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Image processing and identification of lumber surface knots[1]

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Abstract. Surface knot defects seriously affect the quality and performance of lumber. In this paper, an image processing and recognition method was designed using the MATLAB image processing toolbox. Based on numerous prior experiments, two turning coordinate points of piecewise linear transformation were selected for this study and a surface recognition algorithm was put forward. Through defect image processing, morphological processing, feature extraction, the knots could been detected effectively and accurately, and the size and the location of the defects could also be calculated. The knot defects was identified by the following features: length over 0.5, eccentricity under 0.8, average under 180 gray, and gray variance over 30. The knots was detected automatically and positioned accurately using the algorithm. The detection and identification rate of knots was 88.97 %.

Key words. Lumber, surface knots, image processing, recognition algorithm.

1. Introduction

Lumber (as well as veneer, sawn-timber) surface defects (such as knots, cracks, and poles) will seriously affect the quality of lumber, change its normal performance, and result in ineffectiveness [1–3]. Among the numerous lumber surface defects, knots are the most common phenomenon and have the greatest impact on lumber quality.

Visual grading is one of the most important lumber grading systems in North America, in which lumber grading is completed by observing and measuring the lumber's superficial qualities or characteristics [4]. It is difficult to be classified artificially due to the limitations of visual grading, especially on the face of large

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variations of the size and shape of defects. Furthermore, different experiences may cause inconsistent test results, so this grading method cannot meet the detection demands of rapid and continuous lumber production. Based on the computer image processing technology and mathematical morphology theory, this paper puts forward an automatic detection algorithm for knots on the surface of lumber. Also, MATLAB image processing tools are applied in the knot image test experiments to verify the image pre-processing methods.

2. Material and methods

2.1. Images of lumber

In the surface image recognition experiment, a group of 160 JPG format images taken by the digital camera with a resolution of 600×800 pixels were chosen as the test samples. Four of these images are shown in Fig. 1. Color information is removed. Through detection and recognition experiments on these images, the image processing algorithm was developed.

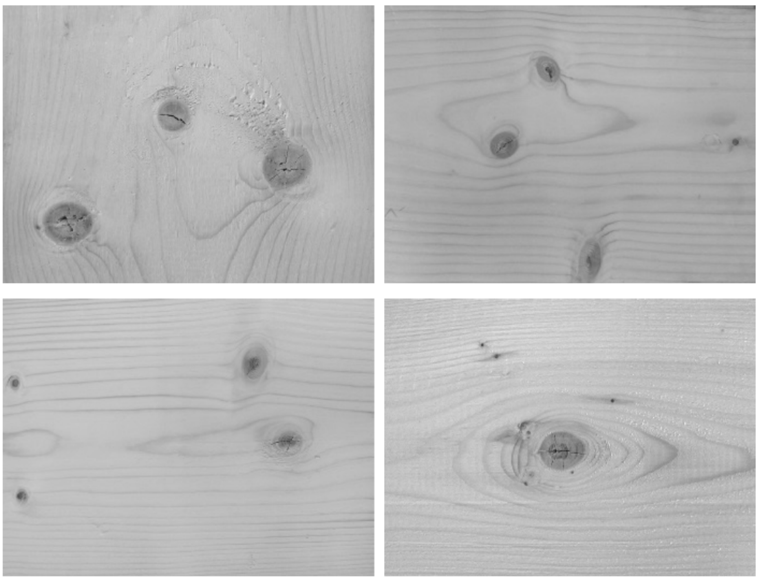

Fig. 1. Gray-scale images of knot defects

2.2. Methods

The image processing and recognition process for lumber surface knots focused on the surface image recognition algorithm. This algorithm consisted of five main steps: digital image pre-processing, image segmentation, morphological processing, feature extraction, and pattern recognition of lumber surface defects. The specific algorithm flow is shown in Fig. 2.

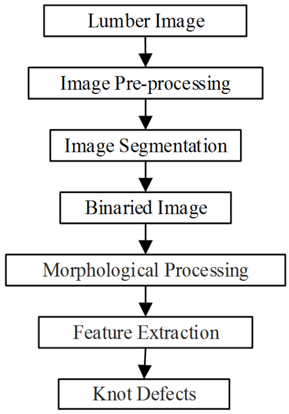

Fig. 2. Flowchart of the surface image recognition algorithm

2.2.1. Image pre-processing: This is an important step of the image processing technique [5]. Image pre-processing is used for image of the previous operation, and the image is usually represented by a matrix [6]. Image pre-processing includes image gray processing, gray-scale transformation, and image smoothing.

