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ORIGINAL ARTICLE

Modeling method. compressive elastic modulus. softwood based. fiber angle Prediction

Yiwei Wang

Electrical, Mechanical CollegeNortheast forestry University

Abstract: [Objective]. Tracheid. softwood not only has. function as a medium. "coenzyme TransportationBut also. a strong support. trees, Its state has close relationship. mechanical properties. timber.The investigation of internal relationship between the distribution of traceid and the mechanical properties of wood is of great significance for the prediction of competitive elastic modal of wood.[Method]This paper stars with the tracheid Effect of constant timber and Introduction A set of detection platform covered the functions of Light Source,Spot collection,Spot analysts

And plate traverse to build the numeric relationship between fiber angle distribution and compressive elastic Modal.First,Beast square method was used to fit the ellipse contour of the dots to measure the fiber angle;Second,By analyzing the measurement error of fiber angle,A filtering method with mean value of 20 was selected to improve the accuracy of fiber angle measurement,, Then. collection. fiber angle. completed after a traversal sampling.FinallyTaking. Mean ValueDiving , standard deviation. fiber angle distribution. two surfaces. plate as input, Compressive modulus. sample as outputA four-layer neural network. 6 inputs, 1 Output. constructed. predict. compressive Elastic Modulus.. Testify. effect. study100 samples. Larix gmelini. processed. accordance. requirement. GB/T 15777-1995. National Standard. compressive Modulus. elasticity, Divided. training, testing samples. proportion. 3:1 after collecting. fiber angle, mechanic truth value. detection platform, testing machines.[REsult].:. Experiment revealed, when. average frequency. filtering. natural 20. Measurement Error. fiber angle acquisition. less. 0. 65 °, same time. Precision. compression modulus. network prediction could reach 90. 80%.[Conclusion]. Compressive elastic modulus. softwood can be predicted by collecting. fiber angle distribution.. Combined transport bill of. Least Squares, filtering method can effectively express. characteristic information, ensure. measurement precision. fiber angle.. Mean ValueDiving 數, standard deviation can effectively describe. distribution characteristics. fiber angle.By selecting different features as input. Elastic modulus prediction accuracy. directly affected.. Experiment. this paper. Double-sided feature as input. Elastic modulus prediction accuracy. highest.

Keywords: Compressive modulus. elasticity;Tracheid Effect;Fiber angle detection;Neural Network

1. Construction of fiber angle detection hardware platform

Fiber angle detection equipment platform mainly consists of Laser Emitter,Color Camera,Lens and auxiliary device,Computer and two-axis slide, its structure as shown in Figure1.Shown.Camera,The laser emitter and the wood to be measured position as far as possible to keep in a vertical line, so that the laser to approach90 °The incident angle is projected on the wood surface to avoid the tangential distortion of the laser spot..By driving the stepper motor, the

two-axis slide can be moved in a given way, so that the test points on the wood can be traversed and the fiber angular distribution can be acquired..

1.1 Laser Light Source

The longer the laser wavelength is, the farther the light travels in the tube..Due to the large Ellipticity of the laser spot produced by the tracheid effect, it far exceeds the ellipticity of the laser beam projected by the laser generator, so there is no strict requirement for the roundness of the laser spot..Laser Power affects the image collected by camera and the complexity of Ellipse Fitting.The laser wavelength of this system is650 Nm, The output power is20 mW, Spot diameter1mmPower stability is less1%.

1.2 Industrial camera

When using large focal length lens to acquire laser spot,

High light intensity in the field will cause overexposure and halo.The halo signal masks the faint scattered spot signals around the spot, which carry the shape information of the spot..The camera of this system chooses pixels

X 480, Adjustable exposure timeUSBIndustrial camera to increase image collection Quality by adjusting exposure to suppress halo Production.

1.3 Lens and auxiliary device

The lens matches the camera and the focal length is50mm.The core area diameter of the spot reaches10 pixAbove, the longest axis of the effective spot area can be reached50 pixAbove.Because the laser power has the characteristics of Run-out, the collected spot is doped with random noise,

By loading2.The polarizer enables0%~50%By adjusting the exposure time of the camera, the stability of the spot acquisition is improved..

2. Fiber angle detection and Prediction of compressive modulus of elasticity

2.1 Fiber Angle Measurement

Laser Projection on the wood surface will scatter into an oval spot, through The ellipse shape outside the fitting spot extracts the long and short axis values, And then define the fiber angular distribution characteristics.The direction of the long axis of the ellipse can be regarded as the direction of fiber growth; the length of the ellipse,The ratio of short axis is defined as the penetration coefficient, which indicates the extent of the fiber to the surface under test..

