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RESEARCH ARTICLE

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Automatic identification for standing tree limb pruning

Abstract To meet the demand of automatic pruning machines, this paper presents a new method for dynamic automatic identification of standing tree limbs and capture of the digital images of *Platycladus orientalis*. Methods of computer vision, image processing and wavelet analysis technology were used to compress, filter, segment, abate noise and capture the outline of the picture. We then present the arithmetic for dynamic automatic identification of standing tree limbs, extracting basic growth characteristics of the standing trees such as the form, size, degree of bending and their relative spatial position. We use pattern recognition technology to confirm the proportionate relationship matching the database and thus achieve the goal of dynamic automatic identification of standing tree limbs.

Keywords standing tree pruning, pattern recognition, image processing, wavelet analysis

1 Introduction

The traditional method for standing tree limb pruning is manual operation of a handheld pruning saw to prune the branches. This method has deficiencies such as low efficiency, limited height and frequent accidents. Many countries advanced in forestry such as Japan, France and Germany are dedicated to studies of automatic pruning technology, trying to develop an automatic pruning machine to resolve the problems and have finally developed a wireless remote controlled pruning machine. Chinese investigators also started to do research on automatic pruning machines (Zhang et al., 2003). Although the applications for the remote controlled pruning machine can improve efficiency and reduce accidents, it is only a wireless semi-automatic machine, which has no visual system and needs workers under the tree to direct the machine. This characteristic may cause accidents such as branches falling down on the workers; so it is very important to study intelligent automatic pruning machines. At present, there is little research on the subject in China. Tian Lei of the Illinois University Agriculture Department in the United States of America developed 'an automatic control system of weed in tomato fields based on machine vision' and 'the crop-dusting system based on the difference GPS'. University of California—Davis developed an accurate crop-dusting system for row crops, based on vision sensors (Zhao and Zheng, 2003). On the basis of forestry image processing in 1999, Nanjing Forestry University commenced research on accurate crop-dusting technology. They used real-time systems to capture and process forest images, as well as fractal theory and neural networks to recognize tree forms. This system can recognize images of simple backgrounds and a single colour, but there are large errors in complex images. We used a digital image processing and pattern recognition technology to establish an arithmetic for dynamic automatic identification of standing tree limbs. We extracted the basic growth characteristics of standing trees such as form, size, bending degree and relative space position and established a basis for research on intelligent pruning machines.

2 Whole configuration and work principle of the identification system

This paper presents a new method for dynamic automatic identification of standing tree limbs to process the captured image, extract basic growth characteristics of crossing branch and trunk of standing trees, such as form, size and degree of bending, calculate their relative proportionate relation, match the database of the growth characteristic to identify the pruned branches and the fork-branches. This method extracts basic growth characteristic of standing trees for identification. This identification system (Fig. 1) manages the intelligent control.

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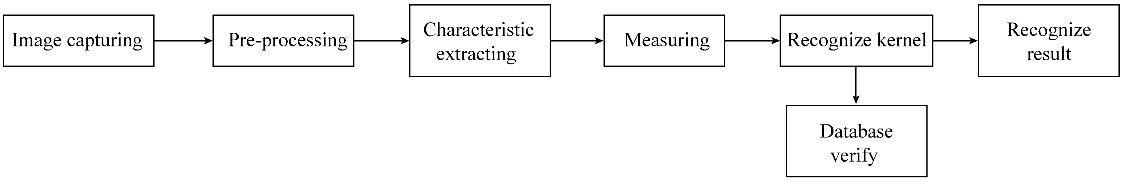

Fig. 1 Flow chart of automated identification system of standing tree limbs

3 Image pre-process

We capture the image of *Platycladus orientalis* by CCD camera and convert it to digital signals to store in the computer by an image capture card.

3.1 Image compressing

There is much redundant information in the data of the captured image. Because we need to transfer the data rapidly and in real time, we must compress the image. Wavelet analysis has characteristics such as a high compression ratio and rapid speed; it holds basic characteristics of images and can resist disturbance during the transfer process (Feisi Technology Product Center, 2003). The grey levels of the adjacent pixels of the standing tree image are highly correlative; so we can use wavelet analysis, adopt an appropriate coordinate transformation to wipe off the correlation and separate the images into approximate and detailed parts through multi-resolution analysis. The detailed part corresponds to the small-scale transient and it is very stable in its scale. The detailed part is saved in its scale and the approximate part decomposed in the next criterion. This process is duplicated and the goal of data compression is achieved.

