Grading System Design of Dendrobium Officinale Based on Machine Vision

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Abstract
Dendrobium Officinale is the rare Chinese herbal medicine. This paper will introduce its low cost grade determining system research mainly from the following two aspects: First of all, choose low cost CCD to do image capture, apply machine vision algorithm to extract the stem edge image, and automatically determine the stem diameter size and determine the uniformity coefficient of its size; Second, carry out the corresponding calculation on the collected images do as to determine the light and darkness of the surface iron green, and use the pattern recognition technique to analyze the joint black spots so as to determine the amount of the black spot and its uniformity coefficient. After the experiment of the Dendrobium Officinale grading system, the equipment was successfully developed.

Keywords: Machine Vision, Grading System, Dendrobium Officinale

1. Introduction
For a very long time, the market supply of Dendrobium Officinale mainly relies on the wild resources. Excessive excavation of human, as well as the extreme slow natural reproduction of the Dendrobium Officinale has led it to the edge of extinction. In the early 1980s, the Dendrobium Officinale had already been listed as the endangered medicinal plant needed key protection in China.

Therefore, under the condition that large-scale of Dendrobium Officinale have been grown in Ningbo, timely screening equipment with low research and development cost and reliable accuracy can improve the economic comparative advantage of the product and improve the farmers’ income. So it is a research direction with high practical application value. At present, there are mainly two kinds of main bases of the Dendrobium Officinale’s grade identification: (1) chemical methods: Determine its effective component from the analysis of its principal chemical components, and then determine their grades; (2) physical method: the identifying people will draw a subjective conclusion after judging the appearance index of the Dendrobium Officinale based on personal experience, main indicators include: diameter size of the stem, uniformity coefficient of the diameter size of the stem, the light and darkness of its surface iron green, amount of the black spots at each section (the joint of the Dendrobium Officinale is in black which is called black joint, its surface is covered with rust spots), uniformity coefficient of the black joint spot, and etc.

Due to the destructive effect of the chemical method and high requirements on the equipment and knowledge reserve, this paper plans to draw on the appearance index used by the physical method which is for determining the grade of the Dendrobium Officinale and apply the machine vision method to achieve the automatic grade determining of the Dendrobium Officinale.

The paper is based on the machine vision technology which is mainly used for solving the problems of the automatic determination of the stem size, determination of the stem size’s uniformity coefficient, determination of the light and darkness of the surface color, the calculation of the black spot, and the other key techniques, so as to achieve the machine operation instead of manual operation of the grade screening of the Dendrobium Officinale. The concrete is shown in Figure 1.

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2. Image Acquisition and Calibration

2.1. Corner Detection and Positioning

Corner Detection mainly includes Moravec, Susa, Harris and the other detecting algorithms [1-3]. Among which, Harris algorithm enjoys the characteristics of uniform corner extraction, angle rotation invariant, simple calculation, high stability, etc. But the positional accuracy is not so high. Therefore, this paper adopt Harris algorithm to do coarse position calculation, and then do accurate positioning with Forstner algorithm.

Considering we need to calculate the corner response function CRF value of all the pixel points within the detection window area when we test with the Harris algorithm, it will involve a large amount of multiplication which will seriously affected the detection efficiency of the algorithm, so this paper improve the algorithm. That is to say: within the neighborhood area of the non-angular point location of the pixel, because each pixel value is basically equal, so their corresponding gradient is very small. While the image pixel region similarity refer to the grey value of testing window center and its similarity degrees to all other pixel gray value within the surrounding N pcs of areas, and we will measure this similarity with the grey value between them. If the absolute value of gray difference between the grey value within the neighborhood area and the grey value of the center point $I_{image(i,j)}$ is less than a certain threshold, we can define that this point is similar to center point. Meanwhile, the similarities counter $n_{like(i,j)}$ belongs to this point should also plus 1. After the ergodic of the center points within all the neighborhood areas, we can get the statistics $n_{like(i,j)}$ of the point amount within the neighborhood area of this point and the similar points. According to the $n_{like(i,j)}$ value, the angular point of the center point can be defined [4].

Forstner algorithm is a very famous feature point positioning operator in photogrammetry, and its basic ideas are: as for any corner of the image, weighted centralized can be done within the optimal window through edge straight lines of each pixel so as to get the oriented coordinate system of the angular point. Combined with the Gray covariance matrix and Roberts gradient of the optimal window [5], search the as small as possible oval point as the final value of the angular point, namely: define the L edge line equation of any rough positioning angular point $(c,r)$ within the best window as:

$$\rho = r \cos \theta + csin \theta$$

(1)

In this formula, $\rho$ is the perpendicular distance from the origin point to the line L, $\theta$ is the gradient angle, $\tan \theta = g_r / g_c$, $g_r$ is the Robert gradient of this point. Suppose the angle point
coordinate is \((c_0, r_0)\), and \(v\) is the distance from point \((c, r)\) to line L, and then the error equation at \((c, r)\) is:

\[
\begin{align*}
\rho + v &= r_0 \cos \theta + c_0 \sin \theta \\
w(r, c) &= \left| \frac{\partial g}{\partial x} \right|^2 + \frac{\partial g}{\partial y}^2
\end{align*}
\]

Through taking \(\rho\) as an observed value, weight \(w(r, c)\) as the square of the gradient mode, through the equation solving, we can get Accurate angular point coordinates \((c_0, r_0)\).

