A NEXT GENERATION PROCESSING SYSTEM FOR EDGING AND TRIMMING

A. Lynn Abbott
Bradley Department of Electrical and Computer Engineering
Virginia Tech
Blacksburg, VA 24061

Daniel L. Schmoldt
USDA Forest Service
Biological Systems Engineering Department
University of Wisconsin
Madison, WI 53706

Philip A. Araman
USDA Forest Service
Brooks Forest Products Center
Virginia Tech
Blacksburg, VA 24061

ABSTRACT

This paper describes a prototype scanning system that is being developed for the processing of rough hardwood lumber. The overall goal of the system is to automate the selection of cutting positions for the edges and ends of rough, green lumber. Such edge and trim cuts are typically performed at sawmills in an effort to increase board value prior to sale, and this depends on a balance between large board size and the removal of undesirable wood characteristics, such as wane and surface defects. This paper is primarily concerned with image acquisition and analysis. Off-the-shelf hardware components are used with in-house developed software to capture images of a board as it moves longitudinally on a conveyor. Unlike most board-scanning systems, the system described here analyzes rough (unplaned) boards. There are some advantages to this approach, such as increased image contrast due to surface moisture. There are also disadvantages, however, resulting from the appearance of the wood in its unplaned state, which pose new challenges in the development of image-analysis algorithms.

INTRODUCTION

In sawmills today, edger and trimmer operators visually examine the surfaces of each board, and then make quick judgments about the placement of cuts based on their knowledge of lumber grades and current lumber prices. Optimizing the value of each board in this manner is a complex decision that is difficult even for experienced operators, for several reasons: First, visual estimates of board surface measure are subjective, and inherently suffer from lack of accuracy. Second, prices can fluctuate rapidly, and current prices need to be used to compute a potential sale value for a given edging/trimming solution. Third, potential edging and trimming settings number in the millions. Even if only a small number of settings are considered, it is difficult even for an experienced grader to make rapid assessments of the different possible grades that would result from the different options. These reasons, together with such fundamental issues as operator training and fatigue, suggest that a strong need exists for an automated solution.

This paper describes a prototype scanning system that has the goal of automatic selection of cutting locations for edging and trimming operations. For a typical hardware sawmill layout (as illustrated in Figure 1), the new system would be placed immediately after the headrig. We focus on the problems of image acquisition, wane detection, and defect detection. The remainder of this paper is organized as follows. The following section describes related work, and discusses the relative merits of rough-lumber processing. The next section describes the imaging geometry and hardware of the system. The next section presents some preliminary results. This is followed by concluding remarks.

