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Segmentation Method of Lingwu Long Jujubes Based on *L*a*b** Color Space

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Abstract

*Collecting Lingwu long jujubes' growth characteristics and identifying maturity compared with growth model are important factors in automatic image monitoring system for fruit maturity. To segment and extract regions of Lingwu long jujubes' against nature scenes in digital images is the key to image recognition. Color space transformation, is used to transform RGB color space to CIE L*a*b* color space, analyze characteristics of three-dimension histogram of each component and increase target display properties by using each component's point operation. Also, the image pixel threshold segmentation method of each component is proposed; then the target image can be obtained by mathematical morphological and logical operation of the extracted image. 50 images of Lingwu long Jujubes are utilized to compare segmentation results of algorithm with those of manual segmentation method. Comparison results show that the proposed segmentation algorithm can be effectively applied to extracting Lingwu long jujubes' images against nature scenes, and its accuracy has reached 92.6%.This algorithm has decreased the segmentation error caused by image noise while extracting targets which has strong robustness to the color distribution fluctuation as well.*

Keywords: *image recognition, color difference, point operation, threshold, morphological*

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1. Introduction

Lingwu long jujube, a geographical indication product of China, is important economic fruit in Ningxia Hui autonomous region. Lingwu long jujube is the fresh fruits which could be kept fresh only up to 15 days in room temperature [1]. Besides, maturity picking period only lasts about 20 days, moreover, this is only for those of eight mature with stems. What's more, fresh period for jujubes of full maturity should be reduced to a week which may cause great loss without picking in time. Taking these problems into consideration, sunny days are proper for picking eight-mature fruits Therefore, automatic image-monitoring for fruits' maturity is essential to pick eight-mature jujubes timely. The maturity can be judged by comparing growth characteristics from images with growth models. Thus, Lingwu long jujubes' recognition technique is important in maturity identification. To segment and extract Lingwu long jujubes against natural scenes in digital images is the key to image recognition.

There are many algorithms in image segmentation such as threshold segmentation, region-based segmentation, watershed, Morkov random field etc. Mainly, the algorithms are used to turn the image into an intensity one, and the edge is recognized as a collection of some points whose grey values change greatly in neighborhood. Classical operators include Sobel operator, SUSAN operator, Laplace operator, Canny operator and so on. However, these mentioned operators are lacking color information and can't distinguish different substances in same brightness either, which can cause missing detection. Color detection has attracted great concerns and some widely used edge extraction algorithms have been improved based on original intensity gradient edge detection operators [2-5]. Instead of brightness, color difference is used to calculate the gap of the core value in the sub-template region and then compared with a fixed threshold value the edge pixel point in the center will be determined. Thus, selection of the threshold value is of great significance. State-of-art algorithms are defining a single color difference threshold value as a global threshold one, and ignoring the impact of global image information on human color difference perception, which can result in over-detection of many negligible edges and poor noise robustness. Hough transformation [6] and watershed

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segmentation algorithm [7] are the common image segmentation techniques that can be used to produce continuous edges and obtain enclosed areas. But watershed segmentation method is vulnerable to over-segmentation reducing the accuracy of target extraction. Many scholars have done great efforts to improve the watershed algorithm. W. S. Yu proposed a color image segmentation algorithm combined marker-based watershed and region merger to suppress over-segmentation [8]. Cheng et al used consistency histogram threshold for initial segmentation and combined regional consistency and color features to merge the original over-segmented images[9]. Patino did area-merging by regional fuzzy relations based on fuzzy C-means clustering algorithm[10]. Roshni V S and S. G. Ren et al extracted Phalaenopsis image area based on watershed and gradient's common edge [11, 12]. Xinjian Chen et al [13] propose a novel method based ona strategic combination of the active appearance model, live wire, and graph cuts for abdominal 3-D organsegmentation. Domingo Mery et al [14] raised a RGB color model segmentation algorithm that separated pears from background pictures. F. Mendoza et al [15] analyzed banana's color, pigmentation and texture information in different periods using L*a*b* color model. Such methods focused on regional texture and gradient information while ignoring the essential image color information.

Lingwu long jujube is of special shape, color characteristics and dense fruit of branches, but no research has been done in image recognition on them. In this paper, many their natural image characteristics, combined color difference component images of color space have been studied and the segmentation problem of recognizing mature Lingwu long jujubes' natural images is solved.

