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Automatic testing of food quality based on single chip microcomputer control system

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Abstract. To improve the efficiency and precision of food quality testing, the automatic food quality testing based on single chip microcomputer control system was studied. The main food selected was fried food. Firstly, the working principle of the detection system, the key technology of appearance quality detection system and the hardware system design overall design were introduced in detail. In addition, the design of communication between PC and MCU, the belt design and the overall structure of the software system design were illustrated. Then, the color appearance detection experiment, the shape appearance test and the error analysis were carried out. The results showed that the automation of the appearance inspection of fried food was realized, which avoided the pollution and accuracy caused by artificial detection, and improved the detection efficiency and accuracy. To sum up, the detection system can be used for online and real-time detection of fried food.

Key words. Single chip microcomputer, detection system, food quality, automatic testing.

1. Introduction

With the improvement of people's living standard, people's concept of food has also undergone a fundamental change. People's demand for food safety has been increasing (Griffin, 2015). The problem of food quality and safety has also been widely concerned by the whole society. In addition, in recent years, food safety problems have occurred in China and caused great threat to people's lives. Therefore, our country now attaches great importance to ensuring food quality (Song, 2016). Food quality testing is the key link to ensure the quality of food. Thus, achieving the rapid, accurate and non-destructive automatic detection of food quality is an inevitable trend of food quality detection, which is of great significance for ensuring the quality and safety of China's food industry.

Nowadays, the detection and elimination of substandard food by domestic and

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foreign food production enterprises still remains in the stage of judging by the human eye and the experience, which is very negative for the mass production. Meanwhile, human eyes' long time observation may produce visual fatigue and the efficiency is low. The detection results are easily affected by the subjective factors, the standard is difficult to unity and the accuracy cannot be guaranteed. Furthermore, artificially picking the unqualified products is likely to cause serious pollution, and restrict the production efficiency (Ding, 2015). Therefore, the food production enterprises have an urgent need to realize the system that can automatically detect and eliminate the unqualified products. On the wire mesh conveyor belt, the workers will pick up the unqualified food. The content of this research is to replace the workers in this process and use machine vision to achieve automatic detection (Uddin, 2015). With the rapid development of machine vision technology and industrial control technology, machine vision has been applied to real-time detection, splitting and tracking of foods for its advantages of non-contact detection, rapid detection, high accuracy and good repeatability (Lickly, 2015). It can significantly improve the efficiency of the unqualified products in food production, ensure the quality of food production, and reduce the labor intensity of operators (Prabha, 2015).

2. THEORIES

2.1. Working principle of the detection system

In order to improve the efficiency and quality of fried food detection, machine vision was used to detect fried foods instead of human vision. An automatic appearance quality detection device for fried foods was designed (Sayad, 2017). The overall structure design of the inspection system for the appearance quality of fried food is shown in Figure 1.

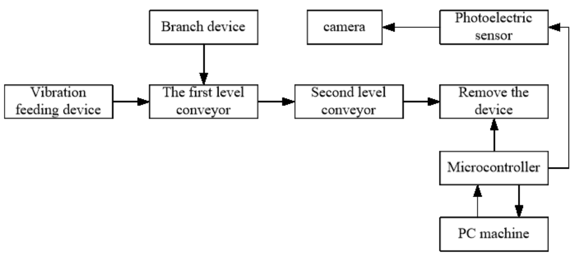

Fig. 1. System overall structure design

Fried food appearance quality detection system principle is to send the fried products on the production line to the vibration feeding device by the lifting device. By the vibration, the fried foods adjoined together are separated and put into the branch device stalled on the first level conveyor belt. The fried food through the branch institutions are orderly and tightly arranged, for being transported on the first conveyor belt. In order to facilitate the subsequent image processing, when fried food enters the second grade conveyor belt, through the speed difference between the first grade conveyor belt and the second grade conveyor belt, products closely spaced are separated so that it has certain distance. In the second grade conveyor belt, it is provided with a photoelectric sensor and image acquisition device. When the fried food passes, photoelectric sensor triggered camera image acquisition by single chip machine (SCM). The image shape and colour are conducted with image processing in the computer. The judgment results after processing conducts communication control through computer interface sending a command. The SCM process the signal and control the electromagnet action. The electromagnet uses the telescopic motion to control the eliminate institution for unqualified products rejection (Aurela, 2015). The work flow is shown in Figure 2.

