Извлечение паренхимы растений с помощью технологии компьютерной обработки изображений

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Аннотация. Люди все чаще используют различные виды растительных продуктов, таких как древесина, но существует много видов древесины, и их трудно анализировать и идентифицировать, поэтому вопрос о том, как использовать вспомогательное оборудование для анализа древесины и достижения цели точной идентификации древесины без повреждения самого продукта, является одним из актуальных на сегодняшний день в области исследований древесины. Осевая тонкостенная ткань содержит важную информацию о зернах древесины, и это один из важных признаков для идентификации древесины. В статье исследуются микроскопические изображения широколиственные древесины, получены изображения микроструктуры поперечного сечения древесины путем фотографирования, а также извлечена полная осевая морфология тонкостенных тканей древесины с использованием технологии компьютерной обработки изображений и других способов компьютерного зрения. Во-первых, изображения осевой тонкостенной древесины были обезшумлены, чтобы устранить некоторые шумовые эффекты и облегчить разделение осевой тонкостенной древесины; затем изображения были обработаны с помощью математической морфологии, чтобы успешно извлечь осевую тонкостенную древесину и морфологию воздуховода из изображений поперечного сечения широколиственной древесины; наконец, осевая тонкостенная древесина была отделена от воздуховода путем вычисления площади замкнутой области.

Ключевые слова: обработка изображений, компьютерное зрение, математическая морфология, паренхима, растение, древесина, экстракция.

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Extraction of plant parenchyma by computer image processing technology

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Abstract. People are increasingly using different kinds of plant products, such as wood, but there are many kinds of wood and it is difficult to analyze and identify them, so how to use auxiliary equipment to analyze wood and achieve the goal of accurate wood identification without damaging the product itself has become one of the important problems to be solved in the field of wood research. The axial thin-walled tissue has important wood grain information and it is one of the important features for wood identification. In this paper, we studied the microscopic images of broadleaf wood, and obtained the microstructure images of wood cross-section by photographing, and extracted the complete axial thin-walled tissue morphology of wood by using computer image processing technology and other ways about computer vision. Firstly, the axial thin-walled wood images were de-noised to eliminate some noise effects, so as to facilitate the separation of the axial thin-walled wood; then the images were processed by mathematical morphology to successfully extract the axial thin-walled wood and duct morphology from the cross-sectional images of broadleaf wood; finally, the axial thin-walled wood was separated from the duct by calculating the area of the closed area.

Keywords: image processing, computer vision, mathematical morphology, parenchyma, plant, wood, extraction.

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INTRODUCTION

Background

With the development of technology, energy will be a major factor limiting development. Wood is an important renewable resource, so it can be said that its value will become higher and higher, and its development prospects are very broad. Currently, wood is used in a wide range of industries, such as furniture, construction, paper making, aviation and so on. Therefore, the correct identification of wood plays a pivotal role in the safe production, product qualification and economic benefits of enterprises. However, there are many types of wood, and there is no shortage of wood of good quality and high economic value. Since different woods have different structural characteristics and are made of different materials, it is very important to correctly and efficiently determine the wood species in order to implement quality-based pricing, ensure product quality, and guide forestry production. Therefore, fast, accurate and efficient identification of wood species is a major research direction and a problem that needs to be solved in the field of wood science. At present, although wood identification has developed from macroscopic identification to microscopic identification, and the accuracy
of wood identification has greatly increased, but microscopic identification requires certain wood knowledge, which is generally mastered only by experts in the wood field, and is difficult to be popularized. Therefore, it has become an important research direction to extract recognition features in wood images by computer vision technology, and then to assist wood recognition [1-3], and thus to achieve accurate and efficient wood recognition.

Wood micrographs are rich in cellular tissues (e.g., ducts, tubular cells, axial thin-walled tissues, wood rays, etc.), which are important for the analysis of wood and can generally be clearly observed through a microscope. Moreover, the morphological characteristics and rules of combination and arrangement of these cell tissues vary greatly in microscopic images of different tree species, and it is due to these differences that wood identification and classification are facilitated. Therefore, how to extract these features from the images and analyze the relationship between these features and wood species will promote the development of intelligent wood identification and is an important research direction in the future.

Through the previous analysis and research on cell features in wood images, we found that many scholars have applied computer vision techniques to the study of cell feature extraction in wood images, and they have done a lot of research work and achieved good results. At the same time, we also see that most of the previous studies have focused on wood microscopic studies, and mainly on the quantification, extraction and analysis of semantic features, including ducts, annual rings, wood rays and other cellular tissues. These are all important features for species discrimination. Then axial thin-walled tissue is also an important feature in broadleaf timber images, but there are almost no studies on the extraction of axial thin-walled tissue. The morphological distribution of axial thin-walled tissue varies greatly from one broadleaf tree to another, which is also an important basis for broadleaf wood identification. Then whether it is possible to analyze and identify tree species based on such differences is also a question worthy of consideration and research.

In the field of digital image processing, people have successfully extracted some features of images using digital image processing methods, such as electronic camera systems. Many scholars also want to apply these methods and techniques to the wood field to achieve intelligent recognition or detection analysis of wood, and these studies have achieved great results. However, not much research has been done on the extraction and analysis of features in cross-sectional images of wood using these techniques. Whether the research on these can be of great significance is another question worthy of consideration and research.
Computer vision-based technologies have a wide range of applications in many fields, e.g., medically assisted diagnosis, target tracking and identification, classification and identification of plant leaves, detection of defects on wood surfaces, etc. Therefore, it is easy to know that the application of computer vision techniques in wood science has been based on good results, for example, in the extraction of ducts and wood rays. Although axial thin-walled tissue is one of the important features in wood micrographs and one of the main features for wood discrimination, mainly for broad-leaved wood, the application of computer vision techniques to the extraction of axial thin-walled tissue in cross-sectional images of broad-leaved wood is less common.

The main purpose of this research is to take the wood microstructure image as the research object and use computer vision technology as the theoretical guide to explore a suitable extraction method of wood axial thin-walled tissue. The implementation of this algorithm has certain theoretical significance and practical value. Firstly, there are various types of axial thin-walled tissues, and the algorithm can successfully separate the images containing only axial thin-walled tissues, and the morphological characteristics of axial thin-walled tissues can be intuitively identified from the images, which lays a certain foundation for identifying wood species based on the morphology of axial thin-walled tissues. Second, the axial thin-walled tissue content of the species can be easily calculated from the images containing only axial thin-walled tissue, which also provides a shortcut to analyze the differences in the content of axial thin-walled tissue between different species.

