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COMPUTER VISION SYSTEMS FOR HARDWOOD LOGS AND LUMBER

P. Araman, Project Leader, USDA Forest Service, T.H. Cho, Research Associate, D. Zhu, Research Associate, and R. Conners, Associate Professor, Virginia Tech University, Blacksburg, Virginia, USA

SUMMARY

Computer vision systems being developed at Virginia Tech University with the support and cooperation from the U.S. Forest Service are presented. Researchers at Michigan State University, West Virginia University, and Mississippi State University are also members of the research team working on various parts of this research. Our goals are to help U.S. hardwood producers automate, reduce costs, increase product volume and value recovery, and market more accurately graded and described products.

The first system is being developed to recognize board defects, clear wood, and board outlines of rough hardwood lumber and to label and define these areas. This information will be fed into two computer programs. The first program will grade the board by National Hardwood Lumber Association grading rules. The second program will simulate the processing of the board into standard or specific cutting or part sizes by two different cut-up methods. A pre-prototype vision system will be described. A system goal is to analyze images of rough lumber in a species independent manner. Illustrations of original board images, results of segmentation, and the results of defect recognition will be shown. We will also discuss some of our current problems.

The second computer vision system deals with log scanning. This system is being developed to recognize log defects, clear wood, and log outlines and to label and define defect areas. This information will be used to sort logs as veneer or sawlogs; to buck long length logs; to determine how to flitch a veneer log; and how to process a sawlog. We will illustrate some of our current recognition progress.

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Computer vision systems and automated or computer-aided processing systems are needed for future hardwood sawmill operations. They are needed for many reason, such as improved recovery, increased productivity, improved resource allocation, improved marketing, reduced costs, and accurate lumber grading.

Hardwood sawmiller are facing many different situations and some confusion that may not get any better. Production has been increasing to a reported 11+ billion board feet (NFPA), due to increasing domestic and export markets. Low grade hardwood sawtimber resources continue to be a major problem because they comprise a majority of our available material in the woods. Inconsistent product quality and less than optimal processing are problems for many producers. Log costs have been increasing, while lumber prices seem to have stabilized. Hardwood sawtimber resources in our forests have been increasing and may be getting better. With the increasing demands, however, keeping enough logs in sawmill yards, is not getting easier.

In recent surveys (Bush 1989 and Bush and others 1990), hardwood lumber customers reported several major concerns: (1) inaccurate lumber grading by producers, (2) inconsistent lumber thickness, and (3) poor quality of the lumber they were purchasing.

To keep and satisfy hardwood lumber customers, hardwood sawmiller need to improve the accuracy of their lumber grading and provide consistent products. They also need to get more value out of the logs they are processing.

Research projects are underway to help the U.S. hardwood sawmill industry automate, reduce costs, increase product volume and value recovery, and market more accurately graded and described products. These are team efforts that are concentrating on advanced processing. The research teams include scientists with the Northeastern, Southern, and Southeastern Forest Experiment Stations of the USDA Forest Service, Michigan State University, Virginia Tech University, West Virginia University, and Mississippi State University. We will focus here mainly on the computer vision systems for rough lumber and logs being developed at Virginia Tech University.

COMPUTER VISION RESEARCH TO ALLOW HARDWOOD LUMBER TO BE AUTOMATICALLY GRADED AND ANALYZED

Automated systems for lumber grading and describing potential furniture cuttings in hardwood lumber are the goals of this research. Defects must be located, properly sized, and identified, and board outlines must be determined. Then computer programs are needed to grade the boards and determine the possible furniture cuttings in the boards. Rip or cross cut first processing for each board must also be checked. The resulting system would generate packages of computer-graded and marked lumber, including information on potential cuttings, and the best initial rough mill processing step.

The basic research on detection, sizing, and identification by computer vision is underway at Virginia Tech. This is proving to be complex problem with rough lumber. Lumber changes in visual appearance as the surface dries. Outside storage and drying can cause color changes, along with problems with dirt. Surfacing boards would take care of most of these problems, but, we need to grade rough rather than surfaced lumber.

We have recently built a prototype image system to collect data from 4 foot long boards. The complete system includes a material handling device, line scan cameras, special lighting, a customized data transfer device, and a computer system. We are designing the image system to process 16-foot-long boards at a realistic industrial processing speed.

