ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 8, August 2016

A Survey on Computer Vision Technology for Food Quality Evaluation

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ABSTRACT: The quality of food products is very important for the human health. The large population and the increased requirements of food products make it difficult to arrive the desired quality. Sorting tons of fruits and vegetables manually is a slow, costly, and an inaccurate process. In this research a vision-based sorting system is developed to increase the quality of food products. The sorting process depends on capturing the image of the fruit or product and analyzing this image to discard defected products. With increased expectations for food products of high quality and safety standards, the need for accurate, fast and objective quality determination of these characteristics in food products continues to grow. Computer vision provides one alternative for a computerized, non-destructive and cost-effective technique to accomplish these requirements. This inspection approach based on image analysis and processing has found a variety of different applications in the food industry. Computer vision has been successfully adopted for the quality analysis of fruits and vegetables, eggs. This paper presents the important elements of a computer vision system and emphasizes the important aspects of the image processing technique coupled with a review of the most recent developments throughout the food industry.

KEYWORDS: Computer Vision, Food Quality Control, Image Processing, Sorting system, HSV color systems.

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I. INTRODUCTION

The increased awareness and difficulty of consumers have created the expectation for improved quality in consumer food products. Quality has been the subject of a large number of studies. The basis of quality assessment is often subjective with attributes such as appearance, smell, texture, and flavor, frequently examined by human inspectors. Consequently Francis (1980) found that human perception could be easily fooled. Together with the high labor costs, inconsistency and variability associated with human inspection accentuates the need for objective measurements systems. Recently automatic inspection systems, mainly based on camera computer technology have been investigated for the sensory analysis of Agricultural and food products. This system known as computer vision has proven to be successful for objective measurement of various agricultural and food products. Computer vision includes the capturing, processing and analyzing images, facilitating the objective and nondestructive assessment of visual quality characteristics in food products. This survey provides a comprehensive review of recent advances in computer vision inspection as applied to fruits and vegetables. It includes the analysis of the different technologies used, together with applications and developments intended for the external quality control of these products. In this research, a fast system for the inspection of food products using computer vision is developed. The system is applied for four different food products namely apples, tomatoes, eggs, and tomatoes. Although, there are many similarities between systems for all products, a special design and training is required for each product. This paper is organized as follow to Introduces the sorting system and the different components to sort food products using computer vision and explains image segmentation required to detect objects and defect regions in the food products.

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II. RELATED WORKS

The related work of computer vision in industry has increased considerably in recent years, and one can find applications in the terrestrial and aerial mapping of natural resources, crop monitoring, precision agriculture, robotics, automatic guiding, non-destructive inspection of product properties, quality control and sorting in processing lines and the general automation of processes. Furthermore, related work in this technology allows for the possibility of studying scenes in regions of the electromagnetic spectrum in which the human eye is not sensitive, such as ultraviolet radiation (UV) or infrared spectral regions.

III. THE FUNDAMENTALS OF A COMPUTER VISION

The organization of a computer vision system is highly application dependent. Some systems are stand-alone applications which solve a specific measurement or detection problem, while others constitute a sub-system of a larger design which, for example, also contains sub-systems for control of mechanical actuators, planning, information databases, man-machine interfaces, etc. Many functions are unique to the application. There are, however, typical functions which are found in many computer vision systems.

Image acquisition – A digital image is produced by one or several image sensors, which, besides various types of light-sensitive cameras, include range sensors, tomography devices, radar, ultra-sonic cameras, etc. Depending on the type of sensor, the resulting image data is an ordinary 2D image, a 3D volume, or an image sequence.

Pre-processing – Before a computer vision method can be applied to image data in order to extract some specific piece of information, it is usually necessary to process the data in order to assure that it satisfies certain assumptions implied by the method. Examples are

- Re-sampling in order to assure that the image coordinate system is correct.
- Noise reduction in order to assure that sensor noise does not introduce false information.
- Contrast enhancement to assure that relevant information can be detected.
- Scale space representation to enhance image structures at locally appropriate scales.

Feature extraction – Image features at various levels of complexity are extracted from the image data. Typical examples of such features are

- Lines, edges and ridges.
- Localized interest points such as corners, blobs or points.

More complex features may be related to texture, shape or motion.

Detection/segmentation – At some point in the processing a decision is made about which image points or regions of the image are relevant for further processing.

- Image recognition – classifying a detected object into different categories.
- Image registration – comparing and combining two different views of the same object.

Decision making -Making the final decision required for the application, for example:

- Pass/fail on automatic inspection applications
- Match / no-match in recognition applications

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IV. SORTING SYSTEM

The vision based sorting system consists of different subsystems. Fig.1 shows the different components of the sorting system.