The process to convert a color image into a gray-scale image is called image gray processing. The purpose of this process is to reduce the difficulty of feature extraction. The color of the defect changes significantly compared with its surroundings, so that after the gray processing, the defect region still could be segmented effectively.

Gray-scale transformation is an important method of image enhancement, which can expand the dynamic ranges of the images, enhancing the contrast to make the images clearer, with more obvious features.

An image obtained in actual practice contains noise. The noise can be reduced through data processing. The main purpose of image smoothing is to reduce an image's noise [7]. This noise stems from lots of ways, including electromagnetic waves outside the system, high-frequency noise interference, thermal noise from within the system, and mechanical jitter noise interference.

2.2.2. Image segmentation: The image segmentation have practical significance in various fields [8]. Image segmentation is one of the most important steps leading to the analysis of processed image data, separating the target from the background [6, 9]. Gray-level thresholding is the simplest segmentation method, also the oldest one, but which is still widely used in simple applications. It is computationally inexpensive and fast [10, 11]. This step is extremely important, as it corresponds to the maximum loss of information [12]. Therefor, selecting an appropriate threshold is the key to image segmentation, which is suggested to be paid close attention to.

2.2.3. Morphological processing: Mathematical morphology is a nonlinear signal processing field which concerns the application of set theory to image analysis [13]. Morphology refers to the study of shapes and structures [14, 15]. Swelling and corrosion are two basic operations in mathematical morphology, based on which a variety of complex operations, such as opening and closing, can be composed [16].

2.2.4. Pattern recognition: Pattern recognition is the process of achieving the description, identification, classification, and interpretation of phenomena and things through processing and analysis of various forms of information of objects and phenomena (e.g., value, text, and the logical relationship). To put it simply, pattern recognition can help identify and classify a set of events or processes using a computer. This is an important part of information science and artificial intelligence.

Commonly used pattern recognition methods include the discriminant function method, the nearest neighbor method, the nonlinear mapping method, feature analysis, and the factor analysis method. In this study, the feature analysis method was adopted.

3. Results

3.1. Image pre-processing

Grayscale images are shown in Fig. 1. Color information has been removed. To highlight the gray range of the image of interest, the details of the other gray levels had to be removed. Piecewise linear transformation was considered as a relatively rational choice to achieve the gray-scale transformation. This transformation enhanced the contrast by stretching the gray level of the needed image detail, and unnecessary details of the grayscale were compressed.

The two turning points of the piecewise linear transformation were chosen here in as (0.35, 0.2) and (0.75, 0.9). The transformed images are shown in Fig. 4. It can be seen that the contrasts of these four images were enhanced significantly after transformation.

A median filter (5×5) and Gaussian filter (7×7, standard deviation 1.2) were combined to smooth the gray-scale image. Figure 4 shows that the surface texture became fuzzy and some glitches in the images were well suppressed.

3.2. Image segmentation

The thresholding method distinguishes between the object and the background by setting a threshold. Multiple experiments were performed to determine the appropriate binarization threshold, which was calculated according to the formula

$$V_{\mathrm{t}} = \frac{V_{\mathrm{m}} - V_{\mathrm{s}}}{V_{\mathrm{m}} + V_{\mathrm{s}}} \cdot V_{\mathrm{thresh}}\,, \tag{1}$$

where V_{t} is the binarization threshold used in this paper, V_{m} is the mean of the gray level, V_{s} is the standard deviation of the gray level, and V_{thresh} is the primary value of Otsu's method, which is one of the most commonly applied methods of image segmentation for selecting threshold automatically because of its simple calculation and ease of adaptation [17].

