

INTERACTIVE SIMULATION OF HARDWOOD LOG VENEER SLICING USING CT IMAGES

DANIEL L. SCHMOLDT
PEI LI
PHILIP A. ARAMAN

ABSTRACT

Veneer producers must make critical processing decisions based solely on external examination of logs. Unlike sawlog breakdown, however, little research has investigated ways in which veneer logs can best be flitched and sliced for increased value. This gap exists largely due to the variety of ways in which veneer is produced and used and the variety of buyers that purchase the finished product. This report describes a veneering simulator that is able to assist veneer producers in their processing decisions. A user can graphically locate and orient veneering objects (flitch table, flitch, and cutting knife) on log CT images and see the resulting veneer produced. The simulator currently allows the user to perform six different types of veneer slicing. Multiple veneer slices or alternative veneering operations (e.g., flat slicing vs. half-round slicing) can be simultaneously viewed and compared. The application of scanner-based simulation tools can help transform marginal logs into profitable raw material.

Once logs have been purchased and delivered to a veneer mill's logyard, the first important veneer-mill processing decision is made. A skilled mill employee must determine how each log should be opened along the longitudinal axis (flitching). This decision is made based on: external bark indicators of internal defects, veneer patterns expected from slicing, and likely buyers for veneers exhibiting particular visual characteristics. Depending on the type of veneer cutting operation(s) that a mill uses and on the factors just mentioned, a log may be cut longitudinally into two to four flitches. This flitching decision involves some guessing about the internal characteristics of each log. Therefore, knowledge about internal log characteristics can improve the flitching decision. To obtain this increased level of internal information it is expected that future veneer mill processing will include some sort of internal

scanning operation to augment human decision making (17).

PREVIOUS WORK

Nevertheless, improved decision making still requires that scanned data are integrated with mill operations, i.e., log breakdown options and value yield (28). Many prior studies have sought to improve *sawlog* breakdown practices (both bucking and sawing) by finding breakdown methods that generate the highest value products. Most of these efforts have relied on simulation to describe and evaluate different log breakdowns, initially without the use of com-

puters (20,21). However, due to the combinatorial problems associated with partitioning a three-dimensional object, such as a log, computer simulations have been used extensively to generate and evaluate alternative log bucking/scaling (12,25,41), and sawing (8,11,14,24,26,27,33-35,37), and to optimize breakdown into the highest value products (6,7,12,13,16,29,30,32,36). Still others have used graphical displays of logs and resulting lumber as part of an interactive simulation of the sawing process (15, 19,24,34). Because of their interactive nature, graphical simulators (18,22,23) have been promoted as sawmill training tools. Each of these simulations has described logs and their defects using physical measurements of the log or its resulting products.

Potential value yield increases from different log breakdown practices vary considerably. For sawing, potential value increases range from 3 to 21 percent (1,4,8,20,21,27,30,35,37,39,40). The exact magnitude of these estimates depends on the type of logs and the sawing strategies compared and the precision of the log and defect geometry representation. For bucking, potential value increases may be much higher, 40 to 50 percent for northern hardwoods (12).

All the studies just mentioned have

The authors are, respectively, Research Forest Products Technologist, USDA Forest Service, Brooks Forest Products Center, Virginia Tech, Blacksburg, VA 24061 -0503; Graduate Research Assistant, Bradley Dept. of Electrical Engineering, Virginia Tech, Blacksburg VA 24061; and Project Leader, USDA Forest Service, Brooks Forest Products Center. This paper was received for publication in April 1995. Reprint No. 8348.
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dealt with sawlog breakdown. No similar simulation and value yield work has been attempted for veneer logs for several reasons. First, a tremendous level of digital detail is required to adequately describe veneer slices because annual ring structure determines veneer pattern. Manual digitizing of growth rings would be time and cost prohibitive. Second, while the National Hardwood Lumber Association grading rules for lumber allow value comparisons for different sawing patterns, there is no comparable valuation procedure for veneer slices that would allow one to compare the value of veneer resulting from different flitching/slicing options. Rather, veneer value is dependent on veneer size, veneer pattern, and buyer preferences. Despite these handicaps, we can still provide veneer mill operators with a tool to help them make better processing decisions.

