Deciding log grade for payment based on X-ray scanning of logs

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Abstract

In Sweden, the payment for a large part of the saw logs is based on both grade and volume. The volume is measured automatically using optical 3D or shadow scanners. The log grade is decided manually by visual inspection. The manual inspection is expensive and often limits the production speed. This makes it interesting to find an automatic method of grading logs for payment.

X-ray scanning of logs is today used at some sawmills for measuring inner properties of logs and based on this information choose the best logs for different products. Hence, this paper aims at studying if X-ray scanning of logs also can be used to decide grade for payment.

The study is based on 160 Norway spruce logs (*Picea abies* (L.) Karst.) and 160 Scots pine logs (*Pinus sylvestris* L.), all with a top diameter of around 180 mm. The logs were scanned with an industrial X-ray scanner and an optical 3D scanner, and then graded by a skilled log grader. Models for prediction of log grade based on X-ray and 3D data were calibrated using partial least squares (PLS) regression.

The log grade was correctly predicted for 86 % of the spruce logs and 81 % of the pine log. For spruce, bow height was the only significant variable while knot parameters were also important for pine logs.

The results are very promising, but must be tested on a larger and more representative material.

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1 Introduction

At Swedish sawmills, logs are measured and graded for two different reasons. One objective is to sort the logs based on dimension and quality, in order to fit each individual log to the right product. The other objective is to collect information for payment.

The log sorting for process control is based on automatic measurements of dimension and properties such as knot structure and heartwood diameter. The length and diameter are in most cases measured using a 3D scanner (Grundberg et al. 2001). The idea of this is to fit each log to the sawing pattern that produces the highest yield. But today, an increasing amount of customers is asking for sawn products with a specific combination of thickness, width, length and other properties such as heartwood content, distance between whorls and high strength. To produce this type of products in an efficient way, it is necessary to choose the right logs already before sawing. Otherwise, the sawmill will produce a large amount of products with low value due to unwanted combinations of dimension and wood properties.

When sorting the logs based on properties of the sawn wood, one alternative is to use data describing the external shape of the log to predict the properties of the sawn wood (Grace 1994). For more detailed non-destructive measurements of inner properties of saw logs, most industrial applications are based on X-ray scanning (Fig. 1). Industrial X-ray scanning of logs makes it possible to measure properties such as heartwood content (Skog & Oja 2009a), density (Oja et al. 2001), knot structure (Pietikäinen 1996; Grundberg & Grönlund 1997), or annual ring width (Wang et al. 1997; Burian 2006). X-ray scanning of logs can also be combined with 3D scanning for improved measurements of heartwood and density (Skog & Oja 2009b) and combined with acoustic measurements to improve the predictions of strength and stiffness (Lycken et al. 2009).

The payment of logs is at all large sawmills in Sweden based on a combination of automatic measurements of volume and manual grading. For most loads of logs, each log is individually graded. This means that the grader has to make decisions about species, amount and thickness of bark and log grade according to the rules defined by the Timber Measurement Council (Anon. 1999). The large number of decisions that have to be made by the grader limits the speed at the log sorting. At many sawmills this fact makes the log sorting, i.e. the manual grading, a bottle neck in the production chain.

Consequently, an automatic grading for payment would be a significant improvement and much work has been done to make this possible. Oja et al. (1998) describe a system that helps the grader by taking high quality pictures of the log ends and combines this information with an automatic log grade based on the external shape of the log. Edlund (2004) presents further development of the automatic grading based on log shape, while Norell & Borgefors (2008) have developed algorithms for automatic analysis of images of log ends.

So far, none of these methods have been implemented for automatic grading for payment. The reason is of course that grading for payment is a very critical process. Before implementing a new method, there must be no doubt that a sawmill using the new, automatic grading will pay the same price for the logs as if manual grading was used. This makes the robustness of the method important and therefore, X-ray scanning becomes interesting as it is little affected by external factors such as seasonal variation in bark or the existence of snow on the logs.

Thus, it is of interest to study the possibility of automatic grading of logs for payment based on industrial X-ray scanning.

