High-quality Tea Flushes Detection under Natural Conditions Using Computer Vision

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Abstract

Detecting high-quality tea flushes from natural background is an crucial step towards a selective tea-picking robot. A tea flushes identification system was developed as a means of guidance for a robotic manipulator in the picking of high-quality tea. Several color indices, including cyan and magenta color difference in CMY color space, channels B, Q, i3 and Yb in LAB, YIQ, i1i2i3 and ARgYb color spaces, were studied and tested. Grey level image was transformed into binary image using Otsu method and then area filter was employed to eliminate small noise regions. Experimental results indicated that these color features were particularly effective for tea flushes recognition. The proposed methods could be used in future tea-picking robot vision system.

Keywords: *Color Indices, High-Quality Tea, Flushes Detection, Natural Conditions, Tea-Picking Robot*

1. Introduction

Manual labor is still the primary option for high-quality tea picking at present. Only the terminal bud and the second even third leaves (these bud and leaves are called flushes) are collected in high-quality tea harvest. However, in the last decades, labor cost has substantially increased. Recently developed tea harvesting machines work in mechanical shearing mode, and can't meet the demand for harvesting high-quality tea. Therefore, the development of intelligent selective picking robot for high-quality tea harvest is considered to be of the utmost commercial and societal importance. Tea flushes identification under natural conditions remains a challenge job in developing the tea-picking robot.

Some studies have been conducted on computer vision techniques for plant material detection and identification [1-5]. Woebbecke et al. [6] studied the use of color indices to separate the weeds from the soil and residue background. They determined that the best segmentation occurred with the modified hue and 2g-r-b (excessive green) contrast index. Bulanon et al. [7] developed a segmentation algorithm for computer vision recognition of Fuji apples based on color image analysis. They found that the red color difference was effective in distinguishing apples from the background.

The objective of this study is to explore the possibility of detecting the tea flushes using computer vision. Several color indices and image processing algorithms were proposed to automatically detect and discriminate high-quality tea flushes and their background (including old leaves, stems, soil, etc.), which could be used as computer vision system for the intelligent tea-picking robot.

2. Materials and Methods

2.1 The Proposed Methods

A set of color images of Longjing tea, which is amongst the finest and most representative of green teas in China, were acquired after germination with a DaHeng camera(HV1300FC, DaHeng Image, Inc., Beijing, China) in Longjing tea plantation (Hangzhou, China). Images were then transferred to a PC for later use.

In this study, color analysis was performed to distinguish the tea flushes from their background. A number of color indices on the CMY values, which included cyan color difference and magenta color difference, and channels B, Q, i3, Yb in LAB, YIQ, i1i2i3, ARgYb color spaces were carried out in an attempt to find effective image processing algorithms. These indices are shown in table 1.

Table 1. Color indices used in tea flushes recognition

Color space	Type	Color indices
CMY	Cyan Color Difference	c – Y*
CMY	Magenta Color Difference	m – Y*
LAB	Channel	B
YIQ	Channel	Q
i1i2i3	Channel	i3
ARgYb	Channel	Yb

Image processing was performed using a laptop with a Intel(R) Core(TM)2 Duo T6600@2.20GHz central processing unit (CPU). Processing software was developed using Visual Studio 2010 (Microsoft Co., LTD., Redmond, WA, USA).

Schematic description of the tea-picking system arrangement was shown in figure 1. The camera was mounted 1200mm above the background surface and top-view images were taken directly above the tea trees. After detection of the tea flushes by the machine vision system, the manipulator approached the flushes with the use of image processing data.