Internal imaging of logs, for example using computed tomography (CT) or nuclear magnetic imaging, can partially mitigate the data collection problem. Internal, nondestructive imaging of logs generates a series of cross-sectional pictures that contain a large amount of detail regarding internal characteristics, such as defects and annual rings (1-3, 5,9,10,3 1,38). Therefore, in one operation, log and defect geometry are made visible and are digitized. From these tomographic images, a graphical simulator can be constructed to allow users to veneer a CT-digitized log interactively. While CT imaging of logs is not currently performed in industrial operations, there are good economic reasons to expect that it will in the near future (4,9,39,40). When CT scanning does come on-line in mills, a graphical simulator becomes a useful tool for quickly evaluating different flitching/slicing alternatives.

This paper includes a brief review of veneer production, steps used to develop the veneer slicing simulator, and some examples of simulator slicing options and simulated veneer appearance.

METHODS

LOG FLITCHING AND VENEER SLICING

A normal veneer log slicing procedure

starts with an expert inspection. A skilled employee decides where to saw the log into sections called flitches. A flitch is a log-length portion of a log that has been sawn along the longitudinal axis. Flitches are later sliced to produce different types of veneer for various kinds of final products. The veneer can be used in furniture, cabinets, custom millwork, store fixtures, architectural applications, flooring, and a variety of other applications. The projected look or "figure" desired in the veneer by the end customer, and the log diameter, will dictate the type of slicing performed. Projected visual effect sells veneer.

An inspector looks at grain characteristics, potential internal defects, and potential veneer patterns to make this flitching decision. The inspector estimates potential grain and veneer patterns by looking at the growth rings on both ends of the log. Many internal defects can be detected by examining outer bark characteristics. Where bark has been removed (as commonly occurs during harvesting at particular times of the year), the inspector has great difficulty "reading" external markings of internal defects. Potential defects deeper in the log are either missed entirely or identified by "educated" guesses. The expert merges this defect information with knowledge of present or potential veneer orders. He decides the type of veneer to produce (flat sliced, half round, quarter sliced, etc.) and where to cut the flitches from the log. Flitches are marked on one end of the log with paint. The marked lines serve as guides for cutting the flitches at the sawmill headrig.

After sawing the flitches, they are "cooked" to soften the wood. Flitches are then taken to a lathe for slicing into the appropriate type of veneer. Veneer slices are then dried, inspected, clipped, measured, and packaged. The veneer from each individual flitch is lightly clipped and kept together during packaging for domestic sales. Veneer destined for export markets is usually more heavily clipped and veneer from flitches of the same log are merged together prior to sale. Manufacturers also produce thinner veneers for export sales. Veneer flitching and slicing decisions are very critical for profit margins for the following reasons: 1) veneer products are variable; 2) it's difficult to get reliable "readings" of defect indicators and potential veneer pat-

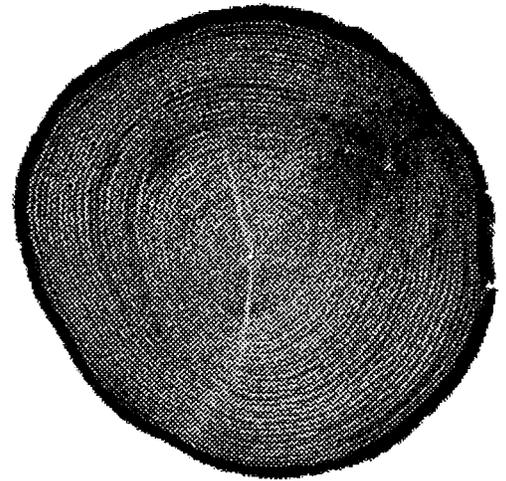


Figure 1. — Different densities are depicted by different gray-level values in this computer-generated x-ray tomograph of a red oak log. Each pixel is approximately 2.5 mm square.

terns on logs; and 3) markets are multiple and varied.

SIMULATOR DEVELOPMENT

Tomographic x-ray scans of logs, as with any other imaged object, are produced by sending x-rays through the specimen's two smallest dimensions. This produces a two-dimensional scan plane image. Successive scan planes are generated through the longest dimension. Therefore, each scan, or tomograph, produces a cross-sectional image (Fig. 1). If successive scans are taken close enough together, then corresponding one-dimensional lines (straight lines or curved lines) in each scan can be combined across many scans for a two-dimensional image, or longitudinal surface. This longitudinal surface is the geometric equivalent of a veneer slice from a log flitch. By automating the process of creating longitudinal surfaces from a set of log tomographs, we have produced a veneering simulator that allows one to see the veneer that results from different flitching and slicing options.