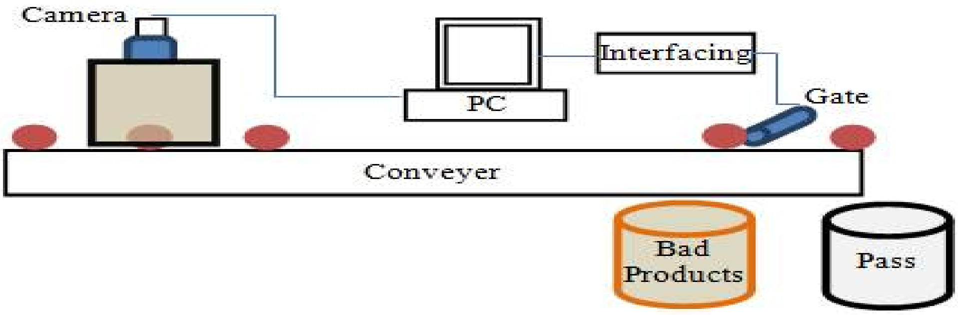

Fig.1. Sorting System

Fast single camera or multiple cameras are used to capture the image of the products. Single camera with mirrors can be used to verify the different sides of the product, while multiple cameras fixed in different directions get more clear images. Usually, isolated box with lighting is used to overcome lighting variation problems and get better images. The captured images are sent to the computer to be processed and analyzed in real time. The decision, "pass" or "fail", is sent as an electronic signal to Interfacing circuits. These circuits drive an electronic valve to open or close the path of the products. By closing the path, the product is pushed to "bad product" store. Finally, the high quality products only will continue to the "pass" store. Sometimes products are classified into more than two classes. The different classes represent different degrees of quality. The vision system consists of many modules, and it is required to finish all processing in real time. Fig.2 shows the different modules of computer vision for food products sorting. The image acquisition module captures an image and stores the image in computer memory. The size and format of the image affects the speed and accuracy of the sorting system. A high resolution image contains many details of the product, but requires large time for processing and classification. Low-resolution image are processed very fast, but the correctness of the system can be reduced. The suitable resolution should be chosen to give acceptable speed with best accuracy.

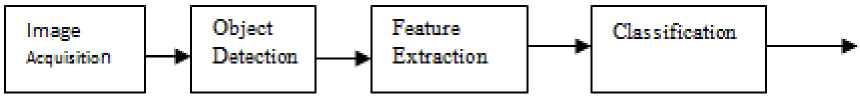

Fig.2 Computer vision system

The first step in processing and sorting the image, is to detect the object or determine the location and borders of the product. This operation is considered as an image segmentation process while the image is segmented into two classes: object and background. After the detection of the object, the area of the object is analyzed again to detect any damages in the product. This process is dependent on the nature of the product and the required classification. The damages can be detected as cracks, holes, or color changes. Image segmentation is required to extract these regions from the product area. Features are extracted from detected regions. For example the color, size, and shape of the hole are extracted to determine if this hole represents damage in the products or not. The final step is a trained classifier, which gives the decision. The next section presents the image segmentation and classification.

V. IMAGE SEGMENTATION

Image segmentation refers to the process of dividing image into regions with characteristics, extracting the targets of interest and deleting the useless part. There are two general approaches of image segmentation, i.e. Region based segmentation and Boundary estimation using edge detection. The main problem for the segmentation is the selection of threshold. In this system, a region-based segmentation is used to detect the food product and isolate it from

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background. Fig.3 shows the detection of peer with region-based segmentation. A scaled image is used to for fast object detection.

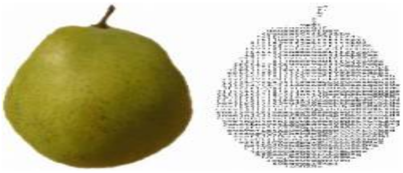

Fig.3 object detection via region-based image segmentation

Fig.3 object detection via region-based image segmentation the small sized image is processed faster than the main image. The size reduction does not affect accuracy while this step doesn't depend on small image details. Some noise can be detected in the background and interpreted as an object region but it can be discarded easily. A connected component analysis is applied and these noisy regions are discarded due to their small size. After this step, defect regions in the food product are analyzed and detected. This detection of regions depends on color differences between the body of the food product and the bad region. For egg, sorting, edge detection is applied to detect cracks in eggshell. It is difficult to extract these light cracks using color segmentation and the edge detection is more accurate for this task. Fig.5 shows the extraction of cracks in egg shell using edge detection.

