COMPUTER-INTEGRATED BREAKDOWN OF HARDWOOD SAWLOGS

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ABSTRACT

This paper describes work in progress concerning the development of an integrated approach to hardwood processing. The motivation for this work, research direction, and research developments are presented.

MOTIVATION

The development of an integrated approach to hardwood processing is motivated by three main factors. Firstly, hardwood timber is an economic staple that impacts mainly family-owned businesses in rural communities. Studies have shown that small to medium businesses have the greatest potential for growth and flexibility in these times of rapid change. Thus, doing work that will enhance and provide assistance in this area is an investment in the future of rural economies.

Secondly, we are faced with the challenge of extracting wood from stocks of increasingly low-grade timber. For the same amount of sound wood to be extracted from lower grade timber, more trees have to be harvested. If we can find ways of improving the extraction process, through improvements in technology or alternative utilization of by-products, then we can minimize waste and get better productivity. Thus, there is an environmental implication in seeking ways to improve the processing of hardwood sawlogs.

Thirdly, there are distinct benefits from taking an integrated approach to solving problems. This is true for hardwoods as well as in traditional industrial engineering products made of metals or other materials. In working on the associated problems of hardwood processing using an integrated approach, we benefit from dual use of technologies and provide the opportunity to solve common problems.

THE INTEGRATED APPROACH

The integrated approach we are taking is grounded in a fundamental philosophy of integration. The basic premise of integration is that some decisions are interrelated, and thus these decisions should not be made separately in isolation (Occeña 1991). Examples of potential candidates for integration can be found at different stages of hardwood processing.

Take for example the interaction between the sawyer and the edgerman. When the sawyer removes a flitch from a log face, there is an expectation of a potential grade for that face. This expectation, however, is not communi-

cated as information to the edgerman who may end up removing too much or too little wane that results in a different grade from that which the sawyer intended.

Another example on a different scale is an end-use manufacturer who may need a six-inch thick dimension stock as a furniture component. To arrive at this dimension from a batch of 8/4 lumber or dimension stock, the manufacturer has to match and glue together several pieces. From an integrated viewpoint, this dimension requirement can be communicated as information to the sawyer who will then saw a six-inch thick flitch for this manufacturer and save a few intermediate steps.

The hardwood industry is quite segmented, with each segment usually concerned only with its immediate input (supplier) and output (customer). In fact, if we examine the entire life cycle of hardwood products, from the raw material (log) to the finished product (for example a piece of furniture), we will find strong interrelationships which can be integrated to arrive at better products at lower cost and less waste. This segmentation is deeply rooted in the current market structure. As a result, a sawmill maybe constrained to saw logs whether or not there is a market for the resulting lumber. Earlier work directed at examining a direct log-to-dimension manufacturing (Araman et al. 1995) is apparently looking in the same direction of integration and a lessening of the market segmentation.

RESEARCH DIRECTION

Several researchers at different institutions are currently hard at work to find practical means of bringing non-invasive internal imaging technologies into hardwood processing. Of these technologies, CT (computed tomograph y) imaging has been the most investigated (Zhu et al. 1991). The major handicap sawyers have is the inability to detect degrading defects before the log face is opened. The ability to see the internal defect configuration ahead of time prior to sawing will provide sawyers with more information on how to extract the best value yield from the log.

We foresee three potential scenarios for internal imaging application in the hardwood sawmill. The first is to provide the sawyer with three-dimensional images directly from the scanner. This will be as if the sawyer has see-through vision to see inside the log, seeing how the internal defects are distributed throughout the log. The sawyer can then take this information into account in making a sawing decision. This scenario is perhaps the most immediately implementable scenario at the moment. It will require collaboration between the imaging people and the headrig manufacturers to bring this scenario to a head. The decision making will still be left up to the sawyer.

The second scenario is where additional assistance will be provided to the sawyer in the form of lookup tables or databases that will recommend a certain course of sawing action for a particular internal image. The sawyer can then make a decision based on a limited set of possible sawing patterns. These lookup tables or databases will be derived from experimental research whereby extensive studies using simulated sawing will be used to conclude a specific sawing pattern for a given internal defect configuration. This scenario is similar to the use of machining tables or the Doyle scale where previous empirical studies have been used to prescribe estimated values for a given set of parameters.

The third scenario is where technology will be fully exploited to not only recommend but actually determine an optimal sawing pattern from the internal imaging information. The sawing pattern will be generated for each log based on the best sawing pattern that will give the highest value yield. With a computer-aided tool such as this, there will be less uncertainty on the chosen course of sawing. The sawyer will still execute the sawing operation,

but will be guided by the generated sawing pattern. With many possible sawing outcomes for a given log, this scenario offers the best solution, but also requires the most effort in terms of technological development.

The current work of improving hardwood processing yield using an integrated approach is predicated on the availability of internal imaging information. With such information available, it will be feasible with current technology to model the log through all of its processing steps, not only the log breakdown, but even down to the final furniture components. The internal log model can be fed back and incorporated in the decision making for practically all of the processing steps: log breakdown, flitch edging and trimming, grading and sorting, drying, cross-cutting and ripping, matching and gluing, and eventual end-use manufacturing.

