

## An Improved Method of Detecting Pork Freshness Based on Computer Vision in On-line System

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**Abstract:** On the basis of computer vision, this paper studied and developed an on-line detection system for pork freshness, which include the overall design of the system scheme, the hardware design and functions, the software functions and detection algorithm. The systematical hardware is composed of image acquisition unit, light source unit, control unit, drive transmission device and computer. For the software implementation of the collected images, the processes include three steps as following: 1) Otsu algorithm was applied to remove the disturbance of background and other noises. 2) The fat areas were eliminated according to color difference between pork fat and the muscle. 3) A new Color Region Ratio (CRR) feature extraction method applying color-layering approach was proposed for the identification of pork freshness. The testing of 100 samples have shown that the CRR feature is highly correlated with pork freshness, reaching 88 % detection accuracy, and it is feasible to use CRR feature to detect the pork freshness. *Copyright © 2014 IFSA Publishing, S. L.*

**Keywords:** Pork, Freshness detection, On-line detection system, Color region ratio, Hardware software design.

### 1. Introduction

The traditional methods of detecting pork freshness include physical, chemical and biological method. However, with these traditional inconvenient methods, it is difficult to detect pork quality in the course of pork storage and transportation, especially for consumers. Therefore, researchers recently become interested in on-line detection method based on the modern technology, which is rapid, simple, convenient and nondestructive.

There are mainly four methods to detect pork quality nondestructively, including NIR (Near Infrared Reflectance spectroscopy) method, dielectric spectrum method and computer vision method. In

NIR method, spectroscopic data was analyzed in the range of near infrared and used to predict the water content, PH and freshness [1, 2]. In the work of [3-5], NIR hyperspectral imaging was used to detect tenderness, the total viable count (TVC) and psychrotrophic plate count (PPC) for predicting the freshness. And it is found that the correlation index R<sup>2</sup> was much higher in detecting tenderness than freshness. In dielectric spectrum method, microwave dielectric spectrum was collected to analyze and predict the low quality pork meat, including Pale Soft Exudative (PSE) and Dark Firm and Dry (DFD) meat in the work of [6, 7]. Though the detection accuracy was high, the low quality meat was also easily to distinguish by eyes. Computer vision method was

mainly analyzed pork image to detect the quality [8, 9]. In the work of [10], lightness in three color space was tested to estimate PSE of pork by images.

Currently, the researches of the on-line detection technology have already made considerable success in China and abroad [11, 12]. But the on-line research for the meat quality is under development. Liao Yitao [13, 14] applied visible/near-infrared diffuse reflection spectrum to finish the on-line detection of the pork intramuscular fat content and pH value. Zhang Haiyun [15] designed the on-line detection device based on near-infrared spectrum technology to carry out the nondestructive detection for the fresh pork quality. However, most of the published researches only have realized online data acquisition, but haven't implemented online detection of pork freshness. In addition, on the domestic market at present, there is no production of high quality on-line detecting system and related equipment for fresh meat quality detection. The detection method of pork quality based on computer vision technology is achieved mainly by analyzing the images or video sequences [16, 17]. This detection method takes the pork color as a basis of detecting pork quality, and thus detects the pork freshness and intramuscular fat content [18].

Combined with machine vision and image processing technology, this paper designs a set of on-line and non-destructive detection system for the identification of pork quality, which can be used to measure the pork freshness that is one of important the indexes evaluating meat quality. Section 2 introduces the overall composition and process of the system. The hardware design and function of every unit is presented in section 3. And section 4 is the explanation of software design including the improved method and algorithms in each step. Section 5 shows the experimental results and discussion. Finally, section 6 is the conclusion of the paper. According to the color information of the pork image, the CRR feature extraction algorithm is employed to measure the pork freshness.

## 2. The Overall Scheme For The System

### 2.1. The Composition of Detecting System

The on-line detection system for detecting pork freshness needs to construct automatic data acquisition and data processing system based on computer vision, which can automatically acquire the pork sample data placed in production line and carry out the real-time processing automation for sample data. The proposed on-line detection system includes a camera, a sample transfer device, a control circuit and computer. The block diagram for the systematical principle is shown in Fig. 1.