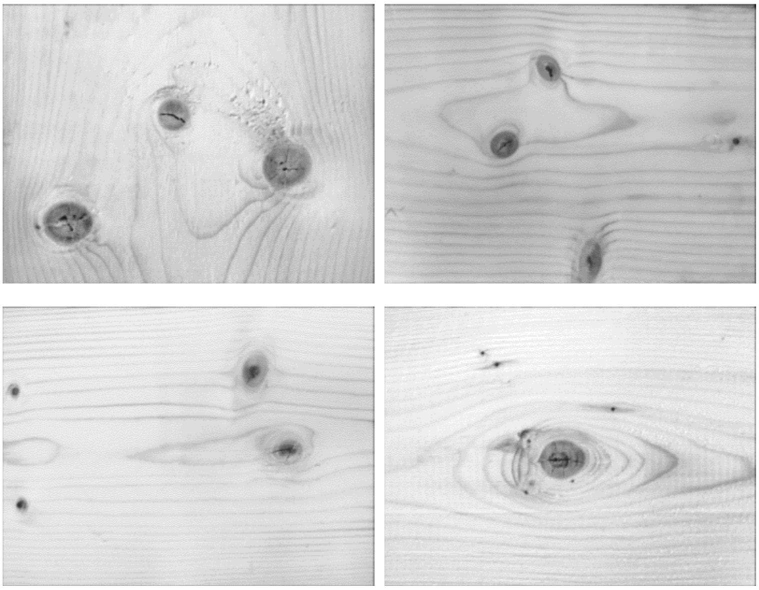

Fig. 3. Gray-scale transformed images

The method assumes that the image is composed of foreground and background classes, and then computes an optimal threshold value that minimizes the weighted within-class variances of these two classes. It has been mathematically proven that minimizing the within-class variance is the same as maximizing the between-class variance [17, 18]. The segmented binary image is shown in Fig. 5.

3.3. Morphological processing

In this paper, binary morphological image processing was carried out, which included the opening operation, closing operation, removal of isolated foreground pixels, and filling of single pixel holes. The processed images are shown in Fig. 6; the smaller isolated interference areas (normally, areas smaller than 8 pixels) were removed, and the edges of the foreground image became smoother. Figure 7 shows the suspected defect extractions from the images.

3.4. Feature extraction

The selection of the defect feature type and defect characteristic extraction algorithm were the key to building the defect pattern recognition system. By analyzing

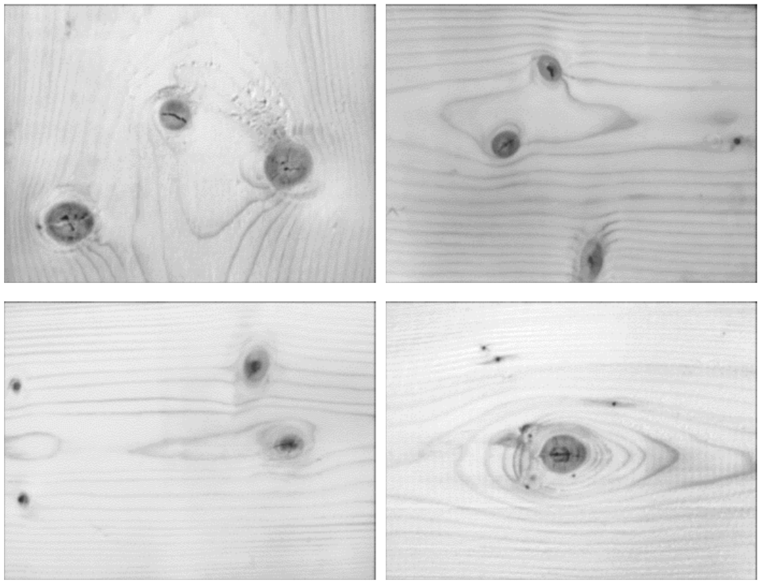

Fig. 4. Image smoothing

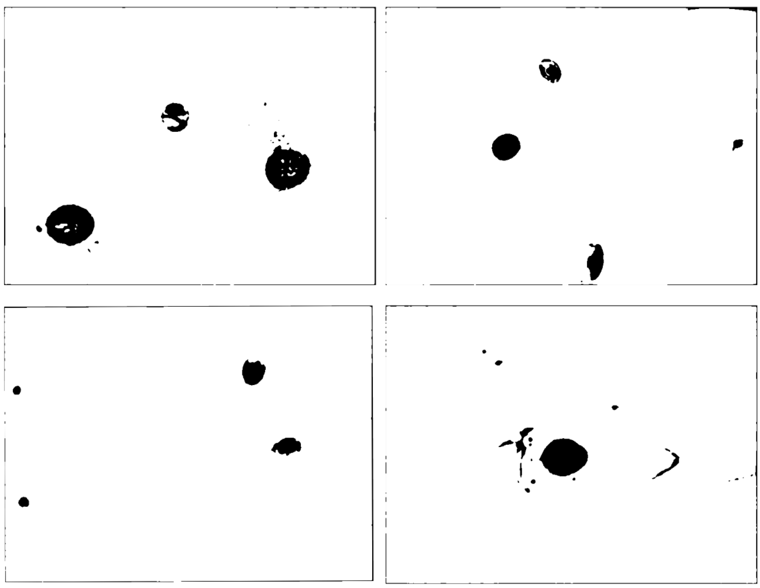

Fig. 5. Segmented images

the internal and external factors of the lumber images, four characteristics were selected as features to be extracted for lumber defects [19, 20]; these were the gray mean, the gray variance, the elongation of the defect contour, and the eccentricity.

