GRASP: A PROTOTYPE INTERACTIVE GRAPHIC SAWING PROGRAM

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ABSTRACT

A versatile microcomputer-based interactive graphics sawing program has been developed as a tool for modeling various hardwood processes, from bucking and topping to log sawing, lumber edging, secondary processing, and even veneering. The microcomputer platform makes the tool affordable and accessible. A solid modeling basis provides the tool with a sound geometrical and topological foundation. Owing to the simulation's flexibility, it can be used in a variety of wood-processing operations. Within any operation, it can be used to analyze processing alternatives, or to aid in the training of personnel.

In the area of production operations, computer simulation has proven to be a versatile analytical supplement to physical testing. In lumber production, computer simulation is of special interest because it enables the repeated sawing of a log sample, in essence a means for examining the effects of several log breakdown patterns and sawmill variables. There have been many previous simulation studies on hardwood log breakdown (e.g., 2,4,6-8,10, 12,13). This type of simulation is of a physical nature that involves geometric representation, in contrast to systems simulation studies (3) that observe the operation of a system over time.

In the late 1970s, Pnevmaticos et al. (7) introduced the first graphic simulation of log sawing using a hybrid graphics terminal. Graphic simulation has the advantage of a visual feedback on spatial relations vital to hardwood processing. Pnevmaticos used truncated cones and cylinders to approximate log shapes, and rectangular boxes to approximate defects. Finding the intersection of the log with the saw was treated as a linear programming problem.

In 1988, Occeña and Tanchoco (4) reported the development of a graphic log sawing simulator as an analytical tool for automated hardwood log breakdown. The log and its defects were represented as nonregular polyhedra and sawing was treated as a Boolean operation between closed solids. The polyhedral model more closely approximated the true shape of the log and its defects than previous log/defect graphics models. It was implemented on a minicomputer platform using device-independent graphics and user-developed programs.

A subsequent paper by Todoroki (12) reported the development of an automated sawing simulation program also aimed at evaluating sawing strategies. Logs were represented as a series of polygon cross sections and defects as cross-sectional whorls. The use of nonsolid models emphasized speed over precision and flexibility in the representation of the log and defects.

The continued interest in developing operation simulators attests to the significance of such modeling tools. Concurrently, researchers have been pursuing studies on non-invasive internal defect detection (1, 11, 14) with the intent of developing the capability to "see" internal log defects. This capability will lead to improved hardwood log breakdown decision making that will yield higher value lumber. A logical consequence of the capability to "see" inside a log prior to sawing is the need to resolve the issue of how such information can best be used to arrive at a higher yield. Studies have shown that irrespective of log grade, the optimal orientation of internal defects with respect to sawing pattern increased value yield over 10 percent on the average, and that a precise knowledge of internal defect location was required (9, 10). Given the importance of a realistic representation of the log and its internal defects, and the usefulness of a tool that will enable repeated interactive sawing of the same log sample, an interactive graphics sawing program for wood processing that runs on a microcomputer has been developed.

This paper describes a prototype microcomputer-based interactive graphics sawing program for wood processing that integrates graphics rendering, solid

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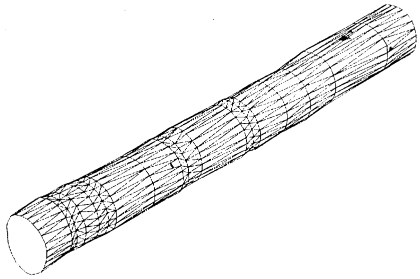

Figure 1. — Reconstructed log.

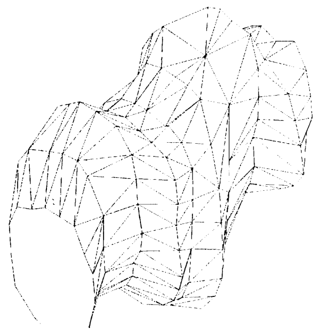

Figure 2. — Reconstructed knot defect.

