AUTOMATIC COLOR SORTING OF HARDWOOD EDGE-GLUED PANEL PARTS

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ABSTRACT

This paper describes an automatic color sorting system for red oak edge-glued panel parts. The color sorting system simultaneously examines both faces of a panel part and then determines which face has the "best" color, and sorts the part into one of a number of color classes at plant production speeds. Initial test results show that the system generated over 91 percent acceptable panels from automatically sorted red oak panel parts, which exceeded target plant production goals. The color sorting system was developed in cooperation with NOVA Technologies and is now commercially available under the name of CESYS by Group Seven Systems.

INTRODUCTION

Color sorting of edge-glued panel parts is an important manufacturing step where color uniformity has an impact on the value of the final products. Manual color sorting of panel parts is very labor intensive and inexact, as different people have different perceptions about color uniformity in hardwood panels. Additionally, color uniformity and consistency of manually sorted panels further decline over a period of time at production speeds.

Because a distinct market preference for color uniformity exists, a number of researchers have proposed and examined systems to better characterize color in wood. However, these systems have not led directly to commercially available systems that can meet the demands of the wood processing industry. In creating a color sorting system that will work in the industry, it must meet the following requirements: (1) be able to accurately and consistently separate parts into appropriate color classes, (2) be able to keep up with the production requirements of the plant, and (3) be easy to operate by plant production personnel. An automatic color sorting system has been developed which now meets all of these requirements. This paper briefly describes the color sorting system along with some initial in-plant testing results.

SYSTEM HARDWARE AND SOFTWARE

For the color sorting system to be useful in an actual application, the system must have a throughput of at least 2 feet (61 cm.) per second. The parts inspected by the system must be able to scan widths from 1 inch (25 mm) up to 7.5 inches (190 mm) and handle random lengths. To accurately gage the color of a scanned part, a high resolution color image of at least 32 points per inch (1.3 points per mm) must be attained. Implementing an accurate color sorting algorithm on such high resolution color image data along with other necessary image processing requirements such as color shading compensation and background extraction cannot easily be achieved to meet the real-time throughput requirements unless special purpose image processing and computing hardware are used.

Figure 1 shows the overall system hardware design used to perform real-time color sorting operations. The system uses color line scan cameras to image the parts, one camera for each part face. The digital data coming out of each color camera controller is input to a special purpose image processing board that was designed and built at Virginia Tech. This board is called the MOdular Reprogrammable Real-time Processing Hardware, or MORRPH (Drayer et al., 1995a and 1995b), The MORRPH boards process the input camera signal and output the color measurement histograms (the relative frequency of colors) from which parts are sorted into appropriate color classes. Without the MORRPH boards, real-time processing would not be possible, Tungsten halogen light sources are used to provide a uniform and consistent illumination source for the system. Consistent illumination is critical to the performance of the color sorting system. Hence, the system is designed to monitor the illumination levels and control them to within certain defined tolerances in real-time. More detail on the hardware description can be found in Conners et al. (1996).

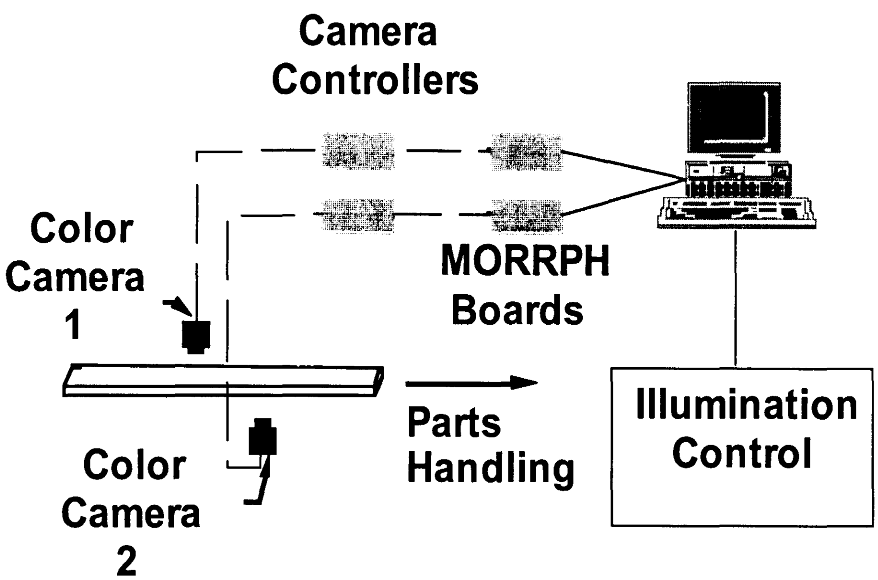

Figure 1. Overall system hardware design for the color sorting system.