Fig. 2 shows the main view and top view of on-line detection system without computer. In Fig. 2(a) is the main view, and Fig. 2(b) is the top view of the

system. In Fig. 2(a), 1 is a camera with two LED lights beside it. It connects to the computer. 2 is an opaque cover for preventing the influence of light outside. 3 is a conveyor belt with grid, which is used for laying pork. 4 is a stepper motor that drive the belt move a grid each time. It is also connected to the computer and controlled by it.

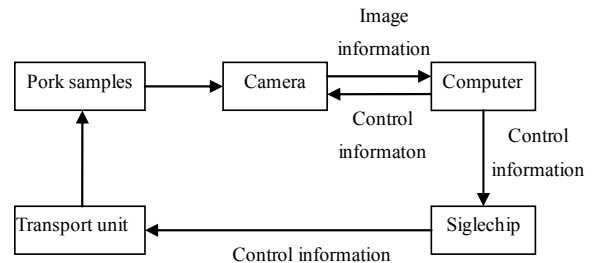


Fig. 1. The block diagram for the systematical principle.

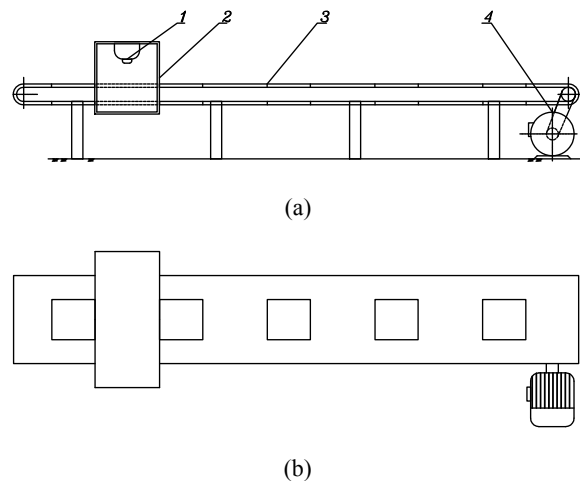


Fig. 2. The main view and top view of on-line detection system.

### 2.2. The Process of Detecting System

The working process of the system is: 1) put the pork sample on the conveyor belt; 2) the stepper motor drive the conveyor belt move in order to make the pork sample arise under the camera lens; 3) the camera shoots the images of the pork sample, and transmit them to the computer; 4) the computer works on the real-time processing and analysis of images to finish the quality detection, then controls the motor move on; 5) repeat the above processes to detect next pork sample. In the whole process, the computer instructs the control circuit to send corresponding control information according to the different work demands.

## 3. The Hardware Design for the System

Only by the coordination of each systematical component, can the system obtain high quality image

information and accurate results. Therefore, the main tasks of the hardware design include the selection of matching equipment, the design of matching mechanism, and the determination of the system parameters, which make the whole system work in a coordinating, steady state. The hardware of the system is composed of image acquisition unit, light source unit, drive transmission device and computer.

### 3.1. Image Acquisition Unit

The camera is the main device to collect image information acquisition. As the core of the system components, its performance parameters directly affect the systematical function. Here we use German AVT F-038 industrial camera, with resolution of 768 x 494 and 6 mm prime lens. When installing components, the camera need keep parallel with the pork sample to avoid the image distortion [19].

### 3.2. Light Source Unit

The light source unit is composed of camera obscure, fluorescent light and fixtures. Its function is to provide sufficient light intensity for collecting image information. Soft and white light is used here.

### 3.3. Drive Transmission Device

Drive transmission device is mainly used to transport the pork samples and adjust its position when carrying out the detection. It consists of the control circuit, stepper motor and conveyor belt. The required space of each pork sample is determined by the movement of the stepper motor and the size of the detected pork sample. When working, the rotation of the motor is driven and controlled by the control circuit and the start/stop motor is controlled by the control signal from the computer to match the camera in finishing image information collection.

### 3.4. Computer

As the core part of system, the computer is in charge of the coordination and operation of each parts of the system, and fulfills the tasks of the image acquisition, real-time processing and the output of the test results. This system selected Siemens SIMATIC IPC547eco industrial computer with image acquisition card, the Intel Pentium dual-core E5300 processor, 2 GB DDR2 800 memories, 800 GB SATA - HD 2.5 "hard disk.

## 4. The Software Design for the System

The main tasks of the software design include image processing algorithms and pork freshness identification. In this section, the whole process of

software methods is introduced, and an improved feature extraction algorithm is presented at part B.

