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Classification of peeled pistachio kernels using computer vision and color features

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ABSTRACT

In this study, an algorithm based on combined image processing and machine learning techniques including artificial neural networks (ANN) and support vector machine (SVM) were implemented for grading peeled pistachio kernels (PPK) into five classes: green, yellowish green, yellow, mixed color and unwanted materials. Initially, the B-component of the images in $L^*a^*b^*$ color space and Otsu thresholding were used for segmentation of the images. Altogether, 72 chromatic and four shape features were extracted from the samples. After carrying out sensitivity analysis, the input vector was reduced to 26. Principal component analysis (PCA) was applied to further compress the size of the input vector to 7. The best ANN classifier had a 7-8-5 structure with correct classification rate (CCR) of 99.4%. The best kernel function for SVM algorithm was radial basis with CCR, C, sigma and the number of support vectors of 99.88, 10, 3.5 and 266, respectively.

1. Introduction

Among nuts, pistachio is one of the most nutritious. In a 100 g serving, pistachio provides 562 calories and is a rich source of protein, dietary fiber, several dietary minerals and the B vitamins, thiamin and vitamin B6. It is a good source of calcium, vitamin B5 and vitamin E. According to FAO (2012), Iran by producing 472097 tons is the biggest producer of pistachio in the world. Pistachio nut has an important role in export of non-oil goods in Iran's economy (Dashti et al., 2010).

Grading and impurities separation are important tasks at the stages of post-harvesting of most crops. Manual methods to perform these tasks have many disadvantages including being time-consuming, expensive, lack of uniformity and results are dependent on taste and experience of different people. In recent years, computer vision based on image processing is one of the modern alternative techniques which has attracted many producer's attention (Jha, 2010; Maftoonazad et al., 2011; Sankaran et al., 2016). Blasco et al. (2009) used image processing to separate unwanted materials from pomegranate seeds and classified the seeds into four classes of white, pink, red and brown. The best index to define the color of samples in the images was R/G ratio in the RGB color space. Computer-generated artificial classifiers that are intended to mimic human decision making for product quality have recently been studied intensively (Kavdir and Guyer, 2008; Rafiq et al., 2015). The coordinated activity of the computer vision and artificial neural networks (ANNs) is simulator to the coordinated activity of human brain and eyes. Combination of the ANN and principal component analysis (PCA) techniques with the help of acoustic effect was used for sorting of open and closed pistachios (Omid et al., 2010). Also ANN was used to classify almonds into five different classes (Teimouri et al., 2015). For this purpose, 215 shape, color, and texture features were extracted from the images of almonds. The number of the inputs in the feature vector were reduced from 215 to 18 by using sensitivity analysis (SA) and PCA (Teimouri et al., 2015). Support vector machine (SVM) has become a popular technique for classification in agricultural applications by finding separating hyperplanes between input data of different classes (Mitra et al., 2004; Nashat et al., 2011). Mizushima and Renfu (2013) reported less than two percent error for grading apple with three different colors using SVM and the image processing. Mollazade et al. (2012) applied image processing and four machine learning techniques such as ANNs, SVMs, decision trees and Bayesian networks for classification of raisins into four classes. They

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found that ANN and SVM were the best classifiers with accuracies of 96.33% and 95.67, respectively.

According to UNECE STANDARD DDP-10 (2010), color is a quality index of peeled pistachio kernel (PPK). The purpose of the standard is to define the quality requirements of pistachio kernels and peeled pistachio kernels at the export-control stage. So, peeled pistachio kernels may be classified according to color. In case of color classification, following color types are defined below (UNECE STANDARD DDP-10, 2010):

(i) Green kernel (GK)

The inside longitudinal section must be green or dark green in color. Not more than 25 percent of kernels, by count, may display light green and/or yellow sections.

(ii) Yellowish Green kernel (YGK)

The inside longitudinal section must be yellowish green in color. Not more than 40 percent of kernels, by count, may display yellow sections.

(iii) Yellow kernel (YK)

The inside longitudinal section of the kernel must display a predominantly yellow color. Not more than 25 per cent of kernels, by count, may display green and/or light green color.