Because the center area of the spot is high brightness and tends to white, and the surrounding halo area is dark red, so the extractionRChannel Two for binarization image processing;Then, applyCannyEdge Extraction, using the least square method for Ellipse Fitting.Set the elliptic general equation:

$Ax^2 + Bxy + cy^2 + Dx + ey + f = 0$(1.)Type:A,B,C,D,E,FFor the coefficients of the elliptic general equation,X,YCoordinates on the Ellipse.

After edge detection, the discrete points are processed by least squares, that is, the formula (2.)Minimum.

Transfiguration (1.)Available:

$A(X-X_0)^2 B(X-X_0)(Y-Y_0) C(Y-Y_0)^2 F = 0$(3.)

Type:X_0ForXItem conversion factor,Y_0YesYItem conversion factor,FConversion coefficient for constant term.

Via simultaneous (3.)With type (1.)Can be solvedX_0,Y_0,FWithD,E,FThe relationship.

$\{^{X'=X-X0}$, Into type (3.), There are:Y' = y-Y_0

At any point, half the distance to the focal length,$B = A^2 - C^2$(CHalf the distance between the ellipse Focus).For the elliptic standard equation,

{X = x' cosTheta-Y'sinTheta

Rotate it-Theta°, Soon Into the ellipseY = x' sinThetaY'cosTheta

The quasi-equation can be simplified as follows:

$A^{2}\cdot Sin^{2}\cdot ThetaB^{2}\cdot Cos^{2}\cdot Theta)X'^{2}\cdot (A^{2}\cdot Cos^{2}\cdot ThetaB^{2}\cdot Sin^{2}\cdot Theta)Y'^{2}\cdot$

Simultaneous (4.)With type (5.)Available equations:

$F = -A^{2}\cdot B^{2}\cdot$

Type:ThetaFiber corner;A,BLong and Short Axis lengths, respectively.

2.2.Modeling of compressive modulus of elasticity Based on Neural Network

Average fiber angle (μ)Reflects the main fiber angle distribution

Trend;Standard deviation of fiber angle distribution (Sigma)It shows the difference of fiber angle distribution and the jumping degree of fiber angle (D)Reflects the main trend of tracheid infiltration.In physics, the mean of fiber angle and the mean of penetration coefficient determine the stress direction of most tracheids..The average fiber angle of two diameter sections of the wood to be measured was extracted.μ,Standard DeviationSigmaMean dive coefficient with fiber angle

D. As the input of neural network, the predicted compressive modulus is the output,

Build6--15--6--1Of4.Among them, the second layer neuron activation function SelectionTansigThird-tier neuron activation function SelectionLogsigFunction.

3. Test Experiment and result analysis

Larch for specimen Selection(Larix gmelinii)Air-dry sawing at room temperatureGB/T 15777-1995《Standard Test Method for compressive modulus of elasticity of timber along grain"Preparation60mm x 20mm x 20

Compressive mechanical specimens.Pick out the faultless specimens100Block and adjust the moisture content12%After scanning the angular distribution of the Two-diameter section of the specimen, the mechanical damage test is carried out to get the true value of.

3.1 Fiber angle detection experiment

For larch and ash (Fraxinus mandshurica)Tracheid scattering contrast.The tracheid Effect of conifer was obvious, but the tracheid proportion of hardwood was small, but the tracheid effect was not obvious..

Description of corner Distribution Characteristics of wood fiber.Where, DirectionA-a'For the THREE-DIMENSIONAL orientation of tracheids in wood,ThetaThe fiber angle is related to the direction of Ellipse long axis;KFor the dive angle, its number

The value is related to the ratio of the long and short axes of the fitted Ellipse .

In order to observe the accuracy of fiber angle measurement, the Single Point Rotation Measurement of wood was completed by controlling the rotation angle.5.Shown.The zero point of detection device detection is defined as the starting point of rotation.6.The relationship between the actual angle of the stepper motor and the measurement angle.Figure6.Indicate:The measured value is in line with the actual rotation angle, and the correlation coefficient is0. 998, The equipment can accurately measure the fiber angle of the wood surface.

