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Research Article

Image Segmentation and Maturity Recognition Algorithm based on Color Features of Lingwu Long Jujube

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Abstract: Fruits' recognition under natural scenes is a key technology to intelligent automatic picking. In this study, an image segmentation method based on color difference fusion in RGB color space was proposed in order to implement image segmentation and recognition maturity intelligently according to Lingwu long jujubes' color features under the complex environment. Firstly, the three-dimensional histograms of each color component which is widely used in color space currently are compared; and then the jujubes' red area and non-red area was extracted respectively, thus, the whole target area is obtained by sum of those areas; then, watershed algorithm combined with mathematical morphology distance and gradient was utilized to overcome adhesion and occlusion phenomena; finally, the maturity level was recognized by the established recognition model of Lingwu long jujubes. The segmentation was tested through 100 sample set and 93.27% of precision rate was attained, so was correct estimating rate of maturity level recognition above 90%. The results indicate that a smaller average segmentation error probability is in this method, which is more efficient in the extraction and recognition of jujubes with red and green and the problem of segmentation and maturity level judgment of adhesive fruits is solved by the method as well.

Keywords: Color difference, image segmentation, lingwu long jujubes, mature level, watershed transform

INTRODUCTION

Lingwu long jujube is one kind of economic fruit of great significance in Ningxia Province whose best harvesting period is only about 20 days. Currently, fruits harvesting merely depends on hand-picking through erecting ladders, which is known for great magnitude and intensity of labor with low efficiency. Moreover, because of high economic value of Lingwu long jujube, its cultivated area is increasing year by year; thus, there is an increasingly strong demand for intelligent automatic picking technology. Specialists of agricultural robots mainly concentrated on research of machine vision and artificial intelligence to fulfill the purpose of replacing hand picking totally using intelligent automatic picking robots. In 1968, Schertz and Brown firstly proposed the application of robots in fruits picking. Levi developed a vision system for detecting and locating citrus fruit in 1988. Kassay in 1992 applied feature matching of stereo vision in getting the 3D coordinates of detected objects, the images of work area of the field or fruit trees was collected through the picking machine with a camera system, then the technology of image processing and analysis was utilized to detect fruits and to guide mechanical arms to pick fruits. Thus, it is very necessary to study how to recognize fruits effectively for intelligent automatic picking.

Due to image segmentation is the premise of fruits recognition, thus, segmentation error directly influences the performance of fruits recognition. Currently, there are many researches on segmentation of fruit images are focused on litchi (Xiong *et al*., 2011), strawberry (Zhou *et al*., 2007), tomato (Arefi *et al*., 2011), papaya (Domingo *et al*., 2012), apple (Ji *et al*., 2012), citrus (Lopez *et al*., 2011), mango (Payne *et al*., 2013), red peaches (Merce *et al*., 2012) and etc. Contemporary there already are lot of image segmentation methods like corrosion expansion method, fuzzy clustering techniques (Sowmya and Rani, 2011), watershed transformation algorithm, active contour algorithm, Support Vector Machine (SVM) tool (Zhang and Wu, 2012), color features (Linker *et al*., 2012), threshold analysis and etc. In image recognition field segmentation algorithms mostly are based on color threshold which are limited strictly by circumstances and light conditions, it works mediocrity when occlusion and adhesion phenomena are happened. Watershed transformation is one of segmentation methods in mathematical morphology based on the topological theory. Because of continuous, smooth dividing lines and good response to weak brink,

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watershed transformation is widely used in image segmentation.

Since irregular shape of Lingwu long jujube with various color characteristics and dense fruit of branches will cause over-segmentation in watershed transformation, a color difference algorithm based on color images combined with a watershed transformation method, which is combined with gradient and distance, was proposed to present a maturity recognition model for Lingwu long jujube.

MATERIALS AND METHODS

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 ThinkCentreM5100T 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 4000×3000 pixels were zoomed out to 400×300 pixels in order to increase the processing speed. An example of adhesion and occlusion image of Lingwu long jujubes is shown as Fig. 1. Matlab R2010b was utilized for images preprocessing-noise filtering that produces input images for latter process.

