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A novel artificial neural networks assisted segmentation algorithm for discriminating almond nut and shell from background and shadow

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ABSTRACT

Segmentation is one of the main steps in image processing, as it influences the accuracy of other processes such as feature selection and classification. In this study, an effective method based on a combined image processing and machine learning was presented and evaluated for segmenting almond images with different classes such as normal almond, broken and split almond, shell of almond, wrinkled almond and doubles or twins almond. One of the major difficulties encountered in segmenting almonds was the existence of shadow on the background of the acquired images. Another difficulty was separating almonds with various shapes and colors from input images. To implement an effective algorithm, initially a suitable set of color features was extracted from the images. Then, sensitivity analysis was used to select the best features. Finally, artificial neural networks (ANNs) were adopted to classify the images into three categories, namely, object, shadow and background. The optimum ANN classifier had a 8-5-3 structure, i.e., it was consisted of an input layer with eight input variables, one hidden layer with five neurons and three neurons as output. To evaluate the performance of the proposed method, the results of our optimum ANN model were compared with Otsu, dynamic thresholding and watershed methods. The mean values of sensitivity, specificity and accuracy for object class (detected almonds from images) achieved by using the proposed method were 96.88, 99.21 and 98.82, respectively. It gave a better accuracy than the mentioned methods. In addition, the proposed method was able to separate the almonds from the background and shadows more efficiently. The processing time of the proposed method was 1.35 s which makes it possible for real time applications.

1. Introduction

Almond is one of the major exported products of Iran. According to the FAO statistics, Iran produced about 167,000 tones of almonds in 2011. After USA and Spain, Iran was ranked third as the producer of this product (FAO, 2011). The price and the quality of the agricultural products like almond mostly depend on the factors like variety and postharvest operations (grading, sorting, etc.).

Image processing is considered as one of the main parts of machine vision (Krutz et al., 2000). Basically, an image processing algorithm may be implemented at three different levels: low level, medium level, and high level. Low level processing includes preprocessing for improving the quality of the input images, like noise reduction and image enhancement. Medium level processing includes segmentation, description, and feature extraction. In recent years, high level processing techniques employing artificial neural networks (ANN), support vector machines (SVM), decision trees (DT), etc. are often used for classification purposes after selecting superior features (Mollazade et al., 2012).

Image segmentation is one of the major steps in image processing, which directly influences the performance of other post-segmentation processes. Postharvest operations such as grading and sorting of almonds can be done automatically after segmenting the images. There are three different methods for separating the region of interest (ROI) from the background. They include threshold based methods, edge based methods, and region based methods (Sonka et al., 1999; Sun, 2000). Thresholding is the simplest method of image segmentation. This method is used where changes in environmental conditions such as light is almost constant or uniform. There are four basic methods to choose the threshold for segmenting images in an image processing task. They include histogram clustering, manual selection, objective function, and isodata algorithm (Zheng and Sun, 2008). Fuzzy technique has also been used to choose the threshold (Tobias and Seara, 2002). The edge based method is used for detecting discontinuity in

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intensity level, which is the boundary of image. Edge detectors that are used often for this purpose include Sobel, Canny, Laplacian, and Prewitt. Finally, region based methods are mainly used for classifying similar pixels using their features in a group (Brosnan and Sun, 2004).

In the recent years, several authors have reported the application of different image segmentation algorithms for discriminating various types of agricultural products from the background. Lee and Archibald (2010) separated dates from the background in the original image using RGB color space. The background color was chosen as blue. They used R and B components for segmenting images by thresholding. One of the problems in this study was the placement of shadow pixels in segmented image. Upon thresholding of the segmented image, parts of date boundary were eliminated. The drawback in this method was removal of some ROI parts from the images. Mollazade et al. (2012) used RGB color space for separating raisins from the background. In this case, the B component of images had a high contrast between raisin and background. Therefore, the Otsu's threshold method was applied on the B component. Also because of the existence of shadows in the segmented images, morphological operators were used for their removal. A disadvantage of this method, for removing shadow from images, was again elimination of some ROI parts from raisin boundary which could contain useful information. Mery et al. (2013) developed a system based on machine vision for quality evaluation of agricultural products. They used pears for assessing the system. A linear combination of the R, G, and B channels was converted into grayscale image. By using thresholding, they separated pear fruit from the background. This method is mostly used in cases in which the created shadow of the product on the background can be easily identified and removed. But when the pixels of the shadow are similar to those of object boundary or object itself, separating whole parts of the object could be a difficult task. Wang et al. (2013) suggested an algorithm to separate the surrounding of different leafs from the background. Otsu method with Canny's edge detector was used for image segmentation. They used the morphology method, logical operations and shape identification algorithms for correcting the segmented image. One of the advantages of this algorithm is its application for online and real time systems. Guo et al. (2013) developed a robust algorithm for separating vegetation from the background. The original images were captured under natural light conditions which contained shadow as well as reflected parts. They used different color components in several color spaces as best features, using DT technique. The images were successfully classified and the vegetation parts were separated from the background. The accuracy of this method was about 80%. Finally, a new method for crop segmentation from original images which were taken under different illumination environment was suggested using morphology modeling and CIE $L^*a^*b^*$ color space (Bai et al., 2013).