The software system provides for three modes of operation: 1) real-time operation, 2) system training, and 3) system setup. Real-time operation involves those functions used in the actual sorting of parts and continually monitoring lighting variations. System training involves those functions used in specifying and characterizing different color classes (reference histograms). System training is based on showing the system a number of part faces that span the range of colors management allow in a given color class. Any number of color classes can be defined. However, the computational complexity goes up as the number of classes is increased. Also from a manufacturing viewpoint, more classes mean more space for sorting bins and more complicated material handling systems. Finally, system setup involves specifying different parameters, tolerances, and threshold values that an operator can use to control and fine tune the operation of the system.

The actual sorting procedure for a particular panel part involves comparing its color histogram to those reference histograms of all defined color classes. The threshold values are used to accept or reject the assignment of a part to each of the classes. Once the acceptance/rejection process is completed for each of the color classes, the panel part is assigned to the color class with the minimum color difference value among all acceptable color classes. If the part has been rejected for all color classes, it is then assigned to the *out* class. The threshold values used to accept or reject parts in a particular class can be manually adjusted. Hence, in those applications where near perfect color sorts are required, the threshold values can be reduced. If, on the other hand, a larger variation of color is acceptable in the panels, the threshold values can be increased. For instances where parts are designated as an *out* class, plant operators can be used to manually determine a part classification. More details on the computation of the color class histograms, threshold values, and difference values are described in Lu et al. (1997).

Once a color class has been assigned for each face of a panel part, a best face analysis is performed. The best face analysis requires that a priority of color classes be specified in advance. The color priority describes which color is most desirable or valuable. Given priority values, the best face analysis selects the part face with the highest priority. If the color of each face is of equal priority, then the best face is assigned to that which is closest to the reference histogram (smallest color difference).

TESTING THE SYSTEM

The accuracy of the color sorting algorithm was evaluated in an actual panel glue-up operation. A set of color samples were selected to define six reference color classes for southern red-oak panel parts. Table 1 lists the six colors and the number of samples selected to train the color sorting system. The selected samples were chosen by experienced mill operators such that any combination of the 25 parts within a class would result in a clear panel. The 25 samples for each of the six classes were then used to train the color sorting system. The end result of the training procedure resulted in six reference color histograms that represented each of the color classes. Light uniformity during the time of training was held constant.

Table 1. Color class description and sample size used to define reference color classes.

Color Class Description	Sample Size
Dark Red	25
Red with Some Green	25
Red with Some White	25
Dark Brown	25
Medium Brown	25
Light Brown	25

After training the system, the performance of the part sorting algorithm was tested. This particular glue-up operation graded edge-glued panels into three categories: 1) clear, 2) acceptable, and 3) unacceptable. Clear panels have approximately the same color across the better face and are the most valuable panels. Acceptable panels have color characteristics that are within acceptable bounds but have some allowable color variation that can be compensated with darker finishes. Unacceptable panels have color characteristics which vary widely across their better face and are typically used to create painted panels.

Table 2 lists the in-plant test results for 17 pallet loads of parts. One load typically contained 900-1000 pieces. Each of these pieces were color sorted with the color sorting system and then glued up into panels required for the production run. The average rate of clear and acceptable panels for the entire experiment was 91.3 percent which was well above those panels resulting from manual color sorting. The highest and lowest rates achieved were 99 and 82 percent, respectively. The lowest rates in the study were attributed to mis-calibrated light levels, dust, and parts that had significantly different color variations that were not represented by any of the six color classes used to train the system. Overall, these results indicate that the system is capable of creating high-quality edge-glued panels. However, proper color class training and maintenance of uniform lighting were found to be extremely critical for accurate results. Proper training requires a good understanding of the total color variability in wood, how to segment the total variability into representative classes, and how changing light standards can affect the performance of the system.

Table 2. Percent clear and acceptable panels generated from various pallet loads of red-oak panel parts.

Pallet #	Clear and Acceptable Panels (%)
1	92.0
2	96.9
3	95.0
4	87.1
5	82.0
6	83.0
7	85.0
8	86.0
9	88.0
10	90.0
11	95.0
12	99.1
13	98.0
14	98.0
15	95.0
16	92.0
17	90.0
Average	91.3

CURRENT STATUS

Figure 2 shows the commercial version of the color sorting system in operation developed by NOVA Technologies in Charlotte, North Carolina. Parts are fed into the system from right to left at speeds of 2 ft/s (61 cm/s). This application used 11 red oak color classes to represent the variability in panel part color. The system inspects both faces of a part, sorts it into a color class and uses a printing device to code the part for color class and best face. As an alternative to printing a code, the system can drive an automatic part sorting system (not shown here). Based on a P90 Pentium processing computer, a minimum spacing of 4 inches (11 cm) between parts is needed to allow the system to process both faces of a part and determine its color class.

