LUMBER GRADING WITH A COMPUTER VISION SYSTEM

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ABSTRACT. Over the past few years significant progress has been made in developing a computer vision system for locating and identifying defects on surfaced hardwood lumber. Unfortunately, until September of 1988 little research had gone into developing methods for analyzing rough lumber. This task is arguably more complex than the analysis of surfaced lumber. The prime motivation for developing such a system is the goal of creating an automatic grading system. This paper reports progress that has been made in developing a vision system for locating and identifying defects on rough lumber. It will point out some problems that are unique to the analysis of rough lumber and will report studies aimed at addressing these problems.

INTRODUCTION. Over the last few years significant progress has been made in developing a computer vision system for locating and identifying defects on surfaced hardwood lumber [1-4]. The motivation for this research is to create the "eyes" for an automatic cutup system to be used in rough mills of hardwood furniture, cabinet, dimension and fixture plants. The research has progressed to the extent that a prototype system for scanning full length sixteen foot boards is currently being designed and will be built in the very near future. (Note that this same prototype will be able to scan rough lumber as well.)

While significant progress on the automatic analysis of surfaced lumber has been made, until September of 1988 little work had been done on developing methods for analyzing rough hardwood lumber. There are a number of reasons for developing a vision system that can locate and identify defects on rough hardwood lumber. Chief among these is that such a vision system would allow the automatic grading of lumber. Such an automatic grading system would have two primary components. The first would be a vision system for locating and identifying defects. The second component would be an automatic system for grading based on the positions of the defects and size of the board. Interestingly, significant progress has already been made on this second component with the development of a grading simulator [5]. Hence all that remains before a fully automatic grading system can be created is the development of the appropriate computer vision methodologies.

Conceptually both the surfaced and rough lumber inspection problems are seemingly very similar. Hence similar methods should be applicable to both. This leads one to begin this research activity by considering methods that have proven useful on the surfaced lumber problem. There are other reasons for beginning in this manner. First, if the same basic methods could be used, research and development time on both problems could be substantially reduced. Secondly, if the same basic methods could be used on both problems then an integration of the methods would seem possible, an integration that would allow the creation of a vision system capable of handling rough lumber, fully surfaced lumber and lightly surfaced lumber.

Unfortunately the computer analysis of rough lumber is arguably more complex than the computer analysis of surfaced lumber. Surfacing the lumber just prior to a computer inspection eliminates a number of analysis problems. The surfacing removes any surface discoloration that may have occurred during drying or that may have occurred during exposure to the elements. It also removes any surface dirt that may have been built up during handling or during storage. The surfacing removes sawn marks, etc. Such structures can cause shadows and highlights. These shadows and highlights can and do pose problems for computer vision algorithms. Since grading can be performed any time from immediately after the board comes off the sawn in a sawmill to some time after drying, there can be a significant variation in surface moisture content. Surface moisture content does affect the color characteristics of the material. Such variations in color can pose problems for computer vision methods.

Further, just as in the case of surfaced lumber, it is desirable that any vision system for grading rough lumber should be able to perform the task in a species independent manner.

Each of the above considerations is a complicating factor in the development of the required computer vision methodologies. This paper describes experiments aimed at investigating aspects of each of these problems.

METHODS AND MATERIALS. In all, three experiments have been performed. Each was directed towards one or more of the problems described above.

Experiment 1

The purpose of this experiment was to investigate how the surface color of a board changes with surface moisture content. The materials used were five samples of freshly sawn red oak that were up to two feet in length. The samples were very clean, with no dirt or debris on them. Areas were marked on each sample. The areas were selected so that they would contain both a defect and clear wood. The defects represented in this study included knots, stain, and bark pockets. Each of the marked areas was scanned immediately after being sawn, one hour after being sawn, eight hours after being sawn, one day after being sawn, two days after being sawn, and three days after being sawn. The resulting color images have a resolution of 512x512x24 bits with 8 bits of color data in each of the red, green, and blue color channels. Hence each picture element or pixel is a three dimensional vector giving the red, green, and blue values of that point on the image. Each of the red, green and blue component values is a number between O and 255 with O indicating the complete absence of a color component and 255 indicating a saturated amount of **a** color component. The spatial resolution used was approximately 64 points per inch. The same lighting conditions, f-stop, gain, and offset were used throughout the experiment. These color images show the change in color of each area as the surface of the material dries. Color histograms were computed for each area on each of the images in which it appeared. These histograms reflect the relative color characteristics of each of the defects as well as clear wood as a function of surface moisture content.

