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A novel segmentation algorithm for clustered flexional agricultural products based on image analysis

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ABSTRACT

The problem for segmentation of clustered flexional agricultural products becomes complex when we perform the duties of counting and classification. A novel algorithm based on concavities and circle fitting is proposed to solve these difficulties. Initially, a circular mask method was applied into the contour images of clustered shrimp, to acquire a series of concavity points. Furthermore, the candidate segmentation lines can be acquired by connecting each two concavity points, and then the correctness for each candidate segmentation line was evaluated by designing four acceptance criterions. Additionally, one new point was acquired by combining adaptive two concavity points together to construct a training model to fit the circle equation, which can transform the erroneous straight segmentation lines into proper curve segmentation lines. Finally, the straight and curve segmentation lines were integrated in one clustered image to achieve the segmentation results. Experimental results revealed that the proposed algorithm achieved a mean accuracy of 92.7% across the clustered shrimp dataset. Other two application examples of flexional agricultural products, such as clustered green pepper and shrimp meat, were also used to test the effectiveness of the proposed algorithm. Segmentation results demonstrated it can successfully segment the images, which indicates the proposed algorithm has the potential to separate clustered flexional agricultural products.

1. Introduction

Recent researches have shown that pattern recognition technology is competent for objects classification and identification (Martinel et al., 2015; Lampert et al., 2014), it also has the potential to become an important tool for food quality inspection (Ding et al., 2015; Ok et al., 2014). Some previous studies (Liu et al., 2016, 2015; Zhang et al., 2014, 2013) mainly focused on food classification with a deliberate classification algorithm in one single channel that only accommodates a single-row of products, this design is highly inefficient. With increasing demands for improving production output, an arrangement with large numbers of touching objects moving on the conveyor belt was adopted by engineers (Mingireanov et al., 2013; Shin et al., 2012). Using this transportation way, it is inevitable for agricultural products to touch with each other forming clusters, especially to some flexional agricultural products such as shrimp, green pepper and shrimp meat. The touching objects will bring difficulties of classification and identification duties on-line. Thus, developing an algorithm to segment large numbers of clustered flexional agricultural products is put on the schedule. This project is also beneficial for counting and classification of large-scale clustered flexional agricultural products.

Some researchers have concentrated on the clustered touching objects segmentation problem. For example, a novel method based on watershed algorithm was proposed to split the joined citrus mass and enable an estimation of fruit size (Shin et al., 2012). The proposed segmentation algorithm could accurately detect and effectively separate each of the touching citrus mass with a relatively fast speed. An algorithm based on watershed and concavities information to segment the clustered rice kernels was invented (Zhong et al., 2009). However, the two methods are inefficient to the flexional aquacultural products especially with large contact surfaces formed between every two flexional aquacultural products in the touching location. Some other researchers have concentrated on the study of touching optical character segmentation problem (Olszewska, 2015; Jiang et al., 2015). For example, a new algorithm based on the convex hull information to split various different orientations of touching character was developed (Roy et al., 2012). In many other research fields, watershed method is widely used as the combination method to complete the segmentation work, such as combining fuzzy cluster analysis with watershed algorithm (Rao and Srinivasa, 2006), setting markers

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in images (Flores and Lotufo, 2010), improving watershed algorithm based on morphological filtering (Yen et al., 2015; Sanchez et al., 2015), wavelet transform (Hammoudeh and Newman, 2015; Chen et al., 2015) and integrating texture in segmentation to avoid the over-segmentation problem (Trias-Sanz et al., 2008).

However, these algorithms introduced above may be useful in specific situations, but directly used them to segment clustered flexional agricultural products, such as shrimp, would lead to the following two problems:

(1) The common problem of the watershed algorithm lies in the unconspicuous contrast intensity of greyscale or color in the touching location, which will produce an erroneous segmentation line. Moreover, this method is easy to generate continuous greyscale variation due to tiny illumination change. The segmentation error using watershed algorithm is shown in Fig. 1a.
(2) High variability of shrimp shapes in different orientations make the problem very challenging for automatic shrimp identification (Ehrlich and Chin, 1980). Based on the concavities information, we used the method proposed by Zhong (Zhong et al., 2009), the segmentation errors are shown in Fig. 1b.