**Current status and development trend of domestic and international research**

*Current status of research*

In recent years, the wood industry is entering a new phase of industrialization and marketization as the field of wood is being studied in depth. Traditional methods of wood analysis are no longer sufficient to meet the needs of the industry and are inhibiting the pace of industrialization and marketization, so new methods of wood analysis are being increasingly emphasized. In the past, research on wood anatomy was mainly carried out manually using light and electron microscopy to observe, count and analyze some characteristic parameters of wood anatomy molecules, which required too much human, financial and material resources and was relatively inefficient. Therefore, exploring intelligent methods for the study of wood anatomical structure molecules has been an urgent problem in the field of wood science and technology.
However, with the development of image processing technology and pattern recognition technology, it provides the possibility to apply computer vision technology to the field of wood dissection. In the 1970s and before, although the theoretical knowledge in the field of wood science was relatively well developed, computer technology was backward at that time, which prevented the use of computer technology in wood science. Morse and others started to develop programs for wood identification and pioneered the use of computer technology in wood science. In the 1970s, the International Association of Wood Anatomists began to use computer technology to analyze and identify wood species using a table of wood identification characteristics as a basis.

With the development of image processing technology and pattern recognition technology, the foundation was laid to study the application of computer vision technology to the field of wood anatomy. In 1980, computer vision techniques were applied to research in the field of wood, mainly for the analysis and measurement of tissue in microscopic images of wood. The main purpose is to observe wood slices under a microscope, take good quality images (images containing at least one annual ring), and then use computer software to analyze, measure, and count the images accordingly. Based on the number and spatial distribution of pixel points in the image, it is possible to calculate and measure the characteristics of some tissues in wood micrographs, such as: cell perimeter, area, etc. McMillin analyzed the characteristics of tissue cells in wood micrographs based on the knowledge of wood science and explored algorithms for intelligent calculation of cell characteristics using computer vision techniques, such as: measurement of cell. In 1983, ILIC and HILLIS also applied computer vision techniques to the measurement of wood cell features and also developed corresponding software systems that can intelligently calculate the area of different cell molecules and their area ratios. Jordan BD successfully explored an algorithm to measure the thickness of wood fiber walls after intensive research and combined with previous experience. Huang YS applied Fourier transform to the field of wood and developed a technique to measure the surface roughness of wood, which can accurately and quickly analyze and measure the surface roughness of wood. 1991, Fujita Twist et al. also did a study on Fourier aspects and proposed a technique to analyze and measure the thickness of cell walls by Fourier transform in conjunction with the characteristics of wood tissue cells. Also, their study on feature extraction of tissue cells in wood microscopic images, according to the characteristics of these cells (such as shape and size), different cells can be distinguished, and also better calculation of wood tissue ratio, which used to require manual measurement, can
now be achieved faster using computers. In the same year, Chizuki Maekawa, Kazuki Iwakiri, and Ttetford RD all applied image processing methods to the field of wood and used them to process wood microscopic images to explore cell arrangement rules, cell wall thickness measurement methods, wood density, and annual rings measurement methods, respectively, all of which achieved better research results and were very convenient for analyzing and calculating tissue properties, as well as facilitating better In 1993, Won Kyu Park applied the image processing technique to the measurement of cell wall area in wood micrographs, and the method was effective and could be used to measure the density of wood (mainly latewood). 1995, Watanabe U. used the Fourier transform method to analyze the shrinkage and deformation of wood cells, mainly for five species of the results of this study showed two main reasons for the anisotropic shrinkage of wood in cross-section: the first is the anisotropic shrinkage of the cells themselves, and the second is the influence of other factors such as tree annual rings [4-6].

Diao applied the Fourier transform to the determination of tissue cell shape and the analysis of cell arrangement rules in wood micrographs, mainly in 10 coniferous species, and proposed a method for calculating cell radial and chordal diameters, while they calculated and analyzed the characteristic parameters of duct cells in cross-sectional images of 18 coniferous species and used them to distinguish different In 1996, Fujia et al. found that the distribution of ducts in microscopic images of wood has a certain regularity, and used 32 Japanese broadleaf microscopic images to experimentally verify the distribution of ducts in different tree species. In 1999, Japanese scholars studied the cell characteristics of seven wood species, classified them, derived the relationship between cell size and density, established corresponding models, calculated their elastic modulus, and performed corresponding experiments for analysis and comparison. Masako KINO et al. also worked out an algorithm to measure the cell wall thickness based on the previous work, using image processing techniques and knowledge of wood science.

The above studies have focused more on the measurement of features such as cell morphology ratios, and the use of image processing technology as an auxiliary measurement method provides a powerful tool for quantitative research and solves problems that could not be measured manually in the past, but have not yet investigated the qualitative description of traditional wood identification features such as ducts, wood rays, axial thin-walled tissue, and other unique object features in wood images (hereinafter referred to as object features), nor have they involved the automatic extraction of such object features.
Unlike traditional computer vision, where object processing involves challenges such as illumination, occlusion, deformation, and the high complexity of the objects themselves, the objects in wood microscopic image composition are relatively stable, with only a few stable objects such as ducts, wood rays, and thin-walled tissues, etc. The images acquired under standard constraints also exclude factors such as illumination, so feature extraction only needs to focus on the characteristics of the objects themselves. Therefore, the study of these unique objects is also an important direction in the field of wood anatomy, which is of great significance for wood identification.

