Ring width detection for industrial purposes - use of CT and discrete scanning technology on fresh roundwood

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ABSTRACT

Various optical scanner technologies are used to detect the outer dimensions of the logs to a high precision; the standards for the measurement of external quality features are under discussion. Automated measurement of inner log features has been in the focus of considerations for some time. Appropriate technology for industrial application is on the market, but the measurement algorithms for internal wood features are not commonly agreed by all stakeholders of the wood chain. However, it is known that inner log features affect the type and quality of products. For numerous applications ring width is one of the most important parameter as it is closely related to wood density.

For this investigation, Norway spruce logs of various ring width were scanned on a 2D (two-plane-) scanner at industrial speed and on a purposed-built wood computer tomograph. The computer tomograph was used both to reconstruct the logs by using 900 planes, and to simulate discrete tomography on two planes similar to the industrial scanner. Ring width of Norway spruce was derived from 3-dimensional images generated by computer tomography (CT) and compared to results on the annual ring width gained from the fast industrial two source x-ray scanner. A problem arising in these studies was a large number of “local” missing values along the length of a log due to wood heterogeneity. Wood features can be detected and measured to a high precision for all points. Thus a combination of 2-D scanners with CT provides the possibility to match information from industrial scanning speed with high scanning resolution. The inner wood features which cause errors in the high speed industrial scanning process can be identified this way.

Reference ring width for the CT measurement was derived on the 3D reconstructions.

INTRODUCTION

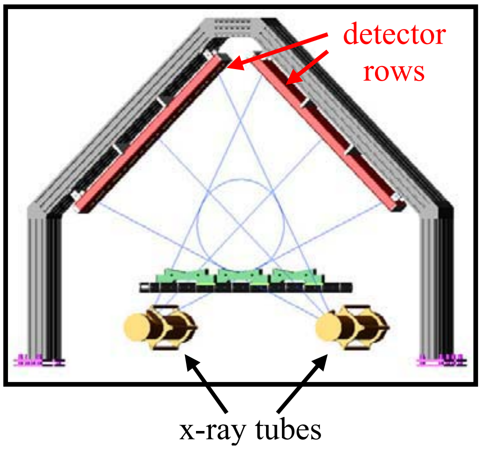
Various optical scanner technologies are used to detect the outer dimensions of the logs to a high precision (Oja *et al.* 2003); the standards for the measurement of external quality features such as curvature and taper are under discussion. Automated detection and measurement of inner log features has also been in the focus of considerations for some time. Appropriate technology for industrial application is on the market, but the measurement algorithms for the internal wood features are not commonly agreed by all stakeholders of the wood chain. However, it is long known that inner log features affect the possible products and product quality that can be sawn from the individual log. Different wood features become important for different production lines (sawmilling, pulp and paper production). For construction purposes, but also for the pulp and paper industry, ring width is one of the most important parameter as it is closely related to wood density. In course of increasing competition and economic pressure on the industry, a demand

for technology and measurement routines has been expressed which allows an automated detection and measuring of the ring width at the mill gate to improve the roundwood pre-sorting prior to production.
In earlier investigations algorithms were developed to detect the annual ring width on fast industrial two source 2D x-ray scanners. A problem arising in these studies was a large number of "local" missing values along the length of a log due to wood heterogeneity which could not be identified by the technology used. The derived "log ring width" value thus was burdened with some uncertainty.

X-RAY TECHNOLOGY

In general x-ray technology uses x-rays produced by an x-ray tube to examine an object by measuring the attenuation caused by this object. This attenuation depends on the material and the density of the object, and is also influenced by the dimension of the object the x-rays as this defines the distance which the x-ray has to pass through the object.

Discrete x-ray scanners
A discrete scanner works with a low number of fixed x-ray tubes and detectors fixed on the opposite direction of the object to be scanned. Fig. 1 shows a possible setting for two tube-detector-pairs and the resulting views generated from two these two scanning planes.



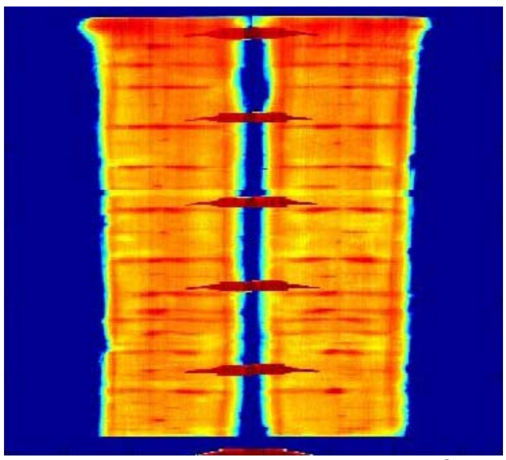


Figure 1: Delineation of a two-source x-ray scanner (here a Microtec Tomolog®) and the image of a log produced by such a scanner

Computer tomograph (CT)
A computer tomograph uses an x-ray tube rotating around the object. During one full-circle rotation several hundred of measurements, i.e. scanning planes are executed. From these hundreds of views a two-dimensional slice of the object called reconstruction is calculated (Kak & Slaney, 1988). Moving along the whole log, a large number of slices are computed resulting in a 3D voxel block defined by all these reconstruction data (Kalender 2003).