Experiment 2

A number of studies involving surfaced hardwood lumber have indicated that simple picture element by picture element (pixel-by-pixel) classification methods can be used to separate areas of clear wood from areas that potentially contain a defect [3,4]. These studies also indicate that the same basic methods will work in a species independent manner. That is given a particular lighting condition one can select an f-stop, gain, and offset so that good digital color images of all the hardwood species can be obtained. Further given a digital color image created in this fashion, the same segmentation methods can be employed with the results being equally good regardless of species.

However, the segmentation methods, i.e., the methods for separating clear wood and defects, reported in References 3 and 4 do sometimes fail. They have difficulty with light blue stain and decay. In late summer of 1988 a study was begun to develop a more robust segmentation method. The resulting method was applied to numerous samples of surfaced red oak, maple, walnut, cherry, hickory, poplar, and even white pine all scanned using the same lighting conditions and scanner settings. The results obtained were very good, being much better than those obtained from the previous method.

The purpose of this experiment was two-fold. The first objective was to determine whether this new segmentation method, a simple pixel-by-pixel method, would work on rough lumber. Stated in a slightly different manner, the goal was to determine how shadows and highlights caused by the rough surface would affect this algorithm. A second objective was to determine whether rough lumber could be processed in a species independent manner.

The materials used were 50 samples of dried rough lumber. These 50 samples included 25 samples of red oak and 25 samples of cherry. These samples were free of dirt and/or debris. These samples came from at least three different saw mills. Each sample was approximately 14 inches long. The samples contained knots, splits, checks, wane, stain, and pith. Attempts were made to select the samples so that obvious as well as relatively obscure defects appeared in this data set. Each sample was scanned using the lighting condition and scanner settings that had been used to image the surfaced lumber samples, i.e., the lighting condition and scanner settings that can image a variety of hardwood species. The color images obtained were 512x512x24 bits of resolution with 8 bits of data in each of the red, green, and blue channels. The spatial resolution was approximately 64 points per inch.

Using these digital color images color histograms were created. These histograms were then examined to determine the extent to which shadows and highlights increase the complexity of the segmentation operation. Then the new segmentation method was applied to each image. The results obtained were examined to determine whether there was any significant difference in quality between red oak and cherry.

Experiment 3

The purpose of this experiment was also two-fold. The primary objective was to determine how moderate levels of dirt and discoloration due to kiln drying affect the quality of the segmentation. A second objective was to further verify that species independent processing is possible on rough lumber. Note that in Experiment 2 red oak and cherry were considered. By comparing the results obtained in this experiment using yellow poplar with those obtained in Experiment 2 additional verification of species independence is possible.

The study involved 15 samples of rough yellow poplar, each sample being approximately 14 inches long. Each sample had spots of dirt appearing on the surface. The samples had been kiln dried and each board's surface was generally dull and somewhat discolored. Each sample was scanned in the same manner as the samples of Experiment 2. The resulting 512x512x24 bit color images were then processed using the new segmentation method.

RESULTS. The results of Experiment 1 were interesting and seemingly have implications to both manual as well as automatic grading. The results clearly indicate that as the surface moisture content decreases there is a greater color difference between defects and clear wood. This implies that grading lumber with high surface moisture content, i.e., freshly sawn material, is a more complex process than grading lumber that has a lower surface moisture content. This implication is valid whether manual or automatic grading is being used. Because of these results it was decided to concentrate all of the rest of these initial studies on dried material, material with very low surface moisture content.

The results of Experiment 2 suggest that the new segmentation method may be robust enough for use in an automatic grading system. It was found that the shadows and highlights caused by the rough surface do reduce the sensitivity of this segmentation method but that satisfactory results are still obtained. The capabilities of this segmentation method are illustrated in Figures 1 and 2. The results also indicate that species independent processing should be possible. Certainly, the new segmentation method gives equally good results regardless of whether a sample is cherry or red oak.

