Computers and Electronics in Agriculture 137 (2017) 59–68

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Computer vision detection of surface defect on oranges by means of a sliding comparison window local segmentation algorithm

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ARTICLE INFO

Article history:
Received 27 July 2016
Received in revised form 22 February 2017
Accepted 24 February 2017

Keywords:
Defect detection
Computer vision
Image local segmentation
Orange surface defect

ABSTRACT

Automatic detection of defective oranges by computer vision system is not easy because of the uneven lightness distribution on the surface of oranges. It means that the methods only directly using global segmentation provide unsatisfactory results when orange images present faint defect characters or inhomogeneous surface. The contrast between sound and defective regions can be used to produce more accurate segmentation results, which is more capable of detecting pixels lying around the defect boundary on orange surface based on the local segmentation method. In this paper, we study and propose a sliding comparison window local segmentation algorithm and also presents the detailed image processing procedure including removal of background pixels, image binarization using local segmentation, image subtraction, image morphological modification, removal of stem end pixels for detecting surface defect in an orange gray-level image. This method is an original contribution that allows successful segmentation of various types of surface defects (e.g., insect injury, wind scarring, thrips scarring, scale infestation, canker spot, dehiscent fruit, copper burn, phytotoxicity).The image segmentation algorithm was tested with 1191 samples of oranges. The proposed algorithm was able to correctly detect 97% of the defective orange. Future work will be focused on whole surface and fast on-line inspection.

1. Introduction

Computer vision technology provides a nondestructive and objective method for external quality inspection of agricultural and food products. For examples, the automatic machine vision system was used to calculate size parameters (Brodie et al., 1994) and quality parameters (Wen and Tao, 1999; Miller and Delwiche, 1991; Li et al., 2002; Blasco et al., 2009; Razmjooy et al., 2012). In recent years, more and more machine vision research focus on the skin defect detection of the agriculture product (Yang, 1996; Tao, 1996; Leemans et al., 1999; Li et al., 2002; Throop et al., 2005; Kleynen et al., 2005; Qin et al., 2012; Dong et al., 2014; Cubero et al., 2016). Blasco et al. (2007) proposed a region-oriented segmentation algorithm instead of pixel-oriented segmentation algorithm for detecting citrus peel defects and stem-end, but this paper doesn't provide how to distinguish stem end from defects. Fernando et al. (2010) developed a general unsupervised method for the directly detection of oranges defect in random colour textures based on a Multivariate Image Analysis and Principal Component Analysis strategy. However, the algorithm of this paper is a bit complex for practical application delivery. Li et al. (2013) proposed to use combined lighting transform and ratio image to detect the common surface defects on oranges. However, if gray-level value of some defects is high, such as insect injury, wind scarring, this leads to the loss of image detection. This method involves digital signal processing which brings difficulties to the practical development. Zhang et al. (2014) proposed to use Lambertian model to approximately analyze uneven distribution of lightness and use the annulus area of object to finish lightness correction. However, in the field of view, if the position of on-line moving fruit is not in the center of camera optical axis or the fruit shape is not a perfect spheres, the distribution of lightness in the annulus area of fruit is still uneven so that the lightness correction effect is not good using averaging method.

The success of the algorithms that perform the image analysis is largely dependent on the segmentation procedure. (Gonzalez and Woods, 2013). Segmentation procedure is an important step that affects the performance of further processing stages in computer vision applications (Cesar and Marco Aurelio, 2014).In digital image processing, binarization techniques can be classified into three main categories, global, local and hybrid methods. If the algorithm of segmentation is based on a single threshold which is applied to all pixels of the entire image, the binarization is called

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http://dx.doi.org/10.1016/j.compag.2017.02.027
0168-1699/

global method, e.g. the famous Otsu's method (Otsu, 1979). For orange images with uneven illumination, global methods provide unsatisfactory results when orange images present faint defect characters or inhomogeneous surface. If the algorithm of segmentation is based on each pixel a threshold according to the gray-level of its neighborhood or according to pixels within a given neighborhood, the binarization is called local, e.g. method of Bersen (1986), Niblack (1986), Sauvola and Pietikainen, 2000, Gatos et al. (2006) and Messaoud et al. (2011). If the algorithm of segmentation combines global and local principles, the binarization is called hybrid method, e.g. method of Kuo et al. (2010).