Color distribution of Lingwu long jujube peel, which varies in different areas and its shape seems close to an ellipsoid, is mainly relied on its maturity. Naturally cultivated Lingwu long jujubes have the following characteristics:

- Initially, Lingwu long jujube peel is green; with the maturity increasing, reddish-brown parts start to appear on the peel. When the reddish-brown parts cover above 70 percentages of the whole peel, it is judged as eight mature. Due to demands of storage conditions of jujubes, eight-mature ones have the longest fresh periods; so only jujubes that is over eight mature are picked to reach the best fresh effect.
- Color distribution characteristics on jujube peel is changing. The stem part of long jujube firstly appears reddish-brown and nether parts increasingly become reddish-brown varied with time; pink comes up early on the light side of jujube peel and the backlight part will not appear reddish-brown until the light side has totally turned into dark red-brown. The adhesion parts of jujubes stay green until both light and backlight parts have changed into dark red-brown. Moreover, jujubes with good sunny and ventilated in the tree firstly change into red and other parts gradually turn red with deepening of the red colorant.
- Leaves of Lingwu long jujubes are green and the stem skin is white with its inner being reddish-brown.

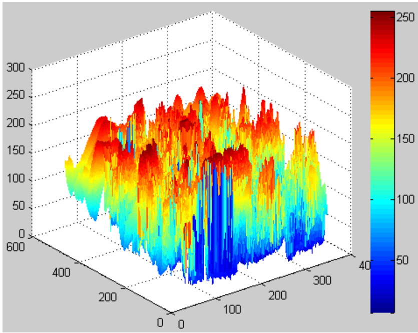
Fig. 1: Adhesion and occlusion image of Lingwu long jujubes

Through the above analysis, it is concluded that only mature jujube is red and its hue will not vary with natural light intensity; that is to say, we merely need the segmentation of red districts out from jujubes images.

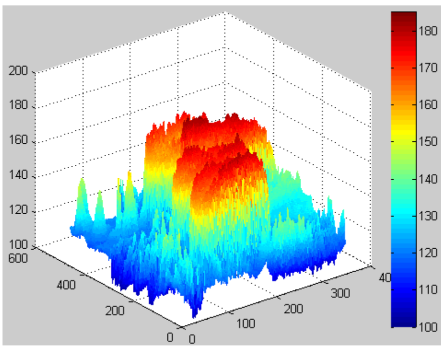
EXPERIMENTS AND METHODS

Most image segmentation methods transfer colorful images into gray ones for threshold segmentation. However, images captured by modern video cameras are colored which are able to carry much more information than gray ones do. It has been confirmed that 10% of boundaries in color images are lost in gray images without being able to be detected compared to color ones; thus, boundaries information provided by color images are richer, which resulting in a widespread concern on boundary detection based on color images.

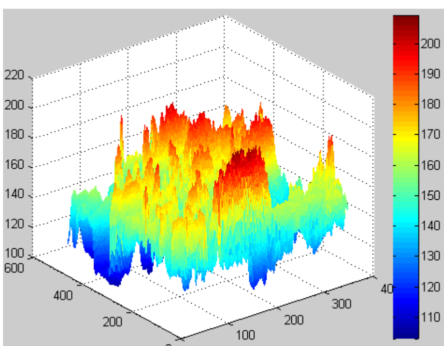
Image segmentation preprocess: In this study, a direct segmentation method towards color images was presented according to the characteristics of research objects. Through analyzing 3D histograms of images in several color spaces, it is found that there is obvious discrepancy between foreground and background in a^*(red/green) component histogram of $L^*a^*b^*$ space and it is easy to recognize fruits, especially red mature ones; S component histogram of HIS space differs most obviously which holds true for HSV space; while C_r (difference between red and the reference value) component outperforms the other two components in YC_bC_r space. Hence, according to the color



(a) L*component



(b) a* component



(c) b* component

Fig. 2: 3D histograms of color components

discrepancy, the collected images can be transformed from *RGB* into other spaces. Whereas this process of threshold segmentation will increase a transformation of color space and hence consume a precious period of time concerning the efficiency needed by the intelligent picking robots. Thence, the method of boundary segmentation is proposed that images in *RGB* space could be segmented directly based on color features, which can fully utilize the advantages of being simple, effective and low hardware-required brought by *RGB*.

Among those widely used color spaces, L^*a*b* space is relatively robust against variations of light intensity which is currently the most uniform space as well. Since it is equipment-independent and applied for natural light conditions, a^*(red/green) component of $L^*a^*b^*$ space is chosen as the research subject and the transformation matrix between $L^*a^*b^*$ and *RGB* space is calculated. As *RGB* cannot be directly transformed into $L^*a^*b^*$, a intermediated transform of *XYZ* space is needed with parameters of transformation matrixes being uniformed and adjusted. The transformation formula can be described as Eq. (1):

$$\begin{cases} L=\dfrac{(13933\times R+46871\times G+4732\times B)}{2^{16}} \\ a^*=\dfrac{378\times(14545\times R-22281\times G+7736\times B)}{2^{24}}+128 \\ b^*=\dfrac{160\times(12773\times R+39695\times G-52468\times B)}{2^{24}}+128 \end{cases} \tag{1}$$

The histograms of each color component in $L^*a^*b^*$ space for every pixel are shown in Fig. 2, it is found that there are several regular patterns corresponding to components which can be used to implement image segmentation and boundary extracting of jujubes image.