2. Research Method

2.1. Setup of experiments

In all experiments, digital camera (FUJIFILM Fine Pix $S1800$ with 12.2 million pixels) was used to collect images. The desktop computer used for processing and analyzing images is a Lenovo ThinkCentre $M5100T$ with a Lenovo Tilapia CRB mainboard, NVIDIA Geforce graphic card 405 with $512M$ in graphic memory, an AMD Phenom II CPU of $2.8G\ \ Hz$ in dominant frequency and a Seagate $ST3500418AS$ disk of $500GB$ equipped operating in $32-bit$ Pro Windows 7 of Microsoft.

The Lingwu long jujubes' images were taken by digital camera FUJIFILM under natural light conditions on a well sunny morning in *Wan-Mu Zao-Yuan of Lingwu Daquan forest centre*. 997 pieces out of 1665 taken photos were chosen in different circumstances such as touching, covering and shadow. 50 of the 997 pictures containing less than 8 jujubes were selected for further processing under JPG format. The initial images in resolution of 400×300 pixels. The picture is shown as Figure 1.

Figure 1. Lingwu Long Jujubes' Natural Image

2.2. Color space transformation

Usually, a color digital image is presented in RGB color space, while each component value of R, G and B changes with the brightness, which means that there is high correlation with each component of R, G and B. So it's not suitable for color image detection in RGB color space. In addition, RGB space is an uneven color space because the color difference of two colors can't represent the distance between two points in the space. Therefore, a uniform color model should be selected to show color images and to detect color edges. In a uniform color space of three-dimension, the same distance between two points represents correspondingly the same color difference of two colors.

International Commission on Illumination suggested that CIE L*a*b* color should be the approximation of uniform color space in 1976. This paper used uniform color space CIE L*a*b*, which can accurately calculate the color difference according with human vision instead of RGB color model, which can produce uneven deviation. A RGB color model multiplied by a 3×3 matrix can get the XYZ color model. The linear relationship between two models is as follows:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.431 & 0.342 & 0.178 \\ 0.222 & 0.707 & 0.071 \\ 0.020 & 0.130 & 0.939 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{1}$$

CIE L*a*b* color system developed from CIE XYZ color model, and the relation of transformation is nonlinear. The corresponding conversion formula is described as:

$$L^* = \begin{cases} 116\times(\frac{Y}{Y_n})^{\frac{1}{3}} - 16 & \frac{Y}{Y_n} > 0.008856 \\ 903.3\times\frac{Y}{Y_n} & \frac{Y}{Y_n} \le 0.008856 \end{cases} \tag{2}$$

$$a^* = 500\times[f(\frac{X}{X_n}) - f(\frac{Y}{Y_n})] \tag{3}$$

$$b^* = 200\times[f(\frac{Y}{Y_n}) - f(\frac{Z}{Z_n})] \tag{4}$$

$$f(t) = \begin{cases} 7.787t + \frac{16}{116} & t \le 0.008856 \\ t^{\frac{1}{3}} & t > 0.008856 \end{cases} \tag{5}$$

Coordinates (X_n, Y_n, Z_n) are equivalent to X, Y and Z value of standard white light (R, G and B equals to 255 respectively); $L*$ is lightness, which corresponds to luminance I of HIS color space; $a*b*$ reflects the chromaticity's color component; component $a*$ turns gradually from green to red; component $b*$ turns gradually from blue to yellow. Every point of color images is mapped to one of L*a*b* color space. The color difference of two colors can be equivalently represented by Euclidean distance between two color point (p, q) in L*a*b* color space. Thus, color difference shows the difference between two colors through numerical methods. The color difference computational formula of two color points is given as following:

$$\Delta E^*_{pq} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \tag{6}$$

2.3. Image Segmentation Algorithm

Grey value of every pixel for every color component in images can be visualized by analyzing each component of 3D histogram from RGB color space to L*a*b* color space. From the difference of color information of each color component in L*a*b* color space, it is obvious that mature jujubes' color is red and immature jujubes' surface is somewhat green-yellow; leaves of the trees are green; surface of branches and trunks is white and interior is red. Then the color of maturity and immaturity is respectively corresponding to a^* and b^* in L*a*b* color space. Each component in L*a*b* is obvious in 3D histogram shown in Figure 2 to Figure 5.