### 4.1. Image Preprocessing

A median filter was used to smooth the original images, while Otsu algorithm was applied to remove the disturbance of the background and other noises. The implementation of the algorithm was firstly to change the original image into grayscale image, then transformed grayscale image to the binary image by selecting an optimal threshold. However, after these algorithms processed the image, there were still small amounts of residue or noise in the background image, which had certain effect on test results. Therefore, these small isolated residue or noises which were less than 400 pixels were removed. Fig. 3 shows the results of removing background of images, which Fig. 3(a) is the original image, Fig. 3(b) is the background image that was removed, and Fig. 3(c) is the pork image without background. From Fig. 3, the pork in the dark blue background is separated accuracy by Otsu algorithm.



(a)



(b)



(c)

**Fig. 3.** The results of removing background by Otsu algorithm.

### 4.2. The CRR Feature Extraction Algorithm for Pork Freshness Identification

Feature extraction is the key point of detecting the pork freshness, because the feature is

significantly associated with the pork freshness. In this paper, CRR based on color-layering algorithm is adopted as the evaluation index of determining the pork freshness. This method is based on the correlation of the meat optics trait and the freshness degree of the meat. The color and luster of pork is mainly determined by the chemical properties of myohemoglobin [20].

Color area ratio method can highlight the special color area in the image and isolate the target from the image [21]. Its basic ideas are: 1) to choose the interested color from the image so as to separate them from the background; 2) to cut a part from the isolated color layered area according to the color threshold; 3) to calculate the feature by computing the ratio of the color layered area and the image separation zone area. In other words, that is to calculate the ratio of the number of pixels in the color layered area and the image separation zone. The CRR computation formula is as follows:

$$C_{\pi} = \frac{\sum n_r(x, y)}{n_l}, n_r(x, y) = \begin{cases} 1 & I(x, y) > T \\ 0 & I(x, y) \leq T \end{cases}, \quad (1)$$

where  $C_{\pi}$  is the Color Region Ratio;  $n_l$  is the number of pixels in the whole image area;  $I(x, y)$  is the color value of pixels in the image;  $T$  is the threshold on the color layer.

This paper takes the red ratio on the colored backgrounds as the feature to improve algorithm performance, because the main color of pork meat is red. The correlation of it is higher than other colors (green or blue) that proved in [21]. The computation formula is as follows:

$$C_{\pi} = \frac{\sum n_r(x, y)}{n_l}, n_r(x, y) = \begin{cases} 1 & \frac{I_R(x, y)}{[I_R(x, y) + I_G(x, y) + I_B(x, y)]/3} > T \\ 0 & \frac{I_R(x, y)}{[I_R(x, y) + I_G(x, y) + I_B(x, y)]/3} \leq T \end{cases} \quad (2)$$

However, when taking pictures, the differences of small lightness change lead to unstable results because of environment light, even the pork is blocked by opaque cover. In RGB color space, the influence of lightness change is hard to eliminate because it is contained in Red, Green and Blue component. That also leads to unstable of the threshold  $T$  in Eq. 2. Therefore, HSL color space was used to solve this problem.

HSL is the most common cylindrical-coordinate representations of points. It was composed by hue, saturation and lightness component. In HSL color space, lightness and saturation are separated, and hue appears to be perceived colors as angular dimension from  $0^\circ$  to  $360^\circ$ . Therefore, the connection between hue and lightness is much weaker. In this paper, hue of image was computed to estimate the threshold  $T$  in Eq. 2 to reduce the influence of lightness change. The computation formula of computing hue by RGB is as follows:

$$h = \begin{cases} 0^\circ, & \text{if max} = \text{min} \\ 60^\circ \times \frac{g-b}{\text{max}-\text{min}} + 0^\circ, & \text{if max} = r \text{ and } g \geq b \\ 60^\circ \times \frac{g-b}{\text{max}-\text{min}} + 360^\circ, & \text{if max} = r \text{ and } g < b \\ 60^\circ \times \frac{b-r}{\text{max}-\text{min}} + 120^\circ, & \text{if max} = g \\ 60^\circ \times \frac{b-r}{\text{max}-\text{min}} + 240^\circ, & \text{if max} = b \end{cases}, \quad (3)$$