As depicted in Fig. 2b, the greatest color difference between jujube and background color features is a^* component which is decided as the datum quantity for image segmentation so as to reduce processing time of segmentation, the equivalent transformation equation from *R, G, B* components was utilized to identify $a*$ component avoiding transforming images from *RGB* to L^*a*b*. The equivalent equation is listed below:

$$a^* \Leftrightarrow 0.33R - 0.5G + 0.17B \tag{2}$$

Taken Eq. (2) and *R-G* color features into accounts, segmentation of jujubes' images are performed as shown in Fig. 3.

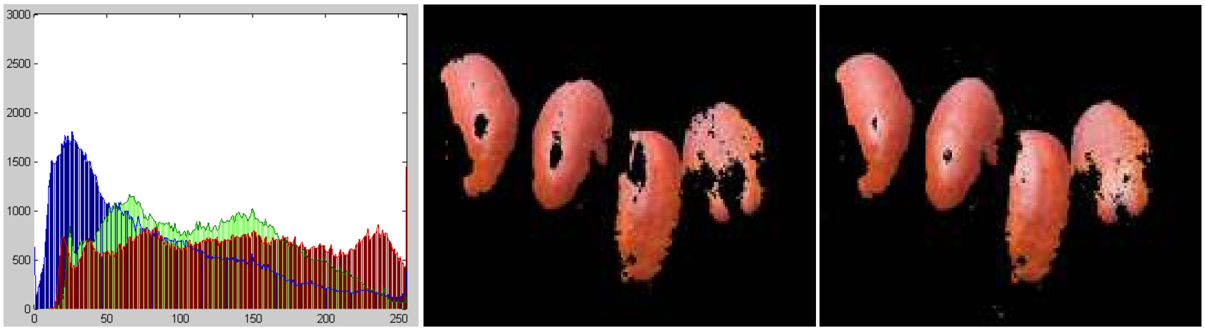
Figure 3f demonstrates that extracted boundaries are merely red edges other than the real ones of original jujubes. As the eight-maturity recognition criterion is that the coverage of red area is over 70 percentages, this criterion can be defined as the picking level. Extracting complete boundaries of jujubes is full of challenges as it is prone to occlusion and adhesion phenomena as well as slight color difference between green edges of long jujubes and background.

As shown in Fig. 2c, color difference between jujubes and background color features is evidently revealed by $b*$ (yellow/blue) component in immature long jujubes images. The equivalent equation was also disposed with $b*$ component as done with $a*$ component as follows:

$$b^* \Leftrightarrow 0.122R + 0.378G - 0.5B \tag{3}$$

Based on Eq. (3) and *2R-G-B* color features, segmentation of jujubes' images are performed as shown in Fig. 3; The threshold value of *2R-G-B* for segmentation is always chosen between 40-50 and 50 was selected for jujubes images in this study after several trial experiments of segmentation.

Figure 4 shows results of boundary extracting of jujubes image processed with threshold segmentation in red color component. As the peel of jujubes is divided



(a) Histogram of *R-G-B* components (b) Segmentation based on *R-G* component (c) Segmentation based on equivalent *a** component

(d) Mixed segmentation based on *R-G* and equivalent *a** component (e) Feature extracting (f) Boundary extracting

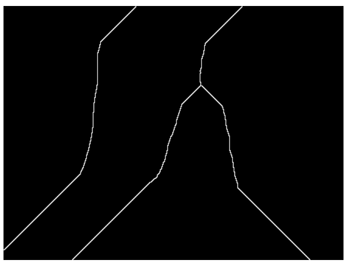
Fig. 3: Color components segmentation and red edge detection

(a) Segmentation based on 2*R-G-B* component (b) Segmentation based on equivalent *a**component

(c) Mixed segmentation based on *R-G* and equivalent *a** components (d) Feature extracting

Fig. 4: Segmentation based color components and green edge detection

Fig. 5: Complete boundary extraction of Lingwu long jujubes



(a) Ridges generated by watershed transformation

(b) Adhesion segmentation

Fig. 6: Adhesion segmentation results

into two parts-red and non-red, real complete boundaries of original jujubes (excluding light affection such as adhesion and occlusion) are able to be obtained through mixture of red and none-red boundaries. An example is shown in Fig. 5.