Our initial simulator was built on top of DIP Station¹ version 1.06. DIP Station is a feature-laden, image-processing software package that was designed primarily for medical tomographic image processing. It contains many image display, manipulation, and enhancement functions. We wrote a user-code module in C,

¹Digital Image Processing for the Macintosh, Perceptive Systems, Inc., Boulder, Colo. Tradenames are used for informational purposes only. No endorsement by the USDA is implied.

as a Macintosh code resource of type XFNA. This code module accesses DIP Station's data structures, image processing functions, and display capabilities to extend the functionality of the original software. Our hand-coded module is automatically loaded by DIP Station at startup. The primary advantage of this initial method of simulator construction is that we were able to prototype an operational version quite quickly.

This implementation of the simulator had a number of problems, however. First, it functioned slowly because it was interacting, at all times, with the image-processing software. Second, the graphical interface features were clumsy and

difficult to integrate within DIP Station. Third, DIP Station requires that a floating point coprocessor be present in order for it to run. Consequently, based on what we had learned from the initial prototype, we coded a second simulator in C as a stand-alone Macintosh application. This version of the simulator eliminates all of the foregoing limitations and is the version we present in the remainder of this report.

We are currently using CT images with 256 by 256 resolution. These images are the same CT images that were collected by and reported in a previous paper (38). Each pixel is 2.5 mm square and successive tomographs were imaged

every 8 mm on center with a thickness of 2.5 mm. Because of these scanning parameters, there are 5.5 mm missing between adjacent columns of a veneer image as successive CT slices are stacked together. This gives the veneer image a severely compressed appearance. To eliminate this, we generate two interpolated pixels between each pair of actual pixels in the veneer image. This augmentation of the veneer image produces a new image that is only slightly compressed, where 7.5 mm represents 8 mm.

Generally, CT images are represented using either 8- or 16-bit data. The simulator will accept either type of data file. It also provides for either 8-bit or 16-bit