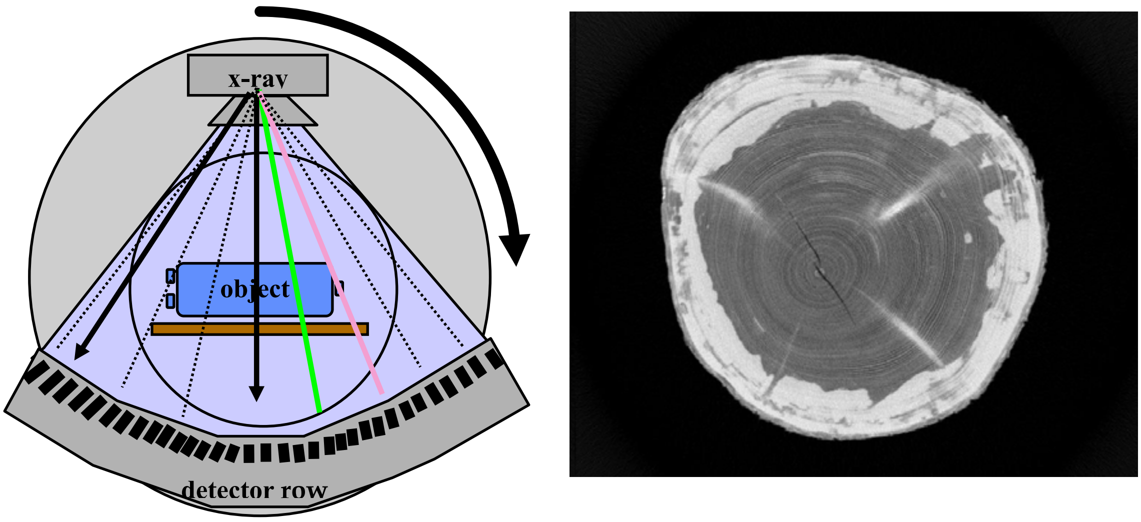


Figure 2: Delineation of a CT and the resulting cross-sectional view of a Norway spruce log produced by a CT

MATERIAL

For this investigation a set of 16 Norway spruce logs were tested. They were grown in the south west of Germany, but in different stands and under different silvicultural management. The logs represent a variation of narrow and wide annual rings as well as small to big log diameter. Thus the logs showed a large variation of the width of the annual rings.
All of these logs were scanned with a discrete two level x-ray scanner (Microtec Tomolog®) in a sawmill in Austria. After that the logs were transported to Freiburg (Germany) and re-scanned with a CT (Microtec CT.Log®).

MEASUREMENTS

At the sawmill the data was gathered with the discrete scanner at a speed of about 120 m/min with a voltage of 120 kV and a current of 9 mA. The logs were all marked at the top, to ensure that the orientation of scan planes at the sawmill was lingering for simulation of the industrial scan on the CT after transportation to Freiburg.
An automatic procedure was used to compute the weighted average annual ring width (ARW_1) of the log. The procedure is based on frequency detection in the attenuation profiles.

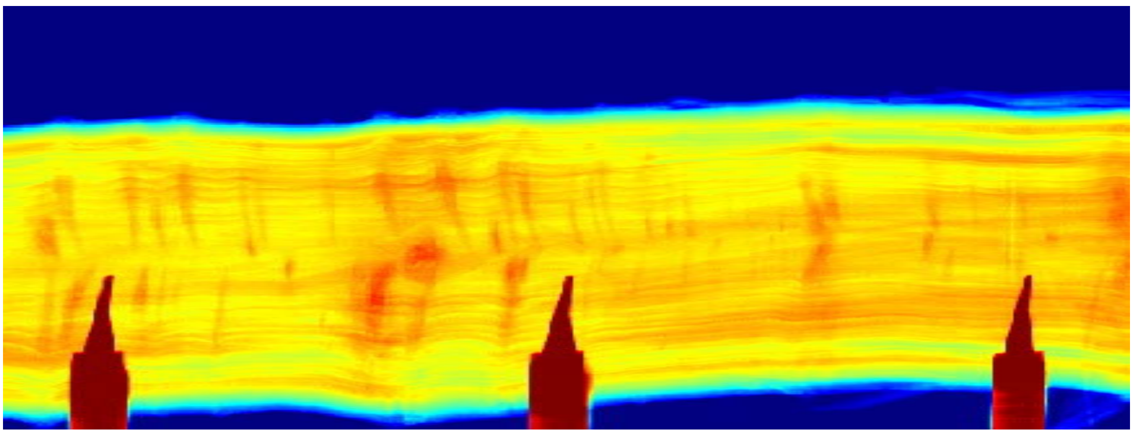


Figure 3: Image of a part of log number 5 gathered with one view of the discrete scanner

The CT measurements were carried out applying a voltage of 180 kV and 11 mA current. A speed of 0.3 m/min was used.

