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Abstract:

This study suggests two approaches in order to define wood product quality in upstream production flow. Both approaches use X ray tomographic information about round timber (raw material). The first one is a "log approach" based on volumetric information. It correlates a log quality with a given product quality. The second one is a "product approach" and is an extension of the first one. It is based on virtual product surface information obtained from images of round timber and its virtual sawing. Both suggested approaches allow having a better knowledge of round timber and so to define more accurately future made product quality. As results, this better product quality estimation reduces real end product downgrading. New downgrading rates are estimated to 5% with the first approach and 1% with the second whereas the actual real rate is from 15 to 20% in sawmills. This better estimation improves all decisions and production flows.

1 Introduction

Sawmills are supplied in round timbers which are long length stems or standard length logs. This raw material input is particularly heterogeneous and also very different in diameter, length and quality. In process output, sawmills have customers who, at the opposite, want to obtain homogeneous products for each order.

To fulfill these constraints, sawmills implement sort out quality systems at different levels of their production chain. Their objective is to evaluate as soon as possible the end products quality coming from round timbers in order to reduce losses due to downgrading in the next steps of the manufacturing process.

Until now, traditional sawmills use human expertise to sort out round timbers by quality (log quality) regarding their potential to produce sawed products corresponding to customer's needs. Then, by another human grading step, end product quality is validated or re-affected and a production plan is generated one time more regarding observed variations of the order.

Our work intents to help or replace human beings to reduce end products downgrading by introducing vision systems and particularly, X ray tomography. Then, it is possible to make the quality classification process faster and more repeatable. It also allows to complete external view of wood material by its internal view, and so, increases accuracy of useful information to a better evaluation of wood quality (round timbers or end products).

One of the main domain difficulties concerns inaccuracy and uncertainty in quality determination. First, characteristics, which have to be taken out and analyzed to determine wood quality, are relatively uncertain. Wood is a material intrinsically fuzzy. For example, knowing boundary between clear wood and defects is often gradual. This implies that is difficult to accurately locate defects and so, obtain accurate characteristics. This uncertainty is reinforced by used sensor which gives only a partial view of needed criteria to express quality.

In addition, quality (log or product) is a subjective notion. Grading is based not only on wood characteristics and defects but also on expert knowledge and feeling. Like so, quality giving out of a log or a product has another uncertainty and inaccuracy part in processing and decision chain.

Generally, downgrade made by sawmill experts reaches a rate between 15 and 20% [Hodges, 1990]. This implies that sawmills must store enough products to satisfy customers' needs.

The aim of the study is to improve product and log quality evaluation before stem transformation. Effectively, this improvement allows waste reduction due to downgrading and so, a better inventory and flow management, from supply to expedition. Our works highlight two approaches: one aims to evaluate log quality based on volume information coming from numeric view of the stem (section 2), and the second one evaluates end products quality based on a virtual view (section 3). Finally, conclusions and perspectives are presented in the section 4.

2 Material development before sawing based on Log: "Log approach"

In this approach, promotion is based on log quality coming from a set of characteristics extracted from stem tomographic images where logs come from. These characteristics represent log defects, log mechanical properties or log dimensions. They allow having a numerical representation of the log. In order to determinate quality, first step is to define all the criteria qualifying quality. Then, decisional thresholds associated to these criteria are needed to specify quality classes and to choose which one has to be attributed to the log.

Even through this approach is able to define a "Log Quality", quality criteria and measurements are determined regarding their impact on the end product. This impact has been deducted from a knowledge modeling work on "Log Quality" and on "Product Quality", but it also has been studied by simulation.

Knowledge modeling work uses NIAM/ORM [Halpin T.A., 2006] and concerns an industrial sawmill application case. A previous study has provided two models specifying the criteria used to define "Log Quality" and "Product Quality" [Almecija

B., 2012]. These two ontological models formalize "qualities" as they are made in sawmills without gain from X ray tomography. Model utilization highlights three kinds of links between both qualities: direct links, indirect links and missing links. The main goals are to reduce the number of missing links, reinforced indirect links and/or add direct links. To do so, two ways are proposed.