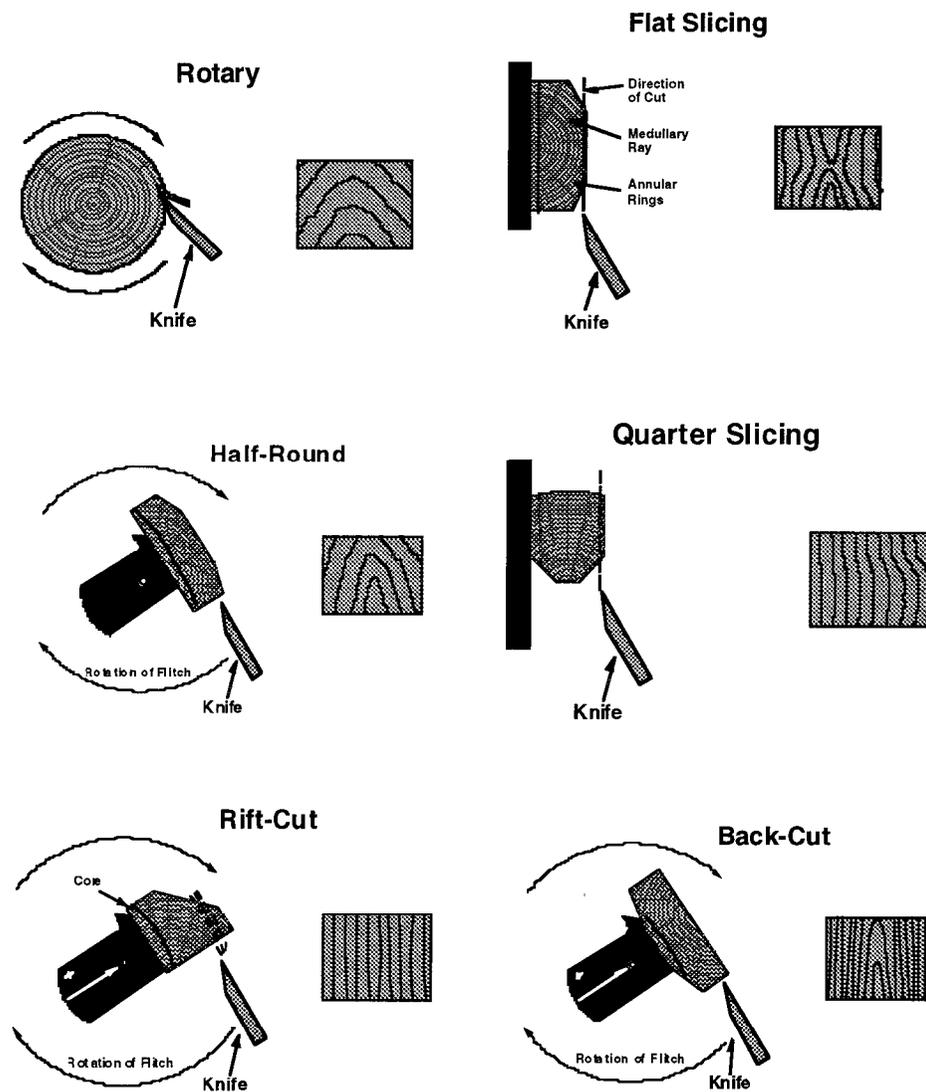


Figure 2. — Six different possible veneer slicing options are provided in the simulator. Some of these drawings were reproduced from *Fine Hardwoods Selectorama—A guide to the selection and use of the world's most popular species*, Fine Hardwood Veneer Association and American Walnut Manufacturers Association, Zionsville, Ind. Reproduced and printed by permission.

display. When the data are in 8-bit format and the display mode is either 8-bit or 16-bit or when 16-bit data and 16-bit display are used, untransformed image data can be used for both calculations and for display. Then, the simulator displays CT images and veneer images quite quickly. However, when the data are 16-bit and the display mode is 8-bit, then the 16-bit data must be scaled for display. This adds considerable overhead to the display of CT and veneer images, i.e., 64,000 additional operations must be performed to generate each display. Consequently, images are displayed more slowly with these data and display settings.

RESULTS

All of the six different types of veneer slicing are included within this application. These include: rotary, flat, quarter, half-round, rift, and back cut (Fig. 2), and represent most of the common veneer slicing operations. The simulator contains a tool palette and various menus to

tailor and control the generation of veneer slices. Using the tool palette, the user can graphically arrange the necessary objects on the CT image (Fig. 3) to perform veneer slicing. For any type of veneer slicing operation that is chosen, the user needs to draw and orient a flitch table, a flitch, and a cutting knife on the CT image. For rotary slicing, however, only the flitch and cutting knife need to be specified. Based on the type of flitch table drawn and the type of flitch drawn, the simulator only permits the appropriate veneer slicing method (Fig. 4).

By default, a single veneer slice will be generated for each slicing operation. This can be changed by selecting "Multiple-Path Veneering" in the **Options** menu. Under this option, the veneering simulator displays on the CT image the location of all veneer slice lines. Currently, slices are taken every 10 pixels for the multiple-path option. This default speeds the simulated veneering process. A future enhancement could make the

frequency of veneer slices user selectable. All of the veneer slices represented by the slicing lines are generated and stored at once. This allows them to be retrieved quickly for later display.

After all the slices have been stored for multiple-path veneering, an image window appears and displays the veneer slice corresponding to the first slicing line in the CT image window. Other veneer slices can be displayed in the original veneer window by moving the cutting knife near one of the other slice lines on the CT image of the log. The slice line closest to the knife position will be displayed in the veneer window.

For single-path veneering, only the selected veneer slice is generated and displayed. Any other veneer slices can be created by moving the knife on the CT image window just as with multiple-path veneering. However, the user is not limited only to previously simulated slices as in the multiple-path option; any log location can be selected.