3.2 Fiber Angle Measurement Accuracy Test

The measurement accuracy of fiber angle determines Max(X(N))And mean filter coefficientsNThe relationship.Among them,G_{I}Wei DiIAverage number of data groups,M(N)For the device inNUnder sub-filtering (1 000-N)Measured value,X(N)Is the device inNUnder sub-filtering (1 000-N)The error of the measured value,ABS(...)Operation for absolute value.

Statistical mean times and maximum error curves are shown in Fig.7.Shown.AbscissaNAverage number of times, ordinateNMaximum error of fiber angle measured by equipment during sub-average filtering.The greater the average number of visible times, the smaller the device error, but the longer the measurement time..Given the online detection time, select hereNFor20The maximum measurement error is0. 65 °Single point acquisition time1 s.

Precision of Model.Sample pointNSub-sampling, whenNTake∞The mean value is considered as the static ideal value of the sampling point..The difference between each measurement and the mean is defined as a single

measurement error..Because the average filter can effectively suppress the Gaussian distribution error, the parameters of the average filter are determined through experiments..The specific steps of the experiment are as follows:

Follow the sample3.:1.The scale is divided into training set and verification set.Follow5mm x 5mmThe fiber angle distribution of the two diameter sections of the specimen was collected at the intervals of the two sections..The average fiber angle of two-sided sections ($\mu_{1.}$,$\mu_{2.}$),Standard deviation of fiber angle (Sigma$_{1.}$,Sigma$_{2.}$),Mean dive coefficient ($D_{1.}$,$D_{2.}$)Wait.6.The elastic modulus of compression is the output.6.¯15--6--1OfBPNetwork structure, in which the activation function is selectedTansigActivation functionLogsigActivation function.By Gradient Descent Method of neurons training Training After of Neural Network in Test Set of output and mechanical true value of related coefficient0. 921Accuracy90. 80%.Table1For sample surface fiber angular distribution characteristics and compressive elastic modulus true value of statistical table2For part test sample of model predictive value and mechanical True Value.

In order to verify model parameters select of effectiveness respectively select wood

Material single fiber angle of statistical value,Double-sided fiber angle of statistical mean as an input construction the prediction model its prediction results of error statistical and mechanical true value between the related coefficient such as table3Shown in which absolute error can reflect predictive value deviate from the true value of the degree relative error the can characterization predictive value of reliable degree and related coefficient reflect the model predictive value and mechanical true value between the related degree.Table3Show that:To double-sided characteristics for input of prediction model its the index is better than to single fiber angular distribution characteristics and double-sided fiber angular distribution characteristics mean for input of Prediction Model.Mechanical predictive value and the true value of the scatter distribution as shown in Figure8The

The the chart the: To double-sided fiber angular distribution characteristics for input of Prediction Model its prediction results more close to in real value.

Note:$\mu_{1.}$Mean angular distribution of frontal fibers;$\mu_{2.}$Mean angular distribution of negative fibers;Sigma$_{1.}$Standard deviation of frontal fiber angle distribution;Sigma$_{2.}$The standard deviation of the negative fiber angle distribution;$D_{1.}$For frontal dive Coefficient Cloth mean;$D_{2.}$Mean distribution of the negative dive coefficient;μFor single-sided fiber angle distribution mean;SigmaStandard deviation of angular distribution of Single-sided fiber;DThe mean distribution of the coefficient of entry on one side;μFor both sides of the fiber

Mean Angular Distribution;SigmaStandard deviation of angular distribution of forward and backward fibers;DMean distribution of forward and backward diving Coefficients.Notes:$\mu_{1.}$Is the average of fiber angle distribution on one side,$\mu_{2.}$Is the average of fiber angle distribution on the other side,Sigma$_{1.}$The standard deviation of fiber angle on one side,Sigma$_{2.}$Is the standard deviation of fiber angle on the other side,$D_{1.}$Is the average of diving efficient distribution on one side,$D_{2.}$Is the average of diving efficient distribution on the other side,μIs the average of fiber angle distribution on the one side,SigmaIs the standard deviation of fiber angle on the one side,D is the average of diving Coefficient

Distribution on the one side,μ. Average value. fiber angle distribution. both sidesSigma. Standard deviation. fiber angle distribution. both sides, D. average. diving distribution. both sides.

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Collection of to improve the collection of efficiency; finally how to optimization compressive elastic modulus of Neural Network Structure looking for optimal network parameters further improve compressive elastic modulus prediction of accuracy still is need in-depth study of orientation.

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