3.2 Image filtering

A mid-value filter is a non-linear processing method to remove noise (Nie and Yong, 2002) that retains the detailed information of pictures while removing the noise. The formula of a mid-value filter is

$$f_{ij} = \text{med}\{f_{i+r,j+s}; (r,s) \in A\} \quad (1)$$

where A is the window whose size is $N = (2k+1)(2k+1)$, f_{ij} the two-dimensional signal, $(i, j) \in Z^2$ and $A \in Z^2$ is the neighbourhood of central position (i, j).

This paper uses one kind of mixed mid-value filter to rid the image of noise; this is a combination of the mid-centre value filter and other linear filters:

$$y_i = \text{med}(\phi_1(x_i), \cdots, \phi_N(x_i)) \quad (2)$$

where y_i is the mixed mid-value filter, and $\phi_j(x_i), j = 1, \cdots, N$ the output of linear filters.

3.3 Image segmenting

The image segmenting is the critical process from the image process to the image analysis. At present, there are over a thousand various types of segmenting algorithms (Zhang and Gerbrands, 1994; Zhang, 2001). In this identification system, the recognition effect is much affected by light; therefore, we adopt the method of threshold value segmentation, which is insensitive to light. We calculated the mean value m and the variance a of the image f, then selected the threshold value T (T=m+a) and submitted the threshold value to binary code:

$$g(x,y) = \begin{cases} 1, & f(x,y) > T \\ 0, & \text{else} \end{cases} \quad (3)$$

To eliminate the effect of the shadow on the threshold value segmentation, we applied the local intensity gradient (LIG) algorithm (Parker, 1991). The original and the segmented images are shown in Figs. 2 and 3. It can be seen from these that the image information is properly saved.

Fig. 2 Original image of the standing tree

Fig. 3 Segmental image of the standing tree

4 Extracting image characteristics

4.1 Elimination of strong noise

We can properly eliminate the noise in the image by mathematical morphology. The morphology operation applied to binary image can also be extended to the domain of grey gradation. There are four basic operations: dilation, erosion, opening and closing. The processing effect of dilation is often displayed as expanding the goal body of the original binary image and contracting the hole. The processing effect of erosion is often displayed as contracting the goal body of the original binary image and expanding the hole. The processing effect of opening is often displayed as smoothing the outline and eliminating the burr and isolated points. The processing effect of closing is often displayed as smoothing the outline, filling the gutter and closing the hole and the crack. A morphological filter can be made up of the opening and closing operations. Fig.4 shows the processing result of Fig. 2 by the mixed operations of many kinds of morphology, from which we can see that the noise is obviously eliminated after the operation.

Fig. 4 Morphology image of the standing tree

4.2 Edge extracting

The object outline in the image is reflected by the gradation discontinuity (Xie and Liu, 2002). Generally, the outline can be divided into the step leap outline and the roof shape outline. The typical edge-extracting algorithm is to inspect the gradation change of each pixel of the image in some domain and use the changing rule of first or second derivatives in the outline of a neighbouring direction to inspect the outline. The usual arithmetic operators are the Roberts, Sobel, Prewitt, Krish and LOG operators. The amount of computing to be done for various typical outline-extracting operators is very great. If we need the computer to recognize a specific goal automatically, we also need to seek the segmenting algorithm of the goal. Therefore, it is difficult to satisfy the real-time request of the system.

We used a mathematical morphology (Soumika and Datta, 2003) to extract the outline of the image. Its formula is

$$\mathrm{grad}(f) = (f \oplus g) - (f \otimes g) \quad (4)$$

where f is the image to be inspected and g the flat element around the origin; $(f \oplus g)$ is the dilation operator of g to f, and $(f \otimes g)$ is the erosion operator of g to f. We measured the difference between the two operated images and obtained the image outline whose width is the radius of the frame elements.

The outline of the inspected image can be seen in Fig. 5. The experimental result indicates that the outline of the image, which is extracted by mathematical morphology, is clearer than those by other methods and its characteristics are more obvious. But this method also has some drawbacks. Because the noise abating ability of pictures, using morphological processing, is bad, the inspection result of the outline can be affected by noise when it is big.