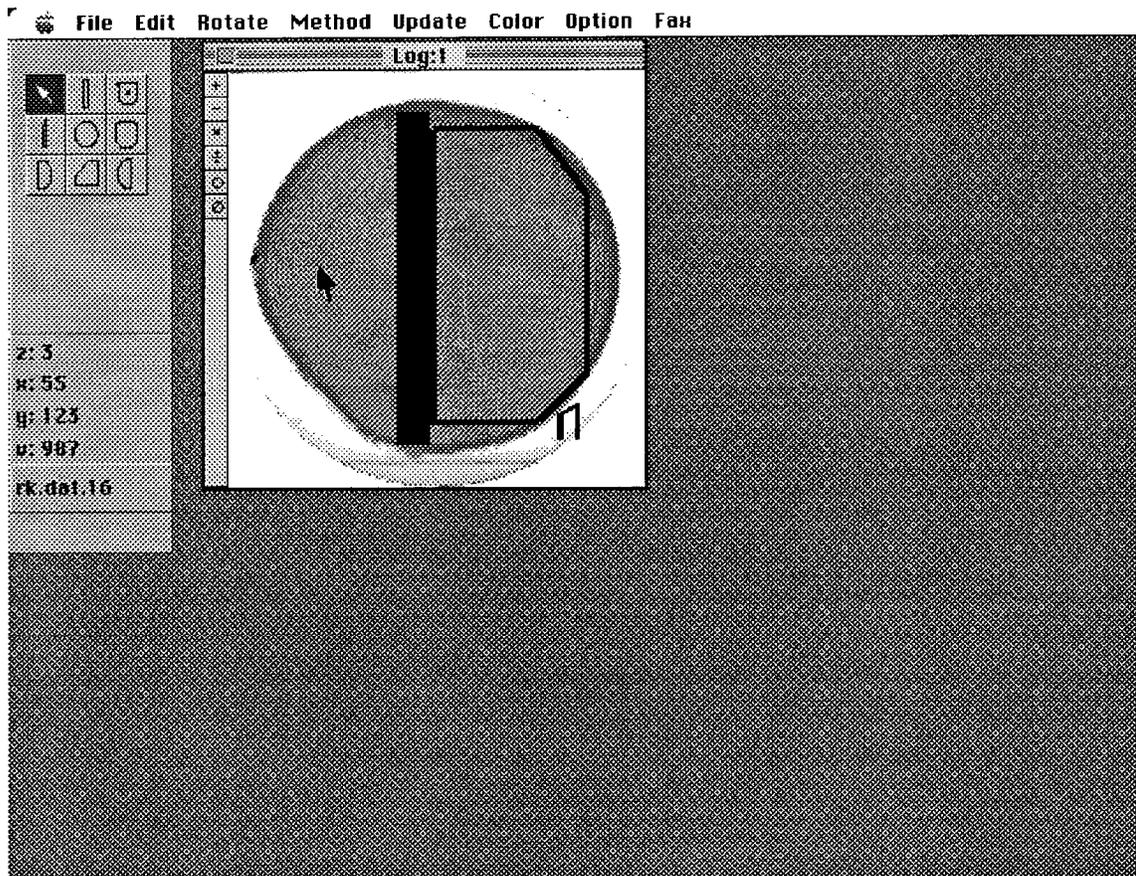


Figure 3. — A screen snapshot of the simulator shows the orientation of the flitch table, flitch, and cutting knife on the log CT image. The simulator's tool palette is located in the upper left corner of the screen. Below the tool palette, slice number (z), x and y coordinates of the pointer, CT number (v) at the pointer location, and data file name are displayed.