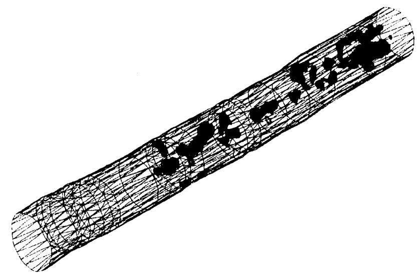

Figure 3. — Wire frame rendering with internal knot defects revealed.

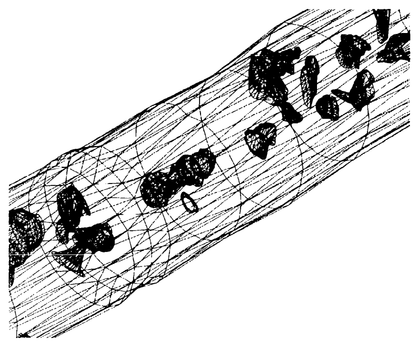

Figure 4. — Zoomed-in view of a section of the wire-frame image.

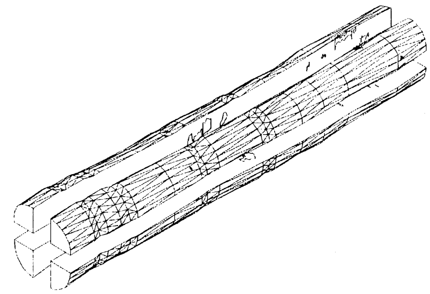

Figure 5. — Quartersawn log for veneering process.

modeling, and data representation. An earlier version of the program founded on the same modeling principles only ran on a much larger computer (minicomputer platform) and did not have a tightly integrated environment (4). The current graphics sawing program, which we call *GRASP* (for GRAphic Sawing Program) is unique in its flexibility to model just about any sawing operation, from bucking, topping, log breakdown, quartering, and veneering, to edging, trimming, secondary processing, even extracting and representing furniture components. It is founded on solid modeling principles, which endows it with a robust foundation in geometry and topology. The implementation on a microcomputer platform makes it an affordable and accessible tool for many users.

DATA RECONSTRUCTION

The input data for *GRASP* can be an object from any stage of wood processing, e.g., timber, log, quarter-log, flitch, board, blanks, etc. They have to be represented as closed polyhedral solids, i.e., a set of concatenated polygonal patches or faces that fully envelopes a region describing the object. In this current development, we focused on logs. The sample data consisted of three approximately 12-foot-long red oak logs.[1] The data came in the form of both CT scan and digitized coordinates, representing the cross-sectional profiles of the log and its internal defects. The log profiles were sampled at 2-inch intervals, and the defect profiles at 1/4-inch intervals, along the length of the log. For these raw data to be usable by *GRASP*, solid representations of the log and of the defects had to be reconstructed from the cross-sectional profiles. The log and its defects were reconstructed as separate solids, while retaining their original relative spatial orientations and locations. *GRASP* itself was used as a tool for reconstruction, uniting the profiles into polyhedral solids. To reduce the magnitude of the resulting data files, the log profiles that did not exhibit significant variation from their adjacent profiles were excluded from the log reconstruction. The same was done for the defect profiles in the defect reconstruction. This data reduction procedure still maintained the integrity of the solid representation(5). Figures 1 and 2 illustrate a reconstructed log and knot defect, respectively. Note the irregular intervals of log cross-sectional polygons resulting from the data reduction.

GRASP PROTOTYPE

FEATURES

The prototype interactive graphic sawing program was implemented on an IBM-compatible microcomputer. The minimum hardware configuration is a 386 CPU with a math coprocessor, 4 MB of RAM, and VGA graphics adapter, which is considered to be lightweight by today's standards. Microcomputers today come with much more power than these minimum requirements. *GRASP* runs on DOS, as well as within Windows and OS/2 as a DOS emulation. The sawing program uses a solid modeler as the core engine for the sawing simulation of the log and defect solids. The basic principles of solid model representation and processing have been described earlier (4).

