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Color image segmentation with genetic algorithm in a raisin sorting system based on machine vision in variable conditions

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ABSTRACT

This study was undertaken to develop machine vision-based raisin detection technology for various lighting conditions. Supervised color image segmentation using a permutation-coded genetic algorithm (GA) identifying regions in hue–saturation–intensity (HSI) color space (GAHSI) for desired and undesired raisin detection in various conditions was successfully implemented. Images from two extreme intensity lighting and dense conditions: under weak lighting and high-density product and under suitable lighting and low-density product, were mosaicked to explore the possibility of using GAHSI to locate desired raisin and undesired raisin regions in color space when these two extremes were presented simultaneously. The GAHSI results provided evidence for the existence and separability of such regions. In the experiment, GAHSI performance was measured by comparing the GAHSI-segmented image with a corresponding hand-segmented reference image. When compared with cluster analysis-based segmentation results, the GAHSI method showed no significant difference.

1. Introduction

It is necessary to pay more attention to the export of non-petroleum products specially dried fruits such as raisin due to considerable amount of currency earned from. According to the latest statistics, Iran is one of the major raisin exporters among countries in the world and however has the second rank. Unfortunately the export value per ton of raisins is the lowest among the countries exporting this product (Anonymous, 2008). One of the important reasons for being low-value raisin is low its quality and lack of uniformity. This product has significant relationship with exporting it. Therefore, it will be necessity to develop a sorting system for automatic quality assessment before packaging. The application of machine vision for raisin sorting is promising recommended because it utilizes spectral and spatial information. One of the challenges in the development of robust detection technology is the variability associated with density product and lighting conditions. In the case of machine vision based on raisin detection, it is essential to correctly divide images into regions which are desired raisins (raisins with desired color content), undesired raisins (raisins with undesired color content) and background (surface of convertor). Image segmentation is an important and perhaps the most difficult image processing task. Segmentation refers to subdividing an image into regions exhibiting "similar" characteristics. Subsequent image interpretation tasks, such as feature extraction and object recognition, rely on the quality of the segmentation results. The difficulty arises when the segmentation performance needs to be adapted to the changes in image quality. Image quality is usually affected by variations in lighting conditions, imaging devices, density and type of product (Gonzalez & Woods, 1992). Despite the large number of segmentation techniques presently available, no general methods have been found to perform adequately across a diverse set of imagery under variable conditions (Galbiati & Louis, 1999).

Various techniques such as artificial neural network (ANN), statistical learning (SL), fuzzy logic (FL) and genetic algorithm (GA) have been applied increasingly for product quality evaluation using machine vision in recent years. Shahin, Tollne, McClendon, and Arabnia (2002) classified apple based on surface bruises using image processing and neural networks. Majumdar and Jayas (2000) classified cereal grains using machine vision and color models.

Du and Sun (2006) reviewed latest advances in learning techniques such as ANNs, SL, FL and GA for food quality evaluation using machine vision. It was concluded are that GA can represent complex, multivariate condition straight forwardly, and it is also a method for approximating discrete-valued target functions. Some of researchers have used GAs for image feature extraction. Hammouche, Diaf, and Siarry (2008) used a multilevel threshold method based on GA, which allows the determination of the appropriate number of thresholds as well as the adequate threshold values. Neto, George, and David (2006) used Gustafson–Kessel clustering and GA for individual leaf extractions from young canopy images. Zheng, Kong, and Nahavandi (2002) developed an experimental system to take images of external metallic surfaces

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and an intelligent approach based on morphology and GAs to detect structural defects on bumpy metallic surfaces. Tang, Tian, and Steward (2000) applied GA and developed machine vision-based weed detection technology for outdoor natural lighting conditions. Until now, most of the image segmentation research has been done under controlled conditions rather than variable conditions though, GA can properly represent complex and multivariate conditions. GAs are a family of adaptive search methods that are modeled after the genetic evolutionary process. An attractive feature of GAs is their high efficiency dealing with difficult combinatorial search problems without being stuck in local extremes through their parallel exploration of the search space. Therefore, they have become powerful alternatives to conventional optimization methods (Alireza, 2007).

The objective of this study was to explore the possibility of detecting—through the use of a GA—relatively stable color regions in suitable color space to segment raisins under two extreme intensity lighting conditions: (i) weak lighting and high-density product and (ii) suitable lighting and low-density product. These color regions then could be used to distinguish raisins at a large variety of conditions.

2. Materials and methods

In this research, an apparatus for sorting raisins has been designed and fabricated based on machine vision system (Fig. 1). The sorter is composed of the following parts:

1. **Conveyor belt**: To transfer raisins under camera location.
2. **Lighting box**: A lighting system consisted of three halogen bulbs (220 V, 60 W) and three CCD color video cameras (PR-565S) installed inside lighting box.
3. **Controlling and processing system unit**: In this section there are a PC for image processing (Intel 3 GHz), capture card (PXC200), pneumatic valves operated by an AVR central processor (Fig. 2) and three DC power sources (Switching 24 V/13 A).

Fig. 1. Raisin sorting apparatus.

Fig. 2. Pneumatic valves controller board.

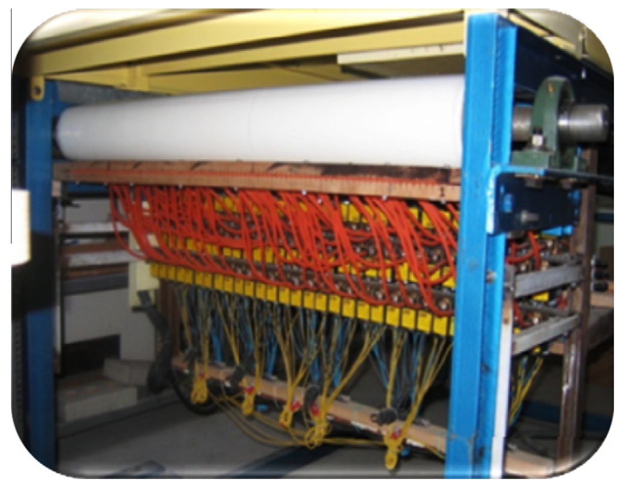

Fig. 3. Sorting unit.

4. **Sorting unit**: In this section there are 90 pneumatic valves (Parker-VE-161.4). The distance between each value is one centimeter (Fig. 3).

In the apparatus, three color video cameras were employed to capture the images. The cameras were mounted at a height of 40 cm on a custom-made camera boom. The output of each camera was routed to PXC200 color frame grabber housed in the PC. An efficient feature extraction algorithm (see next section) was designed and implemented in Visual Basic 6.0 in order to classify the raisins (Abbasgholipour, Omid, & Borghei, 2006). Basically, the algorithm receives the image data in real-time and extracts the required characteristics in accordance with the thresholds extracted by GA. In the other words, the algorithm classifies desired and undesired raisins by color features, and the location (center of gravity) of each raisin on the belt. Based on these features, each pneumatic valve operates and thus undesired raisins can be eliminated, after sending an appropriate signal for opening or closing of valve through AVR microcontroller. The sorting unit is of pneumatic type, consisting of electronic circuitry, 90 pneumatic valves and compressor which separate undesired raisins from desired ones (Fig. 3).

The frame grabber had a resolution of 486 × 640 pixels. Each pixel corresponded to an area of approximately 0.5 mm × 0.5 mm. Images were taken while the conveyor was moving with a forward speed of 15 m/min (250 mm/s) to minimize motion effects. To form a mosaicked image, four images were selected from these images set with images from two extreme intensity lighting and density conditions: under weak lighting and high-density product