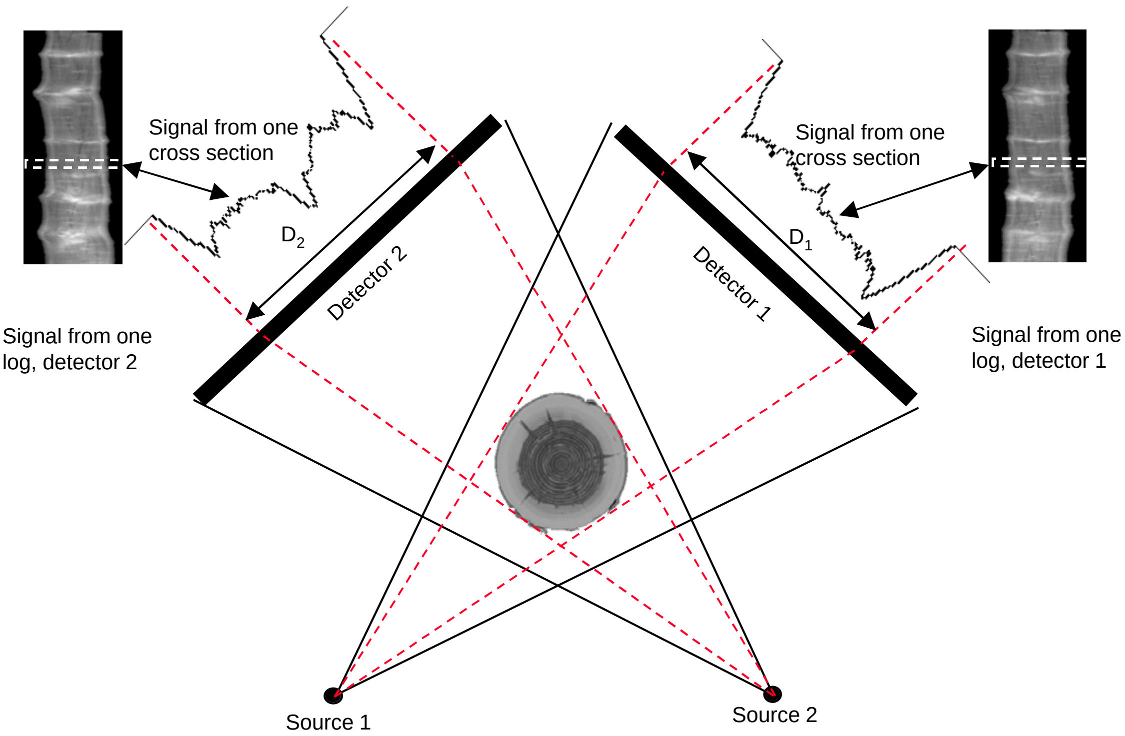

Figure 1: Schematic of the industrial X-ray scanner described by Grundberg & Grönlund (1997).

2 Material and method

The study was made as an extension of a larger project (Lycken et al. 2009) and the material was because of this selected primarily for that larger study. The study is based on 160 Norway spruce logs (*Picea abies* (L.) Karst.) and 160 Scots pine logs (*Pinus sylvestris* L.), all with a top diameter of around 180 mm. The logs come from a sawmill in northern Sweden and were selected randomly from a pile of logs sorted according to top diameter.

The logs were scanned with an industrial X-ray scanner and an optical 3D scanner at normal speed (approximately 120 m/min), and then graded by a skilled log grader according to the rules defined by the Timber Measurement Council (Anon. 1999). For Norway spruce the logs were graded as VMF1, VMF2, VMF8 or VMF9, where VMF1 is the good logs while VMF8 and VMF9 are the worst logs. The Scots pine logs were graded as VMF1, VMF2, VMF3, VMF4 or VMF5. VMF1 are high quality logs with small knots and VMF2 are high quality logs with larger sound knots. VMF4 indicates low quality and VMF5 are the worst logs.

Models for prediction of log grade based on X-ray and 3D data were calibrated using partial least squares (PLS) regression. For Norway spruce, two models were calibrated, one model for separating between VMF1 and VMF2 and another model for separating VMF8 and VMF9-logs from all other logs. For Scots pine one model with five Y-variables was calibrated, one Y-variable representing each of the grades VMF1 to VMF5.

3 Results

For Norway spruce, the log grade was correctly predicted for 86% of the logs (Table 1). But it is important to note that the high percentage to a large extent is reached due to a high percentage of the logs having the same grade (VMF1). For logs predicted as VMF2 according to X-ray and 3D, almost 50% were graded VMF1 by the manual grader. For Norway spruce the variables describing bow height and crookedness based on 3D scanning were the most important.

For Scots pine, the log grade was correctly predicted for 81% of the logs (Table 2). Even though the value is less than for spruce, the model can be said to work better since the logs are spread out more between the different grades for pine compared to spruce. In the model calibrated for Scots pine, variables describing the knot structure are more important than in models calibrated for spruce, but for the worst logs (VMF5), bow height is important also for pine.

Table 1: Automatic grading of Norway spruce logs. Comparison between log grade according to manual grading and log grade according to automatic grading based on X-ray and 3D scanning. Amount of logs in percent.

	Log grade according to X-ray and 3D (%)			
Log grade according to the manual grader	**VMF1**	**VMF2**	**VMF8**	**VMF9**
VMF1	**76**	7	0	0
VMF2	7	**8**	0	0
VMF8	1	0	**0**	0
VMF9	0	0	0	**2**

Table 2: Automatic grading of Scots pine logs. Comparison between log grade according to manual grading and log grade according to automatic grading based on X-ray and 3D scanning. Amount of logs in percent.

	Log grade according to X-ray and 3D (%)				
Log grade according to the manual grader	**VMF1**	**VMF2**	**VMF3**	**VMF4**	**VMF5**
VMF1	***6***	*0*	1	0	0
VMF2	*0*	***33***	3	3	0
VMF3	*1*	*3*	**30**	3	1
VMF4	*0*	*3*	3	**9**	0
VMF5	*0*	*0*	0	0	**4**

4 Discussion

The study is based on a very limited material but indicates that the combination of X-ray and 3D scanning can be a possible method to reach a system for automatic grading for payment. For Norway spruce it is possible that only 3D scanning is enough but for Scots pine the results indicate that X-ray scanning is a necessary addition.

Future work should focus on studies based on a more representative material. The material must be representative with respect to dimension and properties of logs as well as geographic origin of the material. It is also important to register the exact reason for downgrading for each log. This would make it possible to develop specific algorithms for defects such as rot or spike knots.

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