The results of Experiment 3 further confirmed that species independent processing should be possible. This experiment confirmed that not only could red oak and cherry be processed but yellow poplar as well. And more importantly the results of this experiment suggest that spots of dirt on the material do not markedly affect the quality of the resulting segmentation. Such dirt spots are either completely ignored by the segmentation method or marked as an area that might potentially contain a defect. Further, moderate levels of discoloration that occur during the kiln drying process do not affect the quality of the segmentation.

DISCUSSION. These preliminary experiments all suggest that a method exists for satisfactorily segmenting images of rough lumber. As such the first step towards creating a computer vision system for locating and identifying surface defects by size, shape and type on rough lumber seems possible. However much additional work is required.

Currently samples of other hardwood species are being collected so that the robustness of the new segmentation method can be verified. Included in the samples will be those that show some discoloration, i.e., those discolorations typically associated with the drying process. They will also include some that contain dirt spots and other debris. The goal is to collect samples that reflect the set of problems a vision system must be capable of handling.

The prototype system that is currently being designed should, once it is built, allow the collection of a truly representative data set. This system will be such that it can be moved out of the laboratory and to a sawmill so that lumber can be scanned on site.

Because of the potential complexity of the recognition system, a system that will have to deal with and identify the presence surface discoloration, spots of dirt, etc., versus actual grade defects, a study is being undertaken to determine the utility of multispectral information in the recognition process.

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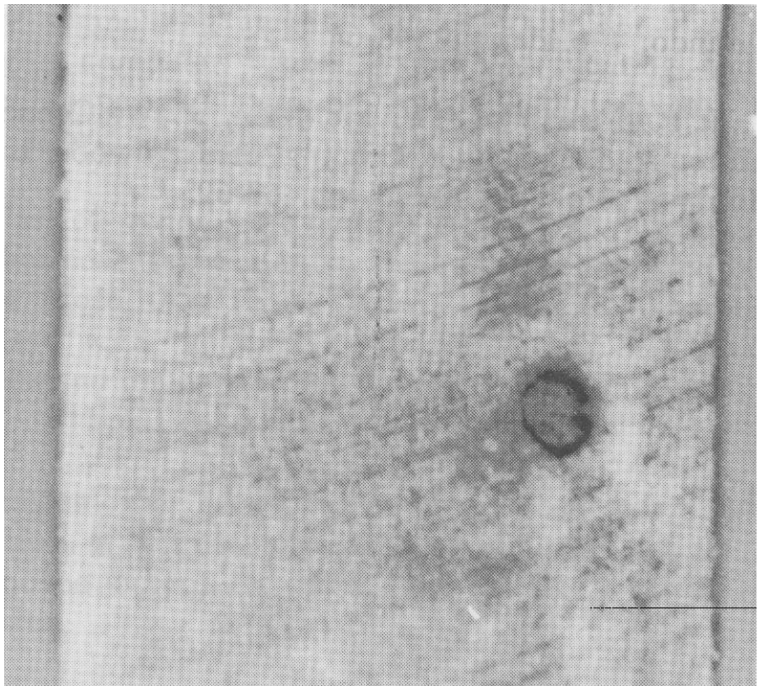