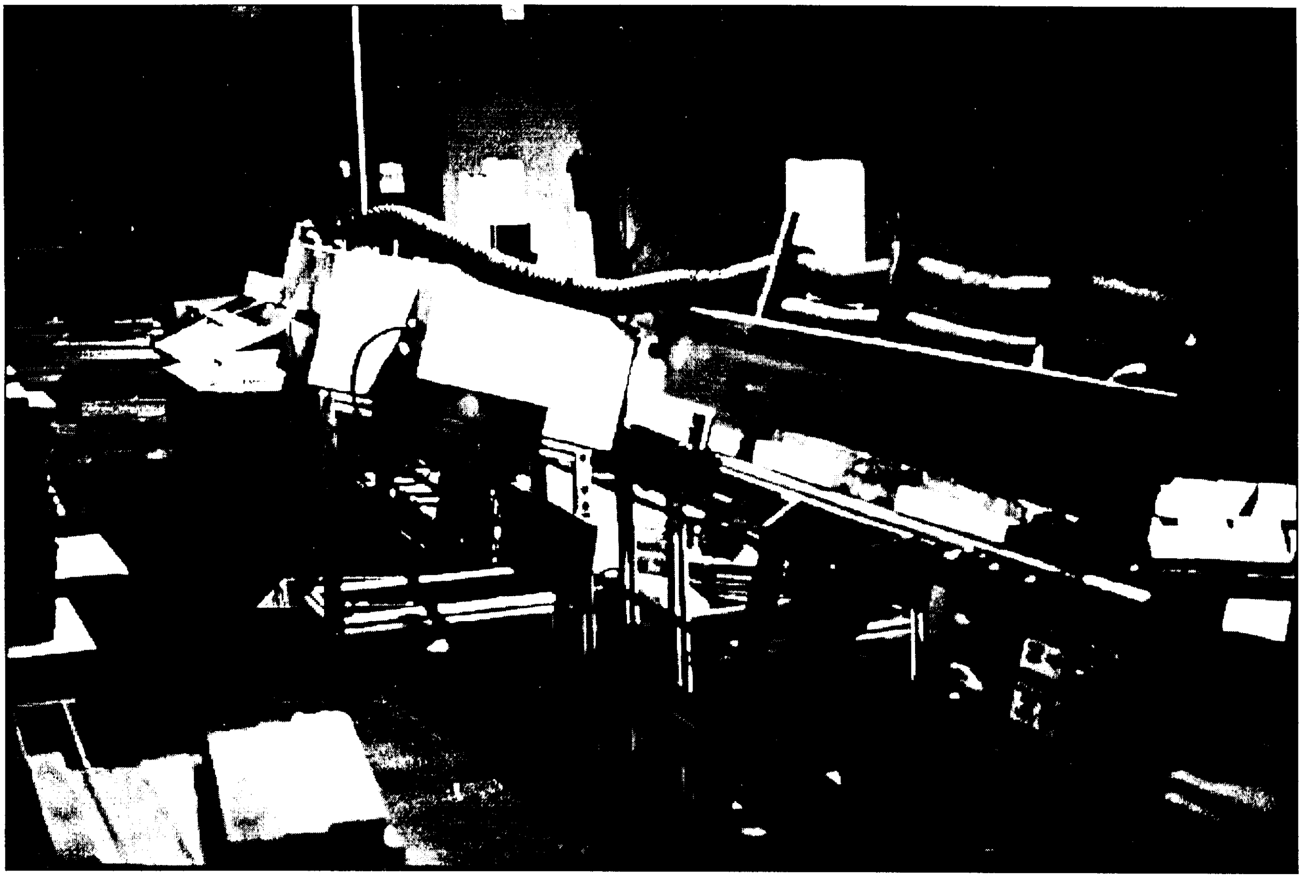

Figure 2. In-plant operation of the real-time color sorting system.

The color sorting system has demonstrated reasonable service maintenance requirements and has been well received by plant personnel. Extensive plant testing has led to enhanced commercial software to better characterize the large color variations present in red-oak panel parts including those variations due to small knots and mineral streaks. Also, the continual increase in speed and decrease in cost of PCs has led to the incorporation of number of improvements in the real-time operation software and hardware. Commercial versions of the system are currently being marketed under the name CESYS (Color Evaluation SYStem) by Group Seven Systems in Hudson, North Carolina.

SUMMARY

This paper has described a color sorting system for use in sorting edge-glued panel parts. Operational in-plant tests indicate that the system performs very well for color sorting red-oak panel parts. The system can be trained for other wood species as well. The introduction of the system into the plant environment exceeded production goals and was well received by plant employees. A commercial system has been developed by NOVA Technologies and is currently being marketed under the name of CESYS by Group Seven Systems.

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