and information associated with the individual can be loaded from a database and reused. Tracing from logs to sawn boards has been described in literature (Flodin *et al.* 2008) and was made an industrial implementation by Skog *et al.* (2015).

The successful industrial implementation of a system capable of accurately and noninvasively tracing almost every log to boards has opened the doors to the digital sawmill industry of the future. In a currently ongoing research project, large amounts of connected sawmill production data will be gathered, forming big data describing the process. Such data give completely new opportunities to analyze and optimize the sawmill production.

OBJECTIVE

The main objective of the research present in this paper was to evaluate the traceability technology in an industrial environment and to elaborate on possible future uses of big data for adaptive production control in the digital sawmill.

MATERIAL, METHOD, EQUIPMENT

X-ray Log Scanning

Most industrial X-ray log scanners use a limited number (typically 1–4) of fixed measurement directions (*e.g.* Aune 1995; Pietikäinen 1996; Grundberg & Grönlund 1997). The most common solution on the market is two-directional X-ray log scanners producing two perpendicular radiographs as the log is fed through the scanner (Fig. 1). The X-ray radiographs of the log contain data describing the internal X-ray attenuation distribution of the log. From these data, it is possible to distinguish many different internal features of the log. Detection of knot structure has been presented by *e.g.* Pietikäinen (1996) and Grundberg & Grönlund (1998).

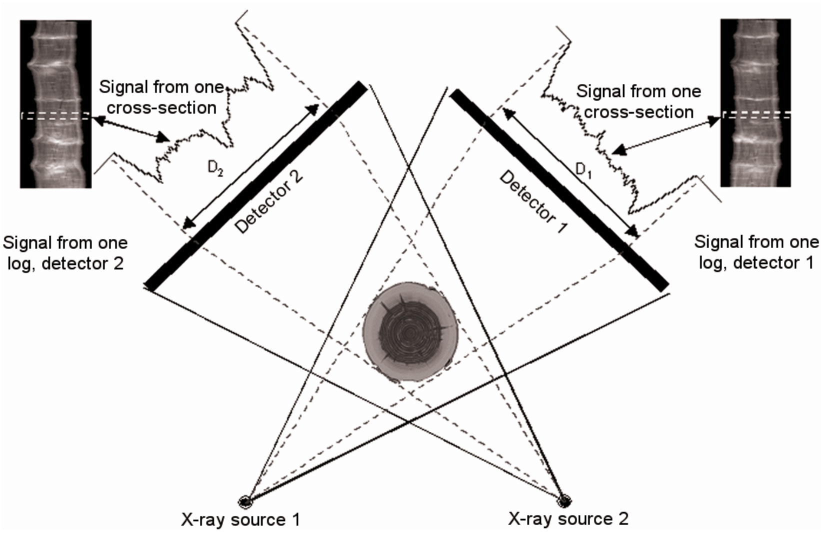

Fig. 1.
Schematic of the X-ray log scanner described by Grundberg and Grönlund (1997).

Board Scanning

Board scanners are vision systems that collect images of the sawn wood. By analysing these images, the board scanner extracts information about board features such as dimension, wane and knots. The RemaSawco RS-BoardScannerQ (Fig. 2) also includes a laser-based tracheid system that measures the grain angles across the board and uses this information to improve the knot detection.

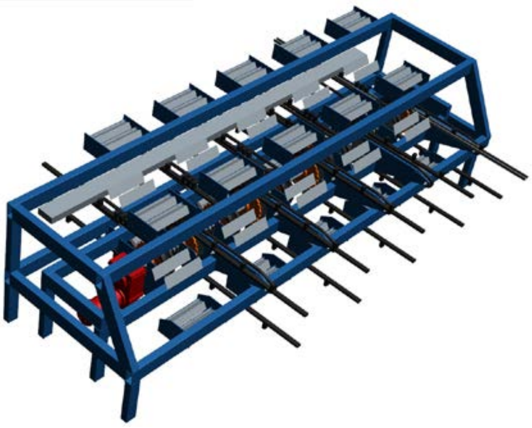

Fig. 2.
Board scanner with traditional vision system and laser-based tracheid measurements (Illustration by RemaSawco).

