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Wood species identification using improved active shape model

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ABSTRACT

In this paper, we propose a robust wood species identification scheme by using color wood surface images. First, a novel wood image acquirement system is devised, and the wood color image is converted into a V_1V_2I color-base image. Second, the corresponding grey histograms for V_1 and V_2 are established. Third, an improved active shape model is used to fulfill the curve deformation of the histogram curve of the standard specimen. This active shape model will then converge to the histogram curve of the test specimen. Finally, wood recognition is performed by comparing the initial and final active shape models with the histogram curve of the test specimen. We have experimentally proved that this scheme improves the mean recognition accuracy to approximately 90% for 5 wood species and that it can also be applied to the Gaussian noisy images. Moreover, the recognition accuracy can be further improved by combining this scheme with the texture feature recognition.

1. Introduction

Wood species recognition is a significant issue in the wood industry so as to judge the physical property and economic value of different wood species correctly [1]. It can be used in some fields of the wood industry such as the wood assortment and the wood price so as to decrease the economic losses from the wood species misclassification. Some visual image characteristics have been used in the wood species recognition, and can be divided into two general categories: wood surface's texture analysis [2,3] and its color analysis [4,5]. For example, we propose a wood species identification scheme based on the image blur information [6]. In this scheme, the blur-invariant-moment features are used in the recognition. The allowed maximum translation speed of the detected wood is also calculated by using image blur information. Recently, the wood spectral reflectance characteristics are also exploited for the species classification. The more common schemes in the literature consider the vibration spectroscopy [7,8] and the Raman spectroscopy [9]. For example, Piuri and Scotti present a scheme for the wood species classification based on the analysis of fluorescence spectra [10]. The proposed scheme partitions the input spectra in different bands equally spaced. The energy contained in each band is used in input to the classifier. This simple experimental setup and the limited computational complexity permit the realization of wood species classification in real-time applications.

However, the current wood species recognition based on color features is sometimes poor especially for those wood species which have similar color structure information. Moreover, for every wood species, the color variations of wood panels usually occur with different growing conditions, exposure time in air, sapwood/heartwood, earlywood/latewood. Therefore, the individual wood panel's color difference consists of the intraspecific color variation and the interspecific color variation. The mixture of these two color variations may decrease the wood recognition accuracy, since the intraspecific color variation may blanket the interspecific color variation. In fact, the current color-based recognition schemes do not take into account these two color variations with different natures.

In this paper, we propose a novel color recognition scheme that considers the above-mentioned color's intraspecific and interspecific variations. This recognition scheme can both effectively tolerate the intraspecific color variation and effectively identify the interspecific color variation. We provide a fundamental experimental framework for a robust/accurate wood color recognition work. This framework can effectively and quickly identify the wood species by means of the color recognition so as to judge the physical property and economic value of different wood species panels correctly. It can be used in some fields of the wood industry such as the wood assortment and the wood price so as to decrease the economic losses from the wood species misclassification.

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0030-4026/

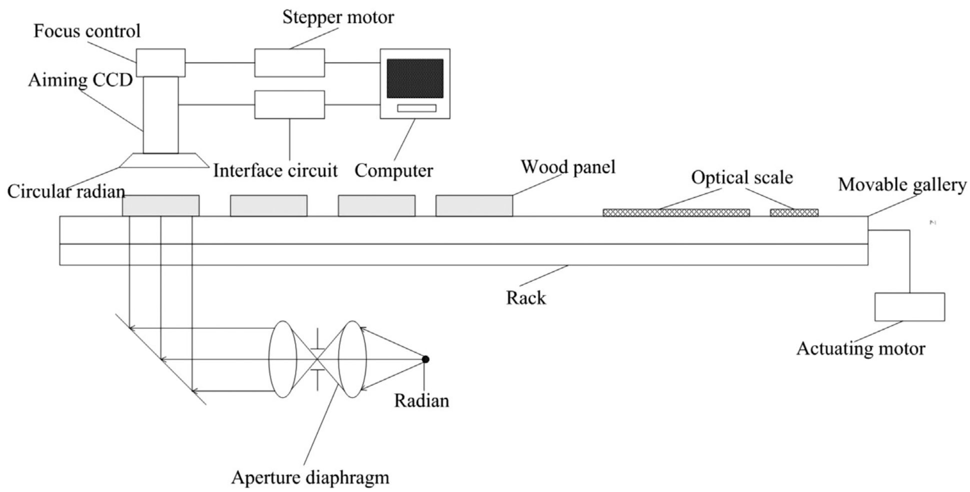

Fig. 1. The structure graph of our 2-D wood image acquirement system.

