Automated computer grading of hardwood lumber

P. Klinkhachorn
J.P. Franklin
C.W. McMillin
R.W. Conners
H.A. Huber

Abstract

This paper describes an improved computer program to grade hardwood lumber. The program was created as part of a system to automate various aspects of the hardwood manufacturing industry. It enhances previous efforts by considering both faces of the board and provides easy application of species dependent rules. The program can be readily interfaced with a computer vision system (to locate and identify defects without human intervention). While such a computer vision/grading system is still under development, this program has additional merit. Potential applications include online evaluation of lumber grade, training of graders, and yield optimization studies.

The USDA Forest Service, Southern Forest Experiment Station, in cooperation with others, is developing an Automated Lumber Processing System (ALPS) to automate the roughmill of a furniture plant (5). Briefly, the ALPS process involves the use of computer vision to determine defect locations and types in hardwood lumber. These data are then used to determine an optimum cutting strategy and to direct a numerically controlled laser that will cut the required parts. The process has been shown to be both economically and technically feasible (1,3,4).

Because the envisioned computer vision system can both identify and locate surface defects, a computer program to simultaneously provide lumber grade could be incorporated in the system. Such data should prove useful to verify the grade of purchased lumber and to compare theoretical versus actual yield of furniture parts. Computer vision coupled to a grading program could also operate as a stand-alone grading system.

Computer programs have been written to grade hardwood lumber (2). However, certain limitations make widespread commercial application difficult. For example, existing programs use National Hardwood Lumber Association (NHLA) grading rules (6) for standard grades and are not readily adaptable to the numerous exceptions allowed for many species. Additionally, the algorithms used consider only one side of the board, whereas both faces of a board are evaluated in the actual grading process. This factor is particularly critical when grading lumber that may potentially grade Select. Perhaps the greatest limitation of existing software is the necessity to adapt the program code so it will work in conjunction with other programs needed to evaluate and control an automated processing system.

The program described here was written to avoid such limitations and enhance the commercial potential. For example, both sides of the board are considered and the grading procedure is somewhat flexible, unlike previous programs. This program is capable of grading a majority of important hardwood species with only minor and easily introduced changes. These changes do not involve modifying the program code but only the numerical data used in the grading procedure. In addition, the program is written as a module that can be

The authors are, respectively, Assistant Professor, Dept. of Electrical and Computer Engineering, Louisiana State Univ., Baton Rouge, LA 70803; Member of Technical Staff, Sandia National Laboratory, Albuquerque, NM; Principal Wood Scientist, Southern Forest Expt. Sta., 2500 Shreveport Hwy., Pineville. LA 71360; Associate Professor, Dept. of Electrical and Computer Engineering, Virginia Polytechnic Institute and State Univ., Blacksburg, VA 24061; and Professor, Dept. of Forestry, Michigan State Univ., East Lansing, MI 48824. This research was sponsored by a cooperative research agreement between the USDA Forest Serv., Southern Forest Expt. Sta., and Louisiana State Univ. It is part of the continuing cooperative ALPS team research effort. This paper was received for publication in February 1987.
© Forest Products Research Society 1988.
Forest Prod. J. 38(3):67-69.

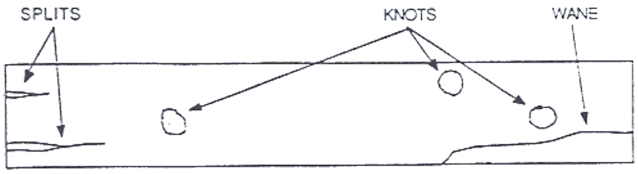

Figure 1 A sample hardwood board.

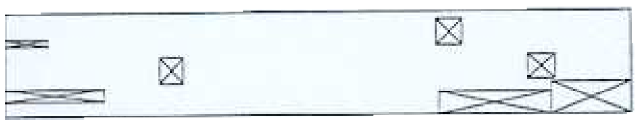

Figure 2. Computer representation of defective regions.

Figure 3. — Clear areas found.

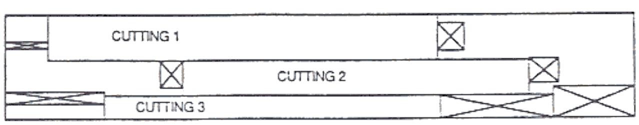

Figure 4. Resolved cuttings.

easily integrated with other software. The program code is generously documented and thus easily understood and modified for a particular application.

Program description

The program first evaluates the board to determine such features as surface measure, length, and width. Consideration is given to defect types on each face and their location. A potential grade is then assigned to each face and the computer evaluates existing clear area to determine the final grade assigned to the board.

The program begins by considering areas that have been identified as nonclear wood. The term "defect" will apply to these regions although not every type of nonclear wood is regarded as unacceptable by the grading rules. The defective regions of the board are described mathematically as being rectangles that enclose the periphery of the defect. The coordinates of the lower left-hand and upper right-hand corners are used to denote the position of the defective region. For each rectangular region, codes identify the type of defect and the face on which it appears. Figure 1 shows one face of a board containing several defects. Figure 2 illustrates a mathematical representation; the marked regions denote the defective areas. Note that the wane in the lower right-hand corner is divided into two regions in order to use as much clear wood as possible in the analysis.

Because this grading program was written specifically to interface with a computer vision system, considerable flexibility is required in handling regions identified as defective. For example, small checks, knots, and burl could be identified as defects by the vision system but may be allowed by a particular set of grading rules. To allow for such potential defects, a system was devised to place these defects on a third planar view of the board, one which is not considered in the grading process. This planar view can be visualized as another face or dimension of the board. Defects that are allowed in clear cuttings are placed on the third plane simply by changing the corresponding code that indicates the face on which the defect occurs. This scheme is useful in the grading of species that require clear cuttings in Firsts and Seconds (FAS) or Select grades but admit sound cuttings in the Common grades. The option of admitting or excluding certain types of defects when searching for cuttings is an important innovation that significantly enhances a grading program's flexibility.