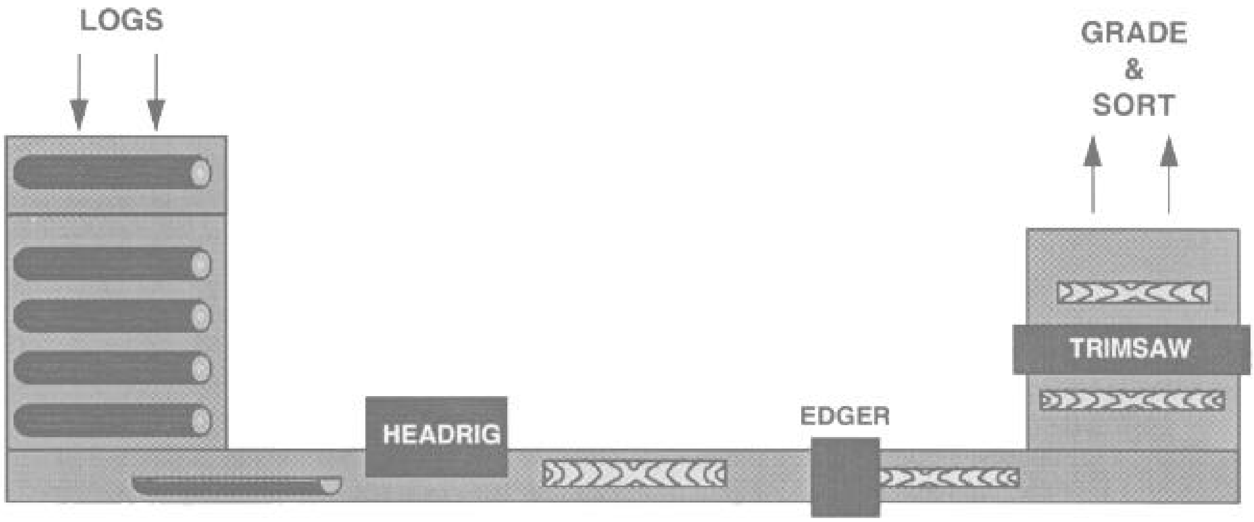
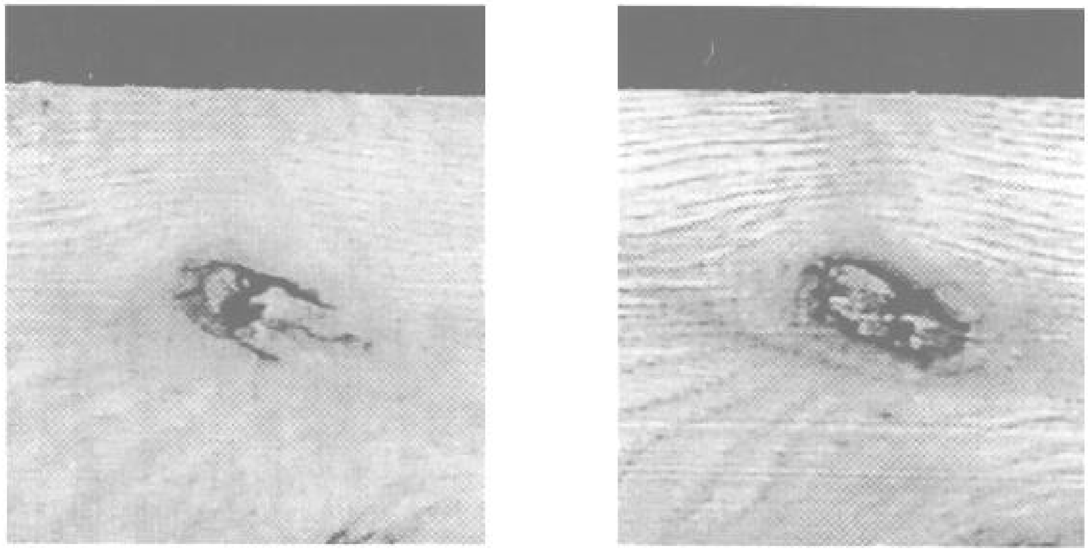


Figure 1. A typical hardwood sawmill reduces logs to boards at the headrig. An edger reduces the width of a board, and a trimsaw reduces the length.

BACKGROUND AND RELATED WORK

Losses from improper edging and trimming can be substantial. Williston (1979) demonstrated that for some mills 45% of a log's original volume is converted into chips from slab boards and from edgings. Most sawmill edger operators remove an excessive amount of wood, and this can result in value losses of 30% (Bousquet 1989). Volume and value losses from improper trimming operations exacerbate the severity of edging losses. Regalado et al. (1992) found, in a case study of 3 hardwood mills, that edging and trimming operations were able to obtain lumber values that were only 65% of optimum. The volume of hardwood lumber produced and the large amount of waste that occurs in current edging and trimming practices makes automation and optimization of edging/trimming necessary to increase profits and to ensure continued operation of rural mills, to conserve the timber raw material, and to create higher value primary products that can compete in a global economy.

Work is in progress to develop a prototype scanning system that can determine optimum edging and trimming solutions for rough hardwood boards. Except for some earlier work (Cho et al. 1990a, Cho et al. 1990b, Conners et al. 1989)—which subsequently abandoned the rough lumber problem and looked instead at surfaced lumber—little has been done to address the vision problems associated with rough lumber. The images in Figure 2 illustrate some of the differences in the two cases. A major emphasis of the work described here is to develop a prototype system that can recognize defects on rough lumber immediately after being cut at the headrig. An early description of the system appears in (Lee et al. 1999).