On one hand, we take into account the gain due to information coming from X ray tomographic image, and we bring other information with a wood matter knowledge model. The main result of this work is a functional model of the control quality system. This model defines all criteria that the system would be able to detect, recognize and measure to identify log quality or product quality. In addition, at a low abstraction level, functional model specification allows also to extract some thresholds associated to a log quality class.

On the other hand, simulations are processed to highlight digital links between "Product Quality" criteria and "Log Quality" criteria, and thus to define the decision thresholds associated to criteria for each "Log quality" class regarding impact on "Product Quality" class. Their implementation is done by an expert having knowledge on wood matter and so, adding knowledge about log or product criteria too. Simulations are mainly processed on log criteria having a geometrical link with one or several product criteria. To do so, a numerical log is then created whose main characteristics can be set (log diameter, knot number, knot diameter, length, etc.). Then, a sawing pattern is applied on this log. This sawing pattern geometrically correlates the created log with the end products having a wanted quality. As result, simulation allows to obtain theoretical downgrading rate of products if sawing transformation is performed. This rate is the mean of all possible angular positions between log and sawing pattern. By doing several of these simulations with different simulated log characteristics, it is possible to establish a data base allowing define theoretical decision thresholds in order to obtain an acceptable downgrading rate of end products.

3 Material development before sawing based on virtual product : "Product approach"

Product approach is an extension of the first approach and aims to determinate directly end products quality that could be sawed in round timber. This approach is based on a "virtual" (numerical) view of the product. Product view is obtained by a virtual sawing process applied on tomographic images. Based on those views (product side images), it is possible to obtain several product characteristics (defect size, number, position, shape …) and to determinate the "virtual" quality of the end product which will be saw.

Defects are identified by using a fuzzy rule classifier with defined criteria as input. It has been chosen for its consistency with the industrial context [Bombardier V., 2010]. In order to determinate product quality, we calculate each defect impact on product. One time merged, those impacts allow defining virtual product quality linked to the one given by expert. Finally, we obtain all products with their characteristics (dimension, length and quality) for a given round timber.

X ray image analysis of the product side coming from virtual sawing is however inaccurate and uncertain. Defect identification and characterization steps are complex and they bring also a part of inaccuracy or uncertainty. To take into account these measurement imperfections, adapted tools like Choquet integral or fuzzy rules are used to evaluate the defect impacts on the product quality. Then, we merge these impacts to each other in order to have a measurement of virtual product quality.

With this extension, sawyer can have an estimation of product quality which will be further made in round timber. It is also possible to optimize angular position (between log and sawing pattern) in order to know which position gives the best products regarding customer needs. However, so as to construct an optimal approach, lot of parameters have to be taken into account about next making process steps and particularly, angular position accuracy of the sawing pattern in the round timber during making process.

4 Conclusion

In this study, we propose a "Log approach" and its extension, a "Product approach", to reduce losses due to end products downgrading in sawmill making process. To do so, we use stem information extracted from X rays tomographic images. This information is then processed in order to estimate more accurately end products quality before log and stem sawing. We either express a "Log quality" or estimate a "Virtual quality".

To highlight existing links between both quality views, we modeled expert knowledge about "Log quality" and "Product quality". Confrontation of both models, added to the gain coming from tomography and wood matter knowledge, allows us to define several criteria that have to be measure on log or product in order to determinate qualities. Sawing simulations allow to obtain digital links between both views. They represent bridges between log quality classes and product quality classes.

Several factors as virtual sawing position, characteristic definition on X-ray images or estimations done during quality attribution, influence the result accuracy regarding real quality of made product. Fuzzy merging method utilization aims to take into account lack of information coming from imperfect measurements done on stem representation.

Perspectives allowing a better detection and identification of characteristics and defects will pass through a jointed use of log volumetric information and product surface information in order to suggest a more accurate product quality.

Proposed approaches estimate reduction of product downgrading rate after sawing inferior to 5% or 1% (compared to actual one from 15 to 20%). Downgrading reduction influences all production flow by reducing stocks, increasing productivity and satisfying customers by an optimal need/production agreement.

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