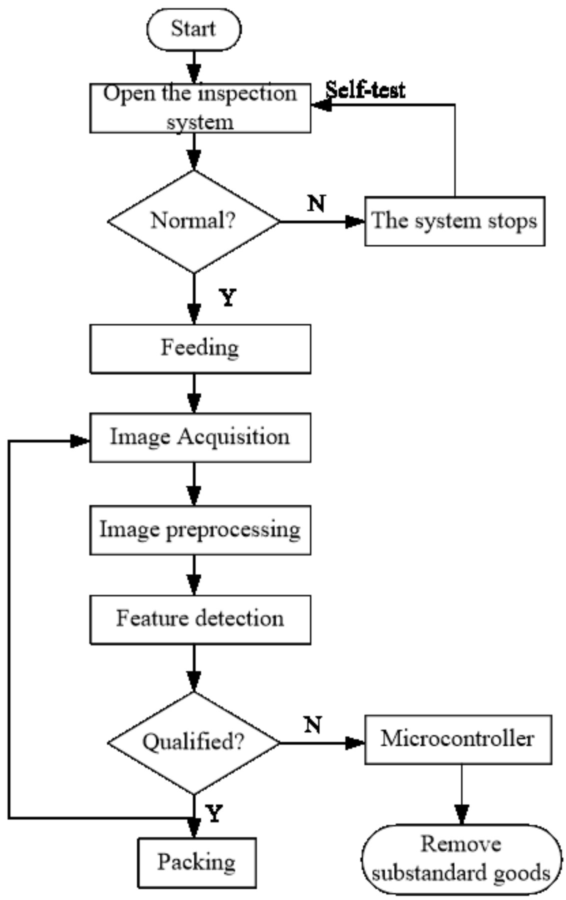

Fig. 2. The work flow chart

2.2. *Key technology of the inspection system for the appearance quality of fried food*

This paper studies the detection method of appearance quality of fried food. The method of machine vision detection is used to conduct colorful image processing of fried food images collected by colorful camera. The color and shape features parameters of the unqualified products are obtained, the results information processed is transmitted to the SCM, and the SCM controls the electromagnet to eliminate. In order to achieve this goal, we need to study the key technologies below:

The study of branch separation method based on the hardware system in the detection system;

The design of the elimination mechanism in the detection system;

The research on edge tracking based edge extraction;

The exploration of method extracting the color feature parameters of the foreground object in the image;

The discussion of method extracting the shape feature parameters of the foreground object in the image.

3. METHODOLOGY

3.1. *Overall design of the hardware system*

The overall design of hardware system can be summarized to five modules, namely vibration feeding module, branch separation module, image acquisition module, light source module and elimination module (Gallocchio, 2016). The hardware is mainly composed of vibrating trough, vibrating feeder, conveyor belt, camera, light source, branch mechanism, single chip microcomputer, photoelectric sensor, knockout plate, and electromagnet and so on. The overall structure tree diagram of the hardware system is shown in Figure 3.

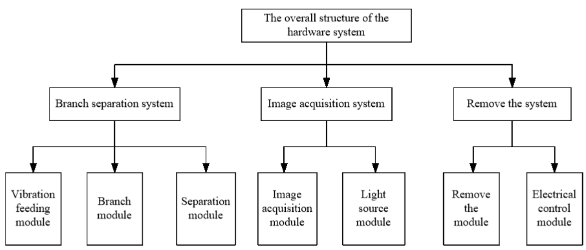

Fig. 3. The overall tree diagram of the hardware system

The functions of the main modules of the hardware system are as follows:

Vibration feeding module: as the frying products are sticky, the movement of granular products in small space will obviously block, which will affect the stability of the system. The vibration feeding module can solve this problem well.

