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Research note

Inspecting pizza topping percentage and distribution by a computer vision method

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Abstract

Topping percentage and distribution are two major features in the quality inspection of pizzas. The extraction of these features highly depends on the segmentation quality of pizza images. However, complex visual features and wide varieties of pizzas make the segmentation task difficult. Traditional segmentation methods are found only partly suitable for most pizza images. Therefore, a new segmentation method was developed by using the region-based segmentation as a dominant method and combining the strengths of both thresholding and edge-based segmentation methods. For evaluating the evenness of topping distribution, a practical method of dividing a pizza image into several equal-area partitions was developed. The experimental results show that the computer vision method developed is suitable for many different types of pizzas with an accuracy of over 90% for measuring topping exposure percentage and distribution.

Keywords: Computer vision; Image processing; Pizza; Quality; Segmentation

1. Introduction

Visual features such as colour, shape and size indicate the quality of many prepared consumer foods. Computer vision systems have been used increasingly in the food industry for quality inspection purposes as a rapid, economic, consistent and even more accurate and objective inspection tool. The food industry now ranks among the top 10 industries using computer vision technology (Gunasekaran, 1996).

Pizzas are known of their wide varieties and attractive appearance. New styles of pizzas are produced in the highly competitive market all the time. Although different pizzas have different visual features, the general features of an acceptable pizza include regular overall histogram; similar sub-histograms of partitioned wedges; uniform colour of each individual topping; similar shape of each individual topping; pre-defined area percentage of topping objects; even distribution of each individual topping; smooth surface; round contour; proper topping overlapping and appropriate height of pizza (Sun & Tang, 1999; Tang, Sun & O'Donnell, 1999). Among them, topping percentage and distribution are the key parameters of pizza quality inspected by pizza manufacturers. These features can be rapidly extracted and analysed by computer vision systems. Unfortunately, at present these quality attributes are mainly inspected manually and therefore in pizza production lines, quality personnel are employed to check each individual pizza prior to packaging.

Inspection of an actual pizza image by computer vision systems is a very difficult task (Sun & Tang, 1999; Tang, Sun & O'Donnell, 1999), as an actual pizza has many different toppings; each individual topping has non-uniform colour and shape; some different toppings such as bacon, red pepper and tomato sauce have similar colour appearance and furthermore overlapping toppings occurs in every pizza. Therefore, in the current study, a computer vision method is developed to determine pizza topping percentage and distribution.

2. Basic image processing

A computer vision system generally consists of five basic components: lights, a camera, an image capture board (frame grabber or digitizer) and computer hardware and software. Lighting is very important as good lighting system can reduce reflection, shadow and some

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noises, and hence enhance an image. The camera together with the frame grabber is used for image acquisition. For high quality image, a high-resolution charge-coupled-device (CCD) camera is necessary. Once an image of an object is captured, it is digitised and processed by the computer for feature extraction and analysis.

The image processing/analysis involves a series of steps which can be broadly divided into three levels as shown in Fig. 1: low-level processing, intermediate-level processing and high-level processing (Gunasekaran & Ding, 1994; Gunasekaran, 1996). The low-level processing includes image acquisition and pre-processing. Image acquisition converts a video analogue image into its digital form so that subsequent processing can be carried out. The purpose of pre-processing is to condition the acquired image by noise reduction, geometrical correction, grey-level correction and correction of defocussing. By pre-processing, the image is enhanced. Intermediate-level processing involves image segmentation and image representation and description. Segmentation is a critical step in image processing since image information extraction highly depends on the segmentation results. The goal of image segmentation is to divide an image into regions that have a strong correlation with objects or areas of interest. In other words, image segmentation is a process for segmenting or partitioning a composite image into its component parts. The segmented image is represented by either a boundary or a region. Boundary representation is suitable for characterising image size and shape while region representation is appropriate for evaluating image texture and defects. Image description deals with the extraction of image features with basic quantitative information of interest so that component parts can be distinguished from each other. High-level processing includes image recognition and interpretation. Recognition is a process to label a component part and interpretation is to assign meaning to the recognised component part. These two last steps are the ultimate goal of image processing so that image analysis data can be translated into useful information for further actions such as process control. In all the image processing steps, a knowledge database is necessary for interaction of each step with it, thus allowing more precise decision making.