We therefore take a systemic approach, examining all of the pertinent steps in the hardwood product life cycle, and paying close attention to where there are strong dependencies for which an integrated decision making approach will have distinct advantages.

RESEARCH DEVELOPMENTS

Currently, the work is focused on primary processing in the sawmill, including log breakdown and flitch edging and trimming. However, it is not a too distant future for the work to be extendable to the downstream operations of cross-cutting and ripping in the roughmill to produce dimension parts, or to be moved up earlier to the bucking and topping decisions, because of the inherently interrelated nature of hardwood processing that is a natural for an integrated approach.

The research functions observe a certain pattern: the log is scanned to extract internal information, the scan information is post-processed to extract profile information and reduce the data set to the bare minimum, the profile information is used to generate solid models of the log and its defects, and the solid models are used to examine the log breakdown and flitch processing operations. Several tools have been developed to assist in the various stages of these research functions. The following sections give a brief description of these tools and the work for which these tools are being used.

Log Scanning

The log scanning operation provides the basic input to the research. The raw data comes in the form of cross-sectional slices depicting image pixel values or transformed Cartesian coordinates. Until industrial scanners of lower resolution and cost compared to medical grade scanners are available, the log scanning operation is currently a limiting step in the process. To compensate for this current limitation, research work has been accomplished to generate additional log and defect data from the available scan data for study purposes. We have developed a robust procedure called LDG (Log and Defect Generator) to "grow" additional log and defect knot data using a hybrid technique that combines Fourier descriptors and mode analysis. We are currently extending the model to generate defects other than knots, and using the model to generate additional study logs (Chen and Occeña 1996).

Profile Extraction

The log and defect data obtained from internal scanning is huge, on the order of 85 to 100 Mbytes of data. Even after the profile has been extracted and converted into Cartesian coordinate data, the data remains large (-8 to 10 Mbytes). To speed up the processing of data, it is desirable to reduce the data to a minimum set that still retains the shape information. A model called GDR (Geometric Data Reduction) has been developed that reliably reduces the data set to more manageable size (~600Kbytes) while preserving representational integrity of the

geometric information. The model essentially eliminates' those slice data which do not exhibit unique centroidal displacement or size characteristics. As an example of its efficacy, the number of slices in a log sample was reduced by 59% with only a 0.03% change in the volume measurement (Occeña et al. 1995).

Solid Modelling

The extracted profile data is then converted into solid models which represent the log and its data, and enable simulated sawing of realistic-looking log and defect solids using regularized Boolean operations. The sawing simulation program called GRASP (GRAphic Sawing Program) is a microcomputer-based graphics program that enables interactive simulated sawing of solid representations of the logs and its defects (Occeña and Schmoldt 1996). The program provides full-featured graphics (rendering, scaling, transformations, etc.) and is currently being integrated with a hardwood lumber grading program to enable immediate evaluation of sawing decisions. This program is being used in evaluating different sawing strategies that take advantage of internal defect information. It is a versatile sawing program that can handle any form of sawing operation.

Breakdown Modelling

Traditionally, log breakdown followed a few log sawing patterns: live sawing, grade or around sawing, cant sawing, taper sawing. Usually a sawmill adopted one of these sawing patterns and used it consistently on all of the logs. Now with additional information available regarding the internal defect configurations, it is conceivable for logs with different defect configurations to be subjected to different sawing patterns on a case by case basis. One early model designed to deal with this defect-specific approach is PDIM (Pattern Directed Inference Model) which generates a log breakdown pattern specific to the internal defect configuration found inside the log. It does this by enveloping the defects in a defect hull and analyzing a composite end-view that represents the density of defects distribution through the log. This model, along with other similar models, is being investigated for effectiveness in arriving at an optimal sawing pattern.

Edge/Trim Modelling

As part of the integrated approach, a rapid edging program was developed that uses the same geometric information obtained from log scanning. This approach eliminates the need for the lumber faces to be scanned. The model called AHEAD (A Hardwood Edging Automated Decisionmaker) combines hardwood lumber grading rules with a branch and bound decomposition procedure to rapidly determine an edging decision. Early tests show edging decisions that are as good as an edgerman, arrived at in less than 3 seconds. This program has potential as a rough-cut tool for estimating edging decisions in real-time applications. The program is currently being evaluated on a larger lumber data set.

CONCLUSION

This paper is the summary of a presentation describing research work that takes an integrated view of hardwood processing. The motivation behind an integrated approach was described, followed by a discussion of the integrated approach itself, and examples of current developments under this project. Work is continuing in the different stages of the research functions, with the ultimate goal of developing an operational tool for sawmill implementation.

The work cannot be completed without the collaboration of all sectors involved: researchers from universities, laboratories, and government agencies, headrig and scanning equipment manufacturers, and the end product manufacturers and users. We hope for a continuing dialogue among the different parties involved. The hard-

wood inventory and environment are changing. The science and technology to meet that challenge are being developed now, but needs continued nurturing and support.

For more information regarding any of the tools mentioned in this paper, please visit our World Wide Web home page for the Virtual Center for Hardwood Integrated Processing (VCHIP) at http://www.missouri.edu/~occenal/vchip, or contact the first author.

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