2.2. Standardization of the Monocular Camera

Image acquisition gained by the camera will be influenced by the distortion; the actual line will be shown as a curve on the image plane. By analyzing the actual projection curve, we can get the distortion coefficient of the shot and the image plane center coordinates [6]. And then use the radial constraints, and put the distortion center and the second order radial distortion coefficient got by the pre-demarcation into the radial alignment constraint equation calibration algorithm so as to get all the values of initial parameters inside and outside. At last, through nonlinear overall optimization, make all the parameters converge to get overall optimal solution so as to achieve camera calibration.

3. Dendrobium Officinale’S Stems Edge Extraction and the Determination of Its Stem Size and the Size Uniformity Degree

3.1. Edge Extraction

Classical edge detection operators include Roberts operator, Sobel operator, Prewitt operator, Kirsch operator, Laplace operator, Log operator and Canny operator, etc [7]. Due to various reasons, image is always facing with random noise interference, it can be said that noises are everywhere. After introducing various forms of differential operation, the classical edge detection methods will be inevitably extremely sensitive to the noise. The results of the edge detection will often detect the noise as the edge point, while the real edge will also not be detected due to the influence of the noise interference. Therefore, during the extracting process of the Dendrobium Officinale stem edge mainly focuses on the accuracy of variety operators for the image detection, and on this account, finds a suitable appropriate operator for this project in the image edge detection.

3.2. Stem Size Measurement

We can carry out Hough exchange to achieve straight line fitting for the image with edges extracted, basic idea of Hough transform is the allelomorphism from point to line. A point in the image, all the lines go through this point should meet the equation \(y = ax + b\), \(a\) is the slope, \(b\) is the intercept. We can write the equation as \(b = -ax + y\), and then refer to \(ab\) plane and we can get only linear equation for fixed point \((x_i, y_i)\). At the second point \((x_j, y_j)\) of the parameter space, there is also a straight line associated with it, and this line associated with \((x_i, y_i)\) intersects at \((a', b')\) point. \(a'\) is the slope, \(b\) is the intercept of the line with points \((x_i, y_i)\) and \((x_j, y_j)\) on \(xy\) plane [8]. Therefore, we can transform the problems in the image space into the parameter space and solve it. And the test can just deal with accumulator in the parameter space. Considering the calculation amount will increase greatly when the line is close to the vertical, so the linear equation can be expressed in the normal formula:

\[
\rho = x \cos \theta + y \sin \theta
\]

So the points in the image space will be corresponding to a sine curve in the new parameter space \(\rho \theta\), we only need to detect the sine curve intersection point if we want to detect the line in the image space. As for all the possible \(\theta\) values in the parameter space \(\rho \theta\), we should calculate corresponding \(\rho\) values and do accumulation to \((\rho, \theta)\) accumulator. If the
accumulated value greater than the predetermined threshold value of \( t \) point \((\rho, \theta)\), it will be taken as the parameters of the linear which should be detected and corresponding to the image space. Through detecting the mean distance between the fitting straight lines, the stem size can be determined.

### 3.3. Determination of the Size Uniformity

Calculate the angle of the two lines fitted in 3.2, and then put forward Multipoint measurement to the stem diameter size, and determine size evenness finally.

### 4. Determination of the Light and Darkness of Dendrobium Officinale’S Surface Color

Carry out the binary image transformation for the collected Dendrobium Officinale image, do statistics on the R, G, B color components Dendrobium Officinale image area and the calculation of its acreage [9], adopt the following formula to do statistics on the color component number of each pixel gray levels within the image area:

\[
S_{cj} = \sum_{y=0}^{n} \sum_{x=0}^{m} f_c(x, y)
\]

\[
S_{gi} = \sum_{y=0}^{n} \sum_{x=0}^{m} f_g(x, y)
\]

\[
S_{bi} = \sum_{y=0}^{n} \sum_{x=0}^{m} f_b(x, y)
\]

Among it, \( f_c(x, y) \), \( f_g(x, y) \) and \( f_b(x, y) \) are the R, G, B color component grey value of pixel point \((x, y)\).