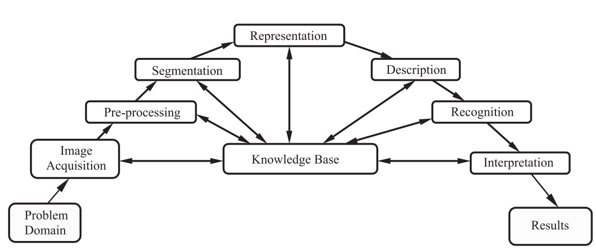


Fig. 1. Basic steps for image processing/analysis.

3. Materials and methods

3.1. System setup

The architecture of the computer vision system used in the experiments includes the following components: fluorescent lights (Kaiserfototechnik, Germany), a high quality 3 CCD Sony XC-003P camera, an IC-RGB frame grabber (Imaging Technology, US) and a Dell Workstation 400 with dual Pentium II system under Windows NT4.0. For experiments, fresh pizzas were purchased from local supermarkets and images were captured using the system.

3.2. Image segmentation

Segmentation methods can be generally divided into three groups according to the dominant features: thresholding, edge-based segmentation and region-based segmentation, illustrated in Fig. 2. Thresholding is a simple and fast technique for distinguishing a certain part of an image from the remaining part with grey-scale level or colour intensity lower than a certain value. For pizza images, the RGB intensity scopes of different toppings are generally overlapping, e.g., the red intensity scopes may be 157–229, 151–188 and 148–205 for pepperoni, tomato sauce and red pepper, respectively. Therefore, thresholding technique is only suitable for very simple images. The application of the edge-based or edge-following segmentation is also limited because completed boundaries are difficult and sometimes impossible to trace or follow in most pizza images. On the contrary, region-based segmentation is a more general-purposed method by grouping pixels or subregions into larger regions according to a set of homogeneity criteria. However, most pizza toppings such as pepperoni have no homogeneous appearance, only region-based segmentation is not sufficient for segmenting a pizza image. Therefore, for processing the pizza images, a new region-based segmentation algorithm was developed, which employs the traditional region-based segmentation as a dominant method and combines the strengths of both thresholding and edge-based segmentation techniques. This new algorithm changes the radial growing mode in traditional region-growing algorithms into a scan line-based growing

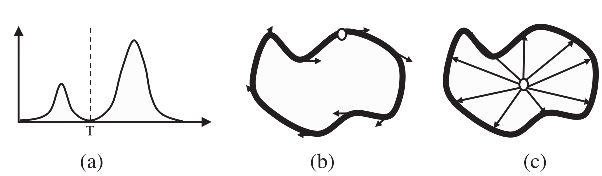


Fig. 2. Typical segmentation techniques. (a) thresholding; (b) edge-based segmentation; (c) region-based segementation.

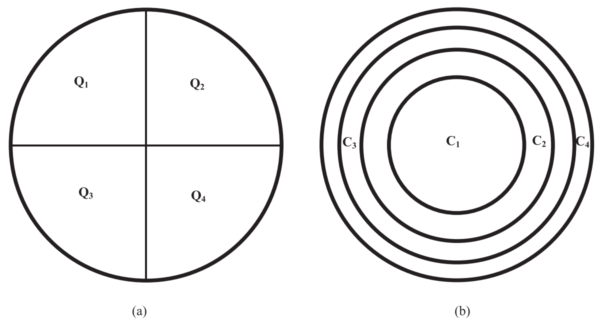


Fig. 3. Determination of topping distribution: (a) four equal-area quarters; (b) four equal-area sections.

