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Detection and Recognition of Wood Defects Based on Gray Transformation and BP Neural Network

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***Abstract* – Wood defect and rot debase wood quality badly. X-ray as a method of measurement was adopted to detect wood defects nondestructively. Due to the changed intensity of x-ray which crossed the object, defects in wood were detected by the differences of X-ray absorption parameters. Therefore images were processed and analyzed by computer. Gray transformation could enhance the contrast of the image obviously and the position of rot could be highlighted. Binary processing was employed for the image after gray transformation. The defects areas of the binary images were filled. On the basis of image processing of nondestructive testing and characteristic construction, defects mathematic models were established through using characteristic parameters. The feature parameters were preprocessed and were input into BP neural network, and then the wood defects could be recognized. The experimental results show that the detection rate can be up to 90% and the performance shows that this method is very successful for detection and classification of wood defects. This study provides a new method for automatic detection of wood defects. It is useful for the scientific selection and effective utilization of wood resources.**

***Keywords* – Detection, Wood Defects, Gray Transformation, Neural Network.**

I. INTRODUCTION

The rot is the most widespread defect in wood [1]. In the rot incipient stage, except the ability of moisture absorption increases and the impact toughness decreases slightly, other indicators have no obvious change. In the rot intermediate stage, the ability of moisture absorption increases significantly, the density of wood decreases, the mechanical strength decreases obviously, especially the wood toughness declines most seriously, followed by resisting bend strength and hardness [2]. In the rot advanced stage, the mechanical strength and the utilization value of wood almost lose completely. The chemical composition of wood also has big changes, such as the Pulp and Paper, fiber yield and paper strength reduce, such as fuelwood, the carbon production and combustion heat value of wood decrease. Therefore detecting wood rot effectively becomes particularly important. So the position, size and edge of wood defect with rot must be extracted. It shows very important significance for the reasonable selection wood and the scientific utilization of wood, and provides a reliable basis for the mechanical judgment at the same time.

BP neural network is a computer system of a lot of simple processing units. According to specific rules, each unit is joined together in BP neural network and information was processed by the respond which comes from the exterior input [3]. Artificial neural networks imitate the human intelligent activities, for instance, consciousness, inspiration and image thinking. Though bionics, BP neural network as a kind of machine imitates human's ability of learning and logical reasoning [4],[5]. It shows great significance to satisfy the demands of more complicated system and the higher designing aims in the fields of detecting and controlling.

This paper is organized as follows. In section 2, wood defects image collection system is introduced. In section 3, wood defect images with rot collected by X-ray are processed. In section 4, some features are extracted from wood images with rot. In the section 5, construct BP neural network of detecting wood defect with rot and identify the type of wood defects

II. WOOD DEFECTS IMAGE COLLECTION SYSTEM

Wood defects influence wood utilization greatly. The limit regulations of wood defects about material have given in all kinds of wood. According to the newest national wood standard, wood defects are divided into ten types. Under the condition of current experiment, two typical defects which are rotten Rot and hollow heart are studied. There are many methods to detect wood defects. Considering of environmental protection, radioprotection, practical operation and cost, X-ray is selected as the testing source. X-ray fluorescence imaging effect is that when some materials such as CaS, ZnS, Pt, Ba(CN)2 was exposed by X-ray, fluorescence sent out from these materials can be observed easily in the dark [6]. And the intensity of fluorescence sent out from the same substance is in the direct ratio to the intensity of X-ray after passing through the wood. The abilities of absorption are different between the defects (such as rotten Rot, hollow heart and so on) and the normal location of wood when X-ray passes through the wood. X-ray intensity of defects is usually higher or lower than normal location of wood. Hence the wood defects can be recognized by testing the intensity of X-ray. The low-light camera as sensor inputs the image in order to transmit datum to computer in the processing system [7]. The principle of this system is to transform the analog signals from low-light camera into digital signal via high speed A/D conversion circuit. Then the signals are stored in image memory. The structure of X-ray wood nondestructive testing system is shown in Fig.1. Based on practical condition, a domestic industry X-ray machine (2005) was to scan to a log. The log image can be formed on

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X-ray absorbing screen coated with fluorescence substance (ZnS or CaS). A/D conversion circuit, the image collection and processing board between the computer and the low-light camera are developed.