Methods based on computational intelligence are effective techniques in classification issue (Hu et al., 1998). They include ANNs, SVMs, DTs and fuzzy logic clustering. Specifically, applications of ANN for problem solving, classification, modeling and regression in different fields are being developed and accepted by many researches (Marini et al., 2008).

Literature review showed that one of the problems in image processing of agricultural products is the existence of shadows in the images. Also different classes of almonds have various shapes and colors which make difficulty for separating them from the background. Accordingly, the aim of this study was to present an efficient algorithm based on image processing and machine learning for segmenting almond images into three classes: shadow, background and object. In order to increase the precision of the proposed method, a noise reduction technique was also developed and applied on segmented images.

2. Materials and methods

The framework for segmenting almond images is presented in Fig. 1. Almonds were obtained from a local market and then different classes of almonds like normal almond, broken and split, wrinkled, doubles or twins and almond's shell were identified (UNECE, 2009). After image acquisition, the components of different color spaces were used as input features for classification purposes. For selecting appropriate features (i.e., useful information to distinguish the pixels of shadow, object and background), sensitivity analyses was performed. Superior features were then used as inputs to artificial neural networks (ANN) classifier for separating the almonds from background and shadow. Finally to validate this technique, our results are compared with other segmentation methods. In the following sub-sections, these processes are described in details.

The algorithms were implemented in Matlab software using a laptop having a core i5 CPU, 2.5 GHz and 4 GB memory.

2.1. Image acquisition

To capture the pictures of almond, a scanner (HP Scanjet 3570c, USA) was used and a green cardboard was selected as the background. The captured images had 300 dpi resolutions with a size of about 22 MB each. The almonds included five categories (UNECE, 2009): normal almond, broken and split, wrinkled almond, double or twins and shell of almond. Training images from different classes of almond are shown in Fig. 2, where (A) shows normal almond, (B) shows broken and split, (C) shows almond's shell, (D) shows double or twins, and (E) shows wrinkled almond. Almonds that two kernels are placed in one shell are called doubles or twins (Fig. 2D). Their shapes and textures are different with normal almond. Wrinkled almonds (Fig. 2E) are almonds of which kernels are not fully developed and their surfaces are shrunk. Again, the shape and color of this class is different from normal almond.

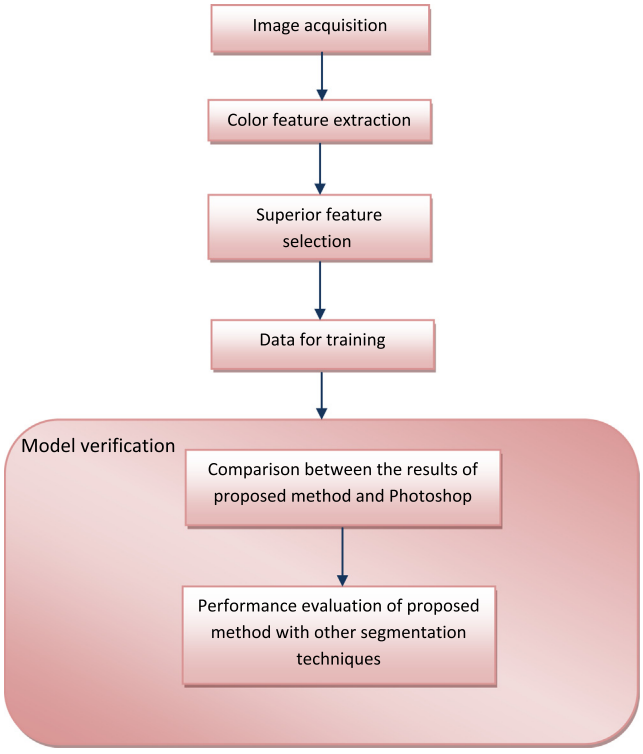

Fig. 1. Steps for segmenting images of almond.