2. Materials and methods

2.1. Wood image acquirement system

One novel wood image acquirement system is devised as in Fig. 1. An image aiming system is the main part of the wood image acquirement system. In Fig. 1, the ray from the radian goes through the collimation path and is projected onto the detected object's surface (i.e. the wood panel). The wood panel image is picked up by a color CCD camera. After a photoelectric transform, this image is sent into the computer by the interface circuit to form the digital image which will be used in the wood recognition task. When multiple wood panels are measured, the working gallery should be moved with a uniform velocity in the X or Y direction, to make every panel's surface enter the view field of the aiming CCD camera sequentially. This operation can be performed by the software operation interface in the computer. In our experimental setup, a Sony WV-CP240EXCH color camera is used to obtain the wood panel images with resolution 768×576. The LED circular radian is used to obtain the uniform lighting conditions as illustrated in Fig. 2 with structure parameters $d_1 = 45$ mm, $d_2 = 100$ mm, $h = 17.2$ mm, $\alpha = 116^{\circ}$. The Navitar zoom optical system is used with structure parameters such as working distance 37 mm $\le wd \le$ 234 mm, numerical aperture $0.018 \le \mathrm{NA} \le 0.1$. This zoom system consists of the frontal lens group, zoom lens group and rear lens group. As for the accurate adjustment of the wood panel position in the *X* direction or *Y* direction, the optical scale can be used to fulfill this task, whose reading resolution is 0.1 μm here. The *X* and *Y* displacements of the working gallery can also be measured by the optical scale.

2.2. Color space conversion

For the color wood panel images, the RGB color base does not appear to give accurate colorimetric information when images are acquired under variable light conditions. In this case, the color levels depend on lightness, which has to be separated from chromatic values. Here we use a color base which is a linear combination of RGB values proposed by Steward and Tian [11]:

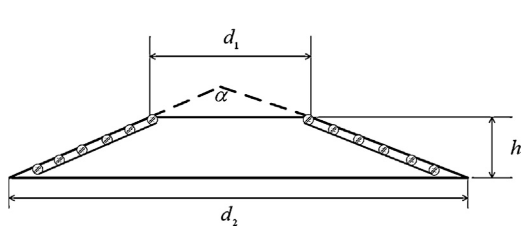

Fig. 2. The structure graph of our circular radian.

$$\begin{bmatrix} V_1 \\ V_2 \\ I \end{bmatrix} = \begin{bmatrix} \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ \frac{-1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & \frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{1}$$

Eq. (1) describes the color base transformation. The vector (V_1, V_2, I) is unitary and perpendicular, so information is fully independent. Here I corresponds to the luminosity element including shadows and reflections, and (V_1, V_2) provides a colorimetric plane. For example, V_1 is defined as the difference between red and green channels. Therefore, we only use the vector (V_1, V_2) for the subsequent wood color recognition to get rid of the disturbance of luminosity, shadows and reflections from the component I.

2.3. Histogram curve convergence by an improved active shape model

Active shape model is a deformable template that can only deform according to criteria defined by a set of training images. This model is presented by Cootes and Taylor [12] and it is suitable for matching objects that can vary in shape. This scheme is based on building a statistical model from training images and then using the model to search for similar objects. The original active shape model has three important features. First, it is usually represented manually with landmarks (i.e. the discrete pixel points) to fulfill its initialization procedure. Second, after its manual initialization, the model shape formed by landmarks is required to be aligned to reduce the impact of rotation, translation and scale. Third, in the curve deformation process, the model's position update parameters $\Delta\theta$, $\Delta\mathbf{x}_c$, Δs for rotation, translation and scale must be calculated in every iteration step.

In our scheme, one improved active shape model is proposed and used in the histogram curve matching. This improved model has three advantages compared to the original model. First, the histogram curve of the standard specimen is set as the initial active shape model $\mathbf{x}_{ini}$ automatically. This initial active shape model will then converge to the histogram curve of the test specimen (i.e. its species is unknown and will be classified by our scheme) to get the final convergent active shape model $\mathbf{x}_{fin}$ after multiple iterations. Second, the shape alignment of our improved model is not