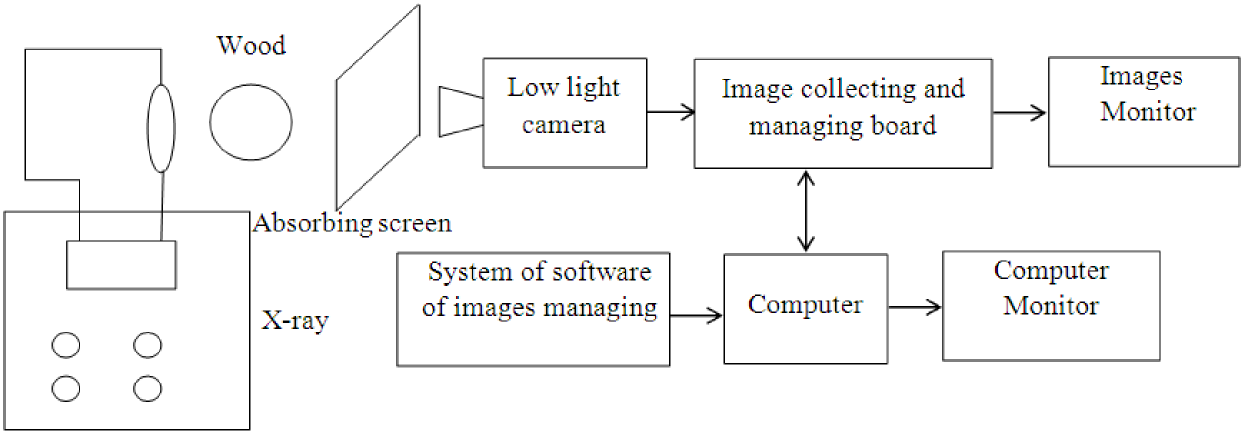

Fig.1. Wood defects nondestructive testing system

When wood has defects, attenuation degree of X-ray is different at defect location. At last, X-ray with different intensity can be obtained.

$$I_h = I_0 e^{-\mu(h+d)} \quad (1)$$

$$I_A = I_0 e^{-\mu A} \quad (2)$$

$$I_X = I_A e^{-\mu X} \quad (3)$$

$$I_B = I_X e^{-\mu(d-A-X)} \quad (4)$$

Therefore

$$I_B = I_0 e^{[-\mu(d-X)-\mu' X]} \quad (5)$$

Where μ' is attenuation coefficient at x .That is $I_d \neq I_h \neq I_B$, shown in Fig.2.

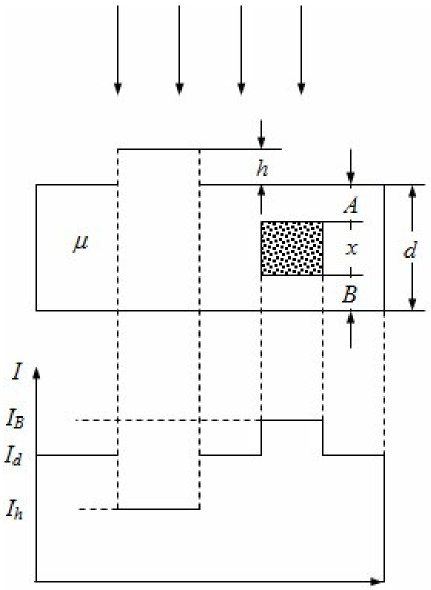

Fig.2. Principle of X-ray testing

III. Wood Defects Image Processing

The gray transformation which is important for image enhancement can increase the dynamic range of the image, expand the image contrast, make the image more clearly and features more obviously [8]. The gray level of image is mapped to a new scope by gray level adjustment [9],[10],[11].The gray level of image is adjusted by the imadjust() function from MATLAB, and the contrast is enhanced.

It is obtained by the stretchlim() function from MATLAB, the gray range obtained by this function is [0,1]. The range of gray is [0,255] for the 256 levels gray image. All the original images of rot are the 256 levels gray image in this study, so if you want to get the gray range of wood rot, the function form needs to be changed into stretchlim()*255. The rot original image is shown in Fig.3, the gray scale concentration range of the rot original image is [86,187].