Data Collection

A total of 22 926 Norway spruce and Scots pine sawlogs harvested in mid Sweden were scanned using an X-ray log scanner of the brand RemaSawco RS-Xray (Grundberg & Grönlund 1997; RemaSawco

2017b). Out of these logs, 884 logs (338 Norway spruce and 546 Scots pine) of varying diameter had been manually numbered on both log ends and followed through the X-ray log scanner.

These 884 logs where then sawn into boards using a 2-ex sawing pattern, while keeping track of the log numbers. This resulted in a total of 1768 boards (676 Norway spruce and 1092 Scots pine), each board being individually numbered, thus estabilshing a true relationship between the logs identities and the corresponding board identities. After drying, all 1768 board were transported to another sawmill that had a board scanner of the brand RemaSawco RS-BoardScannerQ (RemaSawco 2017a). There, all boards were scanned while keeping track of the board numbers.

Altogether, this resulted in one data set containing individually matched X-ray log data and board scanner data of 338 Norway spruce and 546 Scots pine sawlogs and one reference data set contiaining X-ray data of the remaining 22042 logs. The purpose of the reference data set was to ensure that the developed algorithms would not create false positives.

Calculation of fingerprints

Fingerprint algorithms were developed based on the principles described by Flodin et al. (2008). A knot fingerprint was calculated for each log based on the density variations in the X-ray images, and for each board based on the board scanner knot detection. This board scanner offers very high knot-detection precision thanks to the combination of a traditional vision system and laser-based tracheid measurements, which helps avoiding misclassification of dirt and stains as knots.

Matching of data

The knot fingerprints of all 22 926 logs were stored in a database. Each board fingerprint was then compared to all log fingerprints in the database in order to find the best matching log, and a reliability measure was calculated for each match. By setting a threshold on this reliability measure, it was possible to eliminate the most uncertain matches.

The share of boards being matched to logs was calculated using four different reliability thresholds. For each threshold, the share of correct matches was calculated by comparing the suggested best match to the true log identity in the manually matched data set.

RESULTS AND DISCUSSION

Matching results

Fig. 3 shows the matching of a board fingerprint to two different log fingerprints in the database. For most fingerprints, the matching was unambiguous; for Scots pine it was possible to trace 94% out of all boards to the correct log, and for Norway spruce this number was 93%. When using a threshold on the reliability measure, it was possible to reach 99% matching correctness while still tracing around 89% of the pine boards and 87% of the spruce boards. The results for the four different thresholds are shown in Fig. 4.

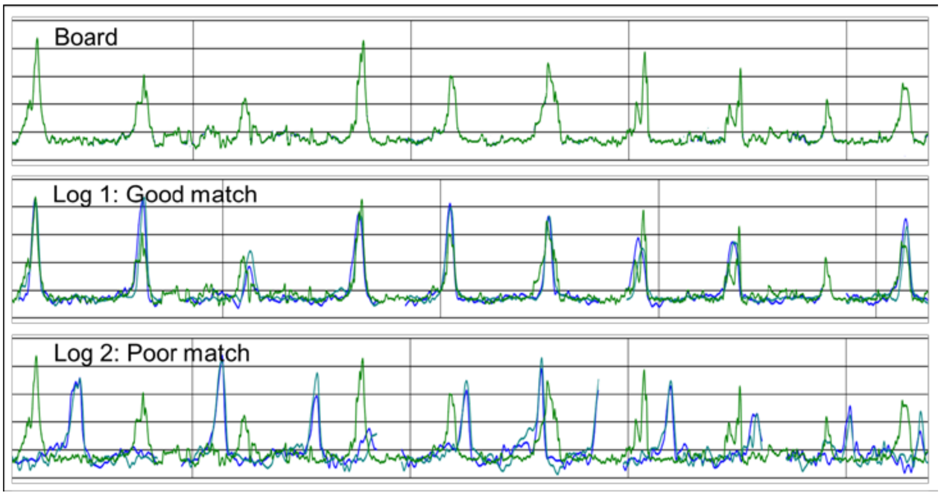

Fig. 3.
Matching of a board fingerprint to two different log fingerprints, log 1 being the correct log.