Figure 2. L*a*b* Color Space Image

Figure 3. a^* Component Image

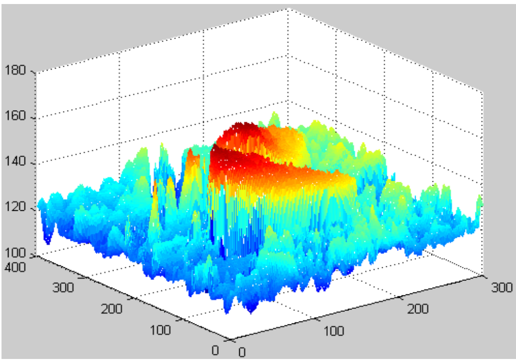

Figure 4. a^* Component 3D Histogram

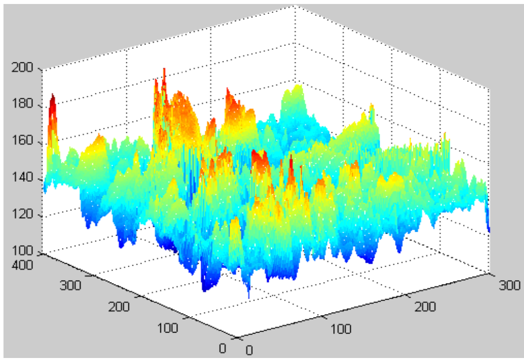

Figure 5. b^* Component 3D Histogram

Pixel's point operation threshold segmentation method is based on characteristics of each pixel's chrominance in L*a*b* color space. The distinct target is of necessity to be extracted with the main background being filtered. The fixed threshold is extracted from target of Lingwu long jujubes or calculated from many testing experiments (Otsu algorithm). Firstly, the "red" target area that indicates maturity is extracted, then, the noise filtration and removal of little targets are done using erosion and dilation of mathematical morphology; finally, Lingwu long jujubes' target area can be obtained. Assumed that $f(i,j)$ stands for an image, the fixed segmentation threshold of "red" is 110, which is the most suitable threshold from many repeated experiments.

$$Edge[a](i,j)=\begin{cases}1 & a(i,j)>110 \\ 0 & a(i,j)\leq 110\end{cases} \tag{7}$$

$Edge[a]$ is the red target. Extracted target area of threshold segmentation image is shown in Figure 6 to Figure 7.

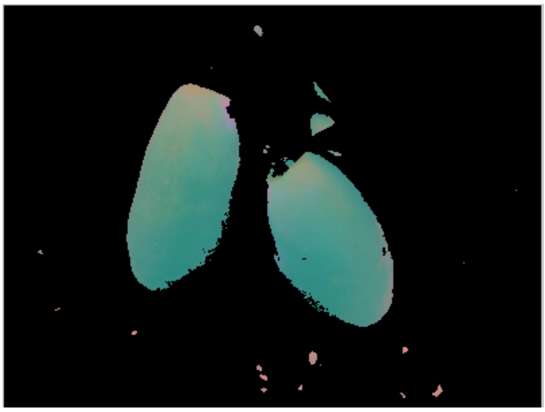

Figure 6. Segmentation Image with Fixed Threshold

Figure 7. Processed Image with Mathematical Morphology

2.3.1. Filter

An improved mean filtering algorithm is used in our work. A is an $N \times N$ area of point (i, j) in initial image $f(i, j)$. T is intensity threshold. The filtering assignment criterion is:

$$F(i,j)=\begin{cases} f(i,j) & 当 \varepsilon \le T \\ \frac{1}{M} \sum_{(i,j)\in A} f(i,j) & 当 \varepsilon > T \end{cases} \tag{8}$$

And, error

$$\varepsilon=\left| f(i,j)-\frac{1}{M} \sum_{(i,j)\in A} f(i,j) \right| \tag{9}$$

The threshold T is above zero and is determined by the global or local features of images. Only the error ε exceeds threshold T, will the noise be handled which can reduce the image blurring.

2.3.2. Erosion and Dilation

Image f is operated by erosion and dilation of element b. They are defined as:

$$(f \oplus b)(s,t)=\max\left\{ f(s-x,t-y)+b(x,y) | (s-x,t-y)\in D_f ,(x,y)\in D_b \right\} \tag{10}$$

$$(f \Theta b)(s,t) = \min\left\{ f(s+x,t+y)+b(x,y) | (s+x,t+y)\in D_f ,(x,y)\in D_b \right\} \tag{11}$$

D_f and D_b stand for respectively definition domain of f and b determined by the width and height of the image.