Figure 1a. Normal view of board with knot

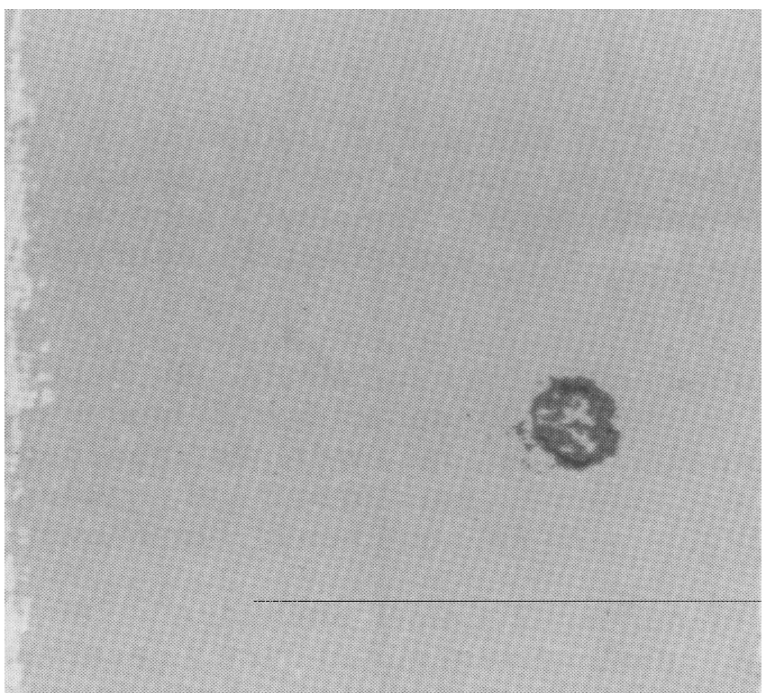

Figure 1b. View of board with knot
using segmentation method

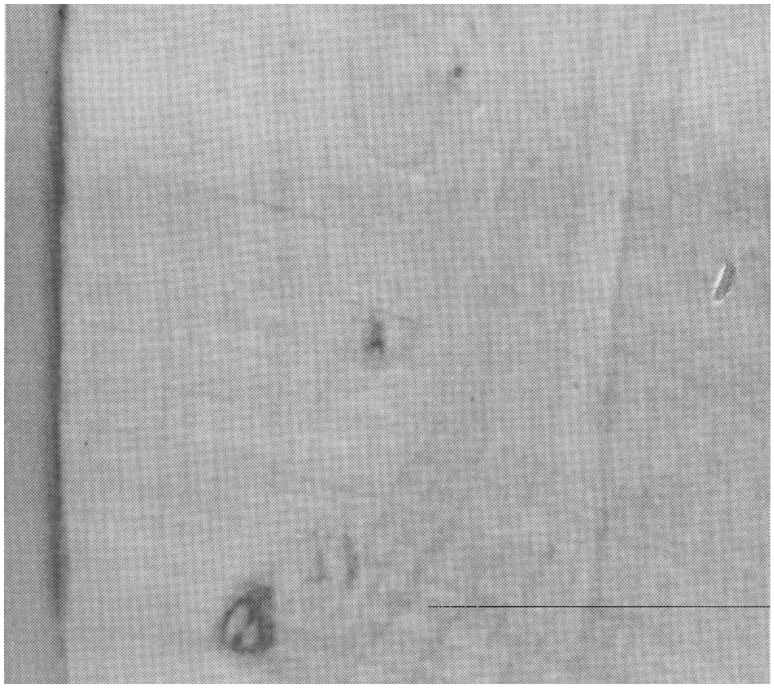

Figure 2a. Normal view of board with defects

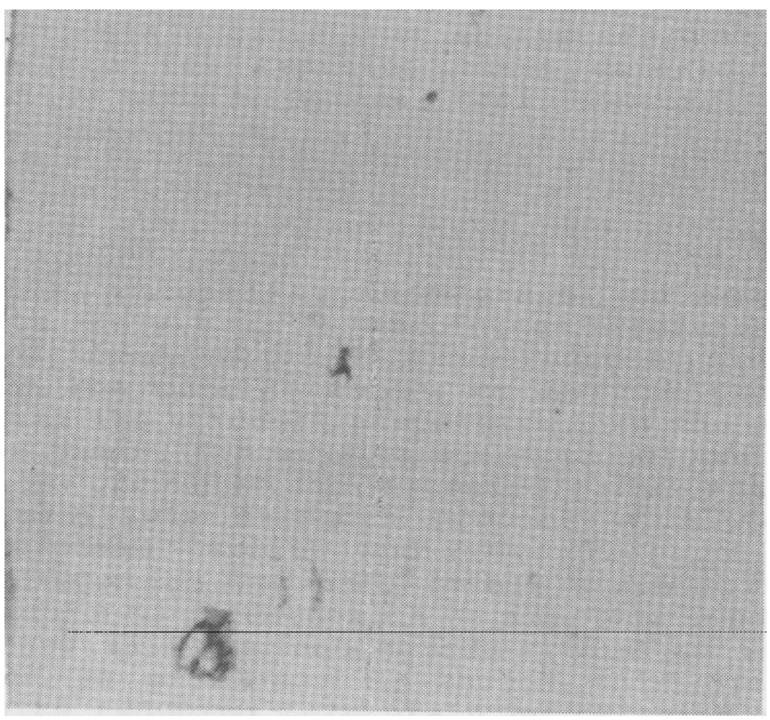

Figure 2b. View of board with defects
using segmentation method

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