ADHESION SEGMENTATION METHOD

In order to suppress influences on real extracted boundaries caused by light variation and compensate adhesion and occlusion effects, it is proposed that a color difference algorithm combined with a watershed transformation method consisting of gradient and distance. The algorithm is illustrated below.

Firstly, corrode original jujubes' images into symbolic ones of independent non-adhesion. Secondly, reconstruct objects through expansion out of symbolic images produced by the first step. Thirdly, utilize a watershed transformation method consisting of gradient and distance to generate dividing lines. In the end, restore the shapes and sizes of original objects through logical calculation. Results of a segmentation experiment are shown in Fig. 6.

In several trial experiments of segmentation testing performed against manual segmentation of jujubes' images, error rate is no more than 5% explicating that the image segmentation method based on watershed transformation is applicable for maturity recognition of Lingwu long jujubes and boundary extracting of other symmetrical images.

IMAGE SEGMENTATION ALGORITHM

In order to avoid over-segmentation and under-segmentation of image segmentation, the threshold values for each color component should be carefully chosen; in this study, the threshold value for *R-G* component is 30 and 50 for *2R-G-B*. According to Lingwu long jujubes' features of shapes and colors, the images are segmented by method based on color fusion technology and then abstract the red and non-red areas by summering the areas, therefore, the problem of adhesion and occlusion can be solved. And those all done by the watershed transformation combined with distance and gradient. The algorithm is described as follows:

- Calculate each color component of *RGB* image, the threshold value of *R-G* component be set as 30, figure out the equivalent a^* component and extract red areas through mix the two components, run Canny boundary detection and store into M_R.
- Set the threshold value of 2*R-G-B* component as 30, figure out the equivalent b^* component and extract non-red areas through mix the two components, run Canny boundary detection and store into M_G.
- Mix red and non-red areas and get the segmentation results, store into M_{RG}.
- Erode M_{RG} with "'*disk*', 10" for three times as the symbolic images, then under masks expand for two times and reconstruct some ideal symbolic images. Values of times for eroding and expansion were collected through a number of image experiments.
- Generate the dividing lines with watershed transformation segmentation.
- Restore the shapes and sizes of original objects through logical calculation.

MATURITY RECOGNITION ALGORITHM

After two years of observation of Lingwu long jujubes in the mature periods, it is summarized the criterion of eight-maturity recognition for long jujubes is that the red value below 150 in *RGB* space covers 2-7% of the whole jujubes area. As for the severe occlusion and adhesion, there is no need for maturity recognition because of single grain picking. Detailed procedures are described as below:

- Calculate the pixel area of each object jujube and obtain the sum area A_Z of jujubes' peel.
- Generate segmented image for former extracted M_G using the dividing lines, filter noises to remove small targets and store into M_{GF} and calculate the pixel area A_L of non-red.
- Compute the ratio between non-red and whole areas:

$$A = \begin{cases} \frac{A_L}{A_Z} \le 2\%, \text{maturity, can pick} \\ 2\% < \frac{A_L}{A_Z} \le 7\%, \text{eight-maturity, can pick} \\ \frac{A_L}{A_Z} > 7\%, \text{non-maturity, wait for picking} \end{cases} \quad (4)$$

- Store the recognized results into registers and files for the next stage of machine picking.

EXPERIMENTAL RESULTS

Segmentation testing of 100 images under natural scenes is done and the result is shown in Table 1 (only partial segmentation results are listed). Total number of wrong segmentation is composed by over-segmentation and under-segmentation and the correct segmentation rate is calculated by ratio of number of correct segmentation to total segmentation. The mean rate is approximately 93.27%. The error rate rises while the occlusion area and number of jujubes increase the segmentation accuracy meet demands of limited

Table 1: Segmentation results of adhesion and occlusion jujubes (sectioned)

Number of jujubes/each	Number of adhesion and occlusion/each	Number of error segmentation/each	Correct rate/%
2	2	0	100.00
3	2	0	100.00
4	3	0	100.00
4	4	0	100.00
3	3	0	100.00
4	3	0	100.00
4	2	0	100.00
4	3	0	100.00
4	2	0	100.00
4	4	0	100.00
4	4	0	100.00
4	3	0	100.00
4	3	0	100.00
4	3	2	50.00
5	2	0	100.00
5	4	0	100.00
5	4	0	100.00
5	3	0	100.00
6	2	0	100.00
6	3	0	100.00
6	3	0	100.00
6	6	2	66.67
6	5	0	100.00
7	5	0	100.00
7	3	0	100.00
7	6	2	71.43
7	2	0	100.00
8	5	2	75.00
8	4	0	100.00
8	8	4	50.00