A computer program is available for grading hardwood lumber by the standard rules of the National Hardwood Lumber Association (Klinkhachorn and others 1989). Another computer program determines the cuttings available in each board. It also compares the yields in cuttings for cross cutting or ripping the board as the first cut-up process. The program is called CORY (Brunner and other 1989).

Information provided from the system will be on individual boards and packages of lumber. Grade mix, total board footage, potential yield in cuttings, and potential distribution of cuttings will be similar to that shown on the tally sheet in Figure 1. Yields in specific or standard size cuttings could be determined as well as which rough mill processing step should be used for the package of lumber--rip or cross cut first. The lumber could be sorted by the supplier for these two rough mill options. The output information shown in figure 1 could easily be modified or expanded.

With the above capabilities, lumber producers could provide the accurately and consistently graded material desired by end users. They could also provide extremely worthwhile information on potential cuttings and processing to end users. End users of hardwood lumber could also use the system to determine which boards should be cross cut or ripped first and the potential cuttings. End users could also verify lumber grades from supplying mills not using the computer vision system. The potential cutting information could help determine the proper lumber grade or grade mix that should be used for different situations.

STATUS OF ROUGH LUMBER SCANNING

The automatic grading of rough lumber requires that several system components be developed and integrated to form a working system. First there are the imaging subsystems used to create digital images of both board surfaces. Next there is a materials handling system for moving boards through the imaging subsystems. A computer is required to collect the data and analyze it to locate and identify the various grading defects. Finally there is the software system that instructs the computer as to how it should go about the analysis. This component is called the computer vision software system.

Significant progress has been made on developing the hardware components. An imaging system prototype has been built and a materials handling system for moving hardwood boards up to 16 feet long through the imaging components is being designed. A full scale prototype for an automatic grading system should be ready by July of 1991. This system will be able to collect image data at industrial speed ranging from 2 to 5 linear feet per second. However, the computer to be initially used with this prototype is not fast enough to allow the processing of image data at the required industrial rates. Experiments will be performed to determine exactly what the computing requirements are. In late 1992 or early 1993 a new computing system, including perhaps some specially designed digital hardware, will be added to the full scale prototype to process the image data at the required speeds.

The key to developing an automatic grading system is the development of the computer vision software system. It is this part of the automatic grading system that presents the most technological challenges. Because of this, up until very recently, most research funds have been directed towards developing the required computer vision methodologies. These computer vision methodologies can be subdivided into two components, a segmentation system and a recognition system. The purpose of the segmentation system is to examine quickly the input image data to find areas that might be a defect. The purpose of the recognition system is to analyze the areas that have been located by the segmentation system and to determine whether a grading defect is actually present and if it is to identify what it is.

Figure 2 shows some of the results that have been obtained from both the segmentation system and the recognition system. Part A shows a black and white version of a color image of a red oak board and a cherry board. Part B shows the segmentation results obtained from these images. Part C shows the results obtained from the recognition system. The segmentation system took approximately two years to develop and test. It has been extensively tested on a variety of hardwood samples including surfaced samples of red oak, white oak, maple, cherry, walnut, yellow poplar, hickory, and even white pine and rough samples of red oak, yellow poplar, and cherry. The recognition has been under development for about 1 1/2 years. The current system has been taught to recognize four types of defects, knots, holes, splits/checks, and wane. It is currently undergoing testing to establish the robustness of the methodologies employed.

Knots have posed a persistent problem in these developmental activities which can be seen in Figure 2. There are some knots in each species that have almost no color difference from that of clear wood. These knots are hard for the segmentation system to locate and even harder for the recognition system to identify. Because of the continuing difficulty, the addition of a x-ray scanning system to the full scale prototype is being contemplated. Adding a x-ray scanner, a scanner that is identical to those used in airports to scan luggage, should not only help in locating the troublesome knots but provide additional capability as well, for example, honeycomb detection (internal splits).

AUTOMATED PROCESSING OF LOGS

Proper determination of the location, type and shape of defects, would allow us to process automatically logs into lumber, rough green parts, or veneer. It would also allow us to convert correctly tree length roundwood to logs. Should a log be processed into veneer or lumber could also be determined. The key at this point is to be able to determine what is inside each log with CT, NMR or some other technique.