In the 1980s, with the development of computer vision technology, scholars in China also began to introduce computer vision technology into the field of wood science research, and engaged in a lot of research work, overcame many technical problems, and achieved a lot of research results. Liu ZQ (1986) studied wood grain characteristics and combined image processing techniques and wood science knowledge to explore the detection and analysis methods of wood surface defects, which also played a role in promoting the research of Chinese scholars engaged in this area. Yang made great contributions in the field of wood and first proposed in 1990 that the features of tissue cells in wood microscopic images could be used to distinguish wood species, and studied the types of these features, mainly more than 50 kinds, such as wood rays, axial thin-walled tissue, ducts, tubular cells, etc. These studies brought great convenience to subsequent researchers and facilitated the development of intelligent wood identification. Zhao Xuezeng (1992) carried out an in-depth study on the roughness of wood surfaces and proposed a corresponding measurement method using image processing techniques. Wang Jinman (1993) studied the features in microscopic images of wood and came up with some characteristic parameters of cells that can be used to distinguish that cell, followed by a corresponding software system that can better analyze and process wood microscopic cells. Yanjie Qu (2000) applied the Fourier transform to wood microscopic image processing, which solved some difficult problems in wood microscopic features, such as fluctuation and periodicity, and provided convenience for the study of evolutionary laws. Sun, L. (2000) studied the changes of some cells in wood cross-grain compression and analyzed the changes by image processing techniques, describing the structural parameters of wood after the treatment. Qi, D. (2001) studied the characteristics of internal defects in wood, proposed a corresponding detection method, and developed a wood defect image processing system. Kunyan Bao also did corresponding research work, applied computer vision technology to wood image processing, and developed a software system, which can extract and calculate a variety of cell feature...
parameters, such as the number of cells, cell cavity area and its distribution, wall cavity ratio, etc.; Haipeng Yu analyzed various representative algorithms for image texture description in 2005, and analyzed the advantages and disadvantages of various algorithms. In 2005, Yu analyzed various representative algorithms for image texture description and analyzed the advantages and disadvantages of each algorithm, which made a great contribution to the future study of image texture features. Wang Han et al. in 2006 applied image processing techniques to the study of wood texture features and achieved good results, establishing some texture feature parameters and also being able to classify images based on some of them, e.g., identifying whether it is a cross-sectional image or a radial-sectional image. Yong-Hua Xie also conducted a study on wood texture features and established a corresponding texture description method, which was mainly implemented by the invariant moment method. Hui Huang studied the characteristics of ducts and wood rays in microscopic images of wood and used mathematical morphology to analyze their characteristic rules. Kechi Wang et al, Xuebing Bai et al, and Hong'e Ren et al, on the other hand, studied the texture characteristics in wood images in depth and used them to discriminate different tree species. Lu Yuehui introduced computer vision technology into the research of wood field, and used the idea of image chunking and then block-by-block recognition to obtain a high recognition rate. Qi Hennian did a lot of research on conduits and finally applied morphological methods to the extraction of wood conduits, and achieved better results. Wang Hangjun et al. applied computer vision technology to the research in the field of wood science and did a lot of research work and achieved a series of results, such as, intelligent identification method of coniferous wood, method of separating conduits in microscopic images of broad-leaved wood, and so on. Ji Zhiwei also engaged in research on conduits, and applied image processing techniques to conduit extraction [7-9].

In summary, scholars at home and abroad have done a lot of research work in the field of wood, and computer vision technology has been widely applied in the field of wood science, and rich research results have been achieved. However, there are still relatively few studies on the extraction of unique objects on the cross-section of broad-leaved wood, only the extraction of wood rays and ducts have been reported, however, the studies on the extraction of axial thin-walled tissues are still relatively rare. Based on this, this paper will discuss how to successfully extract the morphology of axially thin-walled tissues in wood cross-sectional images using computer vision techniques.
Development trend

With the rapid development of computer vision technology and wood science technology, the application of computer vision technology in the field of wood science will certainly be further developed. The main aspects are as follows.

(1) Computer vision technology has been heavily invested in research in the field of wood science and technology. For example, computer vision technology can be used to measure, count, and take morphology of various cell molecules in microscopic images of wood; in furniture manufacturing, computer vision technology can be used to detect defects in wood to facilitate the taking and use of wood.

(2) In the production process of some enterprises, computer vision technology can be used to replace people to identify wood species, which can save costs and ensure better development of enterprises.

RELEVANT THEORIES AND TECHNIQUES IN THIS PAPER

Knowledge of wood science

Microstructure of wood

Wood is classified according to its botanical characteristics: coniferous and broad-leaved wood. The microstructure of coniferous wood differs from that of broadleaf wood. The microstructure of coniferous wood is composed of axial tubercles, wood rays, axial thin-walled tissue and resin channels, etc. The axial tubercles are characterized by their slender and narrow morphology and are arranged in the same direction as the annual rings in the microstructure. Thin-walled tissue generally contains less, sometimes even none, accounting for only about 1%; resin channels are usually a kind of pore formed by cells, and the cells have the role of secreting resin, and their content is even less than that of axial thin-walled tissue, accounting for about 0.1%-0.7%. The microstructure of broadleaf wood is composed of ducts, wood fibers, axial thin-walled tissues, wood rays, gum tracts and broadleaf tubular cells, among which ducts are easily observed in the microstructure of broadleaf wood and consist of some tubular cells, accounting for about 20% of the total volume of broadleaf wood. The content of wood rays is richer and more complex than that of coniferous wood, accounting for about 17% of the total volume of wood; the content of axial thin-walled tissue is much more than that of axial thin-walled tissue in coniferous wood [10-12], and its distribution is also more complex, accounting
for about 2%-15%; the distribution of gum tracts, which are tubular interstices composed of gum-retentive cells, in wood varies greatly depending on the location and The distribution of gum tracts, which are tubular intercellular spaces composed of gum-secreting cells, varies greatly in wood depending on the location, and the number is also small.

In summary, axial thin-walled tissue in needle-leaved wood is very little and difficult to see in microscopic images, so it is not easy to be used for extraction, while axial thin-walled tissue in broad-leaved wood is more abundant and it is also an important feature for the identification of broad-leaved wood. Therefore, in this paper, the study on the extraction of axial thin-walled tissues is mainly conducted on the microscopic images of broadleaf timber.

**Basics of axial thin-walled organization**

*Overview of axial thin-walled tissue.* Axial thin-walled tissue is formed by a number of thin-walled cells strung axially. Its function is for storage and distribution of nutrients in the tree species. The shape of the cells at the ends of the string is different from that of the cells in the middle, with the thin-walled cells at the ends having a sharp shape and those in the middle being mostly cylindrical or polyhedral. The number of cells in a string is approximately the same, or with some minor variations, in the same species. However, the differences between the stacked and non-stacked broadleaf species are quite obvious, with stacked species having about 2 to 4 cells in a bunch and non-stacked species having 5 to 12 cells. For wood species identification, these small differences are of great reference value. The axial thin-walled cells also vary among species, and some may contain crystals, which usually become oil cells, mucilage cells. When containing various types of substances that lead to great changes in cell morphology, they can be called giant cells or heterocytes.

Axial thin-walled tissue has a unique purpose: to store nutrients and promote tree growth in the coming year. The amount of axially thin-walled tissue varies greatly from species to species, with broadleaf and coniferous timber being stark examples, with broadleaf timber being more abundant and coniferous timber being almost absent. Many of the broadleaf species, which defoliate during the winter, need to store large amounts of nutrients, so the axial thin-walled tissue is more developed. Coniferous trees are less defoliated in winter, so most coniferous trees have less axial thin-walled tissue. Although axial thin-walled tissue is an important feature for species identification and a key tissue for nutrient storage, axial thin-walled tissue also has some negative effects, such as causing wood cracking and reducing the strength of wood.
Microscopic characteristics of axial thin-walled tissue. Axial thin-walled tissues are formed by a number of thin-walled cells in axial chains. They are arranged in a certain pattern, mainly in the direction of the tree axis. Axial thin-walled tissue can be observed in cross-sectional images of the wood, and the color of the wood is darker and lighter than that of its surrounding parts, which is generally more obvious when moistened with water [13-15].