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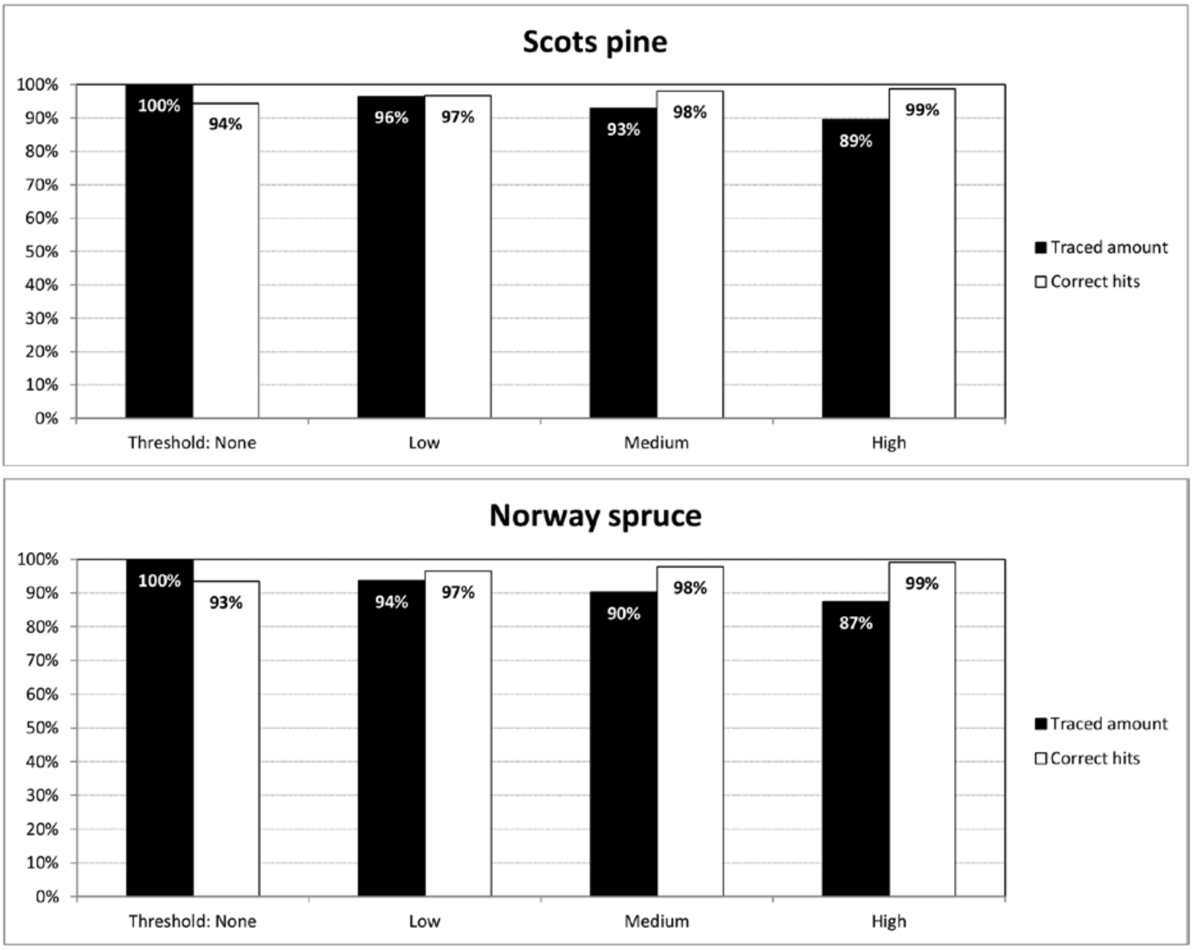

Fig. 4.
The share of Scots pine and Norway spruce boards being traced to logs (black) and the share of correctly traced boards (white) for different thresholds of the reliability measure.

Future Research on the Digital Sawmill

The traceability method described above was found very successful and the host sawmill decided to invest in an RS-BoardScannerQ of their own, which was installed beginning of 2017. This will enable the accurate and noninvasive tracing of almost every log to boards, thereby allowing the collection of big data describing the sawmill process. This data connects the properties of the raw material and the final products, thus offering completely new opportunities to adapt the sawmill production both to customer demands and to actual raw material properties.