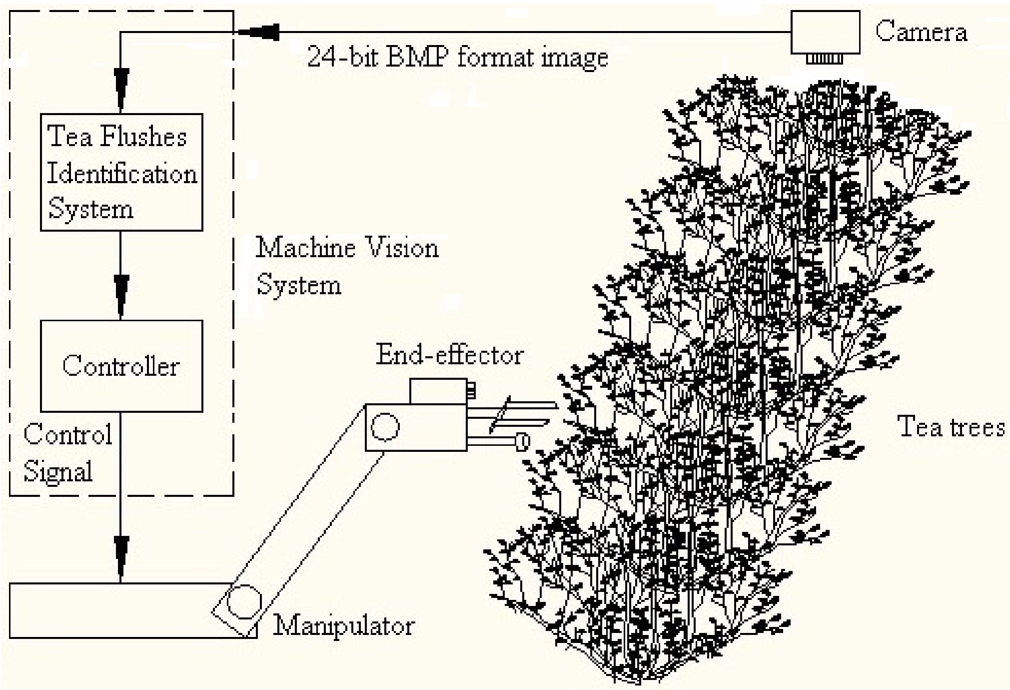

Figure 1. Schematic description of the tea-picking system arrangement.

2.2 Color Difference in CMY Color Space

The color properties of the tea image were analyzed using luminance and color difference model. The color properties used in this model are luminance Y*; cyan color difference Cc; and magenta color difference Cm, which are defined as follows:

$$Y^* = 0.3r + 0.6g + 0.1b \tag{1}$$

$$Cc = c - Y^* = 1 - 1.3r - 0.6g - 0.1b \tag{2}$$

$$Cm = m - Y^* = 1 - 0.3r - 1.6g - 0.1b \tag{3}$$

with r + g + b =1, c + m + y = 1

$$r = \frac{R}{R+G+B},\ g = \frac{G}{R+G+B},\ b = \frac{B}{R+G+B} \tag{4}$$

$$c = \frac{C}{C+M+Y},\ m = \frac{M}{C+M+Y},\ y = \frac{Y}{C+M+Y} \tag{5}$$

where c, m and y are the normalized CMY coordinates ranging from 0 to 1.

These indices, based on normalized RGB and CMY coordinates, are therefore insensitive to the intensity of the light source as well as the viewing and illumination angles [8].

The cyan color difference and magenta color difference of a typical tea image were shown in figure 2. It is very evident that the tea flushes have higher cyan and magenta color difference than the background.

(a) (b) (c)

Figure 2. (a) Original tea image, (b) Cyan color difference, (c) Magenta color difference.

2.3 Color Channels in LAB, YIQ, i1i2i3 and ARgYb Color Spaces

The LAB color space is a color-opponent space with dimension L for lightness, the A component defines a red to green axis and the B component, a yellow to blue axis.

YIQ color model is particularly used in the NTSC video standard for color TV broadcasting. The Y parameter represents luminance. I and Q components represent the color information.

i1i2i3 color space is effective for color image segmentation, commonly used in image analysis, which can be calculated from the RGB color space by use of the following equation [9].

$$\begin{bmatrix} i1 \\ i2 \\ i3 \end{bmatrix} = \begin{bmatrix} 0.333 & 0.333 & 0.333 \\ 0.5 & 0.0 & -0.5 \\ -0.25 & 0.5 & -0.25 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{6}$$

In ARgYb color model, components A, Rg and Yb stand for Achromatic, Red-green and Yellow-blue respectively. The transformation from the RGB color space to the ARgYb color space was performed according to the operation [10].

$$\begin{bmatrix} A \\ Rg \\ Yb \end{bmatrix} = \begin{bmatrix} 0.30 & 0.59 & 0.11 \\ 0.50 & -0.50 & 0.00 \\ 0.25 & 0.25 & -0.50 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{7}$$

2.4 Color Feature Analysis

Image analysis was implemented with Image-Pro Plus software (Image-Pro Plus ver. 6.0, Media Cybernetics, L.P., Silver Spring, Md.). The cyan and magenta color difference, channels B, Q, i3 and Yb of tea image were calculated. A histogram was plotted for tea flushes and background classes. In figure 3, a solid line denotes flushes color distribution, while a dashed line indicates background color distribution.