The content of axial thin-walled tissue in coniferous wood is small and difficult to observe, and is present in a few species, such as fir, cypress, cedar, etc., but they all require microscopy to be observed. The arrangement of axial thin-walled tissues is different in different broad-leaved trees and shows a certain regularity. The clarity and distribution type are also different in different species, and these characteristics are also important parameters for identifying broadleaf timber.

(I) Conspicuousness.

Axial thin-walled tissue morphology is not developed: not visible or obvious under the state of observation with magnifying glass and microscope, such as mullein, maple, holly, etc.

Axial thin-walled tissue morphology developed: visible or clear under the state of observation with magnifying glass and microscope, such as persimmon, sapium, etc.

Axial thin-walled tissue morphology is very well developed: visible or clear under the state of naked eye observation, such as paulownia, sycamore, etc.

(II) The distribution type.

In general, the axial thin-walled tissue morphology can be classified into two categories according to its relationship with the ducts: the first category is the adjacent tubular thin-walled tissue; the second category is the off-tubular thin-walled tissue (Figure 1).

(III) Apotracheal parenchyma.

This refers to thin-walled tissue that does not surround the tubular pore, but is spaced apart from the duct and distributed separately. There are several types as follows.

1. The end of the whorl: at the end of each growth period, alone or variable width of the axial thin-walled cells constitute a continuous or intermittent laminar arrangement. Such as willow, poplar, etc.

2. The beginning of the whorl: at the beginning of each growth period, single or variable width of the axial thin-walled cells constitute a continuous or intermittent laminar arrangement. Such as teak and walnut family genera. The beginning and end of the whorl can be collectively referred to as the whorl boundary-like thin-walled tissue.
3. Scattered: axial thin-walled tissue alone is irregularly dispersed between other tissues such as wood fibers. Such as boxwood, maple, birch, eucalyptus, etc.

4. Tangential: axial thin-walled tissue composed of 1 to 3 cells wide transverse intermittent short tangent lines. Such as persimmon, maple poplar, walnut, etc.

5. Reticulate: if its distribution distance and wood ray separation distance is almost equal width, that is, the reticulate type. Such as hickory genus, persimmon, fenugreek family.

6. Ribbon-like: The ribbon-like axial thin-walled tissue is generally divided into two types: evening-tube type ribbon-like and off-tube type ribbon-like. Sometimes when the two states are difficult to distinguish, can be collectively referred to as banded. This type of axial thin-walled tissue is generally 3 or more cells in width, and also presents a certain arrangement rule, as the heart band. If the width of the axial thin-walled tissue band is the same as or wider than the width of the intervening wood fiber band, it is called broad banding.

7. Trapezoidal: when the distance between the wood rays is wider than the distance between the linear bands, it is called trapezoidal. Such as chicken claw tree.

Figure 1. Axial parenchyma distribution types of hardwood.

(IV) Paratracheal parenchyma.

Pontine axial thin-walled tissues mostly surround the ducts and are contiguous with the duct pores in a light-colored ring. There are several types as follows.
1. Sparse evening tubular: axial thin-walled tissue around the duct alone, or arranged into incomplete sheaths, such as alder, wood lotus, etc.

2. Unilateral evening tubular: axial thin-walled tissue is limited to the lateral or medial distribution of the duct, such as thick-barked incense, date palm, etc.

3. Annular tubular: axial thin-walled tissue completely around the conduit, round or ovoid, such as sycamore, balsam fir, catalpa, big-leafed eucalyptus, etc.

4. Winged: axial thin-walled tissue around the ducts to the left and right, in the shape of a bird-wing arrangement, such as paulownia, acacia, etc.

5. Polyfoil-like: wing-like thin-walled tissues are connected laterally in irregular tangential or oblique bands, such as beech, acacia, palm tree, etc.

6. Banded: axial thin-walled tissue around the duct, showing a narrow or wide band between adjacent pores. The axial thin-walled tissue is also divided into two types: wide band and narrow band. The broad-banded axial thin-walled tissue is easy to observe and is generally visible to the naked eye, and this type of tree species is commonly found in the tropics and subtropics. Examples include: ironwood, ficus, yellow sandalwood, quercus, etc.

**Computer Vision Technology**

Computer vision is the study of specifically how to use computers to understand and analyze things in the hope of replacing the functions of the human eye. To be precise, it is the expectation that computers can acquire those functions of the human eye, that is, the ability to segment, identify, and categorize things independently. Computer vision technology integrates the knowledge of many disciplines into one, and its applications, including image processing technology, pattern recognition technology, and artificial intelligence, are very broad and involve many fields. Because of its wide range of applications, it has attracted the interest of many scholars in recent years, and many scholars have started to join in its research. After years of development, many achievements have been made, and it has its wide application in many fields, such as: medical diagnosis, wood defect detection, target recognition, positioning navigation, etc.

In the future, with the gradual maturity of the technology, computer vision products will be more and more, is bound to make China's computer vision applications produce qualitative changes. Product applications from the low-end to high-end, making the product towards automation, intelligent direction. In addition, personalized service will also be an important means to gain competitiveness in the market in the future. Because different users have different
needs, how to better meet the different needs of customers, will become increasingly important, so for different users to design personalized service products, will be a direction of computer vision in the future.

*Digital image processing technology*

Digital image processing technology is an important part of computer vision. Today, many fields are involved in digital image processing technology, and it is used in a wide range of applications, such as wood defect detection, target identification and tracking, weather forecasting, etc. After the original image is processed, not only the quality will be improved, but also it will facilitate further analysis and processing of the image. Digital image processing technology has the following main components.

(I) Image Enhancement.

Image enhancement is commonly used in image pre-processing, and its function is to highlight the desired features in the image and filter out the unwanted features. Image enhancement is generally divided into two types: frequency domain method and spatial domain method. Frequency-domain method is to apply Fourier method to image processing. Since some noise and unnecessary features in the image are mainly concentrated in the high-frequency region, a low-pass filter can be used to filter out the high-frequency part, i.e., the noise can be removed. If high-pass filter is used, it cannot play the role of noise reduction, but it can enhance the edge signal of the image, so that the unclear image becomes clearer. The better algorithms in the spatial domain method are two: the average method and median filtering. Both of these methods have good results after processing the image, and the image quality will be better for analysis and processing.

(II) Image smoothing.

The purpose of image smoothing is to reduce noise. In the process of imaging, the image will inevitably be disturbed by external and internal factors, which will make some noise in the image. Some noise is not similar or related to the information in the image, while some noise is similar or related to the information in the image. These noises not only affect the quality of the image, but also increase the difficulty of the subsequent image processing. Therefore, it is necessary to reduce the noise in the image. There are three general methods of image smoothing: interpolation, linear smoothing, and convolution. The effect is different after processing by different methods. Therefore, the characteristics of the image should be analyzed in the image smoothing process, and the images with different characteristics should be
smoothed by different methods so that good results can be achieved, one can remove the influence of noise in the image, and the other can maintain the integrity of the image information.