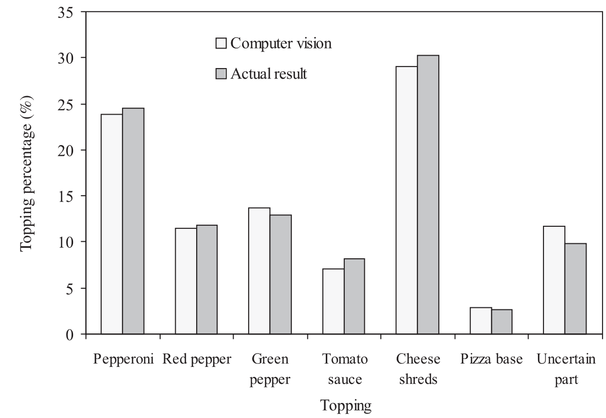


Fig. 5. Topping exposure percentages of the pizza shown in Fig. 4.

mode. The algorithm partitions a pizza image into horizontal or vertical lines after edge detection, and merges the lines into small homogeneous regions and finally merges the small regions into larger regions that represent topping objects.

3.3. Topping distribution determination

In order to determine the topping distribution, a practical method shown in Fig. 3 was developed by dividing the pizza image into four equal-area quarters (Q_1, Q_2, Q_3 and Q_4) and four equal-area radial sections (C_1, C_2, C_3 and C_4). The percentage of the toppings in each quarter and section is then compared. A pizza with more even distribution of toppings will have similar topping percentages in each quarter and section.

4. Results and discussion

Fig. 4 shows an example of pizza images. Fig. 4(a) is the image captured by the computer vision system. The pizza has five types of toppings of pepperoni, red pepper, green pepper, cheese shreds and tomato sauce. It can be seen that similar colours exist in pepperoni, red pepper and tomato sauce, furthermore, some toppings are overlapping. This confirms that traditional segmentation techniques are inadequate for such a pizza image. Fig. 4(b) shows the image after segmentation using the new region-based segmentation technique developed. It can be seen that the new segmentation algorithm can effectively group pixels of the same topping together. As the result, topping exposure percentage can be easily determined by the computer vision method developed.