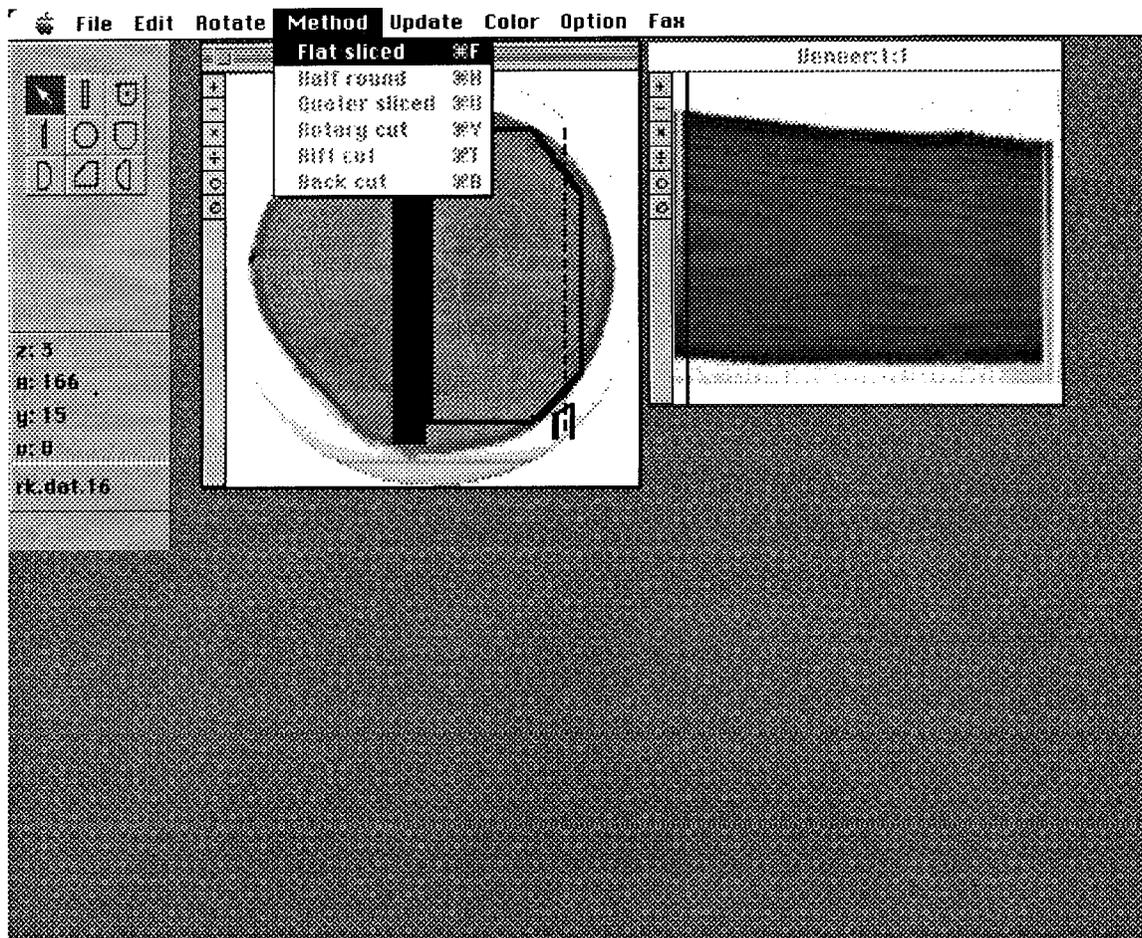


Figure 4. — The dashed line on the log CT image depicts the location of the veneer slice that has been generated and displayed. The highlighted slice of veneer appears in the window to the right. The vertical marker line near the left edge of the veneer image can be moved left or right to view the corresponding CT image.

From the veneer window, the user can move a vertical marker line, which lies near the left edge of the veneer image (Fig. 4), and dynamically see the closest corresponding tomograph of the log displayed in the CT image window. By moving the veneering knife and the vertical marker, the user can cycle repeatedly back and forth between log CT images and veneer slices.

The user can also generate a new set of veneer slices in a new veneer window by changing either: 1) the size, location, orientation, or type of flitch table; 2) the size, location, orientation, or type of flitch; or 3) the location of the cutting knife. However, once the flitch table, flitch, or cutting knife has been changed, only the currently displayed veneer slice remains accessible in any veneer image window. All the other slices (for multiple-path veneering) and the ability to adjust the vertical marker are lost because the reference veneering tools are no longer available. Any veneer images

corresponding to the new veneering settings can then be visually compared to the image remaining in any of the previous veneer windows (Fig. 5). By generating alternative slicing regimes, different slicing operations and different flitch locations can be compared visually in a realistic way.

DISCUSSION

The usefulness of such a simulator is partially dependent on the resolution of the CT images that serve as the data source. Veneer images will lose detail if lower log CT resolutions are used, i.e., increasing pixel size beyond 2.5 mm. If, on the other hand, higher resolutions are used, resulting in greater image detail, then it is possible that the distance between scans can be increased. Increased pixel interpolation for sparser scans would degrade the veneer images somewhat, but probably not beyond the degradation of lower CT resolution. Future research could determine the combination of log CT resolution and tomograph

frequency that delivers acceptable veneer resolution for minimal cost.

Profitability for hardwood veneer mills hinges on several factors. Because mills desire to focus their veneering operations on those logs that have the highest quality wood, proper log selection at the time of purchase is important. Nevertheless, logs are often sold in lots that contain mixtures of high quality and marginal quality material that confound the buyer's ability to select only "true" veneer logs. Therefore, veneer mills must often process logs with less than desirable quality.