(III) Image coding and transmission.

The amount of data contained in a digital image is huge, and if it needs to be transmitted, then a high transmission rate is inevitably required. The increase in the transmission rate then the cost of transmission will also increase, which will make it difficult to mass. Therefore, it is necessary to compress the image before transmission in order to reduce the cost.

The principle of compression of an image is to reduce the amount of data that represents the image. The image can be compressed because of the large amount of redundancy between the amount of data in the image. There are two main types of image compression: the first is lossy compression and the second is lossless compression. Lossless compression is suitable for natural images, if it causes a little loss of image data, but does not have much impact on the overall; lossless compression is suitable for valuable images, causing very little loss and ensuring the integrity of the data.

(IV) Image edge sharpening.

The function of image edge sharpening is to make the edges of different parts of the image clearer and more complete, so that different target areas in the image can be distinguished, which is conducive to target edge extraction, target recognition and target shape extraction, and is helpful for further analysis and processing of the image. There are three main methods: the first is the differential operator; the second is gradient sharpening; and the third is edge detection. All three methods applied to image sharpening can make the contour edges of the image clearer and all have good results.

(V) Image segmentation.

Image segmentation is the division of an image into several parts or regions, and the degree of segmentation is limited by the specific object to be segmented. When segmenting an image, each region is segmented according to the grayscale or texture feature pattern. The essence of image segmentation is to categorize pixels with the same or similar characteristics according to some characteristics of the pixels (such as grayscale values, spectral characteristics, etc.). Image segmentation is a key technique of image processing, which directly affects the recognition effect of images. There are four main methods of image segmentation: the first is the threshold segmentation method; the second is the edge segmentation algorithm; the third is the region segmentation; and the fourth is the specific theoretical segmentation. The
characteristics of various segmentation methods will be introduced in detail in Section «Digital image segmentation methods».

**Data acquisition platform**

The production of microscopic images of wood takes a lot of time and is a very complex task. For axial thin-walled tissue extraction, the quality of the images is directly related to the effectiveness of the extraction of axial thin-walled tissue. Usually, the only way to obtain images is by making slices, then observing them through a microscope, and finally taking pictures of the observed images. The steps for acquiring microscopic images of wood are shown in Figure 2.

![Figure 2. Steps to make microscopic image of wood.](image)

The steps of making microscopic images of wood are: specimen preparation, specimen softening, slicing, filming, temporary slide making, image acquisition, and data output. A square specimen with a chord length of 20 mm, a diameter length of 20 mm and a height length of 20 mm is cut and softened, usually by boiling, until it is sufficiently softened for slicing [16-18]. The softened specimens are sliced with a slicer and then placed in a container with distilled water, at which time the better-quality slices are selected from the container for staining. The staining process is divided into four steps in sequence: the first step is distilled water rinsing; the second step is iron alum solution; the third step is distilled water rinsing; and the fourth step is red dye solution. The sections are then dehydrated with 30%-100% alcohol, followed by a transparent treatment with xylene, and finally placed on a slide with a few drops of glycerol, and the coverslip is pressed down for drying. After drying, the sections can be observed with a
microscope by taking images, each of which contains at least one annual ring. One should find a position with good image quality to take the picture.

Data processing platform

MATLAB was formerly known as Matrix Laboratory, called Matrix Laboratory. It is the most practical and convenient tool for digital image processing. It has a rich and extensive library of functions, and these functions can be used to process arrays. The image can be seen as a two-dimensional array, so it can be easily processed in the MATLAB environment.

MATLAB is a software developed by American MathWorks with great capital and manpower, which has powerful functions for data analysis, matrix calculation and graphics processing. There are other functional toolkits in MATLAB besides the main toolkit, about 30 kinds of toolkits, which can solve the problems in some fields. Other functional toolkits are mainly: communication, finance and finance, simulation logic, optimization, splines, control systems, statistics, image processing, neural networks, signal processing, micro-partial engineering, wavelet toolkit, and so on. With the help of these toolboxes, analytical, computational and design work can be easily performed.

MATLAB has great applications in wood microscopic cell analysis due to its powerful capabilities in digital image processing. The wood image processing used in this paper was all implemented in MATLAB 7.0, from image pre-processing, later morphological processing, all the way to the final separation of axial thin-walled tissues, all of which were analyzed using MATLAB.

Summary of this chapter

This chapter introduces the theoretical basis of wood axial thin-wall extraction, mainly including the basic knowledge of wood science, computer vision techniques, methods of acquiring wood microscopic images, and experimental platforms. The focus is on the distribution characteristics of wood microstructure and axial thin-wall tissue, and some aspects of image processing techniques in computer vision are introduced. At the end of this chapter, the methods of wood image acquisition and the experimental platform MATLAB.
EXTRACTION OF AXIAL THIN-WALLED TISSUES AND DUCTS IN WOOD CROSS-SECTION IMAGES

Both axial thin-walled tissue and ducts are important features for broadleaf timber identification. There are more methods for the extraction of conduits, for example, Qi Hennian et al studied a morphology-based wood conduit image segmentation method; Wang Hangjun et al explored a wood conduit image segmentation method based on image processing techniques and combined with the distribution characteristics of wood conduits; Ji Zhiwei et al proposed a wood conduit image segmentation algorithm based on improved region growth by using the idea of region growth and after research. The intelligent segmentation algorithm of wood conduit image based on improved region growth was proposed by Ji Zhiwei et al. However, the study of axial thin-walled tissue extraction is rare, which is also due to the fact that the texture features of axial thin-walled tissue are complicated and difficult to extract. Therefore, this chapter introduces the principles of several common image segmentation algorithms, illustrates their advantages and disadvantages, and on this basis, the extraction methods of axial thin-walled tissues and conduits are proposed based on the characteristics of wood microscopic image texture structure, which is a preface to the next chapter to study the extraction of axial thin-walled tissues.

Digital image segmentation methods

Digital image segmentation is a very important technique in digital imaging that has been of interest since the 1960s and 1970s. Image segmentation is the segmentation of regions of special significance in an image from other regions of the image, which is fundamental to image understanding and lays the foundation for image analysis. Therefore, the study of image segmentation will promote the development of computer vision technology. However, image segmentation is a difficult technique in image processing, and it is also difficult to achieve good segmentation results. After decades of research and development, the commonly used digital image segmentation methods are as follows:

(I) Threshold segmentation.

Thresholding is the process of determining a suitable threshold value to segment the desired region of an image. Thresholding is the transformation of the input image \( f \) as follows:

\[
y(x, y) = \begin{cases} 
1, & f(x, y) \geq Q \\
0, & f(x, y) < Q 
\end{cases}
\]

(1)
Q is the threshold value, and the gray value of each pixel point in the image is compared with the threshold value, and all pixel points greater than or equal to the threshold value are identified as one class, and all pixel points less than the threshold value are identified as another class. Therefore, the key to threshold segmentation is to determine a suitable threshold value, and the current research attention on threshold segmentation algorithms is focused on the determination of the threshold value.

