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Fast Quality Inspection of Food Products using Computer Vision

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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 makes 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. Signals are send via computer interfacing cards to control sorting gates. Four different systems for different food products have been developed namely, apples , tomatoes, eggs , and lemons. A dataset of 1000 images is used to train and test the vision systems (250 images for each product). An accuracy of 97% with speed up to 200 images/minute has been achieved.

Keywords: Computer Vision, Food Quality Control, Image Processing.

I. Introduction

For several years, the food industry has adopted automated vision-based inspection systems in an attempt to reduce operation costs and increase product quality control[8]. The manual sorting of fruits has many disadvantages such as Great labor intensity , Low productivity,and difficulty to carry out grading standard[1]. Nondestructive detections, like photoelectric detection, the electromagnetic characteristics analysis, Near Infrared Spectroscopy, X-ray analysis, computer vision and so forth, have been used increasingly in the food and agricultural industry for inspection and evaluation purposes as they provide suitably rapid, economic, consistent and objective assessment[7]. The potential of computer vision in the food industry has long been recognized and the food industry is now ranked among the top 10 industries using this technology [10]. Vision-based inspection systems reduce human interaction with the inspected goods, classify generally faster than human beings, and tend to be more consistent in their product classification [8]. Many vision systems have been developed for different food products inspection, such as apples, tomatoes, potatoes, vegetables, eggs, corn, rice, and many other products[1][7][9][10]. Velappan et. al. developed an apple grading system using vision box hardware with the advantages of high precision and high automatization [1]. Mertens et. al. developed a system for the dirt detection on brown eggs by means of color computer vision[8]. An automated measurement of species and length of fish by computer vision has been developed by white et. al. [3]. 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: section 2 introduces the sorting system and the different components to sort food products using computer vision. section 3 explains image segmentation required to detect objects and defect regions in the food products. Section 4 gives the classification process required to determine if the segmented regions are defect regions or not and give the final decision if this product is acceptable or not. Section 5 reports the experiments and results. Finally, Section 6 gives the conclusion.

II. Sorting System

The vision based sorting system consists of different sub-systems. Fig.1 shows the different components of the sorting system.

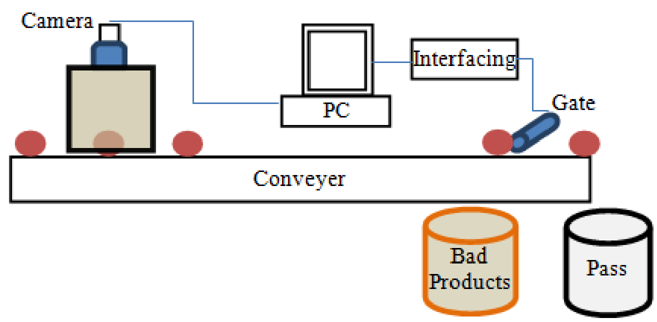

Fig.1. Sorting System

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Fast single camera or multiple cameras are used to capture the image of the products. Single camera with mirrors can be used to check 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 analysed in real time. The decision , "pass" or "fail" , is sent as an electronic signal to interfacing circuits. These circuits drives 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 represents 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 store the image in computer memory. The size and format of the image affects the speed and accuracy of the sorting system. High resolution images contains many details of the product, but requires large time for processing and classification. Low-resolution image are processed very fast, but the accuracy of the system can be reduced. The suitable resolution should be chosen to give acceptable speed with best accuracy.

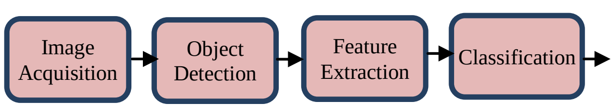

Fig.2 Computer vision system

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 analysed 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. Another image segmentation is required to extract these regions (craks- holes – different colors) 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 a damage in the products or not. The final step is a trained classifier, which gives the decision. The next sections presents the image segmentation and classification.

III. 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[11]. There are two general approaches of image segmentation, i.e. Region-based segmentation and Boundary estimation using edge detection [4]. The main problem for the segmentation is the selection of threshold. Fig.3 shows selection of the threshold based on the histogram of the gray level .