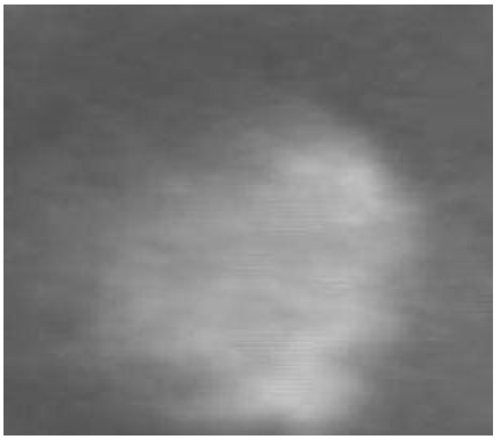

Fig.3. Orginal rot image

The original image of wood defect is adjusted by gray histogram, and the gray maps to the entire gray level range, [0,255]. The image contrast will be obviously enhanced. The image after adjustment is shown in Fig.4. The image definition after gray transformation is high, the differences between the pixels are more obvious, and the defect position is more highlighted.

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Fig.4. Rot image after gray transformation

The color of a binary image is usually pure black and white. In general, zero denotes black and one denotes white. In order to show the variation of the image according to the gray of the image, the 256 levels gray images are transformed into binary images. Appropriate threshold was chosen according to experience [12]. Various kinds of defects can be highlighted in order that the shape, location and size can be determined easily. Because of the different structure of the defective wood and the normal wood, 9binary processing is used to reflect the existence of defects in the wood. But it is very important to choose appropriate threshold for different defects. One kind threshold was adopted to do binary processing for the defect image whose change of gray is very obvious. Binary images of the defect with rot are shown as Fig.5 and Fig.6.

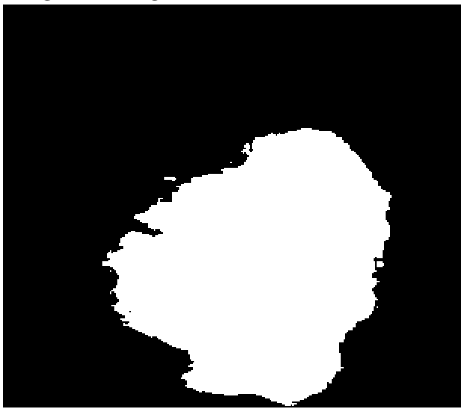

Fig.5. Binary image of the original image

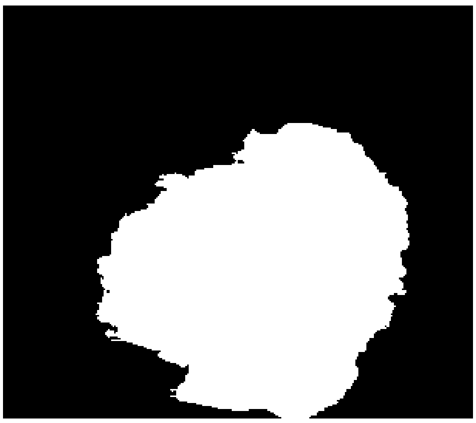

Fig.6. Binary image after gray

If binary image with wood defects contains noise, the inside of wood defect areas should be filled in order that subsequent images are added and the features of the shape with defects can be extracted easily. The binary images with Rot defect in all of above-mentioned images need to be filled. That is shown in Fig.7.

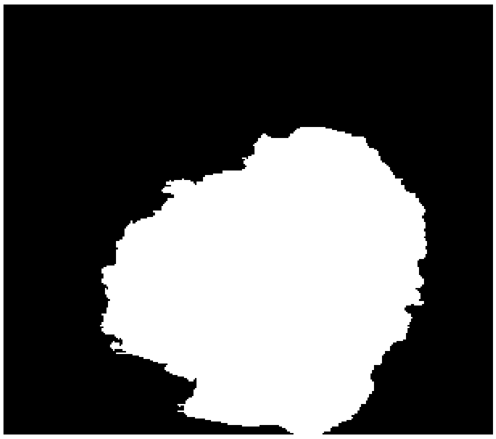

Fig.7. Binary image after filling in rot defects areas

IV. Features Extraction of Wood Images with Rot

Because the effect of Sobel operator is better and faster for edge detection of image, Sobel operator is chosen to extract the edge of wood defect binary image. It is found that the image obtained by the binary processing after gray transformation has a smooth edge from experimental results [13]. The shape of wood defect is reflected truly. In this study, the image edge was extracted directly by the function edge () from MATLAB. Fig.8 and Fig.9 were obtained after edge extraction from Fig.5 and Fig.7. Edge was extracted from binary image after gray transformation was continuous and smooth.