(iv) Mixed Color kernel (MCK)

Lots not included in one of the above categories fall into this category.

(v) Unwanted material (UM)

Also, there is a fifth class called unwanted material (UM). UM includes closed pistachios and pistachio crusts.

Based on this standard, low damage is not considered as a defect. Also in some cases the five mentioned classes have different shape features.

For classification of many agricultural products based on available standards, using one set of color features cannot guarantee proper performance. It is therefore better to combine various features in order to obtain a better classifier with high accuracy among different classes of a product (Teimouri et al., 2015). Combination high technology handling systems, is the most important advantage of artificial classifiers (such as ANNs and SVMs) provided in classification of agricultural products (Kavdir and Guyer, 2008). Researchers also indicated the effectiveness of ANNs and SVMs for classification of products such as raisin and almond nut based on computer vision systems (Mollazade et al., 2012; Teimouri et al., 2015).

The robustness, capability of approximating a posterior distribution and high potential for parallel processing makes artificial intelligence systems a suitable choice for classification of agricultural products. (Mahmoudi et al., 2006).

The purpose of this study was to develop an intelligent system for classifying PPKs using combined image processing and machine learning techniques including ANNs and SVMs based on UNECE standard for preparation of PPKs for export. Therefore, if the processing time of the method is improved further, it can readily be used in an online sorting machine.

2. Material and methods

Steps for developing an intelligent system for PPK included image capturing, segmentation, features extraction, reduction in the dimension of the feature vector, grading of PPKs and finally performance evaluation of the classifiers. A sample image of the five classes of PPKs including GK, YGK, YK, MCK, and UM classes are shown in Fig. 1.

The MATLAB software R2012a (MathWorks, 2012) was used to integrate all algorithms and to implement ANN and SVM classifiers.

2.1. Vision system

A CCD scanner (HP Scan Jet 3570C, California, US) was used for acquiring the images of PPKs. In this research, expert's judgment (opinion) was used for determination of pistachio nut's class. All samples were manually classified by human expert. Altogether, 170 samples were prepared from each class (totally 850 samples) and two images were captured for each class. The images were saved in JPG format with 300 dpi resolution. A total of 10 images were acquired from all the classes. The acquired images were transferred to a personal computer for further analysis.

2.2. Image segmentation

The segmentation step is one of the most important steps in image processing and the performance of next steps is highly dependent on this step (Brosnan and Sun, 2004; Teimouri et al., 2015). One of the segmentation methods which is widely used, is

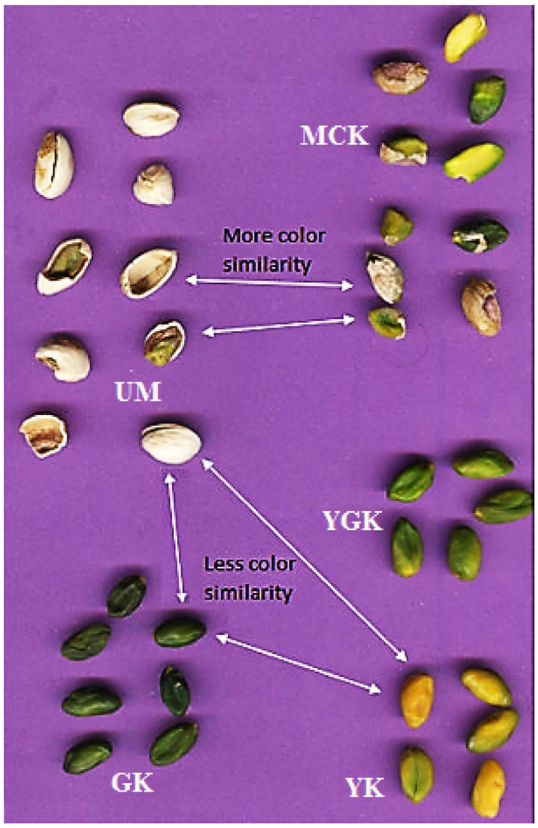

Fig. 1. The different classes of the PPKs based on UNECE standard; GK is green kernel, YGK is yellowish green kernel, YK is yellow kernel, MCK is mixed color kernel, UM is unwanted material.

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