Many local segmentation techniques have been widely applied to deal with the high variation within historical document images, especially in the case of historical documents that very specialized problems have to be dealt with, such as variation in illumination, dark border, smearing, seeping of ink to the other side of the page, general degradation of the paper due to aging and a unclear bimodal pattern (Kavallieratou, 2008). Fruit growth environment is complex, such as climate impact and insect pests which result in complex and irregular surface defects which is most important looses during post-harvesting. Meanwhile, the sharp feature of oranges and many other fruit is approximately spherical, so segmentation process of defects on fruit is easily disturbed by the object image boundary effect (Tao and Wen, 1999; Zhang et al. 2014). The contrast between sound and defective regions can be used to produce more accurate binarization results, which is more capable of detecting pixels lying around the defect boundary on orange surface using the gray-level image local segmentation technology.

The objective of this paper is to develop a novel local segmentation algorithm to effectively detect the various types of surface defects on orange without additional image lightness correction process. To achieve this objective, the detection approach of surface defects on orange based on a sliding comparison window local segmentation is proposed in this study.

2. Materials and methods

2.1. Acquisition of the images

The samples in the experiments consisted of a total of 1191 oranges (Jiangxi Navel Orange). These orange samples were randomly collected from the commercial orchard in Jiangxi province (Li et al., 2013). Each sample had several surface defects with colour, brightness, shape and size. Each defective orange contained one or more surface defects and diseases caused by insect injury, wind scarring, thrips scarring, scale infestation, canker spot, dehiscent fruit, copper burn and phytotoxicity. Table 1 shows nine samples of oranges used in the experiments.

The colour image acquisition system consisted of a CCD (charge-coupled device) camera (Pulnix TMC-7DSP) capable of acquiring images with a size of 640 × 480 pixels and a resolution of 0.28 mm/pixel and a image frame grabber (Matrox Meteor II) connected with a personal computer [Pentium 2.00 GHz, 256 Mb RAM (random access memory)]. The CCD camera was placed 900 mm above the scene. The lighting system consisted of six white fluorescent tubes (20 W each, F40BX/840). Diffuse reflection plate is placed in front of each fluorescent tubes in order to reduce he bright spots of the scene (Rao, 2007). All the elements were mounted inside an inspection chamber. The orange was placed on a blue background plate. The images were acquired by placing the orange manually orienting the side of the fruit that contained the defects towards the camera. Fig. 1 shows nine samples of oranges used in the experiments.

Table 1
Image selection of different type of samples.

Peel type	Images with stem end	Images without stem end	Total
Insect injury	17	23	40
Wind scarring	28	82	110
Thrips scarring	47	125	172
Scale infestation	34	74	108
Canker spot	52	121	173
Dehiscent fruit	28	136	164
Copper burn	17	153	170
Phytotoxicity	16	124	140
Sound	114	0	148
Total	353	838	1191

2.2. The image segmentation description and procedure

It can be observed that the gray-level value of the middle area is greater than that of the edge area, so that it is difficult to detect defect regions in the edge area in Fig. 2. Because of the effect of surface non-uniform brightness on orange, the false detection is inevitable directly using global gray-level threshold segmentation. In the 2D gray-level intensity energy image with false colour, it can be observed that the contrast in local regions can be used to produce more accurate binarization results, which is more capable of detecting pixels (lying around the defect boundary) on orange surface.

The objective of this algorithm is to segment and detect the regions of the surface defects and stem end on oranges. The main steps of image processing consist of removal of background pixels, gray-level image binarization with a sliding comparison window, image subtraction, hole filling and removal of stem end pixels.

2.2.1. Removal of background pixels

The contrast of the blue component image between the fruit and the background in the image was the maximum, so fruit can be segmented from background by blue component gray level histogram (Ying, 2000).Fig. 3 shows blue component image with insect injury orange (a) and the histogram of blue component (b). From the histogram figure, we can find that the proper segmentation threshold of orange and background is 176. The binary mask can be obtained using Eq. (1).

$$IMG_{Mask}(i,j) = \begin{cases} 1 & IMG_{Blue}(i,j) < 176 \\ 0 & otherwise \end{cases} \tag{1}$$

$IMG_{Blue}(i,j)$ is the blue component image of the RGB image; $IMG_{Mask}(i,j)$ is binary mask image; i is the abscissa of pixel; j is the ordinate of pixel.

In general, the object can be achieved by directly segmenting the image at an intensity level. But when the stem end on the orange is orienting the side of the fruit towards the camera, the gray-level value of the stem end center region is similar to the background. It is necessary to remove the zone that the area of which is less than 150 pixels. The orange boundary edge is extracted, then modified by utilizing morphological dilation with a disk-shaped structuring element where the radius is 4 pixels in order to completely remove the orange bound edge in the defect segmentation process. Fig. 4 shows the binary mask (a) and the bound edge after morphological dilation (b).

2.2.2. Gray-level image binarization with a sliding comparison window

Local comparison segmentation method is based on the principle that defines the neighborhood window of the center reference pixel, compares the gray-level value of the observation pixel with