The integrated graphics can render the objects simply as see-through wire-frame images (as is common in computer-aided design (CAD)), as solids with obstructed polygons hidden from view (using hidden line removal), or as realistic-looking shaded objects. Figure 3 shows the log as a wire-frame image with some of its knot defects. Excluding polygons that are normally hidden from view in the rendering process, as in Figure 1, provides the capability to show or hide internal defects as desired.

There are various other features in *GRASP* that are common in graphics-oriented programs, such as multiple views (front, top, orthographic, etc.), windowing (splitting the screen into several windows, each with a different view), magnification or reduction scaling of the image (zoom in/out), and calculation of dimensions (length, width, area, volume, etc.).

[1] Logs were obtained from the USDA Forest Service Southern Research Station, Unit SE-4702, Blacksburg, Va.

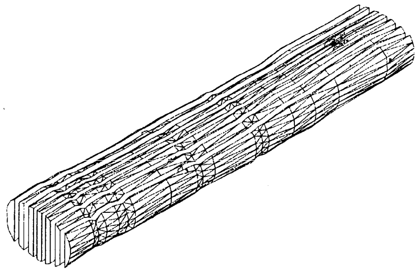

Figure 6. — Live-sawn log.

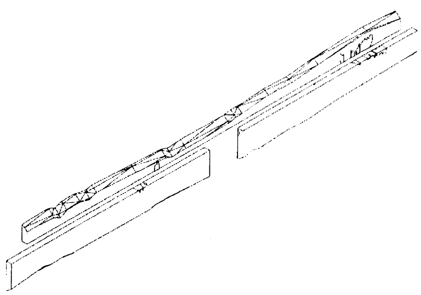

Figure 7. — Crosscutting and ripping of flitch.

Figure 4 illustrates a magnified view of a section of the wire-frame image, giving a closer look at the internal knot defects.

Processing capabilities

GRASP is a versatile tool that can be used to interactively and graphically saw solid representations of wood objects in various stages of processing. It can be used for bucking and topping felled timber, for log breakdown into flitches, for edging and trimming of flitches into lumber, and for ripping and cross-cutting finished lumber into furniture blanks.

The resulting objects of a sawing operation are solid objects themselves. This property allows the same kerf-removal process to continue on resulting objects, akin to the way that downstream secondary and finishing processes operate on the result of preceding operations. In the simulation, kerf thickness is a variable that can be changed to reflect the thickness of the sawblade. **Figure 5** illustrates a quartered log such as would be done for veneer processing. **Figure 6** illustrates a live-sawn log as an example of a log breakdown pattern that can be nondestructively repeated on the same log at different opening faces. **Figure 7** illustrates a board that has been ripped and then crosscut to extract clear-faced blanks as furniture components.

Study implications

GRASP has much potential for analyzing wood-processing operations. It can be used as an analytical tool for research to nondestructively examine different ways of converting raw wood material such as logs into lumber, veneer, furniture blanks, etc. It is also a vertically integrated research tool that can be used during the various stages of physical and mechanical transformation of wood, from primary processing through secondary processing to finished product manufacturing. Its open architecture will allow the model to be embellished, or adapted for other functions. It can also be used for training purposes, providing a flexible, programmable, and nondestructive environment to tailor training for a variety of solid wood processes.

Summary

This paper described the features, capabilities, and implications of the prototype for a microcomputer-based interactive graphics sawing program for wood processing called *GRASP*. It is a versatile program that can handle most solid wood conversion processes, from bucking and topping, to primary and secondary processing, and even manufacturing of furniture components. The program has an open architecture and can be extended for a variety of purposes. We are currently extending it to provide access to lumber-grading programs. We are also studying the means to automatically generate saw controller codes from sawing instructions, and automatically execute sawing instructions in a batch mode. Some potential uses of *GRASP* include research into better ways of improving forest product yield, and training in a flexible and nondestructive environment.

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