(a) (b)

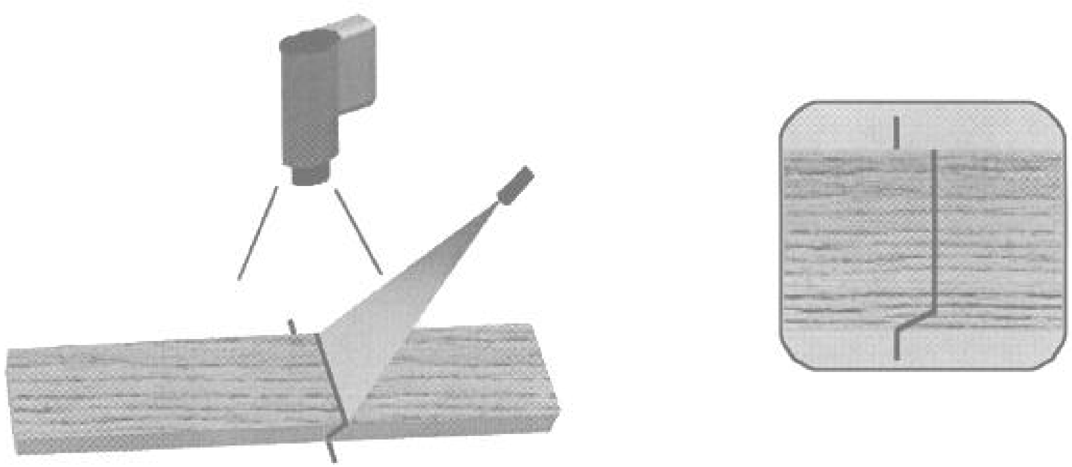
Figure 2. A comparison of intensity images of (a) rough and (b) surfaced lumber. Most scanning systems analyze wood only after it has been surfaced. In the rough state, additional wood fiber, debris, dirt, and saw marks can increase the difficulty of image analysis.

SCANNING SYSTEM

A common method for obtaining thickness (also known as *profile)* information is illustrated in Figure 3. In this technique, known as sheet-of-light range imaging, a plane of light is generated onto an uneven surface. The light that reflects from the surface appears as a 2-dimensional curve in an image, when viewed from an angle relative to the light plane. In our system, for example, the camera is mounted vertically and the laser source is positioned at 45 degrees relative to the lengthwise direction of the board. It is possible with this arrangement to use triangulation to calculate deviations of thickness over the surface of the object. Because many lumber defects (e.g., voids, wane, and splits) are associated with surface irregularity, profiling is extremely useful.

In addition to profiling, two additional lasers are used as illumination sources (Figure 4). Much of this light is reflected from the surface of the wood, but a portion of the light is scattered within the wood, giving a bright region around the point of incidence. The amount of internal scattering depends heavily on the physical characteristics of the wood. The tracheid effect (Soest and Matthews 1985) takes advantage of the differential reflectance of laser light in response to grain angle and different densities on the board. Figure 5 shows a camera view of the tracheid effect, in which the amount of reflectance of laser source varies over the width of the board. One approach to assessing the tracheid-induced scatter is to compute sums of pixel intensity values in a direction perpendicular to the laser line, but not including the central laser line itself. Increased scattering will be detected in this manner, and can be used to detect defects.

The digital camera that is used in this system is the MAPP 2200 "smart camera," developed by Åstrand and Åström (1994). The unit captures images of 256 rows x 256 columns. Unlike conventional cameras, the internal MAPP (matrix array picture processor) sensor contains an on-board processor that is capable of manipulating complete rows of this array. It is well suited to the task of trachied-effect imaging, because it can compute column-wise sums of pixels simultaneously for entire rows. This summation can be performed quickly using analog integration of image rows prior to A/D conversion. This method was initially applied to softwood species because of the abundance of tracheid cells in softwood (Matthews 1987).