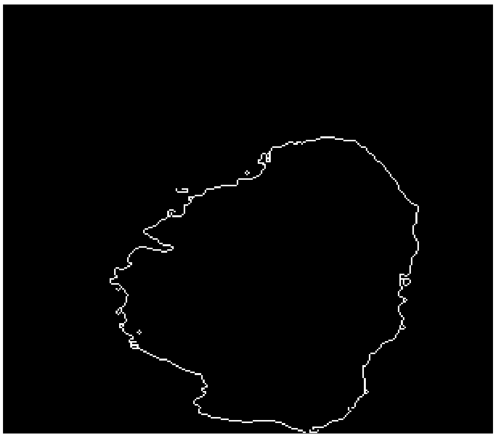

Fig.8. Edge extraction of rot binary image

In the procedure of image processing, the 256 degree gray image is converted into binary image so as to observe transformation of the image according to the gray change of the image [14]. On the basis of experience, corresponding threshold is chosen in order that the wood defects can be found. It is easy to determine the shape, the position and the size of wood defects.

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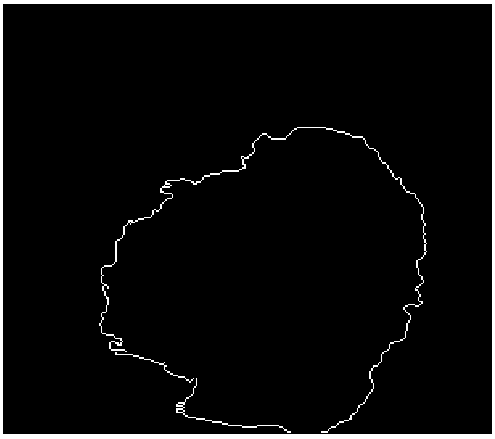


Fig.9. Edge extraction of rot binary image

At first, in order to extract some characteristics, the size and the position of defects are determined. Characteristic data is composed of these characteristics. So pattern recognition is finished. In the process of the determination of the size and position, scanning lines calculate rows and scanning rows calculate lines, which are to find the maximum line L_{max}, maximum row R_{max}, minimum line L_{min} and minimum row R_{min}. After setting the position, scan from the minimum row R_{min} to the maximum row R_{max}. Write down the different values in concrete number group, which is named $M[R_{max}-R_{min}]$. This group saves two boundaries of each line; it is necessary to prepare for the next step of extracting characteristics. Extract the characteristic from the gray scale image which is not binary and then get the number array $BB[R_{max}-R_{min}][L_{max}-L_{min}]$ which refers to the defect characteristics. The parts with defects are fixed with numbers, and the others are fixed with zero. According to formula (6) and (7), the mean and variance of the gray wood defects can be calculated.

$$x_1 = \sum_{i=R_{\min}}^{R_{\max}} \sum_{j=L_{\min}}^{L_{\max}} (G[i][j]) \Big/ n \qquad (6)$$

$$x_2 = \sum_{i=R_{\min}}^{R_{\max}} \sum_{j=L_{\min}}^{L_{\max}} (G[i][j]-x_1)^2 \Big/ n \qquad (7)$$

Where x_1 is grayscale mean of image with detects, x_2 is grayscale variance of image with detects, $G[i][j]$ is the value of defects pixel, n is the number of defects pixel.

The mean and variance of defects will be two input vectors when BP neural network is designed in the next step. Another vector which is called as the ratio of length and width (Z_{xy}) is judged by the size of defects.

