Optik 125 (2014) 5684–5689

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Automatic method of fruit object extraction under complex agricultural background for vision system of fruit picking robot

Xiangqin Wei [a,b,*], Kun Jia [c], Jinhui Lan [d], Yuwei Li [c], Yiliang Zeng [d], Chunmei Wang [a]

[a] State Key Laboratory of Remote Sensing Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100101, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] College of Global Change and Earth System Science, Beijing Normal University, Beijing 100875, China
[d] School of Automation and Electrical Engineering, University of Science and Technology Beijing, Beijing 100083, China

ARTICLE INFO

Article history:
Received 10 October 2013
Accepted 27 May 2014

Keywords:
Automatic
Fruit object extraction
Fruit picking robot
Vision system

ABSTRACT

Fruit picking robot is required for agricultural automation for fruit harvest, and vision system is the important and crucial composition of a robot system. An automatic extraction method of fruit object under complex agricultural background for vision system in fruit picking robot is presented in this study. The method is based on an improving Otsu threshold algorithm using a new feature in OHTA color space. Color features are extracted in OHTA color space and then used as an input for the Otsu threshold algorithm which calculates the segmentation threshold value automatically. Four kinds of fruit images are selected to validate the automatic extraction method. The fruit objects are automatically extracted with this method and the outputs are presented in binary images. Numerous of experiments show that the automatic extraction method can extract mature fruit from complex agricultural background and the extraction accuracy is more than 95%. The results indicate an effective fruit object extraction method for vision system of fruit picking robot.

1. Introduction

Since the 1990s, with the development of computer and information technology, artificial intelligence, machine vision and other new technologies in agricultural machinery are becoming more and more popular. The agricultural robot combined of agronomic technology, mechanical technology, electronics technology, information technology and artificial intelligence technology is now one of the focuses of research in agricultural machinery [1]. The study of agriculture robot can be tracked back to 1980s [2]. Japan developed a robot which is used for spraying pesticide. In the early 1990s, Korea began the research of grafting automation technology, but the result only accomplished part of mechanical operation with lower level of automation and speed. In Europe, agriculture developed countries such as Italy and France, the grafting is also a quite common work. As these countries have not yet had their own grafting robot, part of the grafting work is still manual and some using the grafting robot from Japan. At present, a large number of harvesting robots have been developed, such as tomato picking robot, cucumber picking robot, and so on.

Fruit is an ordinary production in people's life and the agricultural automation for fruit harvest is more and more required. Therefore, mature fruit picking robot is becoming the focus of the researches. The ripeness process of fruit generally can be divided into six periods: immature period, green maturity period, changing color period (fruit color is mainly green), half maturity period (the top of the orange-red fruit extend to fruit abdomen, coloring degree about 50%), maturity (the color of the fruit-specific expand big comprehensive, but the base is still green) and ripening period (fully colored and the color is dense). Fruit picking robot mainly deals with the fruit of half maturity period, maturity and ripening period in accordance with its different uses. The images are randomly acquired by robot visual sensor when robot works. Then, the fruit on different maturity periods will be presented in the same image. The image also may contain the disease leaves or dry leaves which have the similar color with the fruit and the stem support the upright of fruit or other disturbance. Therefore, it is important to develop an effective and automatic extraction method of fruit object for vision system in fruit picking robot [3].

Color-based object extraction is found widely used in the robotics community. Correspondingly, there are numbers of fast object extraction methods used for picking robot at present.

* Corresponding author at: Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, No.20 Datun Road, Chaoyang District, Beijing 100101, China. Tel.: +86 10 64806263; fax: +86 10 64889565.
E-mail address: weixq@radi.ac.cn (X. Wei).

http://dx.doi.org/10.1016/j.ijleo.2014.07.001
0030-4026/

MIT-AI-Lab describes an implementation of an antinational system for a humanoid robot based completely on space variant vision [4]. They use histograms which are constructed in the HSV color space, but the conversion relationship of HSV from RGB color space is non-linear. An adaptive color-based robot vision system using pixel classification method is proposed [5,6]. However, this method needs to divide each pixel into class, so it is difficult for dealing with multiple objects. At present, the available algorithms are unable to adapt to more kinds of fruits perfectly especially in complex agricultural background where disturbance variation is unavoidable.

In this paper, an automatic extraction method of fruit objects under complex agricultural background for vision system in fruit picking robot is proposed. The method is based on an improving Otsu threshold algorithm using a new feature in OHTA color space. The color features in OHTA color space can transform the extraction in one-dimension instead of in three-dimension. A new color feature based on the features which are proposed by OHTA color space is defined. And then an improving Otsu threshold algorithm is used to extract the fruit objects using features in OHTA color space. Finally, real-world fruit images with complex agricultural background are used to test the performance of the proposed method.