(a) (b)

Figure 3. Profile imaging geometry. (a) A camera is mounted vertically, looking downward at a board. A laser source generates a plane of light that is 45 degrees relative to the horizontal. (b) From the camera's point of view, different board thicknesses cause the laser light to appear as a 2-dimensional curve in an image. The deviation of the light from a known location is directly related to the thickness of the board.

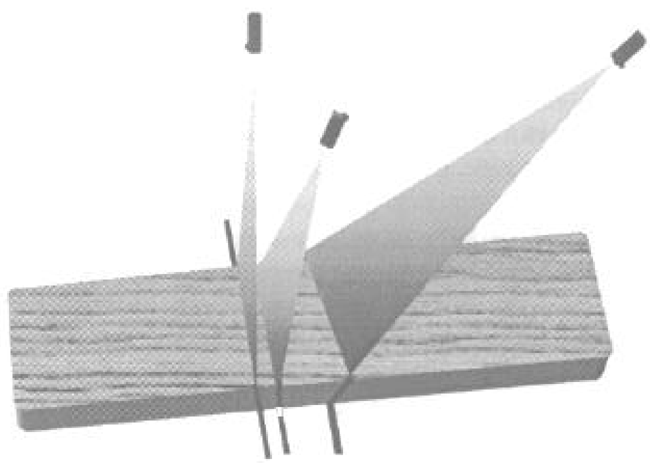


Figure 4. Board scanning with three laser sources. A profile laser is still shown at the right. Two additional laser sources have been placed at each side of the camera (not shown), to provide vertical planes of light for intensity and tracheid imaging.

The camera is positioned to capture a 16-inch field of view, yielding a resolution of 1/16 inch per pixel. During normal system operation, all 3 lasers sources are in operation. The laser line cast by the profile laser is used to identify wane and voids. The lines cast by the other 2 lasers can be used in various ways to collect intensity, tracheid, and grain information.

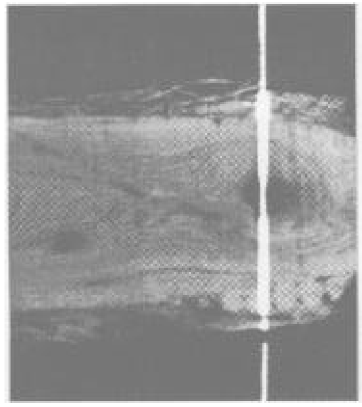


Figure 5. An example of the tracheid effect. An illumination source causes a bright stripe to appear in the image. The thickness of the stripe is closely related to physical characteristics of the wood.

Figure 6 shows example profile, tracheid, and intensity images of a board. In the profile image, darker regions indicate greater thickness values. These measurements can be used to detect many geometrical properties, including dimensional faults. Also, defects that lead to severe discoloration (such as decay, as shown in the upper right area of the board) can also be detected. This is because there is little laser reflection from those areas of the wood. The tracheid image in Figure 6(b) contains less high-frequency information than the intensity image in Figure 6(c), largely because it is the result of analog summation of several sensor rows. For some applications, this is desirable. An example of this is shown in Figure 7, where both images have been thresholded. Because of the inherent smoothing of the tracheid image, fewer spurious regions result. In some cases, texture differences in the 2 images may yield important information related to defects. Figure 8 demonstrates that it is possible to combine information from the profile image with one of the reflectance images. This is a computer-graphics rendering in which tracheid intensity values have been mapped onto the corresponding 3-dimensional locations given by the profile image.