where  $h$  is the hue value;  $r$ ,  $g$  and  $b$  are the red, green and blue value in a pixel of RGB color space image;  $\text{max}$  and  $\text{min}$  is the maximum and minimum value among  $r$ ,  $g$  and  $b$ . By transforming into HSL color space, Eq. 2 is warped as follows:

$$C_{\pi} = \frac{\sum n_r(x, y)}{n_l}, n_r(x, y) = \begin{cases} 1 & I_h(x, y) \in T \\ 0 & I_h(x, y) \notin T \end{cases}, \quad (4)$$

where  $I_h(x, y)$  is the hue value of pixels in the image;  $T$  is a range of hue angle as the threshold on the color layer. In this paper, the range of  $T$  is  $[-32^\circ, 18^\circ]$  as experience of experiments.

## 5. The Experiments And Discussions.

### 5.1. The Experimental Materials and Condition

The pork samples in the experiment, which included feet, offal and legs, were bought from the supermarket and farmers' market. The experiment included 100 samples, 50 for on-line detection, and the other 50 for physical and chemical analysis. The size of each sample was 8 cm long, 6 cm wide and 2 cm thick (It would be much bigger in the practical usage). Laboratory temperature remained at  $26^\circ$ . In the experiment, the pork samples were naturally rotted, until they had an apparently rot stink. There images are collected every twelve hours during three days, which was from 9 a.m. on the first day to 9 p.m. on the third day. The evaluation criterion for pork freshness is defined by GB2722-81 [22], and the total volatile basic nitrogen (TVB-N) value is regarded as the pork freshness indicators. The standard is: when the TVB-N  $< 15$  mg / 100 g, the pork is considered fresh; when the value is between 15 to 30 mg/100 g, the pork is stale meat; when TVB-N  $> 30$  mg/100 g, the pork is rotting. Simultaneously, the chemical detection methods are used to detect the TVB-N value of each pork sample.

### 5.2. Fat Region Eliminating

In this paper, the pork freshness is obtained by analyzing and processing the pork muscle parts, so the pork fat area needs to be removed to minimize the impact on the test results. This paper uses the R layer image in HSL image color space, which is separated

from the background, and employs the characteristics of pork color differences between fat and muscle. The segmented image is given in Fig. 4, in which Fig. 4(a) is the original image and Fig. 4(b) is the segmentation image. Comparing Fig. 4(a) and Fig. 4(b), most of fat area of pork is eliminated, and just a little tiny fat lines in the muscle are remained.

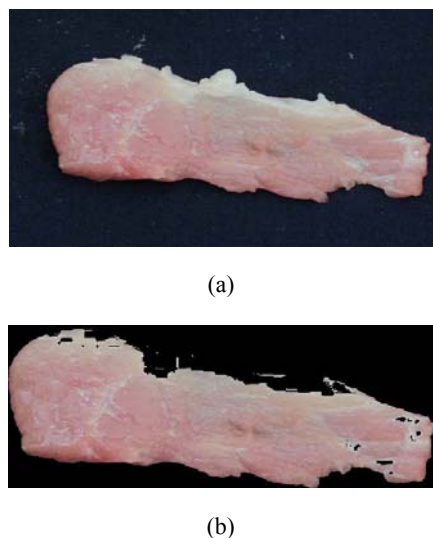


Fig. 4. Eliminating fat by color difference.

### 5.3. Detection Results and Analyzing

The experimental results are shown in Table 1, which lists TVB-N value and CRR average at the 6 time-point of detecting during three days. From Table 1, the pork meat was changed into stales before 9 p.m. on the second day, and rotted quickly less than 24 hours. In this process, TVB-N value increases with the time elapsing, while the average value of CRR is just the opposite. Therefore, CRR value can reflect the change of pork freshness, and the changed trend is inversely proportional to TVB-N value.

Table 1. Average values of pork freshness index in 3 days.

Items	Testing time	TVB-N	CRR
Freshness	1st day 9:00	6.41	0.956
	1st day 21:00	10.37	0.845
	2nd day 9:00	11.94	0.765
Stale	2nd day 21:00	20.18	0.630
	3rd day 9:00	26.82	0.597
Rotting	3rd day 21:00	39.71	0.579

The Fig. 5 gives the distribution and linear regression of the CRR for 50 samples. In Fig. 5, x-axis is the ratio of CRR, and y-axis is TVB-N value (mg/100 g).