While higher quality logs can be easily and profitably manufactured into veneer, the capability to simulate different flitching options may allow mills to further increase the value of high quality logs. Nevertheless, in spite of what can be achieved for high quality logs, overall mill profit margins are more dependent on how lower quality veneer logs are processed. Therefore, mill profits are

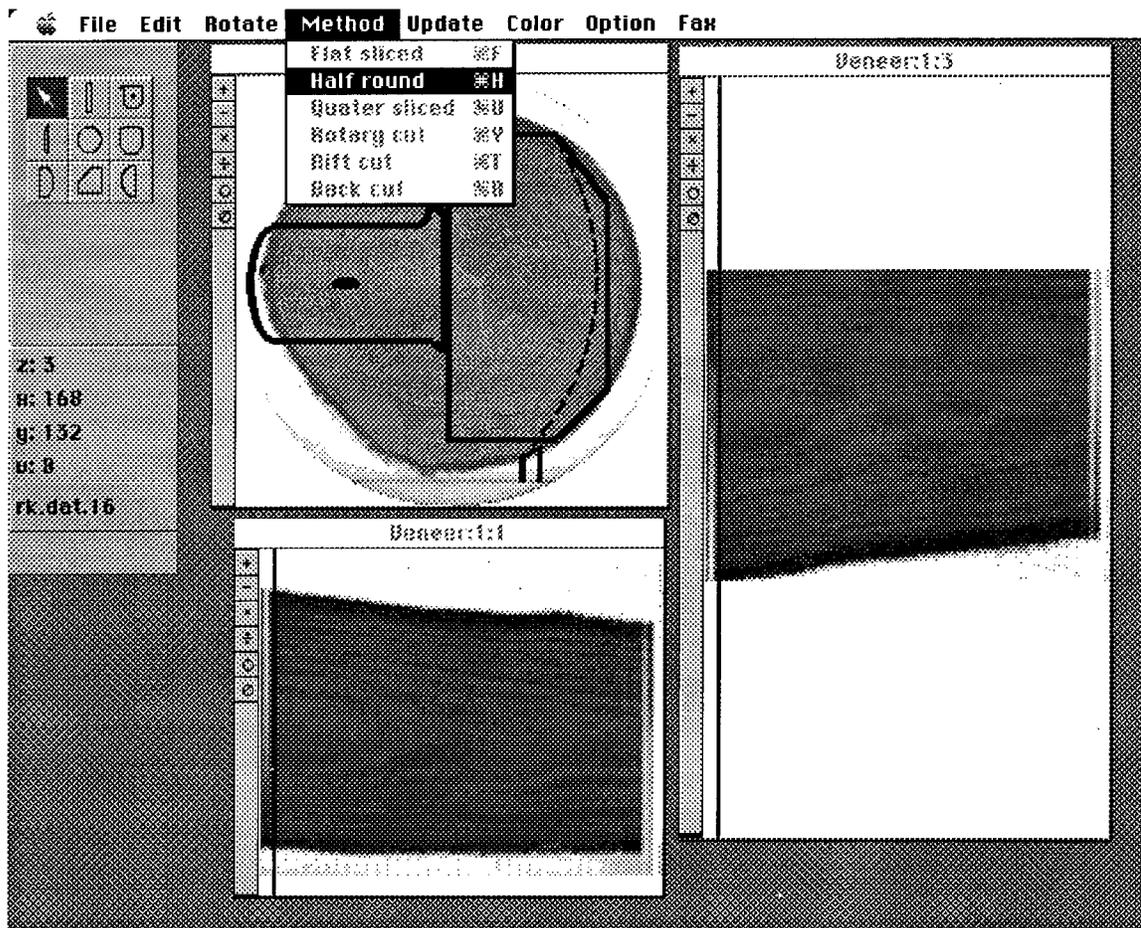


Figure 5. — The flitch table and flitch for half-round slicing appear on the log CT image. The corresponding veneer slice is shown in the window to the right. The user can compare this veneer with the veneer produced by flat slicing (lower image).

critically tied to making good processing decisions for those marginal quality logs. The ability to simulate a variety of veneering options should enable veneer mills to produce salable veneer from marginal quality logs.

As internal scanning of logs becomes part of mill operations, application of simulation tools like these can remove much of the guesswork about flitching decisions. The result will be higher value veneer from a mill's inventory of marginal quality logs, and therefore, increased profit margins. In the meantime, we are using this simulator as a demonstration tool for veneer manufacturers and other industry innovators. It helps people that are skeptical or unfamiliar with CT imaging to visually understand the potential benefits of the information it provides.

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