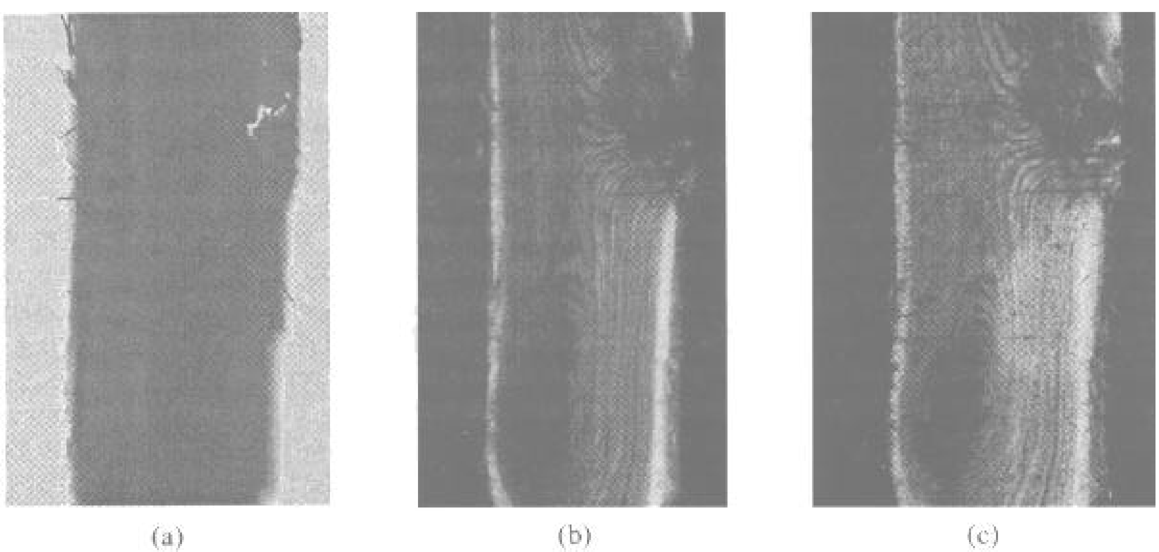


Figure 6. Three different images acquired simultaneously from the same board. (a) Profile image. (b) Tracheid image. (c) Intensity image.

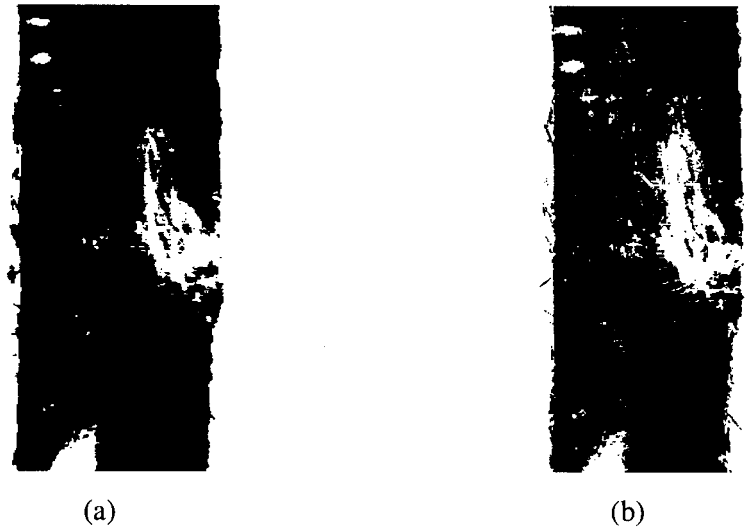


Figure 7. Thresholded versions of the tracheid and intensity images from Figure 6. (a) Tracheid image. (b) Intensity image.

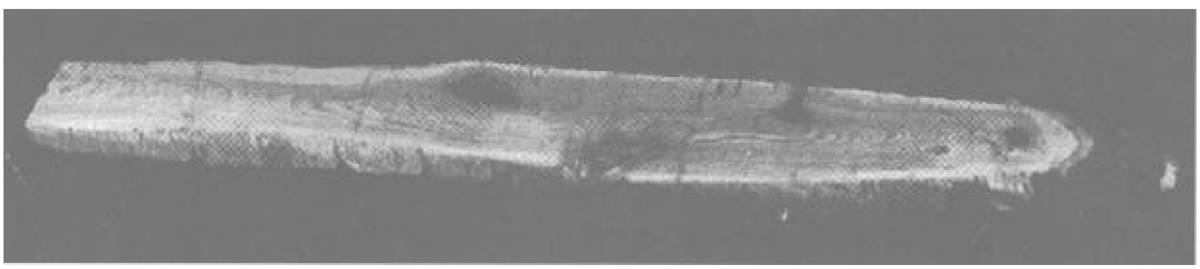


Figure 8. Combined profile and reflectance data. Tracheid image values have been mapped onto a wire-frame representation of the corresponding profile image, and the rendered result closely resembles the original board. Board thickness is accentuated in this image.