A new research project called "The Digital Sawmill" has also been launched, aiming at implementing a more fine grained traceability along the whole process chain, connecting data from all relevant systems in addition to the X-ray log scanner and the board scanner data described here (Fig. 5). The project will investigate how this kind of big data can be used for production optimization and control. Some of the possibilities that will be investigated are:

1. What kind of logs should be used for each product?
2. How should the logs be sorted and handled in order to achieve maximum value of sawn goods?
3. What are the real costs associated with each product?
4. Are there some logs that generate a negative value and should never enter the sawmill?
5. Can X-ray log scanner data be used for non-contact strength grading of boards?
6. How can X-ray data be used for improved decision making in the wood drying process, preserving energy while obtaining better results?
7. Could collected production data be used by industrial customers in further processing plants?
8. The use of connected data for process monitoring: In a sawmill, there are many machine settings that can go wrong and if the process is not being properly monitored, any hard-earned gains from process optimization is quickly being lost. On-line access to connected

production data could allow the mill to quickly detect deviations from expected behavior, thereby avoiding expensive losses in volume or quality of sawn goods.

In short, with access to full information about the relation between raw materials and final products, a world of new possibilities opens up! In the digital sawmill, production control will be adaptive and able to quickly adjust sorting, sawing, drying and trimming to fluctuations both in market demands and incoming raw material properties.

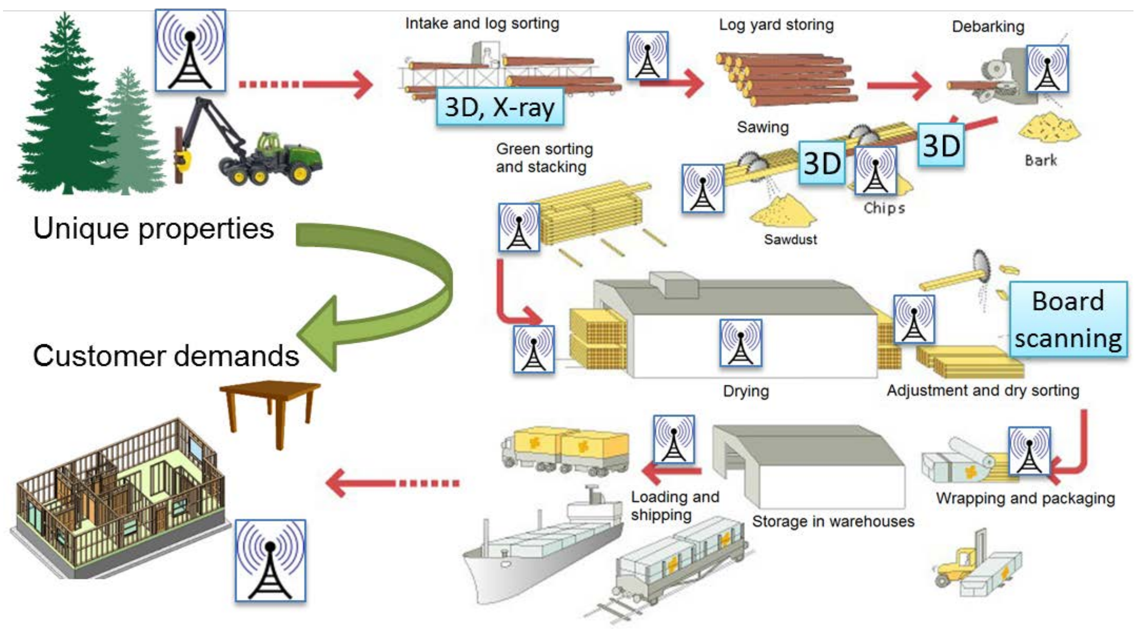

Fig. 5.
The digital sawmill where production data are collected and traced on an individual basis through the whole production chain. The collected big data allows for advanced production control and gives understaning how the unique properties of the raw material are best utilised in order to meet the customer demands on the final products. (Adapted from an image by the Swedish Forest Industries Federation).

CONCLUSIONS

Fingerprint traceability has been proven successful for automatically and accurately identifying which log the sawn boards originate from, for both Scots pine and Norway spruce. It was found that 99% correct matches could be reached while tracing 87-89% of all boards.

Connected production data will provide new information on the relation between raw material properties and final product properties. This information will enable the implementation of an adaptive production control of sorting, sawing, drying and trimming, in order to best meet market demands.

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