Branch separation module: make orderly separation of orderly arranged products on the production line, so that the original ordered but high-density distributed products are orderly and tightly distributed on the production line.

Image acquisition module: mainly use color camera and fixed focus lens to collect color image of fried food.

Light source module: adopt white LED lamp self-made surface array light source, auxiliary light source under illumination box and stainless steel plate coated with paint to provide uniform white illumination for detection system, improve the image quality of fried food, and facilitate subsequent image processing.

Elimination module: when the PC machine determines the unqualified product, the elimination device can eliminate the unqualified products in real time.

3.2. Design of communication between PC and single chip microcomputer

Serial communication is used between PC and MCU. The serial data interface is divided into RS-232, RS-422 and RS-485 (Sun, 2015). Now, the most commonly used are the two kinds, RS-232 and RS-485. Because RS232 is transmitting data from TTL level, its anti-interference ability is poor, and its transmission distance is short. Only one transceiver is allowed on its bus, which only supports point-to-point communication. The transmission rate is low, but it is very suitable for many occasions. The RS-485 has strong anti-interference ability and long transmission distance and allows multiple connections to be connected on its bus. It has multi-station communication capability, and the transmission rate is obviously better than RS-232. For this system, PC only needs to control a single chip microcomputer to complete the elimination action. As a result, RS-232 interface is chosen to be used for direct communication between PC and MCU.

At present, the PC machine is equipped with a standard RS-232 interface and is configured for a 9-pin "D" type connector. Figure 4 is the pin definition for the 9-pin plug. The function of the 9 pins is shown in Table 1.

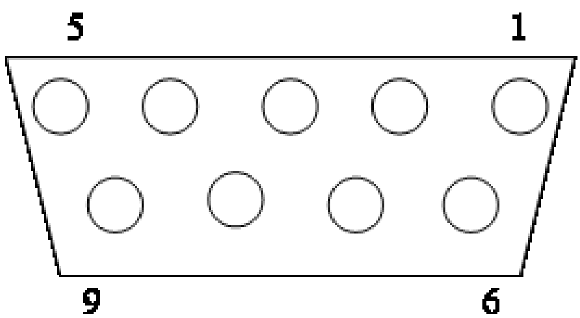

Fig. 4. 9-pin plug pin definition

Table 1. RS-232 Pin function table

Pin number	Direction	Features
1	Enter	Data Carrier Detection(DCD)
2	Output	Send data(TXD)
3	Enter	Receive data(RXD)
4	Output	Data Terminal Ready (DTR)
5		Signal Ground (GND)
6	Enter	Data Communications Equipment Ready(DSR)
7	Output	Request to send(RTS)
8	Enter	Clear to send(CTS)
9	Enter	Ring indicator(RI)

3.3. Design of conveyor belt

The conveyor belt is used to transport fried food and make it move forward. It uses motor to provide power and apply synchronous belt pulley to drive. The conveyor belt is mainly composed of motor, synchronous pulley, synchronous toothed belt, bearing, shaft and speed control box.

Motor type selection: It is known that the conveyor belt is loaded m=l0kg, the speed of the conveyor belt is 0.09m/s, the efficiency of the synchronous belt wheel is η=0.97, the efficiency of the gearbox is η_G=0.66, the diameter of the shaft is D=35mm, and the motor power supply is single phase 220V50Hz, then the output shaft speed of the reducer is:

$$NG = (V \bullet 60)/(\pi \bullet D) = \frac{90 \times 60}{\pi \times 35} = 50r/\min \tag{1}$$

Because the rated speed of the motor at 50Hz is 1500r/min, the deceleration ratio of the reducer is:

$$i = 1500/NG = 30 \tag{2}$$

The torque required for the start of the conveyor belt is the maximum, and the necessary torque is firstly calculated.