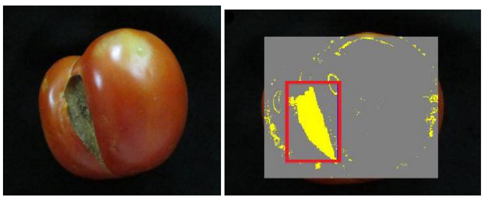

Fig.4. Bad regions detection in tomatoes

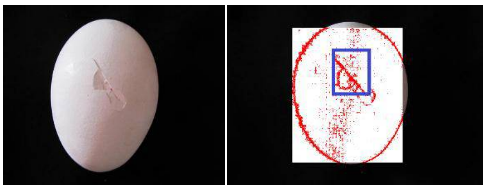

Fig.5. Eggshell cracks extraction using edge detection

VI. CLASSIFICATION

The final result of accepting the product or not depends on many factors. The color is the main factor, but it is not the only factor. The color of the spots in the body of the product, in addition to the color of whole product makes the decision. Cracks extract by edge detection in eggshell contribute in the final decision. While most of all these factors are extracted in the previous stage, the decision still needs more stages. The segmentation and edge detection stages can sense many different color spots in good products or noisy edges in eggshells. The classification stages give the final decision, and establish if this spot is a bad region or not. Fig.6 illustrates the spots in accepted tomatoes, which should be sorted as accepted fruit by the classifier.

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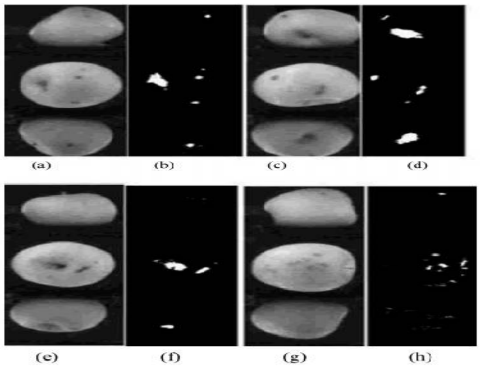

Fig.6 spots in good

In this application we used color, shape, and size features. HSV color space separate color from intensity which make it easy to classify the colors. HSV color systems consist of three color components: Hue, Saturation and Value given by equations 1, 2, 3.

$$H = \begin{cases} \arccos \dfrac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}, & B \le G \\ 2\pi - \arccos \dfrac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}, & B > G \end{cases} \quad (1)$$

$$S = \frac{\max(R,G,B) - \min(R,G,B)}{\max(R,G,B)} \quad (2)$$

$$V = \frac{\max(R,G,B)}{255} \quad (3)$$

Size of region is normalized to the size of the object to generate size invariant feature. Shape descriptors are important to decide the type of the extracted regions and the central moments are used for this task. Central moments are transitional invariant moments and they are given by equation (4).

$$\mu_{pq} = \sum_{j=1}^{M} \sum_{i=1}^{N} (i - x_c)^p * (j - y_c)^q * f(i,j) \quad (4)$$

A neural network is trained based on these features to give the final decision if this product is accepted or not. The neural network has good flexibility and it is an adaptive learning tool. The back-propagation algorithm is used to train the neural network.

VII. SIMULATION AND RESULTS

Sorting systems for different four food products (apples, lemons) are developed. Each product has its stand-alone designed and developed system with some similarities and many differences. A dataset of 1000 images (250 for each system) is used to train and test the vision-based sorting system. The size of images is 640X480 pixels which is a trade-off between small unclear images and large slow processed images. Fig.7 shows a sample of images for bad and good products for the four sets.

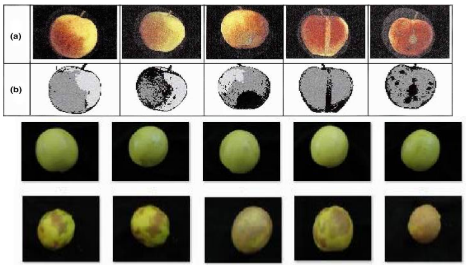

Fig.7 Sample of images dataset for good and bad products of apples, lemon.

Product	Accuracy	speed (image/minute)
Eggs	97%	176
Lemon	96.6%	210

Table.1 . System Accuracy and Speed

Table 1 reports the speed and accuracy of the system for the four different products. These values are measured after Running the system on a PC. The object detection stage is applied on a small scaled image to accelerate the processing. The remaining of the processing use the main image with size of 640X480 to detect all details found in the image.

VIII. CONCLUSION

This paper reviewed the recent developments in the computer vision for the automatic fruit recognition system with various characteristics such as defect, quality, color, texture etc. Computer vision systems have been used ever more in the industry for inspection and evaluation purposes as they can provide rapid, economic, hygienic, consistent and objective assessment. Automatic sorting of food products is an important process to get high quality food. Vision based sorting system is an accurate and fast process compared to manual sorting.

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