Automatic Scanning of Rough Hardwood Lumber for Edging and Trimming

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Abstract

Scanning of unplaned, green hardwood lumber has received relatively little attention in the research community. This has been due in part to the difficulty of clearly imaging fresh-cut boards whose fibrous surfaces mask many wood features. Nevertheless, it is important to improve lumber processing early in the manufacturing stream because much wood material is needlessly edged and trimmed away each day. This paper describes a prototype system that scans rough, green lumber and automatically generates a board profile and recognizes important lumber-degrading defects. This portion of the overall "improved edging and trimming project" is primarily concerned with image acquisition and analysis. Commercially available laser sources and a video camera obtain thickness and reflectance information at 1/16-inch resolution. The resulting images are analyzed in order to detect wane and surface defects. Unlike most board-scanning systems, which process planed wood, this system has been designed specifically for use with unplaned boards in the green state. This presents both advantages and challenges in the development of image-analysis algorithms. The current system is described and some preliminary tests specimens are exampled. A demonstration prototype has been completed and will- be part of upcoming workshops at the Wood Education and Resource Center in Princeton, West Virginia.

Introduction

In most of today's hardwood sawmills, edger and trimmer operators examine each board soon after it leaves the headrig. After a quick visual examination, these operators make judgments about -the placement of cuts based on their knowledge of lumber grades and current lumber prices. Unfortunately, optimizing the value of each board in this manner requires complex decisions that are difficult even for experienced operators.

Several problems exist that adversely affect the decision-making ability of edger and trimmer operators. First, visual estimates of board surface measure and potential board upgrade 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, there exist millions of potential edging and trimming settings. 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. Fourth, edger operators tend to be biased toward the removal of wane beyond what is necessary, and this results in reduced board sizes and lower commercial value. These reasons, together with such fundamental issues as operator training and fatigue, suggest that a strong need exists for an automated solution.

The overall goal of this project is to develop a prototype scanning system that automatically determines cutting locations for edging and trim operations. This paper describes the scanning system portion of the project, whereas a companion paper describes the optimizing application software. For a typical hardware sawmill layout, as illustrated in Figure 1, the new system would be placed immediately after the headrig. The remainder of this paper focuses on the problems of image acquisition, wane detection, and surface defect detection. Following a description of related work and the relative merits of rough-lumber processing, scanner imaging geometry and hardware are illustrated. Some preliminary results and conclusions highlight current progress.

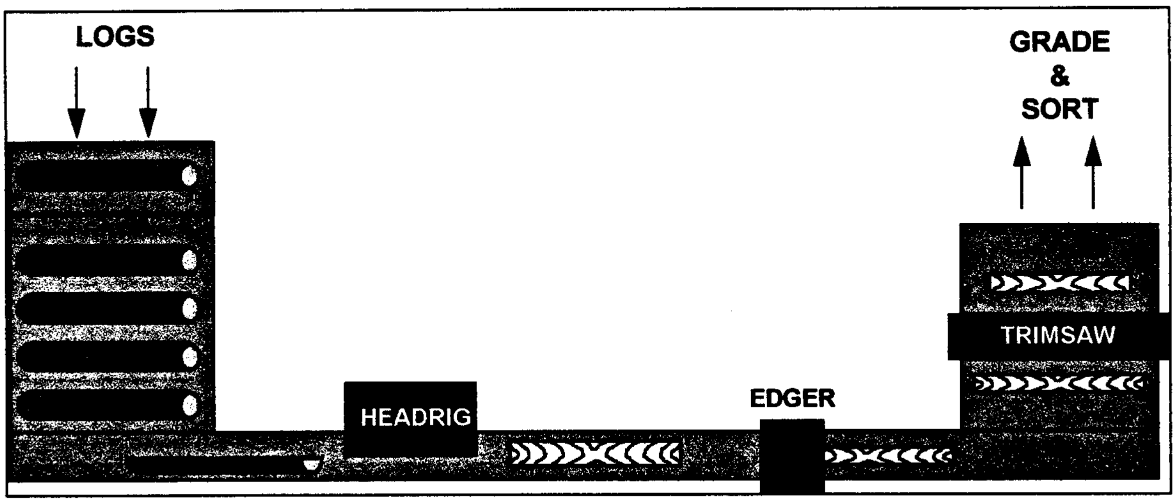


Figure 1. A typical hardwood sawmill reduces logs to boards at the headrig. An edger reduces the width of a board, and a trimsaw reduces the length.