The sample test results at different time point are marked with different symbols:  $\triangle$  for 9 a.m. on the first day, \* for 9 p.m. on the first day, + for 9 a.m. on

the second day, \* for 9 p.m. on the second day,  $\nabla$  for 9 a.m. on the third day,  $\diamond$  for 9 p.m. on the third day. Quadratic curve is the linear regression fitting curve of the CRR feature and TVB - N value. Fitting curve equation is following:

$$y = 30.838x^2 - 97.941x + 72.104, \quad (5)$$

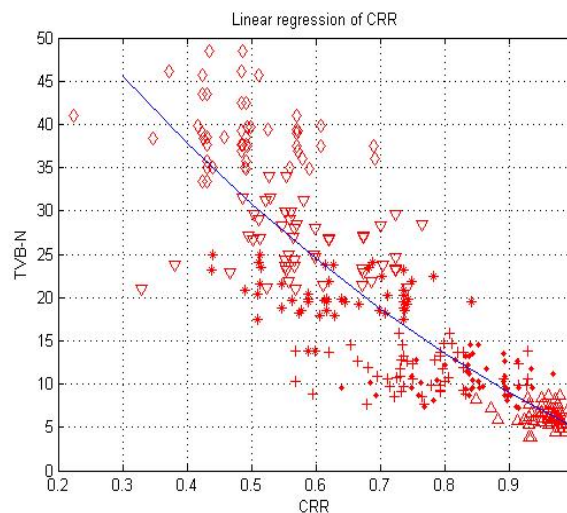


Fig. 5. Distribution and Linear regression of CRR.

From Fig. 5, the fitting curve plotted according to the Eq. 5 shows in good agreement with the data, which is relatively uniform distribution on both sides of the fitting curve. The experimental data are concentrated at the two time points on the first day, which may be due to the individual differences of rotted pork under the same condition, while the experimental data become scattered with preservation time increases. From the ordinate information, the boundary of 15 mg/100 g between the freshness and the stale is obvious, but that of the stale and the rotting is not clear. From the abscissa information, the pork classification is also evident in the different fresh level, but aliasing sample numbers are more in border. Therefore, the pork classification can be divided according to this information and the fitting curve cannot be taken as the evaluation criterion. Meanwhile this paper calculated the correlation coefficient of CRR and TVB-N value in order to measure the correlation of CRR and TVB-N value. The correlation coefficient  $R=0.9683$ , which denotes that the CRR feature is highly correlated with pork freshness.

Furthermore, on account of more aliasing sample numbers in border, which brings in a lot of difficulty to sample classification, this paper uses PNN neural network algorithm to carry out fuzzy classification for the CRR values so as to obtain more accurate classification results. The PNN neural network is trained by 50 samples for training, the other 50 samples for verification test, then comparing with TVB-N value and calculate detection accuracy rate.

Final tests reveal that there are 44 for the freshness correct samples and 6 for detection errors in 50 samples. The detection accuracy is 88 %. Thus, the proposed detecting system for pork freshness can realize real-time detection and display the results, and the overall detection rate reached 42 samples per minute.

## 6. Conclusions

This paper studied an on-line detection system for pork freshness based on computer vision, giving its detection method, and designing the systematical hardware and software. For the collected images, the processes included three steps. Firstly, Otsu algorithm was applied to remove the disturbance of background and other noises. Secondly, the fat areas were eliminated according to color difference between pork fat and the muscle. Finally, CRR feature extraction method applying color-layering approach was proposed for the identification of pork freshness. The testing of 100 samples has shown that the CRR feature is highly correlated with pork freshness and it is feasible to use CRR feature to detect the pork freshness. Furthermore, PNN neural network classification algorithm was presented to finish fuzzy classification for the CRR values and evaluation of the pork freshness. Tentative experimental results demonstrate that this system can accurate, fast, nondestructive testing of pork freshness, reaching detection rate of 42 samples per minute and 88 % detection accuracy.

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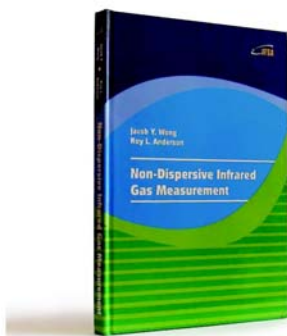
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