After identifying and removing allowable defects in each face, the procedure for assigning a preliminary grade begins. The first check determines if an overlength exists (the length that exceeds the greatest whole number of feet in the length of the board). If an overlength exists, the end of the board that contains the most defective area is chosen as the overlength. The length, width, and surface measure of the board are then evaluated to determine the maximum allowable grade. Wane, splits, shake, and defective area in each end foot are independently tallied for each side. The preliminary grade assigned to each face is based upon this information and the applicable grading rules assigned within the program format.

The second phase of the procedure uses the grade assigned to each face to determine an initial grade for the board as a whole. Next, the program determines the poor and good face. Once determined, the appropriate algorithm is chosen to verify that the board will yield sufficient cutting units as required by the grading rules. Three different routines are needed because of the specific requirements for each grade type. The three algorithms are based on the NHLA rules for FAS, Select, and Common grades. The FAS routine checks the poor face for the required clear area. The Select routine checks if either face of the board can be graded as Select with sound back cuttings, or failing that, as Select with a No. 1 Common back. The Common routine checks that the poor face has enough units to satisfy the Common grade requirement.

Evaluation of the number of cutting units contained in each face is based on a modified version of a grading program described by Hallock and Galiger (2). Rectangular regions in each face that are free of unacceptable defects and larger than the minimum cutting size requirements of the initial grade are located. These clear areas are bounded on four sides by either a defect or a board edge. In many cases, such clear areas overlap and the cuttings from overlapping regions are resolved in an optimum way according to the type of overlap that occurs. Figure 3 illustrates the three clear areas found in the sample board shown in Figure 1, with clear areas overlapping one another. An optimum computer resolution of the overlapping areas is illustrated in Figure 4. The total sum of the resolved cuttings determines the number of cutting units available in each face.

The grading process necessarily considers both faces of the board. In the process of placing cuttings on one face, the location and types of defects on the reverse face must also be considered. When evaluating each face for cutting units, the program allows the option of choosing either clear wood on one face and sound wood on the reverse face, or sound wood on both faces. Part of this option involves the use of the third planar view described in the first phase of the grading procedure. A fourth planar view, which is visible when viewed from either of the two original faces, contains unsound defects from each side of the board. Based on whether or not the particular species and assumed grade require sound or clear cuttings, defects may be moved from the original face to one of the other planar views. Hence, a defect allowed in cuttings is disregarded in the search for clear areas by placing it on the hidden plane. Likewise, an unsound defect that occurs on the reverse face of the side being evaluated is placed on the visible plane. Therefore, the program fully considers the position of unsound defects that lie on the reverse face when evaluating cuttings, a distinct advantage over programs that consider only one board face at a time.

Reconfiguring the rules

The program is capable of grading a large number of hardwood species with only minor modification. The FORTRAN 77 language used to write the program permits a BLOCK DATA statement used solely to specify program data. The rules regarding the grading process were formulated mathematically in terms of program variables that are initialized in the BLOCK DATA statement. The ease of reconfiguration is due to the fact that all numerical data regarding the grading rules are encoded into just one subprogram. The use of the BLOCK DATA feature allows a logical separation of program data and the actual program code. Only the data specified in the BLOCK DATA segment needs to be changed in order to grade lumber using a different set of rules. It is entirely feasible to prespecify a set of BLOCK DATA statements and incorporate a particular one at run-time to grade a given species.

Examples of some of the variables used to mathematically describe the grading rules are 1) the required cutting units for each surface measure of each grade; 2) the minimum cutting sizes allowed; 3) the number of cuttings permitted for each surface measure category for each grade; and 4) whether extra cuttings are allowed in each size category.

Conclusion

The computer grading program summarized here was specifically designed to be integrable with computer controlled manufacturing systems and to be flexible and maintainable. The strategies used overcome some deficiencies of previous grading programs and serve to enhance the programs utility in any automated lumber processing scheme, such as ALPS. An executable version and a well-documented source code are available on 5-1/4-inch diskettes. The software runs on an IBM PC, its compatibles, or on any computer with a Fortran 77 complier. Requests should be directed to the Department of Electrical and Computer Engineering, Louisiana State University.

Literature cited

1. Conners, R.W., C.W. McMillin, K. Lin, and R. Vasquez-Espinosa. 1983. Identifying and Locating Surface Defects in Wood: Part of an Automated Lumber Processing System. IEEE TRANS. ON PAMI, Vol. PAMI-5, No. 6, pp. 573-583.
2. Hallock, H. and L. Galiger. 1971. Grading hardwood lumber by computer. Res. Pap. FPL 157. USDA Forest Serv., Forest Prod. Lab., Madison, Wis..
3. Huber, H.A. 1985. ALPS: for the rough mill. Furniture Design and Manufacturing (2):76.
4. ———, C.W. McMillin, and J.P. McKinney. 1985. Lumber defect detection abilities of furniture rough mill employees. Forest Prod. J. 35(11/12):79-82.
5. McMillin, C.W., R.W. Conners, and H.A. Huber. 1984. ALPS—A potential new automated lumber processing system. Forest Prod. J. 34(1):13-20.
6. National Hardwood Association. 1986. Rules for the measurement and inspection of hardwood and cypress lumber. NHLA, Memphis, Tenn.