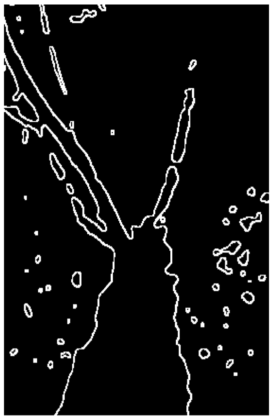

Fig. 5 Outline image of the standing tree

5 Dynamic recognition algorithm for trunks and branches of standing trees

To achieve the pruning goal, this article presents one kind of dynamic recognition algorithm for trunks and branches of standing trees. We first need to distinguish the branches and the fork-branches to be pruned, the bending degree and the trunk diameter. When the degree of bending or the diameter of the trunk is larger than the threshold value of pruning request or there are fork-branches, the machine cannot prune and needs to return automatically to tree root. Therefore, the recognition algorithm is mainly based on the establishment of a characteristic database and the characteristic model of various standing trees. These data are collected in the forest. It mainly includes basic growth characteristics, such as the ratio of trunk diameters at the intersection place of the trunk and branches, the diameter of fork-branches and degree of bending and the inclination angle of branches. In the computer recognition process, after the digital image processing and the characteristic extraction match the characteristic database and the model, recognition of the object to be pruned follows from the pattern recognition technology. The recognition algorithm can be seen from Fig. 6.

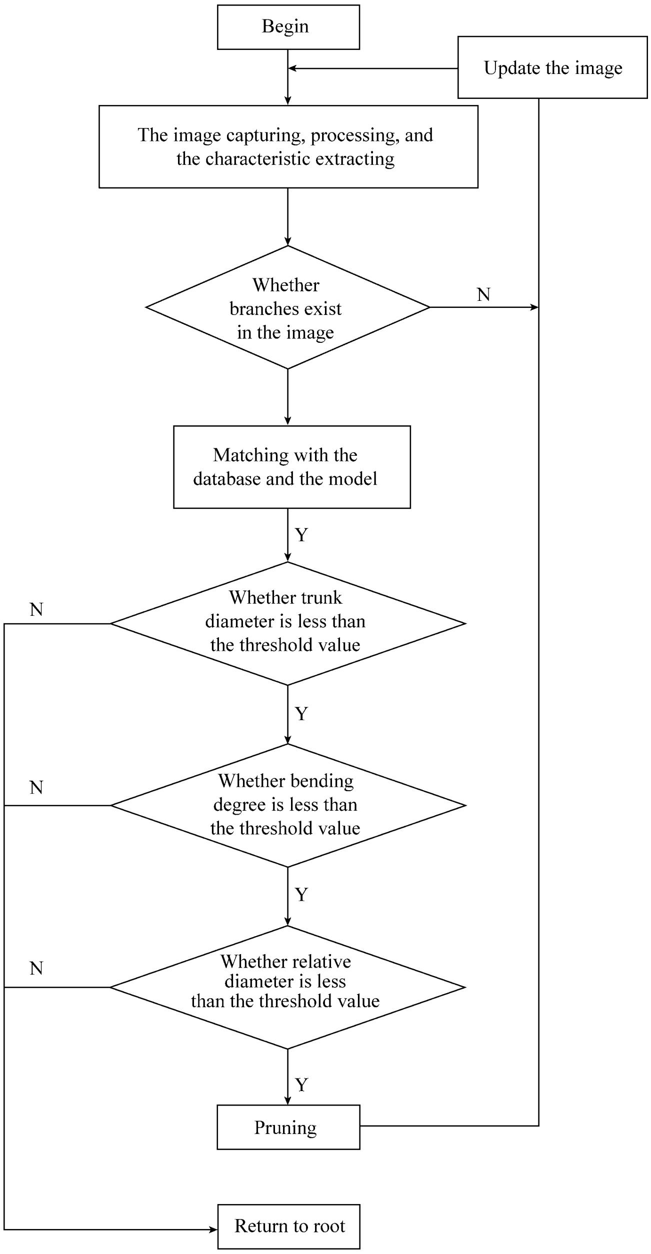

Fig. 6 Recognition algorithm of the standing tree

6 Conclusion and prospect

This article used image processing technologies, such as compressing, filtering, segmenting, noise abating and capturing the outline of the image, to establish a dynamic recognition system frame for an automatic process of pruning trunk and branches of standing trees. We presented an arithmetic for dynamic automatic identification of standing tree limbs and provided a foundation for follow-up studies of automatic identification. In our next research project, we will continue the experiment to survey different species, establish a characteristic trunk and branch database and model and further investigate the computer vision identification through the algorithm presented in this paper.

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