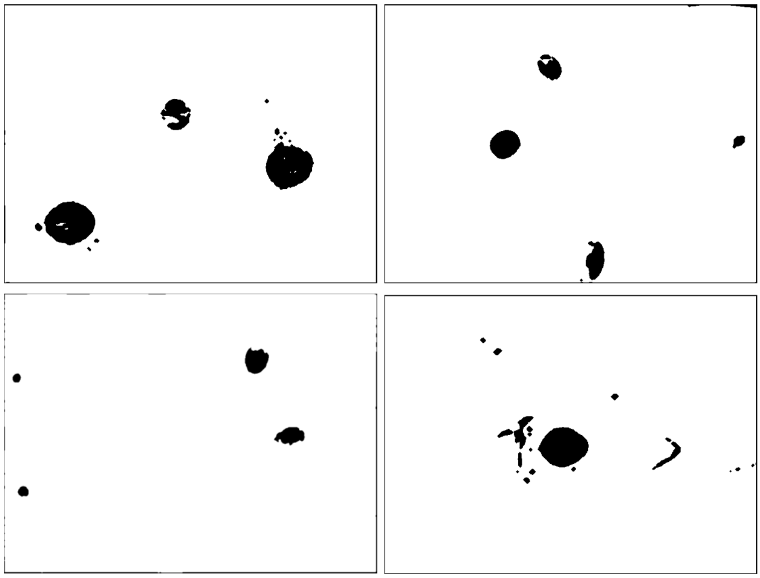

Fig. 6. Morphologically processed images

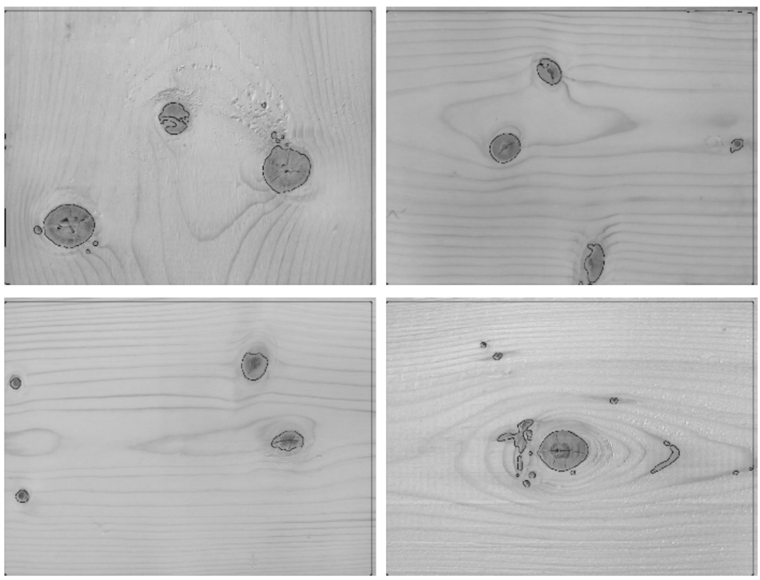

Fig. 7. Suspected defect extractions from images

The gray mean is used to distinguish the different types of defects, such as knots and poles; and the gray variance can reflect the changes in the gray value of the defect, which contributes to distinguishing the types of defects from similar gray means; finally both elongation and eccentricity primarily reflect the feature of the defect's appearance. Here, MATLAB image processing tools were used to compute and analyze the characteristics of the target areas. Basic information about the characteristics, such as the area, centroid, major and minor axis length, eccentricity, gray mean, and gray variance, was extracted for pattern recognition. The size of the defect was reflected by the area, meanwhile the position of the defect was reflected by the centroid coordinates.

3.5. Pattern recognition

Through numbers of experiments based on 160 images and 255 knots (area larger than 30 pixels), knot defects could be identified if they had the following four basic features: length over 0.5, eccentricity under 0.8, average under 180 gray, and gray variance over 30.

The detection results can be seen in Table 1. The number of real knots was 136, of which 121 were detected correctly. The detection and identification rate of knots was 88.97 %, but 18 regions were wrongly identified as knots because their features met the parameters of algorithm for defining a knot. In addition, seven knots were undetected.

Table 1. Statistics of the detected results

Number of real knots	Number of knots detected	Number of knots correctly detected	Number of erroneously identified knots	Number of knots undetected
136	143	121	18	7

The primary factors affecting the accuracy of defect detection are as follows:

(1) The quality of the acquired lumber surface image. With a clearer and more strongly contrasted image, the detection and identification results significantly improved.

(2) The quality of the lumber, for example, sawing ineffectively, the surface glitches, and smoothness could greatly affect the quality of image.

(3) The difference between the knots and the surrounding wood, Detection performance improved with increasing differences.