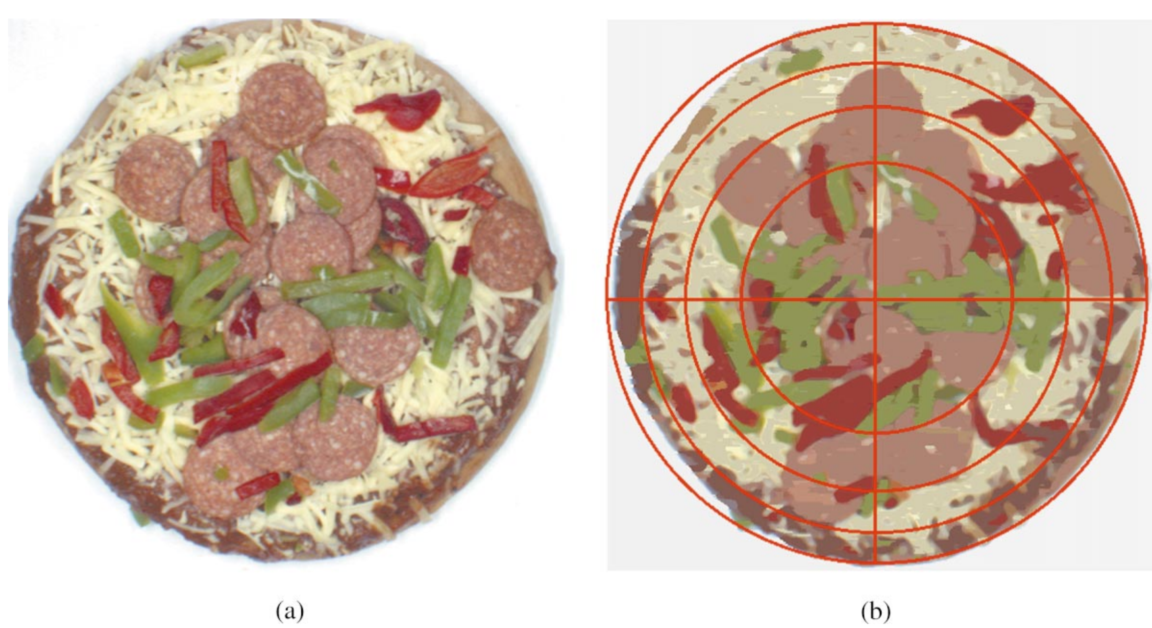
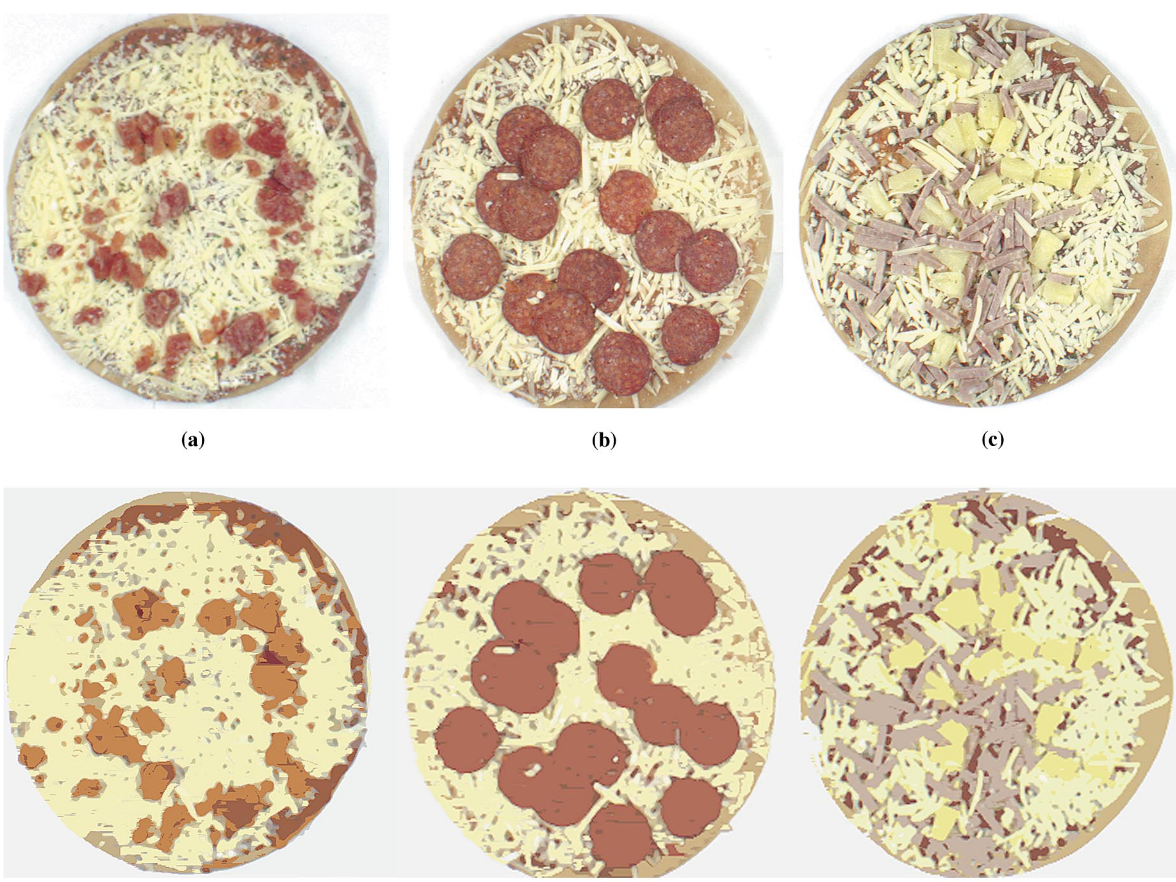


Fig. 4. Pizza images: (a) original image; (b) segmented image.