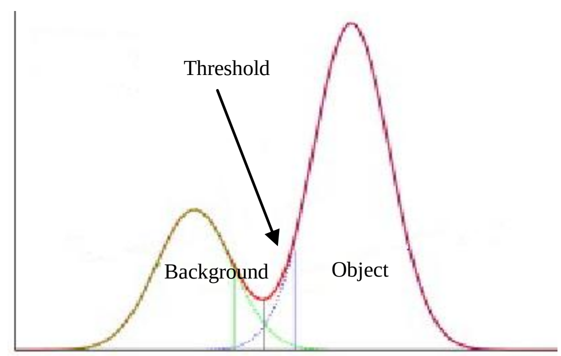

Fig .3 Threshold selection

In this system, a region-based segmentation is used to detect the food product and isolate it from background. A dark background is used to increase the speed of detection and increase accuracy. Fig.4 shows the detection of lemon with region-based segmentation. A scaled image is used to for fast object detection.

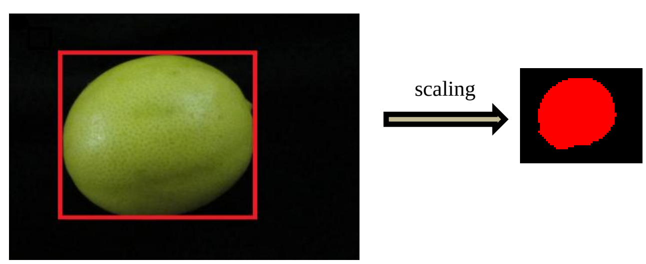

Fig.4 object detection via region-based image segmentation

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, an 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.6 shows the extraction of cracks in eggshell using edge detection.

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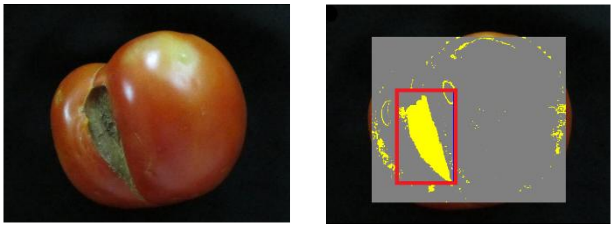

Fig.5. Bad regions detection in tomatoes

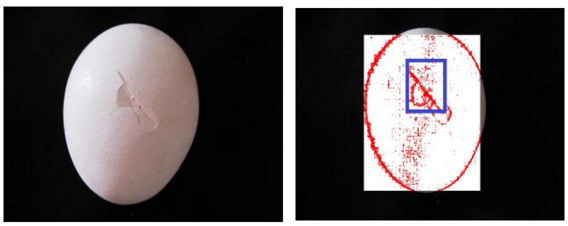

Fig.6. Eggshell cracks extraction using edge detection

IV. CLASSIFICATION

The final decision 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 make the decision. Cracks extracted 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 need more stages. The segmentation and edge detection stages can detect many different color spots in good products or noisy edges in eggshells. The classification stage gives the final decision, and determine if this spot is a bad region or not, and decide if this edge is a crack or a noise. In addition to that the color of the product as a whole has a big impact on its quality and the classifier should decide the accepted colors. Fig.7 illustrates the spots in accepted tomatoes, which should be sorted as accepted fruit by the classifier.

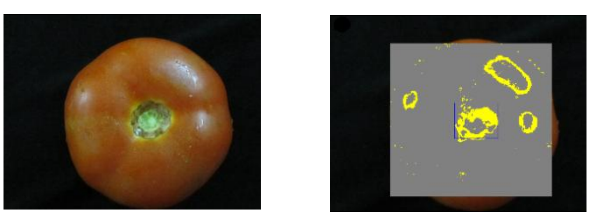

Fig.7 spots in good food products

The classifier give the decision based on a set of features extracted from the image of the product and from extracted regions. In this application we used color ,shape, and size features. There are many color systems and the HSV color space is used. HSV color space separate color from intensity which make it easy to classify the colors. HSV color systems consists of three color components : Hue , Saturation and Value given by equations 1,2,3 [2].

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

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

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

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) [6].

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

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

V. EXPERIMENTS AND RESULTS

Sorting systems for different four food products (apples, lemons, tomatoes , and eggs) 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.8 shows a sample of images for bad and good products for the four sets.

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.

Fig.8 Sample of images dataset for good and bad products of apples, lemon, tomatoes and eggs.

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 with intel core i5 2.5 GHz processor.

TABLE.1 . SYSTEM ACCURACY AND SPEED

Product	Accuracy	speed (image/minute)
Eggs	97%	176
Apples	96%	120
Tomatoes	96.5%	150
Lemon	96.6%	210

VI. Conclusion

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. HSV color space is a vital feature for classifying bad and good food products. The accuracy of this system can be improved by increasing the dataset of images and including different types of defects in the product. Speed of the system can be increased using parallel algorithms based on multicore processors.

Acknowlegment

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