The friction between the belt and the shaft is:

$$F = \mu m \bullet g = 0.3 \times 10 \times 9.8 = 29.4N \tag{3}$$

The load torque is:

$$T_L = (FD)/(2\mu) = (29.4 \times 35 \times 10^{-3})/(2 \times 0.97) = 0.53Nm \tag{4}$$

The necessary torque of the output shaft of the motor is:

$$T_M = T_L/(i \bullet \eta G) = 0.53/(30 \times 0.66) = 0.027N \bullet m \tag{5}$$

Then the power required by the motor is:

$$P_0 = 2T \bullet 2\pi n = 2 \times 0.05 \times 2 \times 3.14 \times 50 = 31.4W$$

Design of conveyor belt:

The calculation of maximum tension is:

In the above formula, Sn suggests the tension (N) for the displacing point; e indicates the bottom of the natural logarithm, e=2.718; μ refers to the friction coefficient of the conveyor belt and the roller; represents the wrapping angle (rad) of the conveyor belt on the roller.

According to the given conditions,φ =190°, the friction coefficient is μ =0.3 and the Euler coefficient of query table is $e^{\mu\varphi}$3.18, then:

Because the conveyor belt adopts a smaller cylinder diameter and takes into account the issue of food safety, the food grade conveyor belt with belt core thin, light weight, rich strength and PU material is used.

3.4. Overall structure design of software system

This software system is mainly composed of fried food inspection and unqualified fried food elimination two parts. The detection of unqualified fried food is mainly in the color and shape of products through the method of machine vision. Through the comparison with parameters of qualified products, the information of detected unqualified fried food is sent to the micro-controller through the serial communication. The micro-controller controls the electromagnet action to realize the unqualified elimination. The software system structure diagram is shown in Figure 5.

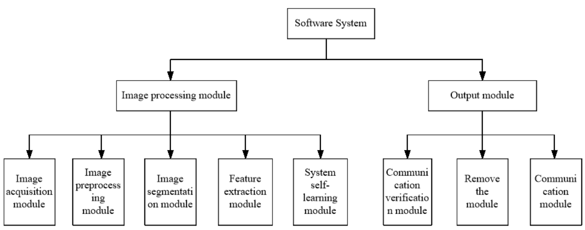

Fig. 5. The software system structure diagram

From Figure 6, we can see that the detection system is divided into image processing module and output module, and the image processing module mainly includes color image acquisition module, color image preprocessing module, image segmentation module, feature extraction module, and system self-learning module. The output module mainly includes the communication check module, the elimination module and the communication module.

The functions of the main modules of the software system are as follows:

Image acquisition module: the image collected by the camera is read into the software in real time and stored.

Image preprocessing module: the read image is corrected to facilitate subsequent image processing. In this paper, we mainly do morphological operations, image segmentation, image clipping and so on.

Image segmentation module: the target object and the background image are separated from the captured image, and the target image is extracted.

Feature extraction module: the shape and color feature of the image are extracted and the data is analyzed. It is judged whether it is within the qualified interval, and the judgment result is given.

Self-learning module: the color and shape features in the standard sample library are defined. The redefined standard sample library will enable the system to learn and adapt to different products.

Output module: the processed results are issued to the single chip computer, and the electromagnet is controlled to achieve elimination.

4. EXPERIMENTS

4.1. Method experiment for system

Conveyor belt background experiment: in order to collect fried food images with good quality and easy segmentation, color selection of the conveyor belt is very important. Several colors selected in this paper are black, blue, green and white. According to the experimental results, finally, white is selected as the belt color. Because fried food is food, the belt material selects PU material. PU is a non-toxic food grade conveyor commonly used with food hygiene approval.