Due to the different size of Dendrobium Officinale, the area of it will be different even under the same condition of photography which will results in the different pixels amounts of the Dendrobium Officinale area in the image. Then direct comparison for the gray histogram of the gray values is meaningless [10]. For this purpose, we can use the each color component grayscale pixel number and the ratio of total number instead of the grayscale to count, namely:

\[
T_{cj} = \frac{S_{cj}}{S}
\]

\[
T_{gi} = \frac{S_{gi}}{S}
\]

\[
T_{bi} = \frac{S_{bi}}{S}
\]

Among it, \( T_{cj} \), \( T_{gi} \), \( T_{bi} \) are the specific values of R, G, B grayscale pixel number and the total pixels amount; \( S \) is the total pixels amount of the Dendrobium Officinale area in the image. We can do the mean square error calculation \( S \) for the each color component data of to be detected Dendrobium Officinale and the each color component data of the standard Dendrobium Officinale [11], so we can get the indicator data to do judgment according to the color.
\[
\begin{align*}
\Delta r &= \sqrt{\frac{\sum t_{ij} - T_i}{r_i}} \\
\Delta g &= \sqrt{\frac{\sum t_{ij} - T_j}{g_i}} \\
\Delta b &= \sqrt{\frac{\sum t_{ij} - T_k}{b_i}} 
\end{align*}
\]

(7)

Among it, \( t_i \) and \( T_i \) are the specific value of be detected and standard Dendrobium Officinale grayscale image pixel number and the total pixels amount. Upon on this, we can finally decide the color grade of the Dendrobium Officinale.

5. Results and Analysis

5.1. Statistics of the Dendrobium Officinale's Black Joint Spots Amount

The black spot is very obvious in the Dendrobium Officinale image, therefore, we can set threshold, and extract spots edge image through image segmentation and the later picture smooth treatment, and achieve the number statistics of the black spots amount at last.

5.2. Measurement and Calculation of the Uniformity Coefficient

As for the collected image \( f_{<s>(x, y)} \), \( x, y = 0, 1, \ldots, N - 1 \) its gray level is \( L \). We can use the followed formula to compress the grey grade to \( L_{s} \) (\( L_{s} < L \)) so as to reduce calculation amount:

\[
f(x, y) := \frac{f(x, y)L_{s}}{L} \quad x, y = 0, 1, \ldots, N - 1
\]

(8)

And then we can process the image with the gradient operator, and get the gradient image \( g(x, y) \), and \( x, y = 0, 1, \ldots, N - 1 \). And then, we can compress gradient value of the gradient image, that is to say:

Set the maximum value of \( g(x, y) \) as \( G \), we can compress it into \( Gr \) (\( Gr < G \)), so

\[
g(x, y) := \frac{g(x, y)Gr}{G}
\]

(9)

among it, \( x, y = 0, 1, \ldots, N - 1 \)

At this point, we can define the co-occurrence matrix of the gray scale gradient as followed:

\( H(i, j) \) is the figure, in \( f_{<s>(x, y)} \) \( f(x, y) = i \) and the gradient image \( g(x, y) = j \) number of pixels. Namely:

\[
H(i, j) = \{(x, y) | f(x, y) = i, x, y = 0, 1, 2, \ldots, N - 1\}, \text{ and then it will be the uniformization of the co-occurrence matrix } H, \text{ we can define that:}
\]

\[
S = \sum_{i=0}^{L-1} \sum_{j=0}^{L-1} H(i, j), \quad H(i, j) := \frac{H(i, j)}{S}, \text{ the coefficient of extracting texture feature of the co-occurrence matrix will have:}
\]

(1) Angular Second Moment:

\[
E(\delta, \theta) = \sum_{i=0}^{L-1} \sum_{j=0}^{L-1} P^2(i, j)
\]

(10)
Inertia moment:
\[
I(\delta, \theta) = \sum_{k=0}^{l-1} k^2 \left[ \sum_{i=0}^{l-1} \sum_{j=0}^{l-1} p(i, j) \right]
\]
(11)

Entropy:
\[
H(\delta, \theta) = -\sum_{i=0}^{l-1} \sum_{j=0}^{l-1} p(i, j) \log p(i, j)
\]
(12)

Inverse difference moment:
\[
L(\delta, \theta) = -\sum_{i=0}^{l-1} \sum_{j=0}^{l-1} \frac{p(i, j)}{1 + (i - j)^2}
\]
(13)

In addition, there are some other indexes can be used to determine the homogeneous degree of the spots such as variance, average sum, average variance, entropy, average, differential variance, differential entropy and others [12]. Finally, determine the Spots uniform level of the Dendrobium Officinale by choosing typical indicators.

5.3. Hardware Architecture and the Corresponding System Software

Design of system hardware: adopting DSP processor and FPGA equipment to design a reliable hardware system and corresponding driver circuit, preamplifier circuit, interface circuit, and etc.

Software design: Based on image processing algorithms mentioned above design suitable software for FPGA or DSP, and complete system design combined with hardware so as to optimize and improve the software running speed [13, 14].

6. Conclusions

The paper introduces machine vision technology into the grade determining area of Dendrobium Officinale which promote the practicality of the machine vision technology on the grade determining of the traditional Chinese medicine, make up the deficiency of the past subjective screening relied on the traditional experience and lay a foundation to achieve the machine operation instead of manual operation of the grade screening of the Dendrobium Officinale.

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