PRELIMINARY RESULTS

Although the prototype scanning system is still in development, this section presents some preliminary results. Figure 9, for example, demonstrates the system's ability to detect wane. Part (a) of the figure shows a trachied image for reference, and the processed output appears in part (b), where the darker portions at the top and bottom of the board represent wane. Although the problem might appear to require only a simple threshold, wane detection is not so simple in practice. This is illustrated in Figure 10, in which columns 400 to 600 of the corresponding profile image are depicted. Reflectance differences act as a noise influence in thickness estimation, and this precludes the use of a simple threshold for the purpose of wane estimation. With more sophisticated processing based on surface fitting and curvature analysis, however, reasonably accurate wane boundaries are detected.

Early results of our defect-defection work appear in Figure 11. In this case artificial neural nets are used to detect clear wood, knots, and decay. We have adopted a modular approach, in which neural nets of different types are trained separately for different types of defects. Post-processing will be used to refine the initial labels assigned by the neural nets.

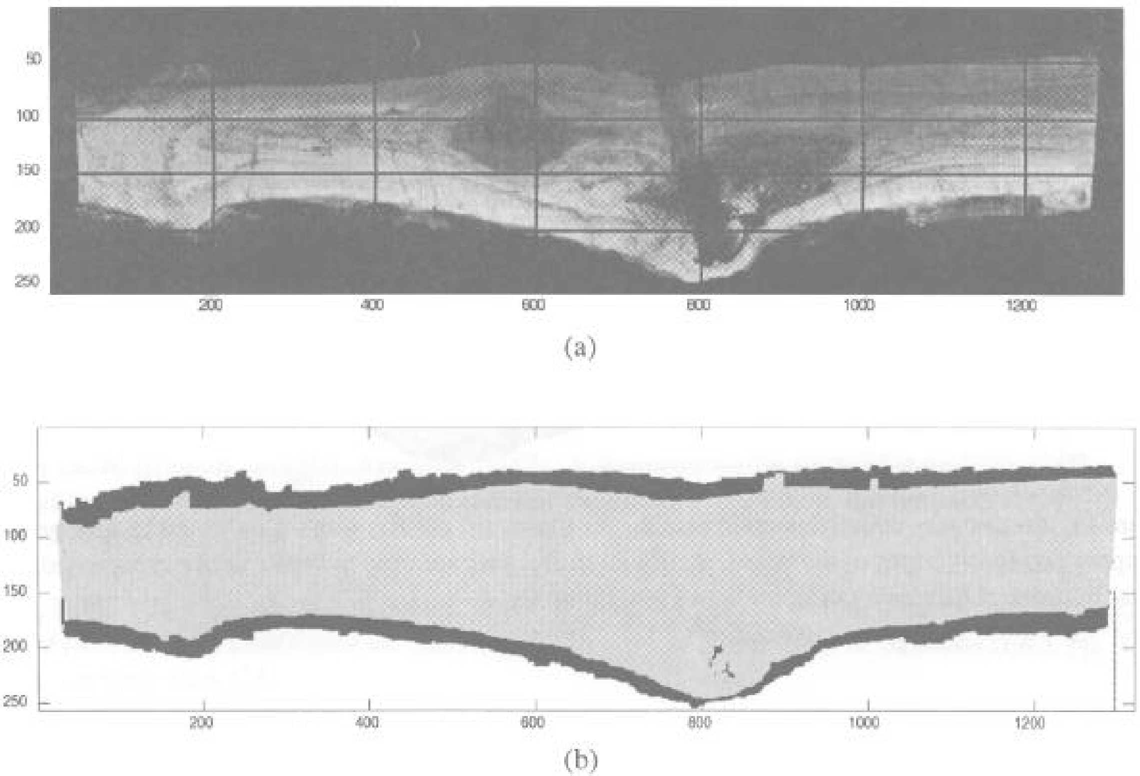


Figure 9. Initial results for wane detection. (a) A tracheid image has been obtained for a rough board of red oak. (b) Wane regions of the board are indicated in the upper and lower portions of the image. In addition, small void regions have been detected and are indicated as small dark patches near the lower center part of the board.