From the dataset gathered with the CT two planes with orientation angles similar to the industrial scanner were selected to simulate discrete scanning in laboratory conditions. Using the information on the orientation of the log, the simulated measurements match the log orientation from the industrial scan tests at the sawmill. Fig. 4 shows the corresponding view, i.e. same plane orientation of log, as measured in the sawmill (Fig. 3). In contrast to the direct image from the discrete industrial scanner, on the simulated view in the CT there is no conveyor visible as the logs are fixed on both ends.

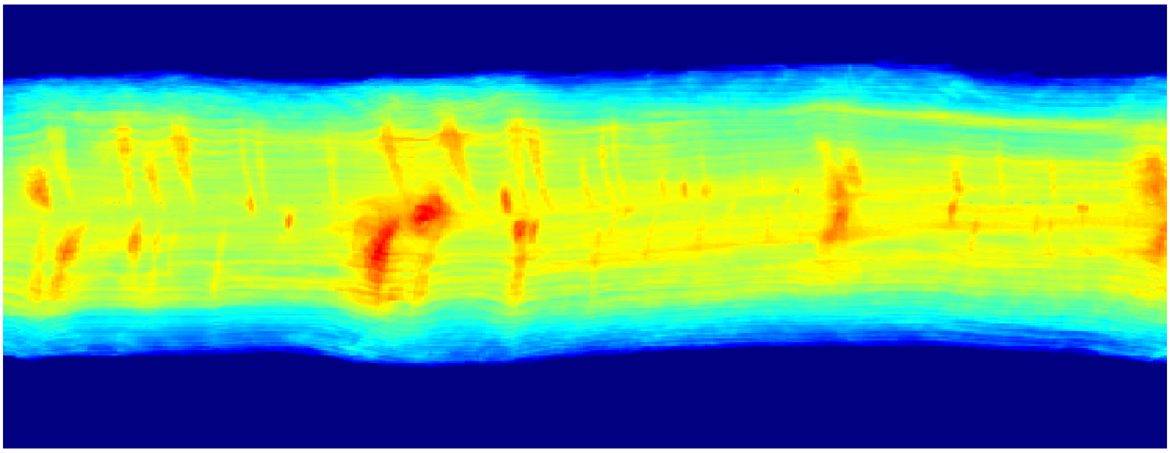


Figure 4: Simulation of the image of a discrete scanner from CT data of the same part of log 5 that is shown in Fig. 3 using the same orientation

For validation of ARW calculation in the industrial scanner, CT full tomography reconstruction of the log on basis of 900 planes was used. One slice per log was selected randomly for ring width detection on the digital image (ARW_2). Ring width was determined as quotient "radius over number of rings on the radius". Number of rings was counted by visual identification of ring boundaries and numbering of individual rings. The radius of the log was determined on the basis of number of pixels and the known pixel size. Automatic procedures to detect annual rings exactly to the correct number are not good enough for a comparison yet.

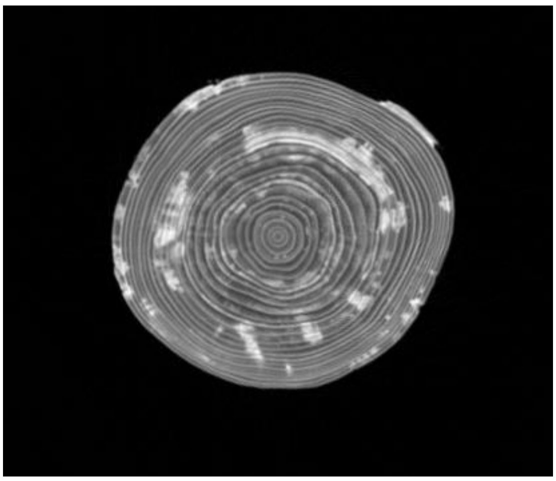


Figure 4: Slice from CT data of log 5 (the log is partly dry)

For cross-validation of x-ray ring width detection with conventional measurements methods, from each log a disc was cut from the butt end and the annual ring width was determined manually as reference measurement (ARW_0).