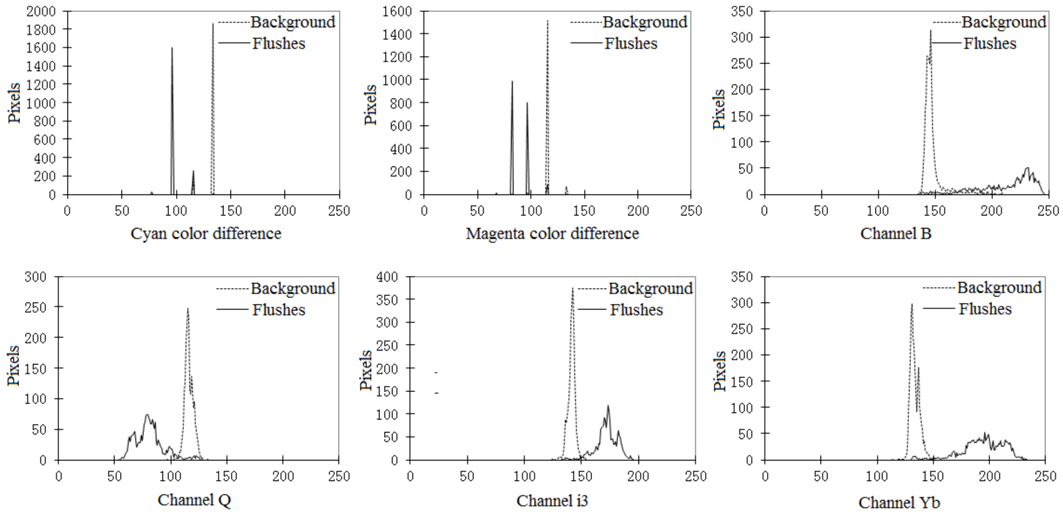

Figure 3. Histograms of flushes and background pixels.

Examination of the image histograms indicated that the distributions of cyan and magenta color difference, channels B, Q, i3 and Yb of flushes and background were separated obviously. Thus, it is feasible to segment flushes from the background using these color indices.

3. Results and Discussion

In a second step, the grey level image was transformed into a black-and-white image to obtain a binary image using the method of Otsu [11], which is based on an analysis of the histogram resulting from the gray level image calculation.

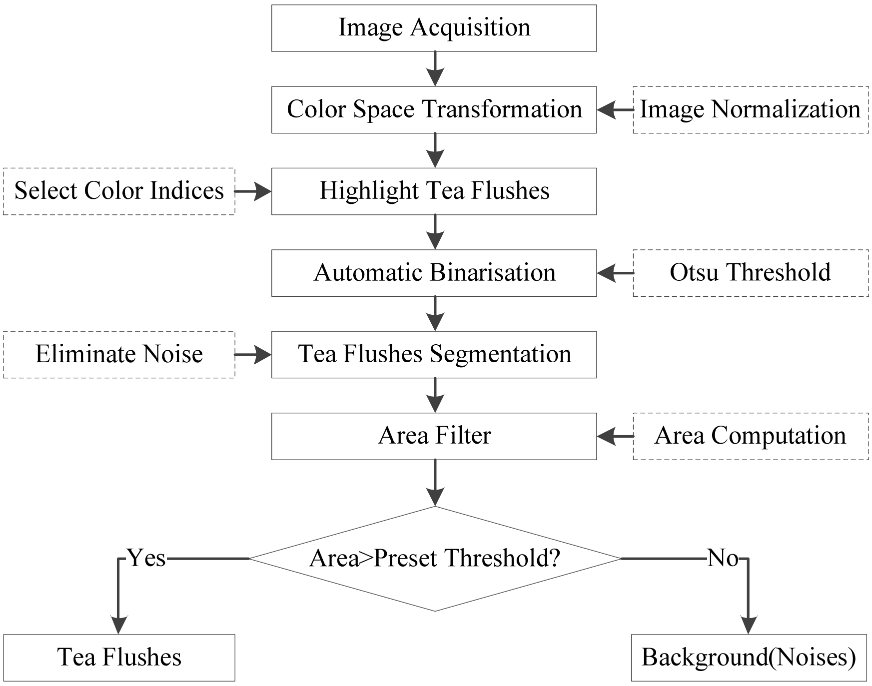

Figure 4. Flowchart of the process of tea flushes detection and discrimination.