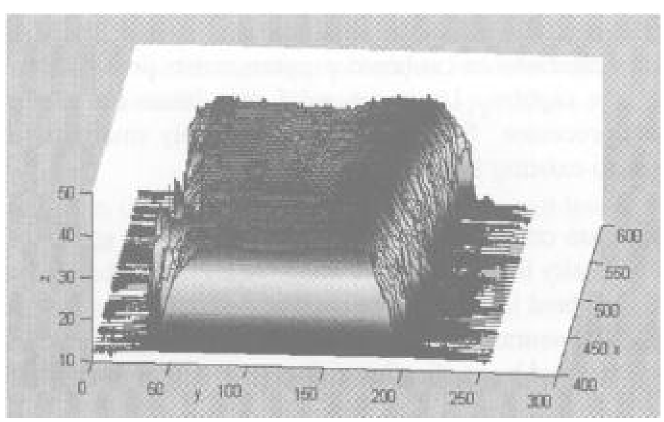


Figure 10. Another representation of profile image data. This diagram shows thickness values for a short portion of a board (only columns 400 to 600 from the image).

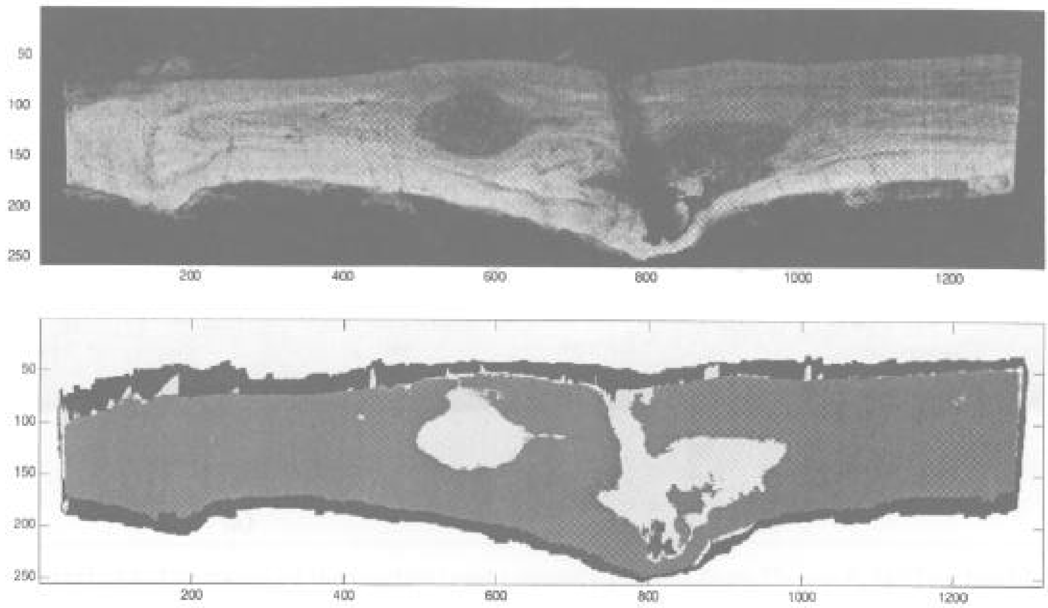


Figure 11. Preliminary defect detection results. As illustrated earlier, wane is indicated in dark gray at the upper and lower edges of the board. Artificial neural nets are used to detect decay, clear wood, and knots (in order of increasing brightness in the diagram).

SUMMARY

Recent advances in imaging and computing technology offer the potential to make dramatic improvements in the automation of hardwood sawmill operations. This paper has described a prototype system that partially addresses the problem of selecting optimal edging and trimming solutions. We have integrated materials-handling hardware, image acquisition hardware, and image analysis software for the purpose of detecting wane, decay, knots, and voids for rough lumber. The remaining component of this system is the software to determine optimal edging and trimming solutions, given the board information generated by this scanning system. An optimization algorithm is being developed as a separate study and is not reported here.