Background and related work

Losses from improper edging and trimming can be substantial. Williston (11) demonstrated that for some mills 45% of a log's original volume is converted into chips from slab boards and from edgings. As described above, most sawmill edger operators remove an excessive amount of wood, and this can result in value losses of 30% (2). Volume and value losses from improper trimming operations exacerbate the severity of edging losses. In a case study of 3 hardwood mills, Regalado et al. (9) found that edging and trimming operations resulted in lumber values that were only 65% of optimum Because of the large amount of waste that occurs in current edging and trimming practices, computer-controlled optimization of edging/trimming operations is essential for increasing profits. This, in turn is necessary to ensure continued operation of rural mills, to conserve the timber raw material, and to create primary products of higher value that can compete in a global economy.

The images in Figure 2 illustrate some of the differences between rough lumber and planed lumber. In the rough state, boards commonly hold additional wood fiber, debris, dirt, and saw marks. All of these can increase the difficulty of image analysis. These difficulties are mitigated somewhat if the wood is still in a fresh "green" state when imaged. The additional moisture that is present immediately after log breakdown tends to produce images with higher contrast, particularly near some defect types, and this can be used to advantage during image analysis. Very little work has addressed image-related problems that are specific to rough lumber. Some early research (3-5) considered defect detection in rough lumber, but they subsequently abandoned the rough lumber problem and looked instead at surfaced lumber.

(a) (b)

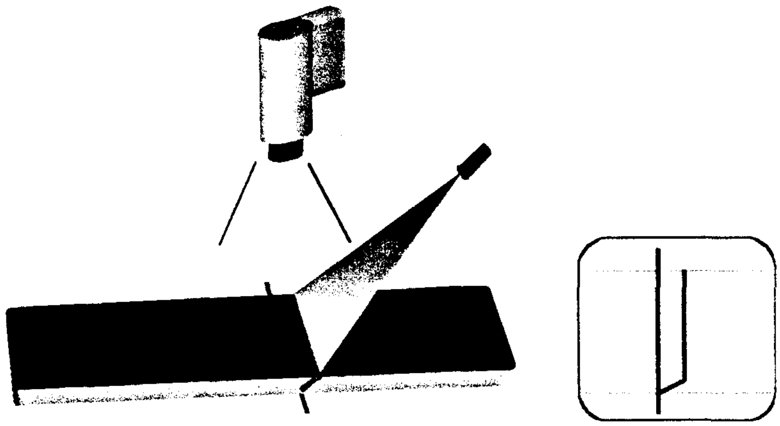
Figure 2. A comparison of intensity images of (a) rough and (b) surfaced lumber illustrates some visual differences. Most scanning systems analyze wood only after it has been surfaced.

Our own work has led to the development of a prototype scanning system for rough hardwood boards. A major emphasis of the work is to develop a prototype system that can recognize surface defects on rough lumber immediately after being cut at the headrig. Work is in progress to determine optimum edging and trimming solutions based on those defects. Early descriptions of the system appear in Lee at al. (6, 7).

Scanning system

Our prototype system uses pinch-rollers to move a board under a video camera that is mounted vertically, looking downward as depicted in Figure 3. The camera is positioned to capture a 16-inch field of view, yielding a resolution of 1/16 inch per pixel. The figure illustrates a single laser source that is used to obtain thickness (profile) information for the board. Two additional lasers, not shown in the figure, are used to obtain reflectance information. All three laser sources are solid-state devices, producing fan-shaped sheets of light.

