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Design, development and evaluation of an online grading system for peeled pistachios equipped with machine vision technology and support vector machine

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A B S T R A C T

In this study, an intelligent system based on combined machine vision (MV) and Support Vector Machine (SVM) was developed for sorting of peeled pistachio kernels and shells. The system was composed of conveyor belt, lighting box, camera, processing unit and sorting unit. A color CCD camera was used to capture images. The images were digitalized by a capture card and transferred to a personal computer for further analysis. Initially, images were converted from RGB color space to HSV color ones. For segmentation of the acquired images, H-component in the HSV color space and Otsu thresholding method were applied. A feature vector containing 30 color features was extracted from the captured images. A feature selection method based on sensitivity analysis was carried out to select superior features. The selected features were presented to SVM classifier. Various SVM models having a different kernel function were developed and tested. The SVM model having cubic polynomial kernel function and 38 support vectors achieved the best accuracy (99.17%) and then was selected to use in online decision-making unit of the system. By launching the online system, it was found that limiting factors of the system capacity were related to the hardware parts of the system (conveyor belt and pneumatic valves used in the sorting unit). The limiting factors led to a distance of 8 mm between the samples. The overall accuracy and capacity of the sorter were obtained 94.33% and 22.74 kg/h, respectively.

1. Introduction

Pistachio nut is the top non- petroleum export of Iran that accounted up to 60% of global pistachio market. It has an important role in Iran's exports and economy as a non- petroleum good [1]. Due to drawbacks of manual grading such as subjectivity, tediousness, labor requirements, availability, cost and inconsistency, an automated grading system needs to be developed. Recently, several researchers have conducted their efforts on developing the grading system. The methods extend from manual-machine grading, where the features are determined manually, under laboratory conditions to

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machine vision systems for automated high-speed fruit sorting [2]. It is clear that mechanized grading of pistachio nut reveals many advantages including elimination of wages behalf of manual grading, more uniformity and more hygienic product compared to manual methods. Therefore, design of full-automatic sorting machines can attract more customers and supports to Iran's position in export of this worthwhile produce. Among many available methods for quality evaluation of the crops, machine vision (MV) systems have proven to be the most powerful [3,4]. A MV system consists of two main parts: hardware and software parts. These systems like the human eye are strongly influenced by lighting system. This part has a significant effect on the quality and resolution of the captured images and also considerably affects overall performance and efficiency of the MV system [5,6].

Computer-generated artificial classifiers that are intended to mimic human decision making for product quality have recently been studied, intensively [7]. Omid et al. [8] designed and evaluated an intelligent sorting system for open and closed-shell pistachio nuts. The system included a feeder, an acoustical part, an electronic control unit, a pneumatic air-rejection mechanism and ANN classifier. The recognition was based on combined PCA of impact acoustics and ANN classifier. To generate useful features, both time and frequency-domain analysis of recorded sound signals were performed. In a recent study, a new method based on MV system was developed for egg volume prediction [9]. Two methods of egg size modeling (i) a mathematical model based on Pappus theorem, and (ii) an ANN model were developed and validated. Mollazade et al. [10] applied MV and various artificial classifiers for grading raisins into four classes. To provide uniform lighting and to eliminate the environmental noises, they used two fluorescent tube lightings above the samples and put a black cover on the imaging set. There is no doubt that purity of the agricultural products from unwanted materials is one of the requirements and it is an important task at post-harvesting industries of most crops [5]. A full-automatic system has been developed to remove the unwanted materials from pomegranate seeds and classify the seeds into four classes [11]. Another research proposed an algorithm based on image processing for grading chestnuts. The algorithm was successfully applied on the online sorting systems [12]. Mustafa et al. [2] developed a sorting and grading system based on image processing and Support Vector Machine (SVM). The developed system captured fruit's image using a regular digital camera. Then, the image was transmitted to the processing level where feature extraction, classification and grading was done using MATLAB. The fruit was classified using SVM. ElMasry et al. [13] developed a fast and accurate computer-based machine vision system for detecting irregular potatoes in real-time. Supported algorithms were specifically developed and programmed for image acquisition and processing, controlling the whole process, saving the classification results and monitoring the progress of all operations. The experiments showed that the success of in-line classification of moving potatoes was 96.2%. Kaur and Singh [14] developed machine vision system to grade the rice kernels using Multi-Class SVM. Multi-Class SVM classified the rice kernel by examining the shape, chalkiness and percentage of broken kernels. They concluded that the system was enough to use for classifying and grading the different varieties of rice grains based on their interior and exterior quality. Teimouri et al. [15] combined artificial neural network with machine vision to identify five classes of almond according to visual features. The images of five classes of almond including normal almond, broken almond, double almond, wrinkled almond and shell of almond were acquired, segmented by Otsu's thresholding method and classified by ANN. Olgun et al. [16] developed wheat grain classification system by machine vision and SVM classifier.

According to performed studies on production and processing steps of pistachio kernels (PK), after cracking of close pistachios some cracked pistachio shells (PS) remain. The purpose of this study was to develop an automated system for sorting of PKs from unwanted PSs by using MV technique and SVM classifier.

2. Material and methods

Fig. 1 shows a schematic of the developed automated system for sorting PKs from the PSs. The MATLAB software (version R2012a) [17] was used to integrate all algorithms.

2.1. System components

The sorter consists of five main parts including a conveyor belt, images acquisition unit, pneumatic components, electronic unit and a personal computer. The conveyor was used to transfer pistachios into the range of view of the camera. Samples were carried by a PVC infinite conveyor belt with size of 25 × 180 cm and thickness of 1 mm. The conveyor was driven by an AC one phase electric motor with power of 60 W. In order to control the conveyor speed, a gearbox with ratio of 50 was used which reduced the speed of the motor to about 25 rpm of driver roller of the conveyor. To capture images without any noise and having a uniform light, a lighting chamber made of fabric was used. Two fluorescent tube lamps and a CCD color video camera were installed inside the lighting box. The lamps were installed about 25 cm above the conveyor belt to capture uniform images without shadow. Illuminating tubes were used together with high frequency electronic ballast to avoid the flicker effect. ElMasry et al. [13] also used a cubic chamber for imaging system in sorting potatoes. In that system, fluorescent tube lamps were used as lighting unit. The used camera (Proline, Model 565S, UK) was equipped with a CS lens mount (3.5–8 mm focal length, 480 vertical TV lines resolution). The acquired images were digitalized by a capture card and were transferred to a personal computer for further analysis. Pneumatic method was used to sort and separate the samples. The main components of the pneumatic unit were a laboratory air compressor with a cylindrical container of 15 liter and working pressure of 7 bar, hoses and 7 solenoid-pneumatic valves, 24Vdc. The pneumatic valves were installed under the tail end of the conveyor (Fig. 1). An electronic device was designed and fabricated as an interface between the computer and the pneumatic system. The ATMEGA16 microcontroller was the main component of the electronic system.

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