The scanning system uses a commercially available “smart camera” system, the MAPP 2200, for image capture. This camera is unique in that it contains an on-board programmable processor to perform image processing operations in parallel with image capture. Low-cost, solid-state lasers are used as illumination sources. A standard PC serves as the host processor. Such a system is relatively small and can be moved into sawmills without extensive modification to existing facilities.

Three different types of images are collected simultaneously during one scanning operation, and we refer to them as profile, tracheid, and intensity images. Profile image analysis can be used to determine the presence of wane and voids. Intensity and tracheid images can be used to detect reflectance-related features, such as bark, decay, and some knots. A modular neural-network approach is currently being developed for defect detection. Defect and wane locations will be used by application software to determine optimum edge and trim locations.

Technological advances during the past few years have made this prototype system feasible at a relatively low cost. Ultimately, such a system will significantly improve the utilization of hardwoods by improving the quality of sawmill output and by reducing waste.

ACKNOWLEDGEMENT

This work was partially supported by USDA NRI Competitive Grant #97-36200-5274.

REFERENCES

Åstrand, E. and A. Åström. 1994. An intelligent single chip multisensor approach for wood defect detection. *Proceedings of the Symposium on Image Analysis,* K. Malmqvist (Ed.), March 8-9, Halmstad University, Halmstad.

Bousquet, D. M. 1989. Saving volume and making money at the edger. *Northern Logger and Timber Processor,* June.

Cho, T.H., R.W. Conners, and PA. Araman. 1990a. A computer vision system for automated grading of rough hardwood lumber using a knowledge-based approach. *Proceedings: IEEE International Conference on Systems, Man, and Cybernetics,* pp. 345-350, Nov. 4-7, Los Angeles, CA.

Cho, T.H., R.W. Connors, and P.A. Araman. 1990b. A computer vision system for analyzing images of rough hardwood lumber. *Proceedings: 10th International Conference on Pattern Recognition,* vol. 1, pp. 726-728, June 16-21, Atlantic City, NJ.

Conners, R.W., T.H. Cho, and P.A. Araman. 1989. Automated grading of rough hardwood lumber. *Proceedings: 3rd International Conference on Scanning Technology in Sawmilling,* R. Szymani (Ed.), pp. XVI-1-15, Oct. 5-6, San Francisco, CA.

Lee, S.-M., A.L. Abbott, and D.L. Schmoldt. 1999. Using an embedded-processor camera for surface scanning of unplaned hardwood lumber. To appear in *Review of Progress in Quantitative Nondestructive Evaluation,* vol. 19, D. O. Thompson and D. E. Chimenti (Eds.), July, Montreal, Canada.

Matthews, PC. 1987. Wood, light, and objective scanning. *Proceedings: 2nd International Conference on Scanning Technology in Sawmilling,* R. Szymani (Ed.), Forest Industries/Wood World, San Francisco CA.

Regalado, C., D.E. Kline, and PA. Araman. 1992. Optimum edging and trimming of hardwood lumber. *Forest Products Journal 42(2):* 8-14.

Soest, J.F. and PC. Matthews. 1985. Laser scanning technique for defect detection. *1st International Conference on Scanning Technology in Sawmilling,* R. Szymani (Ed.), pp. XVII-1-4, Oct. 10-11, Forest Industries/ World Wood, San Francisco CA.

Williston, E. 1979. Electronics in the sawmill: Opportunities areas and leverage points. *Proceedings of the Electronics Workshop,* Sawmill and Plywood Clinic, Portland OR.

PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL HARDWOOD SYMPOSIUM

West Virginia Now—The Future For The Hardwood Industry?

EDITED BY

DAN A. MEYER
NATIONAL HARDWOOD LUMBER ASSOCIATION
MEMPHIS, TN

Canaan Valley Resort & Conf. Center
Davis, West Virginia
May 11-13, 2000

ACKNOWLEDGEMENT

Assistance in producing the Proceedings of the Twenty-Eighth
Annual Hardwood Symposium was provided by the

USDA Forest Service
Southern Research Station
Asheville, NC