Branch separation experiment: in the image acquisition, the image acquisition part of the detection test device requires that products on the conveyor belt are neatly and orderly arranged and the interval tries to maintain a consistent state. In the branch experiment, fried food had no adhesive or jump phenomenon; in the separation experiment, through the branch, products arranged closely together achieved the orderly separation, in accordance with the subsequent testing requirements.

Light source experiment: light source design is the key part of machine vision. Good light source system can collect better image, which greatly reduces the difficulty of image processing system. The system uses 1.30 million pixel color CMOS for the collection of fried fish tofu. Different light source designs are used to make experimental comparison of the collected images.

4.2. Quality and appearance experiment

Color and appearance test experiment: the color detection is the difficulty of this paper, but also the focus of the paper. Unqualified products on fried food production line are mainly due to fried phenomenon, which is reflected in the color as black. In the static condition, French fries are taken as samples for experiment. Select the RGB space and HSV space for the experiments to extract each component of each space, calculate the difference value and the mean value, and select two images for the contrast diagrams of gray scale variance and mean value, as shown in Figure 6 and Figure 7.

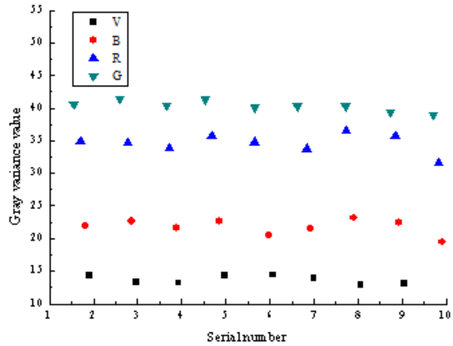

Fig. 6. RGB and HSV space gray components of the variance comparison chart

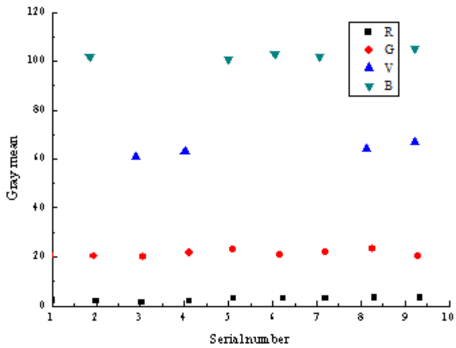

Fig. 7. RGB and HSV space gray components of the average comparison chart

hrough Figure 7, we can see that the three components of R, G, B and V have small gray scale variance. From Figure 8, it can be seen that the gray scale mean value of four components of R, G, B and V are smaller. Finally, the color space chosen in this paper is RGB color space for color detection, and 10 images of French fries that are fried in the laboratory are collected, including under heating, qualified products and overheating. The mean of three components of the RGB space and the difference between any two components are calculated, respectively.

Because this system is designed according to the actual production line, in the actual production, under heating products are picked out not as unqualified products. Only two kinds of qualified products and overheating are considered in actual production. Through the method, the most common fried fish tofu on production line is collected and detected, and the mean value of B component is extracted. 10 images are collected in the test, in which there are 5 qualified images, and the results are shown in Table 2. There are 5 unqualified images and the results are shown in Table 3.

Table 2. B average of qualified Fried food

Fish tofu serial number	B mean
1	76.82
2	77.61
3	83.18
4	79.07
5	77.33

Table 3. B average of unqualified Fried food

Fish tofu serial number	B mean
1	58.45
2	48.07
3	47.57
4	53.17
5	52.59

According to the data of Table 2 and Table 3, we do the characteristic statistics of B mean value. Based on the normal distribution formula, the standard deviation σ of B mean value of oil fried tofu is calculate μ as 8 and the mean value is 83. According to the principle, the result is shown in Table 4.

Table 4. Selection of sigma and B mean

The σ value of fish tofu	B mean
$\mu - \sigma$	75
$\mu - 2\sigma$	67
$\mu - 3\sigma$	59

It can be seen from the previous table that the final fried fish tofu takes $\mu - 2\sigma$, then the mean value of B component is 67, and the color segmentation value of qualified products and unqualified products is 67.