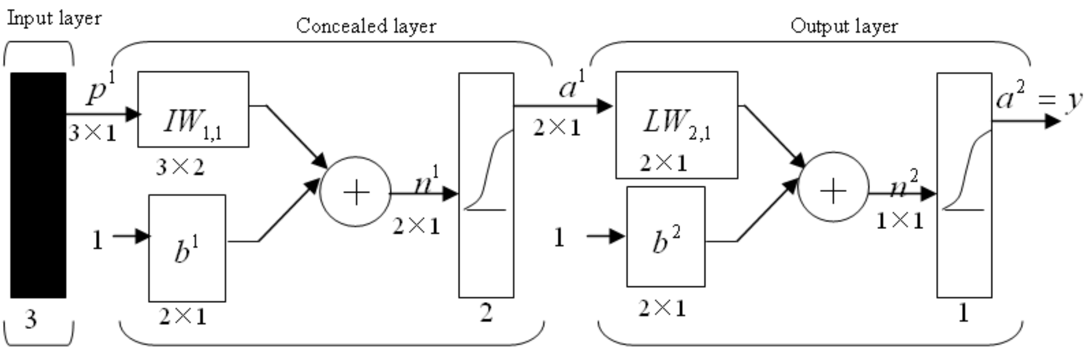
$$Z_{xy} = (R_{\max}-R_{\min})/(L_{\max}-L_{\min}) \qquad (8)$$

V. The Structure of Wood Defects Detection Networks Authors and Affiliations

Where m is the number of concealed layer nodes; n is the number of input layer nodes; l is the number of output layer nodes. The number of concealed nodes calculated by formula (4) is 2.

Apply BP neural networks model to identify wood defects; and adopt the grade descend method; minimize the error to the request. At first, image processing board could be acted as input characteristics [15]. Input vector (x_1, x_2, x_3) can be averaging, variance and division of length and width. This step is a process of classifying characters; the imported images are identified into the nerve networks by a certain way. According to experimental results, the coefficient matrix of the input layer and middle layer are W_1, middle layer and output layer are W_2. This is an advantageous way for the networks learning and features recognition.

According to the networks request and output request, the S function is selected as output layer transfer function. If output value is 1, then the defect is rot. If output value is 0, then the defect is not rot.



$$a^1 = \log sig(IW_{1,1}p^1 + b^1) \qquad a^2 = \log sig(IW_{2,1}a^1 + b^2)$$

Fig.10. Neural networks model

If banding the BP neural network with available features together, satisfying recognition result would be obtained. The established BP neural network model is shown in Fig.10. Wood defects features are extracted according to the analyses of image processing model, these features can be directly inputted into networks joint as parameter in networks training and pattern recognition and they can be transferred to the characteristic database. In order to improve networks self-adaptability and recognition mode based on the original training net, BP neural network model should be studied again.

Fifty samples are adopted to train the network. Ten samples are chosen respectively from each kind of wood defects sample which is not trained, and then they are conducted simulation for sophisticated BP network. Analytical results are shown in Table 1. The results are close to the target value after network learning. When the limited threshold value is defined a value whose absolute value is beyond 0.80, output of detection result is 1. When the absolute value of learning result is between 0 and 0.80, output of detection result is 0. At this time the type of wood defects can not be judged. From the Table 1 we can see the ratio of recognition attains to 90%. The above analysis and experiment results show that it is possible to finger out and classify wood defects effectively in quantitative detection by the way of combination of ANN and pattern recognition.

Table 1: Simulation of part sample

Type of defects	Learning result	Detection result	Target value	Ration of recognition
Rot	0.8623	1	1	90%
	0.8970	1	1	
	0.9762	1	1	
	0.9999	1	1	
	1	1	1	
	0.8236	1	1	
	0.6847	0	1	
	0.9761	1	1	
	0.9236	1	1	
	0.8198	1	1	

VI. Conclusion

The entire experiment shows that BP neural network can replace man-made detection for recognition of wood defects. The positions of defects become obvious through gray transformation of original image. The image which is obtained by the binary processing of an image after gray transformation saves farthest the edges of wood defects. The position and size of defects can be known by scanning the edge of wood defects. The result of wood defect image plus is that defects regions take apart completely with their background. BP neural network can not only improve the accuracy of defect classification, but also is a research method that promotes development of wood science. Moreover, if this method is applied to product line, the efficiency of wood production and the extent of automation are improved. The type, size and position of wood defects can be judged according to the recognition result. The wood utilization and economic value will be promoted greatly. So combination of BP neural network and pattern recognition is an effective and intelligent method to achieve classification of wood defects. The experiment results show that it is virtual and feasible to detect and classify of wood defects by BP neural network.

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