Table 1
Topping distribution (%) of the pizza shown in Fig. 4

Methods	Pepperoni	Red pepper	Green pepper	Tomato sauce	Cheese shreds	Pizza base	Uncertain part
Quarter Q_1	25.1	5.6	12.4	5.4	40.7	0.9	9.9
Quarter Q_2	31.3	14.5	9.4	1.5	27.7	5.6	10.0
Quarter Q_3	15.2	20.5	17.0	10.7	20.8	1.0	14.8
Quarter Q_4	23.5	5.6	16.3	11.0	26.4	3.4	13.8
Radial area C_1	35.5	18.0	34.4	2.4	2.8	0.3	6.6
Radial area C_2	34.3	14.3	14.1	0.3	25.0	0.0	12.0
Radial area C_3	17.4	10.7	2.1	3.8	53.1	1.0	11.9
Radial area C_4	6.3	1.5	2.9	23.6	36.1	11.5	18.1

Fig. 5 shows the topping exposure percentage determined by the computer vision method as compared with the actual results. The comparison shows that the new algorithm can reach an average accuracy of 90%. The comparison of the topping distribution in each quarter and section is given in Table 1. The comparison shows some interesting results. For example, the comparison of four quarters indicates more cheese shreds and fewer red peppers in Q_1; more pepperoni and pizza base and less tomato sauce in Q_2; generally accepted but more red and green pepper than other quarters in Q_3 and more tomato sauce and fewer red peppers in Q_4. Especially in Q_2, 5.6% of the pizza base is covered with no topping, which would be considered by most consumers as unattractive



(a) (b) (c) (d) (e) (f)

Fig. 6. Pizza images and their segmented images: (a) tomato pizza; (b) pepperoni pizza; (c) pineapple pizza; (d) segmented tomato pizza; (e) segmented pepperoni pizza; (f) segmented pineapple pizza.

Table 2
Exposure percentage (%) of the three pizzas shown in Fig. 6

Pizza type	Cheese shreds	Tomato sauce	Pizza base	Tomato	Pepperoni	Ham	Pineapple	Uncertain part
Tomato pizza	53.4	8.7	4.8	16.9	–	–	–	16.2
Pepperoni pizza	37.7	3.8	6.2	–	36.9	–	–	15.4
Pineapple pizza	29.6	7.4	10.7	–	–	18.5	18.1	15.7

pizza appearance. The comparison of the topping distribution in the four equal-area sections illustrates more green peppers in C_1; less tomato sauce in C_2; more cheese shreds and fewer green peppers in C_3 and more cheese shreds and tomato sauce in C_4. Furthermore, most of the pizza base without topping coverage occurs in C_4. This means that better arrangement of the toppings is necessary.

The new algorithm is also used to segment different types of pizza images. Fig. 6 shows the comparison of the pizza images before and after segmentation. The results confirm that the new region-based segmentation method is capable of processing different types of pizzas. Based on the segmented images, the topping exposure percentages of each pizza topping are determined and the results are listed in Table 2, which again shows the average accuracy of over 90%.

5. Conclusions

1. The image of a pizza is normally complicated due to many different toppings. For inspection of pizza quality, a computer vision system was set up.
2. A new region-based segmentation method was created to process pizza images and the method is suitable for different types of pizzas.
3. A practical method of dividing a pizza image into several equal-area partitions was developed for measuring topping distribution evenness.
4. The results show that the computer vision method can inspect topping exposure percentage and topping distribution evenness with an average accuracy of 90%.

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