Shape and appearance detection experiment: according to the different types of fried food detected, the selected shape characteristic parameters are also different. In the detection of fish tofu, the shape characteristic parameters are area, perimeter and rectangle. In this experiment, 10 images were collected, with 5 images of qualified products and the results were shown in Table 5. There were 5 unqualified products and the results were shown in Table 6.

Table 5. Shape feature parameters of qualified fried food

Fish tofu serial number	Area	Perimeter	Rectangle
1	18252	595	0.81
2	16406	698	0.77
3	18096	630	0.84
4	16656	635	0.82
5	19085	672	0.78

Table 6. Shape feature parameters of unqualified fried food

Fish tofu serial number	Area	Perimeter	Rectangle
1	34584	838	0.89
2	33481	804	0.88
3	34902	365	0.89
4	10221	886	0.92
5	10412	269	0.94

According to the normal distribution formula, the standard deviation of oil fried fish tofu area is 919, the mean value is 17879, the standard deviation of perimeter is 29 and the mean value is 646; the standard deviation of rectangle degree is 0.02, the mean value is 0.81, and the result is shown in Table 7.

Table 7. Selection of sigma and fired tofu with fish meat characteristic parameter values

The σ value of fish tofu	Area	Perimeter	Rectangle
$\mu \pm \sigma$	(10690,18978)	(617,675)	(0.79,0.83)
$\mu \pm 2\sigma$	(16041,19717)	(588,704)	(0.77,0.85)
$\mu \pm 3\sigma$	(15122,20636)	(559,733)	(0.75,0.87)

It can be seen from the table that, the final area of fried fish tofu takes $\mu \pm 3\sigma$, and then the qualified area of fish tofu area is (15122, 20636); the perimeter of fish tofu takes $\mu \pm 3\sigma$, and then the qualified range of the perimeter of fish tofu is (559, 733); fried fish tofu rectangular degree takes $\mu + 2\sigma$, and then the segmentation value of qualified products and unqualified products is 0.85.

4.3. Error analysis

From the analysis above, the detection system can detect the appearance quality of fried food by the method of machine vision. Influenced by environment light, human factors and mechanical system, this system still has some errors. With comprehensive consideration, the error is mainly composed of the following parts:

The error of illumination system: because the light source of detection system is made by LED soft light, the stability of light source is not very good, and the intensity of illumination will change a lot, which will cause certain influence on image acquisition and affect subsequent detection.

The conveyor belt speed error: the power of conveyor belt is provided by the motor and the motor drives the rotation of the synchronous belt wheel through the synchronous belt. The synchronous belt wheel drives the driving shaft to rotate, and the driving shaft is driven by friction force to the conveyor belt. The conveyor belt will work for a long time; the wear of various factors will change the speed, which will make the elimination cause error.

The feature extraction error: because the color and shape characteristic parameters of qualified products are obtained by analyzing 10 samples, the number of these samples is less. Therefore, the statistical analysis of the data will inevitably produce deviations, and the appearance detection of the subsequent fried food will produce error.

5. CONCLUSIONS

This paper mainly focused on the research on the automatic quality testing of fried food in food quality. Based on the microcontroller control system, the use of machine vision detection technology was proposed. Through the introduction to working principle of detection system, the key technology of appearance quality detection system, the hardware system design, the design of communication between PC and MCU and the overall structure design, the real-time food image on the conveyor belt were obtained. In addition, the relevant image processing algorithm was used to identify the shape, color and appearance of food. Through the color appearance detection experiment, shape appearance detection experiment and error analysis, the unqualified products identified were removed by subsequent device. Moreover, automatic detection of the appearance of fried food was realized, which avoided pollution and accuracy caused by artificial detection and improved the detection efficiency and accuracy. The experimental results showed that the detection system could be used for real-time detection of fried food.

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