We are currently conducting an extensive study at Mississippi State University trying to determine the optimal sawing strategies for hardwood logs using best opening face decisions with the grade sawing method. Maximum benefits from this research require knowledge of what is inside each log.

To more effectively convert medium- and low-grade logs to end products, we are conducting research to produce green dimension blanks directly from logs. We are not stopping with any form of lumber. We hope to improve volume and value recovery while producing higher value products. To maximize the benefits from this research we will need information on internal defects in logs and external defects **in** sawn boards.

To more effectively convert tree length roundwood to logs and to determine which logs to process into veneer or lumber and how to process logs into veneer, we need to know the internal characteristics of the logs. We plan to conduct log optimization research in the future as our abilities to scan improve. Currently scanning is expensive and accurate interpretation of scan data is needed.

STATUS OF OUR CT SCANNING RESEARCH

The thrust of this research is to develop the computer vision methodologies required to locate and identify internal log defects. The computer vision software system being developed can, once again, be divided into two systems, a segmentation system and a recognition system. The segmentation system is supposed to locate areas that might contain an internal defect. The recognition system is then supposed to determine whether a defect is actually present at each location provided by the segmentation system and if a defect is present, identify what it is.

Figure 3 illustrates some of the capabilities of the current segmentation and recognition systems. Part A shows a CT image "slice." Part B shows the results obtained from the segmentation system. Part C shows the results obtained from the recognition system. The recognition system can identify three defect types--bark, knots, holes/splits.

A major problem in this research area is the cost of getting CT image data of logs. The present research has had to use available data of a single red oak log. Hence, the robustness of the approaches used are in question. The desire must be to develop species independent methods for performing the analysis. This goal cannot be reached until data from a number of different species is obtained. The thrust of the current research is to obtain data from more species and to develop and test species independent methods for performing this analysis.

ARE COMPUTER SYSTEMS TO GRADE LUMBER, AND PROCESS MATERIAL IN THE FUTURE FOR HARDWOOD SAWMILLS? WE HOPE SO.

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FIG. 1 - EXAMPLE TALLY SHEET FOR THE
COMPUTER ANALYZED LUMBER

BATCH INFORMATION

SOURCE ___HARDWOOD CO.___

SPECIE ___RED OAK___

LENGTHS ___9 & 10___

THICKNESS ___5/4___

TOTAL BD FT ___1500 BD FT___

DATE ___1-15-90___

GRADE MIX

FAS ___5%___

SEL ___3%___

1C ___67%___

2C ___25%___

3C ______

POTENTIAL YIELD IN:
__X__ STANDARD LENGTHS
_____ SPECIFIC LENGTHS
(LENGTHS ARE DISPLAYED
IN GRAPH BELOW)
(WIDTHS ARE RANDOM)
IS ___72___ %

DISTRIBUTION OF POTENTIAL CUTTINGS
BY LENGTH

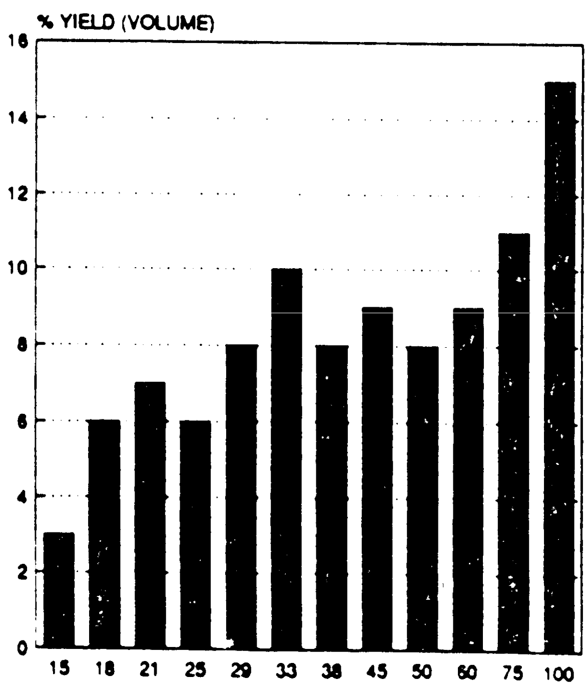

Figure 1. Example tally sheet for the computer analyzed lumber.