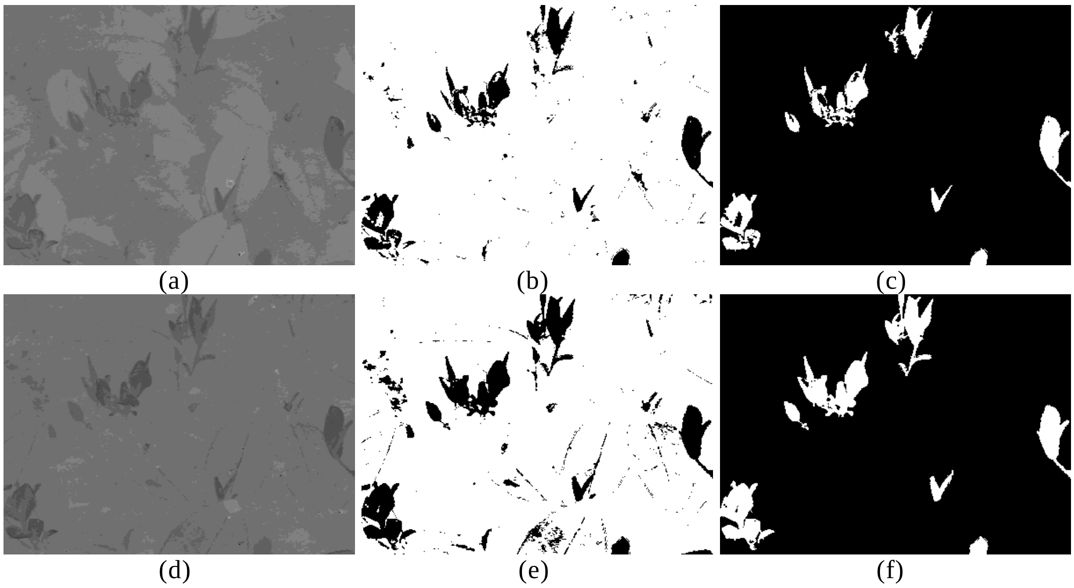

Figure 5. Tea flushes identification based on Cyan and Magenta color difference: (a) Cyan color difference, (b) Binary image, (c) Image after area filter, (d) Magenta color difference, (e) Binary image, (f) Image after area filter.

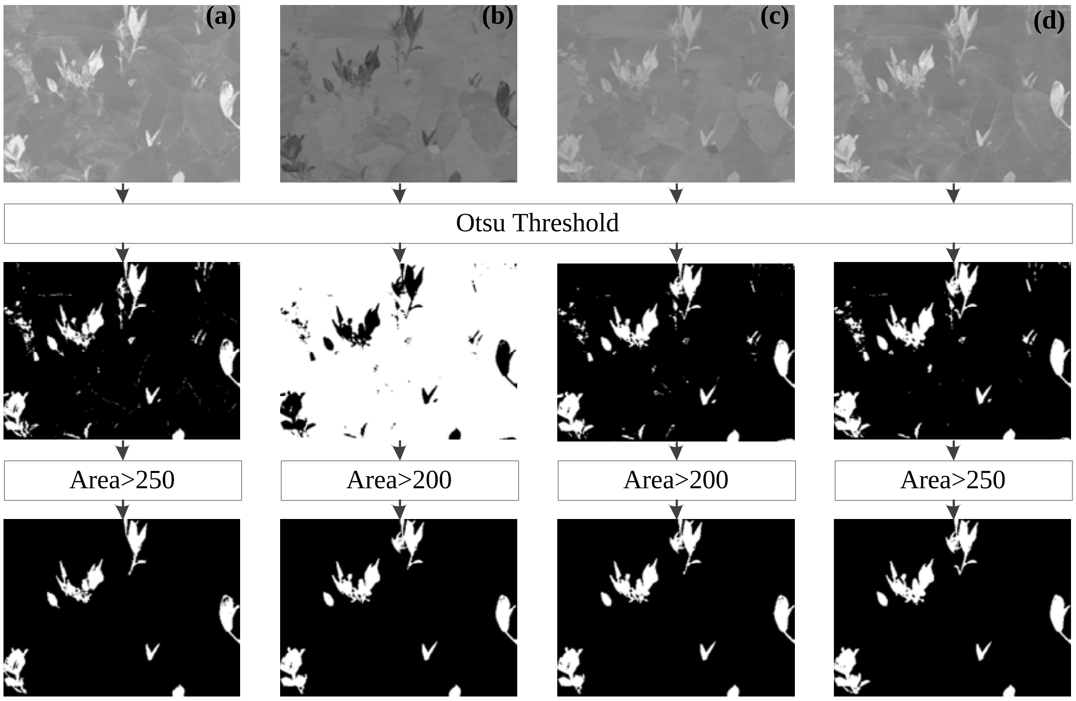

Figure 6. Example of flushes recognition in LAB, YIQ, i1i2i3 and ARgYb color spaces: (a) B channel of the LAB color space, (b) Q channel of the YIQ color space, (c) i3 channel of the i1i2i3 color space, (d) Yb channel of the ARgYb color space.