The profiling technique that we use is quite common, and is used here to identify wane and voids. Because of the placement of the laser source, with the plane of light angled relative to the surface of the board (approximately 45 degrees in our system), triangulation can be used to determine small variations in board thickness. Greater board thickness causes larger offsets of the bright laser curve in the image. Our system obtains thickness measurements at 1/16-inch spacing, along both the width and length of each board. Because many lumber attributes, particularly voids and wane, are associated with surface irregularity, profiling is extremely useful. Some existing commercial systems use a variation of this approach to determine board edges and to guide edge saws, although those systems are not concerned with defect detection, and obtain measurements at much lower resolution lengthwise on the board.



(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 thickness causes 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 shows the profile laser along with the two additional sources. These are positioned at the side of the camera for reflectance (brightness) imaging. 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" (10) 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 video camera that is used in this system is the MAPP 2200 "smart camera," developed by Åstrand and Åstrom (1). 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 simultaneously. It is well suited to the task of tracheid-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 by Matthews (8) because of the abundance of tracheid cells in softwoods.

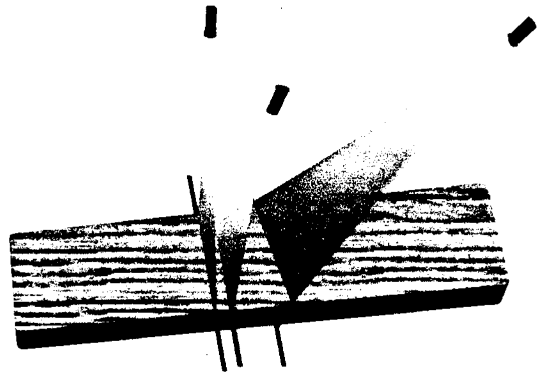


Figure 4. Board scanning with three laser sources. A profile laser is still shown at the right. Two additional laser sources have been placed at each side of the camera (not shown), to provide vertical planes of light for intensity and tracheid imaging.

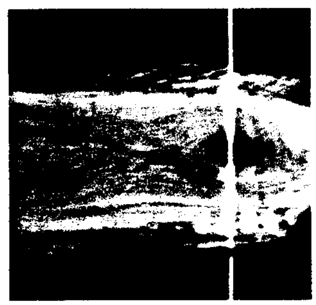
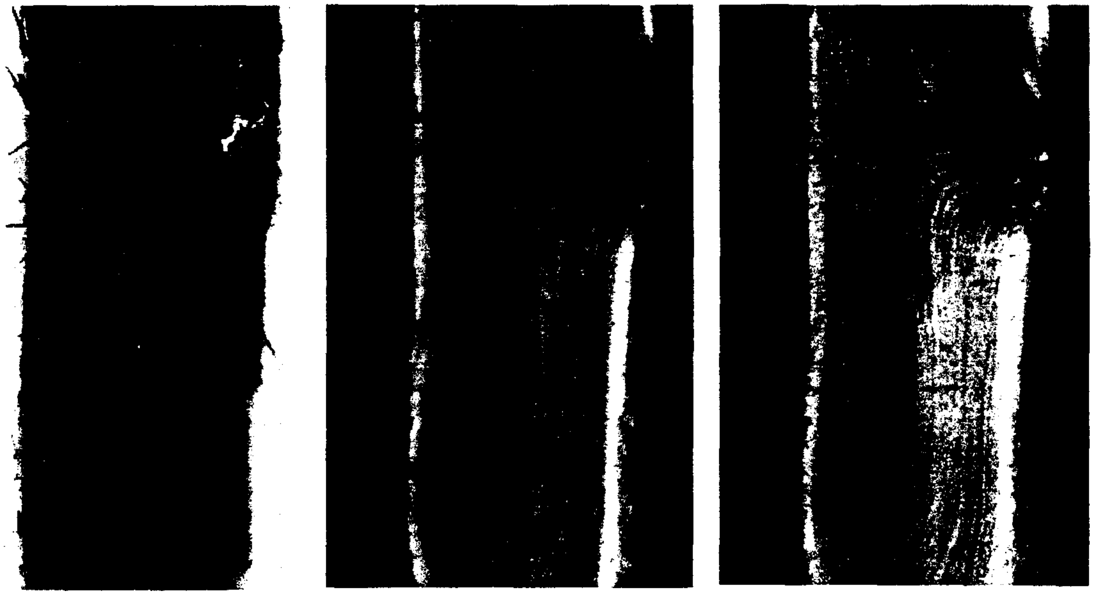


