AUTOMATIC CLASSIFICATION OF COMPRESSION WOOD IN GREEN SOUTHERN YELLOW PINE

Jan Nyström

Ph.D. Student
Division of Wood Technology
Luleå University of Technology
SE 93187 Skellefteå, Sweden

and

D. Earl Kline†

Associate Professor
Department of Wood Science and Forest Products
Virginia Tech
Blacksburg, Virginia 24061-0503, VA

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ABSTRACT

Compression wood is a feature in softwoods that is undesired in sawn wood products due to its tendency to bend and crook as the moisture content changes. An automatic compression-wood detection method was developed and tested on southern yellow pine lumber in the green condition. Sixteen lumber specimens were scanned using both a color camera and an X-ray scanner. Color information was shown to have significant and consistent differences between compression wood and clear wood. However, X-ray information was found to contain large density variations in green lumber due to inconsistent moisture content that would mask density variations arising from compression wood. Therefore, it was concluded that X-ray information would not be useful in detecting compression wood in green southern yellow pine lumber. A multivariate regression model was developed based only on color information from one of the board samples. A nonlinear prediction model was produced by using the original color image data and expanded variables derived from the color images. The model based on one board sample was then applied on all boards. Classified images of the board surfaces were produced and compared to manually detected compression wood. An overall accuracy of 87% was observed in the classification of compression wood.

Keywords: Compression wood, color scanning, X-ray scanning, nondestructive evaluation, machine vision, image processing.

INTRODUCTION

Compression wood is a special type of tracheid cells produced by the living softwood tree in those areas exposed to excessive compressive stress during growth—for example, the lower part of the stem in a leaning tree. This type of wood has a tendency to shrink more in the longitudinal direction than normal wood when dried, due to a larger microfibril angle (Timell 1986). This tendency is often the cause of bending and warping of planks and boards during the drying process. Sawn wood containing excessive compression wood is undesirable because of the low value and the handling problems it may cause in the sawmill process. To minimize waste production and unnecessary material handling of the wood products, compression wood should be detected and rejected at an early stage of the production, i.e., in the green condition.

Compression wood is difficult to detect visually, especially on tangential and radial wood surfaces. The most reliable way to detect compression wood is with a microscope where the special properties of the compres-

† Member of SWST.

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sion wood cells, as round cross section, intercellular spaces, and helical cavities in lumen, can be observed (Timell 1986). On a macroscopic level, destructive testing methods are available to measure the amount of light transmitted trough thin cross sections of wood since compression wood absorbs more light in the grain direction than normal earlywood and latewood. These methods can be performed manually with white light (Anon 1941; Timell 1986) or automatically using a color vision system (Andersson and Walter 1995). Nondestructive methods to detect compression wood are rare; however, techniques have been employed to separate compression wood from normal wood in the dry state by measuring the spectral reflection using an imaging spectrometer (Nyström and Hagman 1999). Since compression wood has a higher density than normal wood, it should also be possible to detect using X-ray scanning. X-rays have been used for detecting various internal defects in wood (Bond et al. 1998; Grundberg 1994; Lindgren 1992) based on density differences, and it has been shown that compression wood can be detected in dry spruce (Nyström 1998).

The overall goal of this investigation was to detect compression wood, both automatically and nondestructively, in green newly sawn boards of southern yellow pine (*pinus* sp.) (SYP). To address this goal, this study focuses on gaining a basic understanding of how compression wood appears in X-ray and color image data. The specific objectives of this study include:

1. Assess the use of X-ray and color image data for the detection of compression wood in green SYP.
2. Evaluate the accuracy of a multivariate regression model for automatically detecting the occurrence of compression wood from green SYP image data.

MATERIALS AND METHODS

Materials

Sixteen SYP lumber specimens used for this investigation were collected at a sawmill in southern Virginia, USA. The lumber specimens all were 32 mm (1-¼ in.) thick and 150 mm (6 in.) wide. The length of the lumber varied from 1.6 to 2.4 m (5 to 8 ft). The boards used in this investigation were selected to contain compression wood of varying degrees at some part of the surface. All boards were scanned approximately 3 h after sawing. To minimize surface drying, the lumber was closely packed together and covered with plastic during this 3-h period.

Scanning methods

The boards were scanned using Virginia Tech's lumber scanning system (Fig. 1) (Conners et al. 1997). Scanning generated combined X-ray and color images with a crossboard resolution of 1.2 pixel/mm (30 pixel/in.) and a downboard resolution of 0.63 pixel/mm (16 pixel/in.). The X-ray and color systems were calibrated to have identical spatial resolution so that a pixel location on either image could be referenced to the same location on a lumber specimen.

X-ray scanning.—Scanning with X-rays gives an averaged image of the wood density throughout the lumber thickness, not only on the surface. This average wood density can be useful for detection of compression wood since it has a higher density than normal wood. The X-ray system employed an EG&G Astrophysics X-ray source with the radiation energy set to 100 keV and 0.6 mA. The X-ray sensor was a 256-pixel line array manufactured by FISCAN. The images were shade-corrected using a linear function, and the contrast was optimized by calibrating the minimum level (highest absorption) with a target of 45-mm-thick polyethylene.