(A)

(B)

(C)

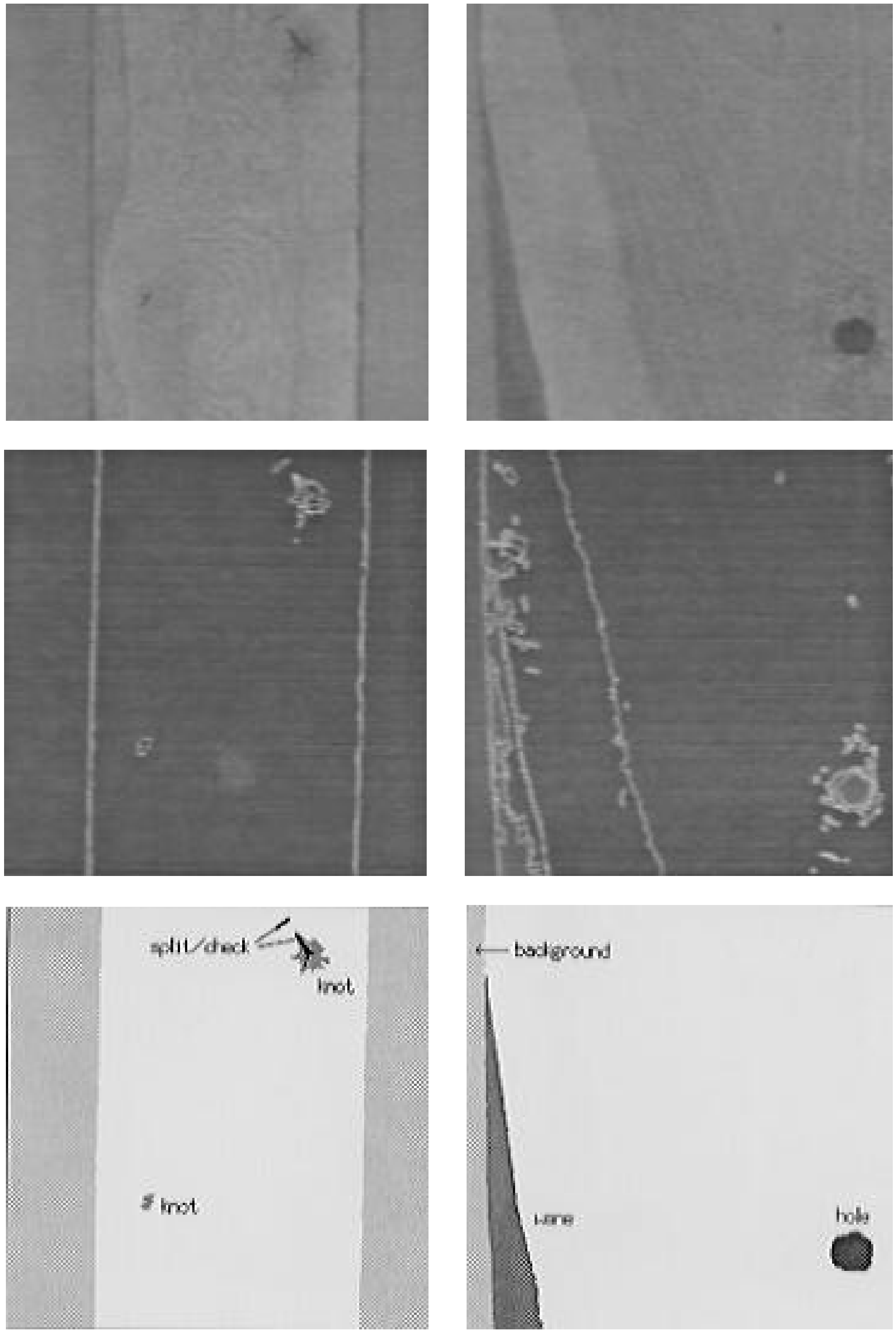

Figure 2. Part (A) Black and white versions of color images of red oak and cherry boards. Part (B) The results of the segmentation system. Part (C) The results obtained from the recognition system (white area represents clear wood).

(A)

(B)

(C)

Figure 3. Part (A) A 256x256 image slice of a red oak stem. Part (B) The results of the segmentation system and resulting boundaries around bark and defects. Part (C) The results of the defect recognition system and labeling.