Because of color similarities between flushes and background, some background pixels were misclassified as flushes (noises). These pixels generally were spread disjointedly within the image. An area filter using a thresholding technique was found to be effective in eliminating the relatively small noise regions. The area of each regions were calculated. Objects smaller than a preset threshold (derived through trial and error) were considered as noise and filtered. Objects larger than the threshold were considered as flushes.

The flowchart in figure 4 gives an overview of the entire process of tea flushes detection and discrimination. Figures 5 and 6 represent the results when the indices were applied to the entire tea image.

Results show that cyan and magenta color difference improved the contrast of the test areas of the interest between the flushes and background, and the channels B, Q, i3 and Yb also significantly distinguished tea flushes from the background.

4. Conclusion

Algorithms to automatically recognize the tea flushes for a tea-picking robot were developed. Several color indices, including cyan and magenta color difference in CMY color space, channels B, Q, i3 and Yb in LAB, YIQ, i1i2i3 and ARgYb color spaces were successfully tested to separate tea flushes from backgrounds for images taken under natural conditions. The color indices and segmentation algorithms described have a potential for the intelligent tea-picking robot development.

Future work will concentrate on the development of robust and high-performance algorithms to determine the 3-D location of flushes. Other technologies such as stereo vision would somehow enter into the algorithm to obtain the depth information.

5. Acknowledgments

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6. References

[1] Jian Song, "A Quick Target Identification Method for Eggplant Picking Robot", JCIT: Journal of Convergence Information Technology, vol. 6, no. 11, pp. 41-47, 2011.
[2] Xavier, Burgos-Artizzu, P, Angela, Ribeiro, Maria, Guijarro, Gonzalo, Pajares, “Real-time Image Processing for Crop/weed Discrimination in Maize Fields”, Comput. Electron. Agr., vol. 75, no. 2, pp.337-346, 2011.
[3] Berge, T. W., S. Goldberg, K. Kaspersen, “Towards Machine Vision based Site-specific Weed Management in Cereals”, Comput. Electron. Agr., vol. 81, no. 2, pp.79-86, 2012.
[4] Jian Song, "Target Location Based on Ultrasonic Ranging and Vision Information for Picking Robot", JDCTA: International Journal of Digital Content Technology and its Applications, vol. 6, no. 1, pp. 193-199, 2012.
[5] Jin Xiaojun, Chen Yong, Sun Yanxia, “Research Advances of Weed Identification in Agricultural Fields” , Journal of Agricultural Mechanization Research, vol. 33, no. 7, pp.23-27, 2011.
[6] Woebbecke D, Meyer G, Von Bargen K, Mortensen D, “Color Indices for Weed Identification under Various Soil, Residue, and Lighting Conditions”, Trans. ASAE, vol. 38, no. 1, pp. 259-269, 1995.
[7] Bulanon D, Kataoka T, Ota Y, Hiroma T, “A Segmentation Algorithm for the Automatic Recognition of Fuji Apples at Harvest”, Biosyst. Eng., vol. 83, no. 4, pp. 405-412, 2002.
[8] Gee Ch, Bossu J, Jones G, Truchetet F, “Crop/weed Discrimination in Perspective Agronomic Images”, Comput. Electron. Agr., vol. 60, no. 1, pp. 49-59, 2008.
[9] Philipp I, Rath T, “Improving Plant Discrimination in Image Processing by Use of Different Color Space Transformations”, Comput. Electron. Agr., vol. 35, no. 1, pp. 1-15, 2002.
[10] Avi Naiman, “Color spaces and color contrast”, The Visual Computer, vol. 1, no. 3, pp. 194-201, 1985.
[11] Otsu N, “A threshold selection method from gray-level histogram”, IEEE Trans. Syst. Man Cyber, vol. 9, no. 1, pp. 62-66, 1979.