Threshold segmentation has its unique advantages, such as simple and efficient processing of data. With the focus on efficiency, threshold segmentation methods are widely used. Threshold segmentation generally has two forms: global thresholding and local thresholding. For an image, global thresholding determines only one threshold value, and threshold segmentation processing is performed with one threshold value, which has its own range of application and is generally suitable for images with significant differences in pixel gray values. In many cases, the distribution of gray values in different regions of the image presents different characteristics, and the global threshold is not very suitable for image segmentation. In this case, it is necessary to use local thresholding for image segmentation by using the distribution characteristics of different regions at all. Although local thresholding has its advantages, it also has shortcomings [19-21]. The disadvantage is that it is easily affected by noise, which in turn affects the segmentation effect. Therefore, in the image processing process, the threshold segmentation method is generally not used alone, often used together with other segmentation methods.

(II) Edge segmentation.

One important way of image segmentation is by edge detection, i.e., detecting places where gray levels or structures have abrupt changes, indicating the end of one region and the beginning of another. This discontinuity is called an edge. Different images have different gray levels, and there are generally distinct edges at the boundaries, and this feature can be used to segment the image.

The pixel values of the edges of each part of the image have differences and discontinuities, and this feature can be used to distinguish different parts of the image, which is generally achieved by using derivatives. Commonly, there are step-like edges, and their positions can be distinguished by finding the first-order derivative and second-order derivative. So edge detection as well as segmentation are most commonly used by differential operators. For edge segmentation, first-order and second-order differential operators are commonly used. The first-order differential operators are: Prewitt operator, Sobel operator, Roberts operator and
so on. Second-order differential operators include Laplace operator, Krish operator and so on. The differential operator is represented by a structural template, and the differential operation is implemented by using the structural template and the convolution of the image.

The disadvantage of edge segmentation is also obvious, that is, it is easy to be affected by noise, and its application range is also narrow, only for simple, low-noise images.

(III) Region segmentation.

Region segmentation is the combination of similar or identical nature of pixel points together to form a region, so that the effect of segmentation is achieved. Region growth is the most basic and effective way of it. The principle of region growing is: firstly, a part or region to be segmented is identified in the image, secondly, a seed pixel point is identified in the region, then the pixel point is used as the starting point for growth, and the surrounding pixels with the same or similar properties are combined into a region. Finally, each newly merged pixel point is used as a new seed pixel point, and the above operation is continued until there are no more pixel points that satisfy the condition. Following the above operation, a region is formed.

The key to region growth is the determination of seed pixel points, the determination of similarity conditions, and the region growth criterion. The determined seed pixel points can be either single pixel points or multiple pixel points combined into one region. The similarity conditions are the texture characteristics of the image, such as: gray level, gradient, texture, etc. [22-24]. The region growth criterion is basically based on the local nature of the image, and different growth criteria all have some effect on the segmentation of the image.

The biggest advantage of the region growth method is that it is very simple to compute and works very well with some images, such as homogeneous target images. However, its disadvantages are also obvious: it is sensitive to noise and slow in segmentation, especially when processing a large amount of data.

(IV) Theory-specific segmentation methods.

In recent years, with the development of digital image processing technology, some new methods of image segmentation have emerged. For example, cluster analysis, fuzzy set theory, genetic coding, mathematical morphology, neural network, etc.

Although there are many image segmentation algorithms, in order to get a good segmentation effect, when choosing an image segmentation method, we must depend on the situation of the specific segmentation object. In the process of studying the segmentation of wood recognition features, we found that wood images are inevitably affected by noise during the acquisition process, and wood image texture features are also complex, so it is difficult to
get good segmentation results with the commonly used segmentation methods. Therefore, this paper combines the distribution characteristics of axial thin-walled tissues in wood cross-section images and previous research on morphology-based wood conduit extraction methods, so this paper decides to apply the morphology method to the extraction of axial thin-walled tissues, and after several experiments, we found that only the morphology method cannot successfully extract axial thin-walled tissues. However, it was found that the morphology of axial thin-walled tissues and ducts in wood cross-sections could be well extracted by image pre-processing and setting appropriate structural elements for morphological processing. In the following sections, the mathematical morphology theory and the mathematical morphology-based algorithm for axial thin-walled tissue and duct extraction in this paper will be discussed step by step.

Mathematical morphology theory

In 1960, mathematical morphology began to emerge as a new nonlinear operator and a new type of theory with a target and a focus on the analysis and study of the geometric properties of images. Since the analysis of image information starts from the geometric properties of the object, mathematical morphology has its unique advantages and is well suited to analyze and process image information, and these operations are realized by the basic operations of mathematical morphology. The main idea is to use structural elements with certain morphology to process images for the purpose of feature extraction.

The development of mathematical morphology is based on set theory, and digital images can be regarded as special cases of sets, and mathematical morphology also has a good mathematical foundation, so it can be said that these have laid a certain theoretical foundation for mathematical morphology to be good for the analysis and processing of images. The application of mathematical morphology in image processing has certain advantages: first, it simplifies images, maintains their basic morphological properties, and removes unwanted structures; second, it has a natural parallel structure, which greatly increases the efficiency of processing.

Mathematical morphology has the following basic operations: i. expansion; ii. erosion; iii. open operation; iv. closed operation. For binary and grayscale images, they have different characteristics. In addition, these four basic operations can be combined into other operations by which images can be analyzed and processed, such as: image enhancement, image restoration, image denoising, image segmentation, etc. The basic idea of mathematical
morphology is to select a suitable structural element as a "probe", and combine the basic operations to obtain, detect and study the structural features of the image, so as to achieve the purpose of analysis and processing of the image. Mathematical morphological methods have great applications in image processing, and they are used in almost all aspects of image processing, such as image segmentation based on the concept of watershed, analysis based on morphological filters, skeleton extraction based on erosion operations, image coding and compression, target recognition, image reconstruction, etc. It can be said that so far, there is no method like the mathematical morphology method, which has both unified ideas, rigorous theoretical basis, and powerful application space and practical value.