It was evident after scanning the boards that compression wood was difficult to detect in green lumber with X-rays. It was found that density changes associated with moisture variations in the wood masked the smaller density changes associated with compression wood (Fig. 2). The darker regions in the green lumber X-ray image in Fig. 2a are more dense due

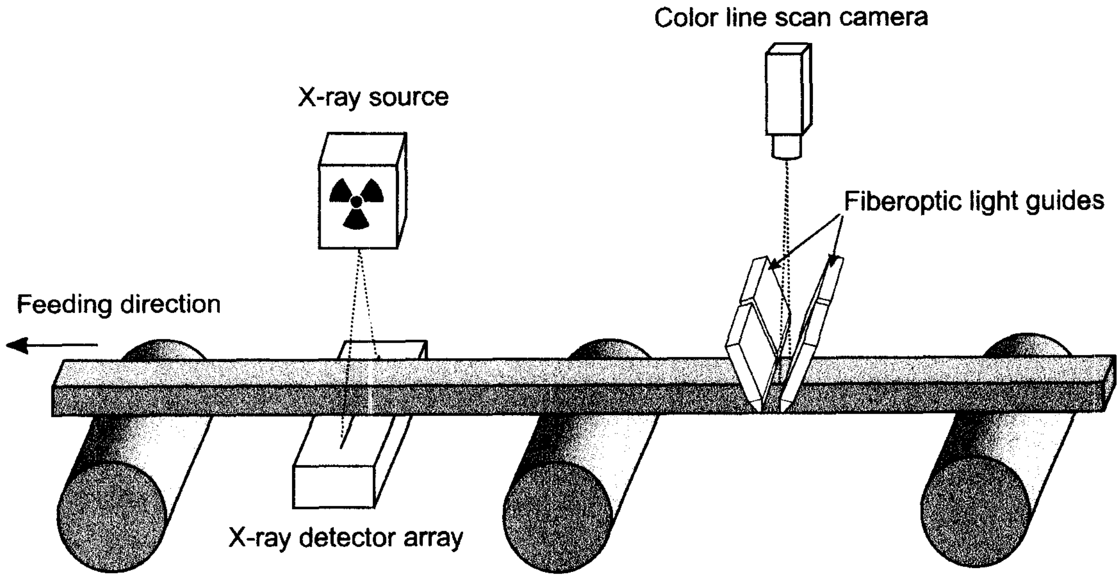

FIG. 1. Setup of the X-ray and color scanner system.

to higher moisture retained in the sapwood of SYP. After the lumber is dried, higher densities associated with moisture are removed (Fig. 2b) and compression wood can be readily observed through contrast enhanced images (Fig. 2c).

Color scanning.—It was observed that compression wood on the surface of the newly sawn SYP lumber appeared as a "reddish" color. This color appearance, if significant, could be utilized for the automatic detection of compression wood using a color camera. Color images were collected using a Pulnix TL-2600 RGB line scan camera with a resolution of 864 pixels. The camera was mounted perpendicular to the wood surface, and four

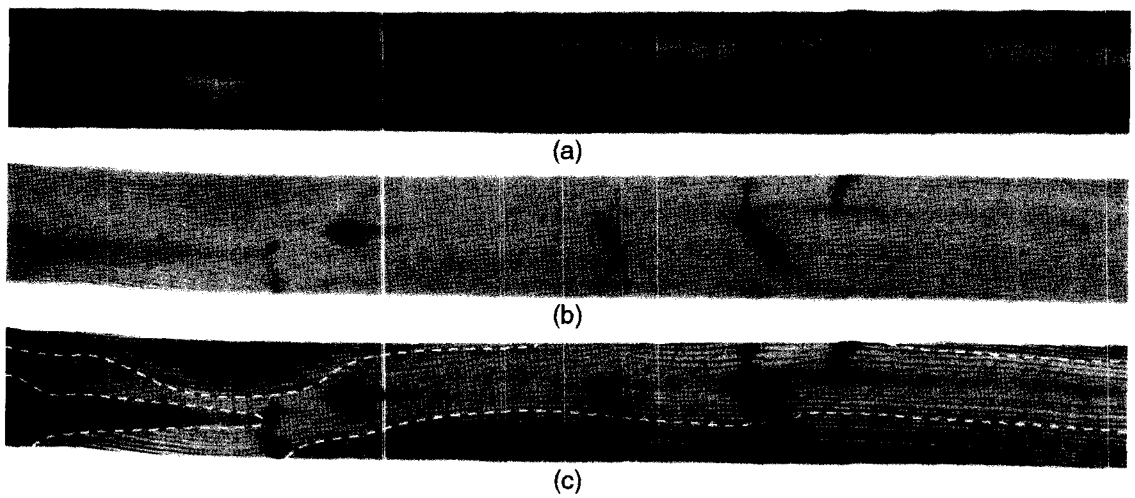

FIG. 2. X-ray images of Board 13 in green (a) and dry condition (b). Image (c) is a contrast-enhanced version of (b) with manually observed compression wood areas denoted between the dashed lines and board edges.