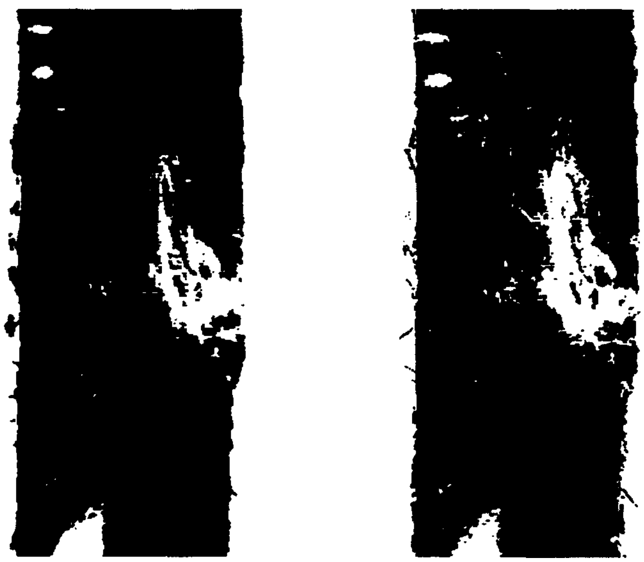
Figure 5. An example of the tracheid effect. An illumination source causes a bright stripe to appear in the image. The thickness of the stripe is closely related to physical characteristics of the wood.

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.



(a) (b) (c)

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



(a) (b)

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

Preliminary results

The prototype scanning system is nearing completion. Although it is not yet in final form, this section presents some preliminary results that have been obtained with the system Figure 9, for example, demonstrates the system's ability to detect wane. Part (a) of the figure shows a tracheid 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.

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.

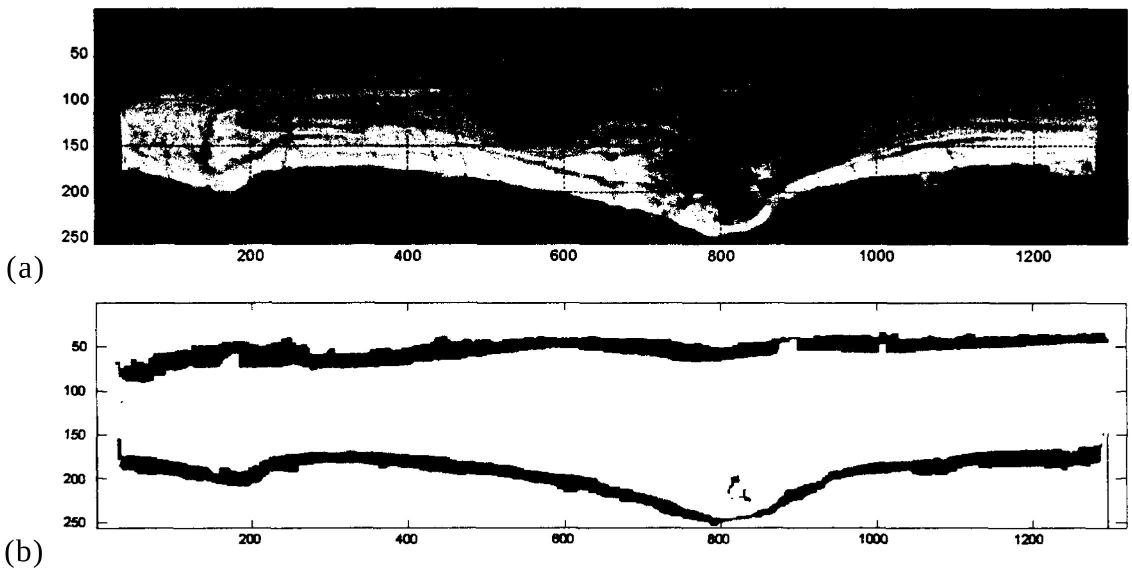


Figure 9. Initial results for wane detection. (a) A tracheid image has been obtained for a rough board of red oak. (b) Wane regions of the board are indicated in the upper and lower portions of the image. In addition, small void regions have been detected and are indicated as small dark patches near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