Therefore, in this article, a novel method based on concavities and circle fitting was proposed to solve the aforementioned problems. Meanwhile, some similar flexional agricultural products such as green pepper and shrimp meat were used to test the generalization performance of the proposed algorithm. In an ideal situation, all the split lines are all the straight lines, which is easy to solve. However, not all the straight lines are correct. For the erroneous split lines, we have constructed a training model for acquiring new point to fit a circle equation, which can transform the erroneous straight lines into the correct curve lines. Then, all the straight and curve segmentation lines are integrated in one clustered flexional agricultural products image to achieve correct segmentation results. The proposed algorithm has the merits of overcoming the over-segmentation problem brought by watershed method and it can also overcome the errors produced in segmenting the touching bended shrimp. The main objective of this research is to develop an algorithm that separates clustered flexional agricultural products with various touching scenarios.

2. Methods

2.1. Background segmentation and contour extraction

The background segmentation is an important step in the process of extracting contour of clustered shrimp. The proposed method in the latter sections is completely on the basis of the extracted shrimp contour. Because color of the food-grade conveyor belt (used for transportation of shrimp in the classification system) differs from the color on the surface of shrimp, the color contrast difference between the surface of conveyor belt and shrimp is considered in the background segmentation.

After the original color image (Fig. 2a) is translated into grey-level image, consider the grey histogram of grey-level image, the object peak and the background peak are obviously different (Fig. 2b). Based on this difference, the threshold can be acquired by averaging the two peak values:

$$th = \frac{p1 + p2}{2} \tag{1}$$

where th represents threshold, $p1$ and $p2$ represent grey values of the two peaks. Set the pixel value in the grey-level image where the grey value exceeds the calculated threshold as zero and make a binarization to the result image (Fig. 2c). As shown in Fig. 2c, there appear some intermittent connectivity areas because shrimp tentacles attached on the shrimp body. Image maximum connectivity region was used to eliminate them and median filtering was used to smooth image edge (Fig. 2d). Transmit the single-channel image to three-channel image, record all the x-coordinate and y-coordinate of zero pixel values in the three-channel image, and then set these coordinate in original color image as zero. Therefore, one object of clustered shrimp is extracted individually in Fig. 2e, and shrimp contour (Fig. 2f) is obtained by using the classic canny edge detection (Canny, 1986) based on grayscale image. The extracted shrimp contour is shown in Fig. 2f.

2.2. Concavity points foundation and detection

Normally, the shrimp head and tail are sharply convex, and the backside of shrimp has a gentle convexity (Fig. 3a). However, the inner side of shrimp body (Fig. 3a) is concave under the curly posture. In most cases, it is hard to produce an intact cluster without any concave part when shrimp inner side touches with shrimp head or shrimp tail or backside of shrimp, because the orientation of every shrimp is disordered and unsystematic. Moreover, a regular pattern is difficult to be found between each two touching shrimp. Thus, the touching position is actually concave or nearly concave. According to this precondition, all the concavity points in the image can be detected using circular mask based method (Zhong et al., 2009). In order to make a self-contained section, this method is briefly explained below:

First, one circle is painted at each pixel location along shrimp contour, treating each pixel as the center of the circle. Coordinate of center is denoted (a, b), arc lengths between each two points on the circle are all denoted $\pi/20$, thus each point coordinate on the circle can be defined:

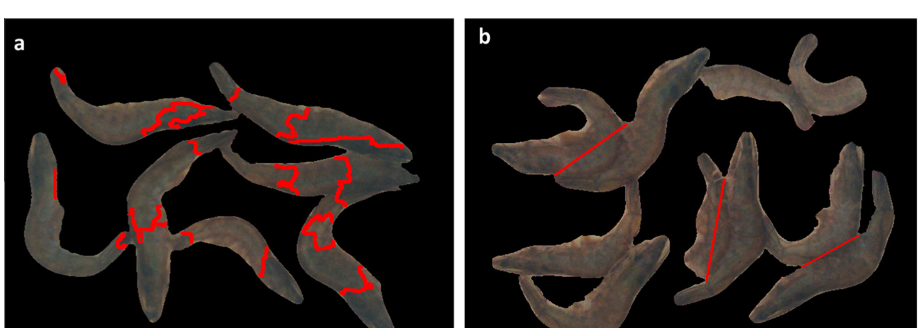

Fig. 1. Segmentation errors for the two touching scenarios: (a) erroneous segmentation lines produced by using watershed method; (b) erroneous segmentation lines produced by using Zhong's method.