4. Conclusion

(1) The aim of this knot detection project was to accurately detect the location and size of a knot on digital lumber images, with an emphasis on achieving efficient use of lumber. The image processing algorithms designed here could detect knots defects effectively and accurately; the size and the location of the defects could also be calculated.

(2) The consistency of the knot's color greatly influenced the recognition results. The sawing effect of lumber was also an important factor affecting the image quality. Using image processing technology to automatically detect and accurately position

the knot defects is significant for statistical analysis and controlling cutting work.

(3) Through statistical analysis of major defects of the lumber images, the entire lumber could be comprehensively evaluated. However, there are still some limitations to the current algorithm. And the software was designed only for circular knots. In the future, research will focus on other cases.

References

[1] J. X. Yin, X. W. Lou, M. L. Huang: *Application of grey histogram to wood surface defects' detection.* Journal of Zhejiang Forestry College (2008), No. 03, 272-276.

[2] X. B. Bai, Z. S. Wang: *Segmentation method of timber surface defects based on CV model and mathematical morphology.* Development & Innovation of Machinery & Electrical Products (2011), No. 05, 75–76+100.

[3] J. Yang, W. Zhang, W. Hu, W. Shang, W. Qu, inventors: *Image acquisition system for sawn timber surface defects and detection method.* China patent CN 102313747 B, 5 June 2013 (2013).

[4] W. Guo, H. Ren, Y. Yin, J. Jiang, C. Long: *Summary of visual grading on structural lumber in North America.* World Forestry Research (2007), No. 05, 57–62.

[5] G. Padmavathi, P. Subashini, M. M. Kumar, S. K. Thakur: *Comparison of filters used for underwater image pre-processing.* International Journal of Computer Science and Network Security *10* (2010), No. 1, 58–64.

[6] M. Sonka, V. Hlavac, R. Boyle: *Image processing, analysis, and machine vision.* 3rd edn. Nelson Engineering (2008), 114–162.

[7] P. Pouladzadeh: *An image processing and pattern analysis approach for food recognition.* Thesis, University of Ottawa, Ontario, Canada (2013), 14–22.

[8] M. Hanmandlu, O. P. Verma, S. Susan, V. K. Madasu: *Color segmentation by fuzzy co-clustering of chrominance color features.* Neurocomputing *120* (2013), 235–249.

[9] S. K. Sinha, P. W. Fieguth, M. A. Polak: *Intelligent system for condition monitoring of underground pipelines.* Computer-Aided Civil and Infrastructure Engineering *19* (2004), No. 1, 42–53.

[10] J. Cheng: *Automated detection and time lapse analysis of dendritic spines in laser scanning microscopy images.* Thesis, Northeastern University Shenyang, China, Electrical and Computer Engineering (2009), 60–65.

[11] D. Bajracharya: *Real time pattern recognition in digital video with applications to safety in construction sites.* Thesis, University of Nevada, Las Vegas, Computer Science (2013), 20–23.

[12] Y. Zhang: *A novel image processing platform development for preprocessing images with two-phase microstructures containing isolated particles.* Thesis, Wayne State University, Detroit, MI (2010), 4–9.

[13] N. P. Brouwer: *Image pre-processing to improve data matrix barcode read rates.* Thesis, University of New Hampshire, Electrical Engineering (2013), 24–26.

[14] K. Parvati, B. S. P. Rao, M. M. Das: *Image segmentation using gray-scale morphology and marker-controlled watershed transformation.* Discrete Dynamics in Nature and Society (2008), 307–318.

[15] B. Tang, J. Kong, X. Wang, G. Jiang, L. Chen: . *Steel strip surface defects detection based on mathematical morphology.* Journal of Iron and Steel Research *22* (2010), No. 10, 56–59.

[16] Q. Ruan: *Digital image processing using MATLAB.* Beijing, China: Publishing House of Electronics Industry (2005), 252–284.

[17] Y. Ramadevi, T. Sridevi, B. Poornima, B. Kalyani: *Segmentation and object recognition using edge detection techniques*. International Journal of Computer Science & Information Technology (IJCSIT) *2* (2010), No. 6, 153–161.

[18] N. Otsu: *A threshold selection method from gray-level histograms*. IEEE Transactions on Systems, Man, and Cybernetics *9* (1979), No. 1, 62–66.

[19] L. Li, J. Zhang: *Research on extraction method of image feature for wood surface defects*. Wood Processing Machinery *22* (2011), No. 02, 9–14.

[20] K. Wang, X. Ba: *The pattern recognition methods of wood surface defects*. Beijing, China: Publishing House of Science Press (2011), 62–65.

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