CORY: a computer program for determining dimension stock yields

Technical Note

Charles C. Brunner
Marshall S. White
Fred M. Lamb
James G. Schroeder

Abstract

CORY is a computer program that calculates random-width, fixed-length cutting yields and best sawing sequences for either rip- or crosscut-first operations. It differs from other yield calculating programs by evaluating competing cuttings through conflict resolution models. Comparisons with Program YIELD resulted in a 9 percent greater cutting volume and a 98 percent reduction in execution time. A microcomputer version for MS-DOS machines is available.

The high cost of hardwood lumber makes any yield increase important in the furniture rough mill process. The greatest potential for increased yield lies in improving the sawing decisions made by machine operators. Several computer-based models of cut-up operations have been designed with the intention of maximizing yields from various cutting strategies (1-7) and could potentially be used to train machine operators to make better sawing decisions. When machine vision systems make automated production lines possible, these computer models will be needed to determine sawing sequences for each board.

CORY (Computerized Optimization of Recoverable Yield) is a computer program developed to rapidly calculate random-width, fixed-length cutting yields and best sawing sequences (l). CORY was originally intended to analyze short, low-grade, unedged boards that previously required large execution times because of their many defects and wane. However, CORY can also calculate yields from any compatibly formatted board data.

The program models a single-bladed sawing process that is user-specified as either rip-or crosscut-first. Subsequent changes in operation (rip to crosscut or vice versa) occur only when a yield increase will result or if it is necessary to complete the removal of a cutting.

An exponential weighting function, similar to those found in earlier yield-calculating programs (6,7), permits the emphasis in yield to be varied between total area and longer cutting lengths. The function has the form WL^{wf}, where W is the cutting's width, L is its length, and wf is an exponential weighting factor of one or greater.

Program input

The user must specify the following: 1) the type of first operation — crosscut or rip; 2) the cutting-quality type – clear-two-face, clear-one-face (primary face clear with sound defects allowed on the back face), or sound-two-face (sound defects allowed on both faces); 3) the yield emphasis – area or longer cutting length (weighting factor of 1 or 2, respectively); 4) the level of analysis — complete board, abbreviated board, or aggregate sample; and 5) cutting bill information consisting of minimum and maximum widths and up to 10 cutting lengths. The individual board data consist of a board identifier, the number of defects, and the board's best (primary) face. Individual defect data include location, type, and board face association. The board and defect dimensions are specified in Cartesian (x-y) coordinates.

Program output

The program supports three levels of analysis. The first is a complete board analysis that reports kerf line

The authors are, respectively, Assistant Professor, Dept. of Forest Products, College of Forestry, Oregon State Univ., Corvallis, OR 97331; Associate Professors, Dept. of Forest Products, School of Forestry, VPI&SU, Blacksburg, VA 24061; and Principal Wood Scientist (retired), USDA Forest Serv., Southeastern Forest Expt. Sta., 200 Weaver Blvd., Asheville, NC 28804. This research was supported in part by a grant from the USDA Forest Serv., Southeastern Forest Expt. Sta. This is paper FRL 2339, Forest Res. Lab., Oregon State Univ. This paper was received for publication in December 1987.

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TABLE 1. – *Comparison of the CORY and YIELD programs*[a]

	(A) CORY	(B) YIELD	(C) Difference (A-B)	(D) Percent change ((C/B)100)
Cutting yield (%)	51.17	46.93	4.24[b]	9.03
Execution time (sec.)	0.15	10.10	–9.95[b]	–98.47

[a] All values are per board averages. Cutting yield is the cutting volume expressed as a percent of board volume. Execution time is for an IBM 3081 computer using the IBM G1 FORTRAN compiler. The sample was comprised of defect data for 25 short, low-grade, unedged red oak *(Quercus* spp.) *4/4* flitches. A weighting factor of one was used to emphasize area yield.
[b] Paired-difference t-test significant at the 99% confidence level.

location (x-y coordinates), individual cutting dimensions, and complete board yield information. It is used when an indepth analysis of the sawing sequence is desired. The microcomputer version supports screen graphics to display the board and its sawing solution. The second is an aggregate sample analysis that reports descriptive statistics (total, mean, standard deviation, and maximum and minimum values) for the yield and sawing operations for all boards in the input file. A frequency table of dimension stock pieces by length and width, which includes the percentage of total cutting volume recovered in each cutting length class, is also produced. The third level is an abbreviated board analysis that reports complete yield and partial dimension stock information in a condensed format for each board. No kerf line or cutting bill information is included. This option is used primarily to create input data files for other programs, such as commercially available statistical packages.

Program algorithm

Board sawing is a two-dimensional variant of the "cutting stock" problem. Such combinatorial optimization problems typically result in "combinatorial explosion" where only a few inputs create an extremely large number of solution paths. This results in a situation that precludes the use of exhaustive search methods.

CORY limits the number of solution paths by using a heuristic, or rule-of-thumb, to select the most promising kerf lines. These solution paths (kerf lines) are then evaluated to a limited degree and selected on the intermediate results. The evaluation procedure uses a clear-area orientation with conflict resolution models to make direct comparisons between competing clear areas. This "clear area world view" is created by converting the board's defect data into all the clear areas that are compatible with the cutting bill. This approach contrasts with that of other programs that repeatedly calculate clear-cutting areas using board defects with various sets of potential kerf lines (2-5,7).

Kerf line selection and evaluation occur within a section of the board. Possible kerf lines are selected from a specified number of the board section's largest clear areas. These kerf lines are then evaluated using a limited number of the board section's largest clear areas. Program execution begins with only one board section – the entire board. Once a kerf line has been selected, the board section is then "sawn," creating two new board sections. Sawing decisions made for one board section are independent of those for other sections. This process continues until only one clear cutting remains in each board section. The cutting yield and sample statistics are then calculated and printed, along with the sawing sequences, as requested by the user.

The program was tested to determine the optimal number of largest clear areas to use in the algorithm's search strategy for: 1) selecting possible kerf lines (breadth of search); and 2) calculating each potential kerf line's yield (depth of evaluation). These tests indicate that kerf lines should be selected from those associated with aboard section's two largest clear areas and should be evaluated with a yield estimate calculated using the five largest clear cuttings.

Program evaluation

The program was evaluated for efficiency and effectiveness by statistically comparing its performance with Program YIELD's performance (7) under identical conditions. Data for 25 flitches were analyzed by both programs on a mainframe computer. Cutting bills were structured so both programs had identical random-width, fixed-length cutting classes. The results, shown in Table 1, indicate that CORY increased recovery 9 percent and reduced execution time 98 percent.

Further program development

CORY was developed in WATFIV-S on a mainframe computer as a research tool; however, a 'C' language version for MS-DOS compatible machines has also been developed. This version features a menu-oriented user-interface and graphics output for displaying aboard with its sawing solution. Execution times average approximately 2 seconds per board on a 10 megahertz IBM AT compatible computer with a math coprocessor. These execution times should make the algorithm suitable for process control applications.

The program is being modified to model sawing solutions for fixed-width cutting bills and multiple rip-first processes and to provide an optimization function that uses a value look-up table similar to that used in OPTYLD (3) and CROMAX (2). This work is being funded under the USDA/Michigan State University Wood Utilization Special Grants Program for Eastern Hardwood and is in progress within Oregon State University's Department of Forest Products Solid Wood Processing/Machine Vision Group.

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