One of the major features of mathematical morphology is its rigorous mathematical theoretical foundation, which has made a great impact on the theory and technology of image processing. Nowadays, mathematical morphology has formed new methods and theories in the field of image processing and has become an important research direction in the field of image analysis and processing, and its applications have been widely used, penetrating into digital image analysis and processing in many disciplines. The basic idea of morphology is shown in Figure 3:

![Figure 3. Basic idea of mathematical morphology.](image)

**Extraction of axial thin-walled tissue and ducts based on mathematical morphology**

The extraction of axial thin-walled tissues of wood is very difficult. This is because (1) the features of axial thin-walled tissues in some wood images are not obvious, and the texture features of axial thin-walled tissues are also complicated; (2) wood microscopic images are affected by the external environment during the production and acquisition process, and there
is a lot of interference information in the images; (3) the distribution of axial thin-walled tissues varies greatly among different tree species, and it is difficult to find a suitable axial thin-walled tissue for all tree species. It is difficult to find a suitable extraction method for all tree species. All these factors affect and limit the development of axial thin-walled tissue extraction technology [22].

![Flow char for the extraction of axial Parenchyma and pores](#)

**Figure 4.** Flow char for the extraction of axial Parenchyma and pores.
In this paper, we study the characteristics of wood images and the actual situation of recognition feature extraction in wood images, and propose a morphology-based extraction method for axial thin-walled tissues and ducts. In this paper, we first grayscale the image, converting the color image into grayscale image, which is to avoid chromatic aberration affecting the extraction effect, and then binarize the grayscale image, which is the image showing obvious black and white effect, and also can remove the influence of some normal textures in the wood image, and finally, according to the wood image characteristics, select the appropriate structural elements for morphological processing of the image, and complete the extraction of axial thin-walled tissues and conduits is completed. The flow chart of this algorithm is shown in Figure 4.

In this section, the extraction process of axial thin-walled tissues and ducts is discussed step by step and experimentally demonstrated.

*Image grayscale processing*

Wood display images are obtained by making wood slices, then observing them through a microscope, and finally taking photographs. The wood micrographs usually obtained by photographing are true color images, and each pixel is represented by three components, i.e., red (R), green (G), and blue (B), and the value of each component is between 0 and 255. Since the color image has three components, the arrangement and combination of information is complicated, which is not conducive to the extraction of thin-walled tissues and ducts in the wood axial direction, so grayscale processing of the color image is required.

![Gray processing of microscopic image about Castanopsis megaphylla](image)

*Figure 5.* Gray processing of microscopic image about Castanopsis megaphylla (a) wood microscopic image; (b) the image after gray processing.
The conversion of the color image to grayscale can be achieved by the following equation (2). Figure 5 shows the microscopic image of macropyramidal cone and the image after grayscale processing.

\[ f(x, y) = 0.3R(x, y) + 0.59G(x, y) + 0.11B(x, y) \]  

(2)

*Image noise reduction processing*

Wood microscopic images are susceptible to the influence of other external factors (e.g., interference from noise) during the production process, which in turn leads to image quality degradation and is detrimental to the extraction of axial thin-walled tissue and duct morphology. Therefore, noise reduction is necessary to reduce the influence of noise and improve the quality of images before morphological processing is performed. Further analysis of this noise information reveals that the general noise energy is concentrated in the high frequency part, while the image spectrum is distributed in the middle and low frequency parts. According to this feature, median filtering can be used to denoise.

Median filtering is a common nonlinear signal processing technique that can reduce noise while also effectively preserving edges and reducing blur. Its main idea is to take the median value as the new value of the gray value of the center pixel after sorting the gray value of the pixels in the window according to their size. The window is generally used as a square, too small generally b*b, and b is an odd number.

Let \( f(x, y) \) be the microscopic image of wood, \( g(x, y) \) be the median filtered image, and the filter window is \( W \), \( g(x, y) \) can be calculated by Equation 3:

\[ g(x, y) = \text{Med}\{f(x-k,y-l),(k,l) \in W\} \]  

(3)

*Image binarization*

*Fundamentals of binarization.* Image binarization is the conversion of all pixel points in an image into two values: 0 and 255, and the binarized image will show a black and white effect. Binarization is used to convert grayscale images into binary images that reflect the overall or local characteristics of the image by determining a suitable threshold. In the analysis and processing of digital images, binarization is increasingly used, especially in practical image analysis and processing systems [23]. One of the advantages of binarization is that there are
only two kinds of pixels in the binarized image, and there are no multi-level values of pixels, which makes the amount of data compressed greatly and facilitates the processing of data, and it is also easier to analyze the image for further processing. For image binarization, the selection of the threshold value is the key. All pixels greater than or equal to the threshold value are grouped into one category, represented by the gray value 255, and all pixels less than the threshold value are grouped into another category, represented by the gray value 0. Binarization works better if closed, connected boundaries are used to define regions that do not overlap. The threshold segmentation method works better if the gray values of the image have uniform consistency and the region to be segmented is in a uniform background of gray values of other regions. If the background difference of different regions is not on the gray value, then it can be transformed to the difference of gray value and then segmented by using the thresholding method. Based on the complexity of image features, dynamic adjustment of thresholding is increasingly meeting the need of binarization, and the threshold can be dynamically adjusted to observe the effect of its processing image in real time.

*Common methods of binarization.* Depending on the selection of the threshold, binarization algorithms are classified into fixed and adaptive thresholds. The more commonly used binarization methods are: bimodal method, P-parameter method, iterative method and OTSU method.

*Binarization features of this paper.* The basic idea of the maximum interclass variance method (sometimes called the Otsu method) proposed by Otsu in 1979 is to set a threshold to segment the image into two groups, one group of grayscale corresponding to the target and the other group of grayscale corresponding to the background, then the intraclass variance of these two groups of grayscale values is the smallest and the interclass variance of the two groups is the largest.

Let \( f(i, j) \) be the gray value at the point \((i, j)\) of the \(N \times M\) image with gray level \(\mu\), and it may be assumed that \(f(i, j)\) takes the value \([0, m-1]\). Letting \(p(k)\) be the frequency with gray value \(k\), we have:

\[
p(k) = \frac{1}{MN} \sum_{f(i,j)=k} 1
\]

(4)

Assume that the target and background segmented with a gray value \(t\) as the threshold are:
\{f(i,j) \leq t\} and \{f(i,j) > t\}. Thus, the target component ratio.

Target section points:
\[
o_b(t) = \sum_{i \in \Omega_b} p(i),
\]
(5)

Background part scale:
\[
N_b(t) = MN \sum_{i \in \Omega} p(i)
\]
(6)

Background section points:
\[
o_1(t) = \sum_{i \in \Omega} p(i)
\]
(7)

Target mean value:
\[
\mu_b(t) = \frac{\sum_{i \in \Omega_b} ip(i)}{o_b(t)}
\]
(9)

Background mean value:
\[
\mu_1(t) = \frac{\sum_{i \in \Omega} ip(i)}{o_1(t)}
\]
(10)

Total mean value:
\[
\mu = o_b(t)\mu_b(t) + o_1(t)\mu_1(t)
\]
(11)

The Otsu method states that the formula for finding the optimal threshold \(g\) for an image is:
\[
g = \text{Arg} \ Max_{0 \leq t \leq 1} \left[ o_b(t) (\mu_b(t) - \mu)^2 + o_1(t) (\mu_1(t) - \mu)^2 \right]
\]
(12)

Although the Otsu algorithm is also used to calculate the threshold of the image, the binarization in this paper has a special feature: instead of global binarization, the image is divided into four pieces, and the Otsu algorithm is used to calculate the threshold for each piece, and then the binarization is performed separately.