Table 2: Maturity recognition results of Lingwu long jujubes (sectioned)

Number of jujubes /each	Number of manual rare recognition /each	Number of machine rare recognition /each	Number of manual being rare recognition /each	Number of machine being rare recognition /each	Correct rate /%
2	2	2	0	0	100.00
3	3	3	0	0	100.00
4	3	3	1	1	100.00
4	4	4	0	0	100.00
4	0	0	4	4	100.00
4	1	0	3	4	75.00
4	4	3	0	1	75.00
4	3	3	1	1	100.00
4	4	4	0	0	100.00
4	4	4	0	0	100.00
5	5	5	0	0	100.00
5	5	5	0	0	100.00
6	6	6	0	0	100.00
7	3	3	4	4	100.00
8	8	7	0	1	87.50

number of jujubes (commonly no more than 8) under natural scenes.

Table 2 describes sectioned results of maturity recognition of Lingwu long jujubes contrasted with manual recognition. It can be concluded that the error rate of recognition approach is below 10% and recognition criteria are higher than manual ones. The adhesion and occlusion are not take into consideration in those experiments, this method based on correct segmentation of red and non-red areas is subject to serious peel shadows. The correct rate of maturity recognition is prone to selected threshold values of *R-G* and *2R-G-B* components which may lead to incorrect segmentation.

CONCLUSION

In this study, an image segmentation approach based on color difference fusion in *RGB* color space is proposed in order to implement image segmentation against complex natural backgrounds and recognize intelligently maturity according to Lingwu long jujubes' color features. As for the problem of adhesion and occlusion phenomena, the watershed transformation combined with distance and gradient algorithm is utilized to solve over-segmentation and under-segmentation. Through experimental tests of image segmentation, the correct ratio of long jujubes reached up to 93.27% and the accurate ratio of maturity recognition was above 90% compared to manual recognition, it is justified that recognition approach could be applied in automatic picking devices. The further research will concentrate on accurate image segmentation for the challenging situation where there are over 10 objects with severe adhesion and occlusion phenomena in long jujubes' image.

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REFERENCES

Arefi, A., A.M. Motlagh, K. Mollazade and R.F. Teimourlou, 2011. Recognition and localization of ripen tomato based on machine vision. Aust. J. Crop Sci., 5(10): 1144-1149.

Domingo, D.L., B.P. Serrano, E.P. Serrano and E.J. del Rosario, 2012. Digital photometric method for determining degree of harvest maturity and ripeness of 'sinta' papaya (*Carica papaya* L.) fruits. Philipp. Agric. Sci., 95(3): 252-259.

Ji, W., D. Zhao, F.Y. Cheng, B. Xu, Y. Zhang and J.J. Wang, 2012. Automatic recognition vision system guided for apple harvesting robot. Comput. Electr. Eng., 38(5): 1186-1195.

Linker, R., O. Cohen and A. Naor, 2012. Determination of the number of green apples in RGB images recorded in orchards. Comput. Electron. Agr., 81(2): 45-57.

Lopez, J.J., M. Cobos and E. Aguilera, 2011. Computer-based detection and classification of flaws in citrus fruits. Neural Comput. Appl., 20(7): 975-981.

Merce, T., F. Davinia, P. Tomas, T. Marcel, N. Miquel and P. Jordi, 2012. Definition of linear color models in the RGB vector color space to detect red peaches in orchard images taken under natural illumination. Sensors, 12(6): 7701-7718.

Payne, A.B., K.B. Walsh, P.P. Subedi and D. Jarvis, 2013. Estimation of mango crop yield using image analysis: Segmentation method. Comput. Electron. Agr., 91(2): 57-64.

Sowmya, B. and B.S. Rani, 2011. Colour image segmentation using fuzzy clustering techniques and competitive neural network. Appl. Soft Comput., 11(3): 3170-3178.

Xiong, J.T., X.J. Zou, L.J. Chen and A.X. Guo, 2011. Recognition of mature litchi in natural environment based on machine vision. Trans. Chin. Soc. Agric. Mach., 42(9): 162-166.

Zhang, Y.D. and L.N. Wu, 2012. Classification of fruits using computer vision and a multiclass support vector machine. Sensors, 12(9): 12489-12505.

Zhou, T.J., T.Z.H. Zhang, L. Yang and J.Y. Zhao, 2007. Comparison of two algorithms based on mathematical morphology for segmentation of touching strawberry fruits. Trans. Chin. Soc. Agric. Eng., 23(9): 164-168.