2.3.3. Steps of the algorithm

Step 1: Transform RGB color space to L*a*b* color space;

Step 2: Get 3D histograms of each color component;

Step 3: Use gray value of $a*$ to do fixed threshold segmentation and save maturity target area as $I1$;

Step 4: Decrease noise, filter and exclude little targets using erosion and dilation of mathematical morphology;

Step 5: Acquire the target area of Lingwu long jujubes and calculate the area.

3. Results and Analysis

To verify the validity of the segmentation algorithm, 50 natural images of Lingwu long jujubes as shown in Figure 1 were selected to do segmentation experiments. Error segmentation number is the pixel number's difference between the target's pixel number of manual segmentation and that of the segmentation algorithm. Error segmentation rate is error segmentation number divided by target pixel number of manual segmentation. Statistical testing results are shown in Table 1 and the average error rate is 7.4%.

Table 1. Experimental Data of Segmentation

Number	Total pixel number of the used algorithm	Pixel number of manual segmentation	Error segmentation number	Error segmentation rate
1	17953	19216	1263	6.57%
2	85725	93562	7837	8.38%
3	10236	11865	1629	13.73%
4	29643	32526	2883	8.86%
5	36269	38239	1970	5.15%
6	15625	17215	1590	9.24%
7	30965	36526	5561	15.22%
8	96568	98574	2006	2.04%
9	84256	86592	2336	2.70%
10	9216	10358	1142	11.03%
11	9986	11245	1259	11.20%
12	8765	8896	131	1.47%
13	90568	112354	21786	19.39%
14	73845	78124	4279	5.48%
15	55892	66598	10706	16.08%
16	85326	89512	4186	4.68%
17	25648	28957	3309	11.43%
18	38956	40215	1259	3.13%
19	25624	26589	965	3.63%
20	81254	85962	4708	5.48%
21	50924	58268	7344	12.60%
22	24128	26591	2463	9.26%
23	85469	88659	3190	3.60%
24	65924	68503	2579	3.76%
25	95641	99254	3613	3.64%
26	71012	77265	6253	8.09%
27	23512	26023	2511	9.65%
28	80457	88693	8236	9.29%
29	53200	56812	3612	6.36%
30	81234	84236	3002	3.56%
31	71412	77969	6557	8.41%
32	79265	84980	5715	6.73%
33	77451	79856	2405	3.01%
34	74120	85692	11572	13.50%
35	64032	66183	2151	3.25%
36	32764	35981	3217	8.94%
37	74035	77656	3621	4.66%
38	23569	26815	3246	12.11%
39	90018	96258	6240	6.48%
40	17568	18627	1059	5.69%
41	73654	78490	4836	6.16%
42	85364	88252	2888	3.27%
43	94593	98207	3614	3.68%
44	53127	56980	3853	6.76%
45	18249	19354	1105	5.71%
46	63892	66528	2636	3.96%
47	53726	60215	6489	10.78%
48	82360	89268	6908	7.74%
49	65931	70124	4193	5.98%
50	83269	90967	7698	8.46%

The binary image comparison of manual segmentation and the algorithm segmentation is shown in Figure 8 to Figure 9. It's easily found that the effect of algorithm segmentation is almost same as manual segmentation. There are only minor segmentation errors and the expected purpose of image segmentation has been achieved.

Figure 8. Result of the Algorithm Segmentation

Figure 9. Result of Manual Segmentation

4. Conclusion

It has been found that few related papers were useful in segmentation of Lingwu long jujubes because of their image characteristics. In this paper, a segmentation algorithm has been proposed based on operating each component's point of pixels in L*a*b* color space. Although the segmentation problem has been solved well, the segmentation results rely on the threshold selection while extracting target area so that the results may not come out as expected. Now, the selection of threshold is mainly by experiences and experiments. Further research on threshold selection should be carried out to get a more scientific way. Compared with manual segmentation, the pixel number of algorithm segmentation is smaller. This is mainly caused by touching and sheltering. In addition, the biggest difference comes from the difference between red and green of the jujubes that the actual edge may not correctly be extracted by segmentation. Model comparison is only related with the red area in the process of monitoring maturity, thus it's successful to monitor maturity with such segmentation algorithm.

In this paper, a segmentation algorithm based on operating each component's point of pixels in L*a*b* color space has been proposed to segment natural images of Lingwu long jujubes. This algorithm has reduced the segmentation error caused by noise while extracting targets and has strong robustness in color distribution fluctuation. The images of jujubes have been well extracted from nature scenes. The segmentation accuracy has reached 92.6% through testing 50 natural images of Lingwu long jujubes.

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