2. Materials and methods

A fruit picking robot system is composed by many blocks, such as vision sensor, pressure system, and vision system. Always, the fruit picking robot system processing flow can be seen in Fig. 1. For robot system, vision sensor is ideal for robot system due to its low cost, wide availability, high data content and information rate. Extracting target information about the world is crucial to operating effectively and making vision an appealing sensor. Object extraction method is an important part of machine vision [7]. Additionally, it is essential to process the sensory information in minimum time. Consequently, it is crucial that image processing algorithms are fast in addition to being robust and that is the objective of this study.

2.1. Image acquisition

Images were collected in an orchard in Beijing of China. Four types of fruit are selected to validate the extraction method, which are strawberry, tomato, pomegranate and persimmon. The images were taken around the mature period of each type fruit and all the pictures were taken under natural daylight conditions. Finally, twenty images for each type of fruit are acquired and the total image number is 80, and the background of each image is variation, including simple and difficult background. The digital camera used to capture color image of fruits on the orchard in this study is SONY T20.

2.2. Feature selection in fruit object extraction

Color is usually combined of red (R), green (G) and blue (B) which are usually called three primary colors [8]. From the three primary colors, different kinds of color spaces can be calculated by using either linear or nonlinear transformations. Several color spaces, such as RGB, HIS, CIE, L*u*v*, are used for color image segmentation, but none of them can surpass the others for all kinds of color images. Selecting the best color space is still one of the difficulties in color image segmentation.

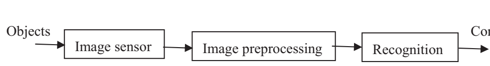

Fig. 1. Theory work chart of a fruit picking robot.

In this paper, the OHTA color space is selected for processing the fruit object extraction under complex agriculture background. The OHTA color space is a group of orthogonal color characteristics set (I_1, I_2, I_3) which is summarized based on eight different color image experiments [9]. Compared to traditional HIS and HSV color space, the conversion relationship of OHTA color space and RGB color space is linear. It can not only conquer the problem of color singularity when be used to conversion between non-linear color space (e.g. HIS, HSV, etc.) and RGB color space, but also having a simple calculation. There are two kinds of expressions for the OHTA color space, and the conversion from RGB color space as formula (1) and (2):

$$\begin{cases} I_1 = (\mathrm{R} + \mathrm{G} + \mathrm{B})/3 \\ I_2(\mathrm{R} - \mathrm{B}) = /2 \\ I_3 = (2\mathrm{G} - \mathrm{R} - \mathrm{B})/4 \end{cases} \tag{1}$$

$$\begin{cases} I'_2 = \mathrm{R} - \mathrm{B} \\ I'_3 = (2\mathrm{G} - \mathrm{R} - \mathrm{B})/2 \end{cases} \tag{2}$$

where R, G and B are the three primary colors of RGB space, I_1, I_2, I_3, I'_2 and I'_3 are the features of the OHTA space.

Using the expressions, color image can be converted from RGB space to OHTA space in which the problem can be solved in one-dimension instead of three-dimension. According the characteristic of the fruit image, the features I_1, I_3 and I'_3 cannot be used for extracting ripe fruits from the complex agricultural background, whereas the feature I_2 and I'_2 can be used for extracting the ripe fruits from the surrounding environment. But it is also found that not all of the disturbances are divided from the image well. In this study, another feature is defined in the OHTA color space according to the characteristics of the fruit images that acquired by robot visual sensor. The formula is given as follows:

$$I'_1 = \mathrm{R} - \mathrm{G} \tag{3}$$

where R, G and I'_1 have the same meaning as in formulas (1) and (2).

After selection of the features, the next key problem is to decide the threshold value whose object is to extract the fruit object. Histogram is one of the most simple and useful tools in the digital image processing. It is the function of gray which plots with intensity scale as horizontal axis and with pixel numbers as vertical axis. In order to compare all the features, the histogram is shown in the same intensity scale and pixel numbers.

2.3. The image segmentation method

Generally speaking, image segmentation is defined as the technology and process that divide the image into regions with the same characteristics and extract the regions of interest [10]. The characteristic can be expressed by gray, color or texture etc. and the target can be a single region or a number of regions, which is related with practical application. The generally used image segmentation algorithms are gray histogram segmentation algorithm [11], clustering segmentation algorithm [12,13], the algorithm based on the stochastic model and region-based segmentation [14,15]. In this study, an improved adaptive threshold segmentation algorithm based on Otsu is selected for its automation and efficiency. Compared with the gray histogram segmentation algorithm, the improved Otsu algorithm is based on the color characteristics and uses more information of the image, so it can remove the background more effectively, and this will help us do further analysis about the image. Clustering segmentation algorithm and the algorithm based on the stochastic model are based on complicated mathematical formulas, but this algorithm