RESULTS

For the set of 16 logs the results of the different measurements are shown in Table 1. Due to geometrical size of the detectors, for very small ring widths below 1mm the resolution both of the CT, and for the discrete scanner is not sufficient. For ARW_2 "no measurement" is reported in Table 1 when no annual rings could be detected due to these resolution limitations. For the discrete scanner, the automated analysis system is not able to consider these size limitations. Thus a ring width value (ARW_1) is produced which is too high in comparison to the manual reference ARW_0. Ring width for the simulated discrete tomography derived from CT data could not be derived yet, but the evaluation is in progress.

Table 1: Results of the different measurements of the annual ring width

Log number	ARW_0 [mm]	ARW_1 [mm]	ARW_2 [mm]
1	6.4	6.8	6.0
5	7.5	6.6	5.2
7	6.3	7.2	6.5
18	6.5	6.8	6.9
35	1.3	7.5	no measurement
44	0.5	7.7	no measurement
48	0.9	8.1	no measurement
57	0.5	3.7	no measurement
67	4.8	3.0	5.3
68	4.6	3.0	5.1
69	3.3	2.7	4.1
73	5.9	5.2	5.2
76	4.2	6.9	5.1
79	2.6	3.0	3.9
82	3.3	2.8	2.9
84	1.9	3.1	no measurement

In Fig. 6 the two measurements ARW_0 and ARW_1 are plotted at the x- and the y-axis respectively. The blue squares represent the values that can be recognised with the installed resolution on the scanners; the red triangles the ones that could not be measured in CT. Linear regression is calculated only from the blue measurements, giving a R^2 of 0.59.

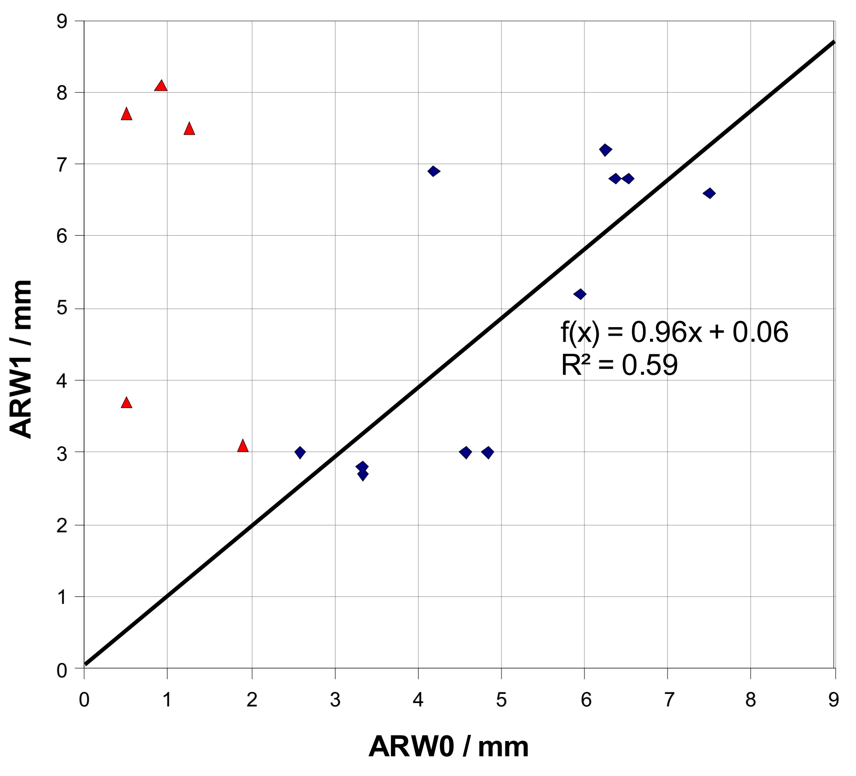


Figure 6: Relation between ARW_1 and ARW_0

CONCLUSION

From earlier studies we know that a measurement of the annual ring width with an industrial two-view-scanner is possible (Andreu & Rinnhofer 2003, Burian, 2006). Problems arise from resolution limitations due to the given size of the x-ray detectors. High attenuation by high water content in the wood obscure as well the contrasting attenuation of different wood density (Longuetaud *et al* 2007) which is the basis for the ring detection. Our investigation show a similar accuracy in ring width measurements as Burian (2006).
The next steps will be to calculate annual ring width for simulated discrete tomography views derived from CT. Thus a combination of 2-D scanners with CT will provide the possibility to match information from industrial scanning speed with high scanning resolution. The inner wood features which cause errors in the high speed industrial scanning process can be identified in CT scanning. At the same time CT will provide discrete scanner simulations for direct validation of the results obtained from industrial scanners.

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