Some defect-defection results appear in Figure 11. In this case artificial neural nets have been 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 is used to refine the initial labels assigned by the neural nets. Visual examination of Figure 11 compares favorably with what one would expect from the image in Figure 9 (a). The one notable exception is the saw-smeared decay region located around column 800. Because this is an extremely rare event, we do not view it as a serious system failure.

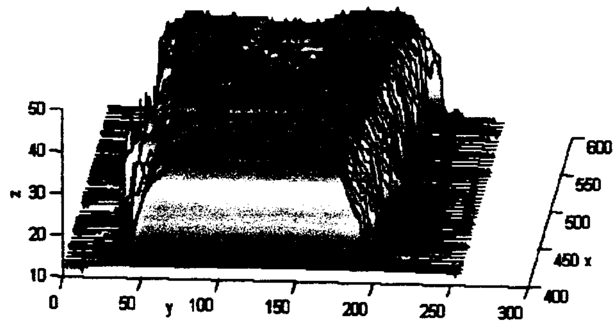


Figure 10. Another representation of profile image data. This diagram shows thickness values for a short portion of a board (only columns 400 to 600 from the image).

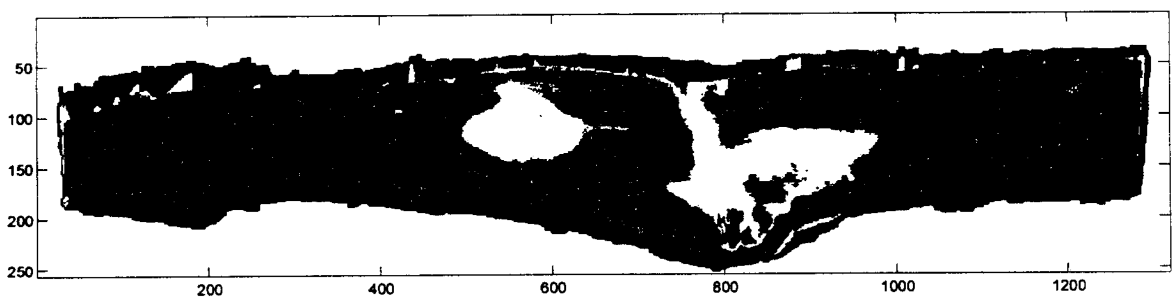


Figure 11. Example defect detection results for the board in Figure 10 (a). As illustrated earlier, wane is indicated in dark gray at the upper and lower edges of the board. Artificial neural nets are used to detect decay, clear wood, and knots (in order of increasing brightness in the diagram).

Summary

The potential exists fir dramatic improvements in efficiency of hardwood sawmilloperations, made possible by recent technological advances in imaging and computing technology. This paper has described a prototype system that partially addresses the problem of selecting optimal edging and trimming solutions. We have developed an integrated system of materials-handling hardware, image-acquisition hardware, and image-analysis software for detecting wane, knots, decay, and voids in rough lumber. Knowledge of the locations of these lumber-degrading features, along with knowledge of grading rules and current market prices, are needed for the selection of optimum saw positions.

The reason for targeting rough, unplaned lumber is that high-speed, computer-aided decisions made earlier in the production chain offer the greatest potential for economic gain. Rough lumber poses unique problems, however, because of the presence of fiber strands and saw marks that are not typically present after planing.

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. These have been placed in an effort to exploit the tracheid effect, in which light scatters within the fibrous material of the wood before being reflected to the imaging device. A standard PC serves as the host processor. The prototype system is relatively small, and can be moved into sawmills without extensive modification of existing facilities.

Technological advances of 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. A companion benefit that comes free of charge is that each board processed by such a system will have a consistent computer grade, which thereby eliminates the need for human graders later in the processing chain.

Acknowledgement

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