Global binarization, which is setting a global threshold \(Q\), divides the data of the image into two parts: the group of pixels larger than \(Q\) and the group of pixels smaller than \(Q\). The pixel group larger than \(Q\) is set to white and the pixel group smaller than \(Q\) is set to black. The binarization change formula is shown in Eq. (12). However, the pixel distribution characteristics of different regions of an image are different. However, the pixel distribution
characteristics of different regions of an image are different, and the global binarization has
great defects in representing the details of the image. In order to remedy this defect, the global
binarization is used for the whole image. this paper, the whole image is divided into four regions
of the same size, and each of them has an independent in this paper, the whole image is divided
into four equal-sized areas, each with a separate threshold, so that the binarization can highlight
the black-and-white effect and facilitate the extraction of axial thin-walled tissue and duct
morphology.

Mathematical morphology processing

Basic operations of mathematical morphology. The basic operations of mathematical
morphology are expansion and erosion, and there are three types of images processed: binary
images, grayscale images, and color images. This paper focuses on morphological processing
of binary images. The difference between binary images and other images for morphological
processing is that binary images can be regarded as sets, and the other two images are regarded
as image functions.

(I) Expansion.

Expansion is the operation of "lengthening" or "thickening" a binary image. This
particular way and the degree of thickening is controlled by a set of elements called structural
elements.

Mathematically, expansion is defined as a set operation. A is expanded by B, denoted A
⊕ B, and is defined as:

\[ A \oplus B = \{ x | \left( \hat{B} \right) x \cap A \neq 0 \} \]  

(13)

The above equation shows that the process of expanding A with B is to first map B about
the origin and then translate its image by x. Here the intersection of the images of A and B
cannot be the empty set. In other words, the set obtained by expanding A with B is the set of
the positions of the origin of B when the displacement of B intersects at least one nonzero
element of A. According to this interpretation, Eq. (13) can also be written as:

\[ A \oplus B = \{ x | \left( \hat{B} \right) x \cap A \subseteq A \} \]  

(14)
Diagrammatic representation of the expansion operation:

Figure 6 gives an example of expansion, where the shaded part in figure (a) is the set A, the shaded part in figure (b) is the structural element B (with the origin at the point marked "+"), which is reflected in figure (c), and the two shaded parts in figure (d) (where the darker color is the expanded part) together are the set $A \oplus B$. The expansion expands the image area as seen in the figure.

(II) Erosion.

Erosion is the object of the "shrinkage" and "refinement" binary image. As in expansion, the manner and extent of contraction is controlled by a structural element.

A is corroded by B, denoted $A \ominus B$, which is defined as:

$$A \ominus B = \{x \mid (B)_x \subseteq A\}$$

(15)

The above equation shows that the result of corrupting A with B is the set of all A's where B is still in A after translation $x$. In other words, the set obtained by corrupting A with B is the set of B's origin positions when B is completely included in A. The above equation can also help one understand the operation of corrosion with the help of related concepts [25-27].

(III) Illustration of the corrosion operation.

Figure 7 gives a simple demonstration of the corrosion operation. The set A in Fig. (a) and the structural element B in Fig. (b) are the same as in Fig. 6, while the shaded part in Fig. (c) gives $AB$ (the light color is the part belonging to A now corroded). From the figure, it can be seen that the erosion has shrunk the image area.
Selection of structural elements. The appropriate structural element is crucial to the effect after morphological processing of the image. Just like the filtering window in the signal processing, different morphological structural elements can be selected to remove different noises or extract different structures from the image. The structural elements can be regarded as a small set of images, and an origin can be selected for each of the different structural elements as its reference point to participate in the morphological processing. Both expansion and erosion operations in the basic morphological operations can filter out specific image details that are smaller than the structural elements, thus smoothing the image contours without distorting the image globally. Closed operations can fill gaps and connect short interruptions smaller than structural elements, so they can be used to fill defects in the image and thus smooth the image contours. The open operation generally has a separating effect, such as removing spurs smaller than structural elements, cutting off thin and long laps, etc., and can therefore be used to filter out spurs and raised parts of the image.

In applying mathematical morphology to segment axially thin-walled tissue and duct morphology in wood images, the selection of structural elements is crucial. Structural elements are the basic operators in morphological processing, and the selection of appropriate structural elements for image processing is directly related to the quality and effect of the processed images. The key to the selection of structural elements is how to determine the shape and size of structural elements. The effect after processing is different for different shapes of structural elements.

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**Figure 7.** The demonstration diagram of corrosion effect.
(I) Shape of structural elements.

Theoretically, any geometrically shaped structural element can be used for morphological processing, but in practice, not all shapes of structural elements are available, and the selection of structural elements must satisfy the geometrical characteristics of the processed image. The shapes of structural elements are generally classified into two types: symmetric structural elements and asymmetric structural elements. In morphological processing, symmetric structural elements are generally used. This is because an offset may occur when applying asymmetric structure element operations [28-30].

The geometric shapes of structural elements can be classified as: disc, rectangle, rhombus, square, line segment, hexagon, octamorphism, etc. Disc-shaped structural elements are homogeneous in all directions, and the results after the operation are independent of the directions. Squares, rectangles, rhombuses, hexagons, and eight deformations can be seen as variants of disc shapes. The results after processing of different structural elements are very different, so it is said that different structural elements should be selected for different geometric characteristics of images.

(II) Size of structural elements.

After the shape of the structural element is determined, we have to determine the size of the structural element. The size of the structural element is too large or too small to facilitate the extraction of features in the image. How to determine the size of structural elements is described in the next section.

**SUMMARY AND OUTLOOK**

This thesis introduces the research background and significance of the topic, the current research status and development trend at home and abroad, the main research content of the thesis, and the organization. The required knowledge is analyzed, e.g., microstructural mechanisms of wood, distribution characteristics of axial thin-walled tissue, computer vision techniques, etc. Theoretical and technical support is provided for the thesis research. The acquisition of experimental data for this paper and the platform for processing the data are then also presented. Then the extraction methods of axial thin-walled tissues and ducts in wood microscopic images are proposed. Various methods of image segmentation are first analyzed and combined with previous studies, a mathematical morphology-based algorithm for the extraction of axial thin-walled tissues and ducts is proposed.
In the subsequent study, we will carefully analyze each step of the algorithm process and try to analyze and verify the effectiveness of the algorithm through experiments.

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