Metal surface defect detection based on MATLAB

Zhipeng Li ,Jun Zhang ,Tao Zhuang ,Qiuyue Wang

Electronic Engineering Institute, Tianjin University of Technology and Education

Tianjin, China

1477127941@qq.com, studentandzhang@126.com, 1005720919@qq.com, wang_qiu_yue@126.com

Abstract: **For the detection of surface defects in the production of metal, this article mainly focuses on the detection of surface defects in more spoons that we use in our restaurants. Due to the fact that the defects on the surface cannot be detected with the naked eye, a surface defect detection system for spoons based on MATLAB is proposed. The image acquisition module and the image processing software design module are used to identify and detect surface defects of the spoon, and the detection efficiency is high, good real-time performance. For the defect of the spoon surface, irregular shape and other characteristics, the edge detection algorithm and the description method of texture features were proposed to realize the accurate detection of defect features.**

Keywords: Defect detection; Image processing; Feature extraction; Texture features

I. INTRODUCTION

MATLAB is a new type of scientific computing software that uses data in the form of matrices. Due to the development of the information age, the advantages of metal surface defect detection technology are becoming more and more obvious. And the traditional metal surface defect detection method is mainly artificial visual inspection, the accuracy standards for artificial visual inspection are different, the detection speed is slow, and it cannot adapt to the rapid development of industrial automation[1-3]. In order to solve this problem, it introduces the machine vision[4] online detection system. Compared with artificial visual inspection, machine vision adopts non-contact measurement methods, mainly through image preprocessing, image comparison and defect detection algorithms, and texture feature description methods. Not only has the characteristics of high efficiency, high degree of automation, but also can achieve high resolution accuracy and speed, safe and reliable. Therefore, it has been widely used in the field of industrial metal product testing. In particular, this article focuses on the spoon surface defect detection system.

II. Spoon defect detection design and collection

A. Spoon surface defect detection system

According to the need of the spoon surface defect detection system. This article designed a set of overall plans including image acquisition module, image preprocessing and analysis module, and software algorithm. The image acquisition module includes a spoon to be detected, a camera, an image capture card, etc. The image preprocessing and analysis module includes the image graying, image enhancement, image feature extraction, image feature analysis, etc. Finally, judge by the result of defect detection. If qualified, it is a qualified spoon, otherwise it is a defective spoon. The schematic diagram of the composition of the spoon defect detection system designed in this paper is shown in Fig.1.

978-1-5386-4509-3/18/$31.00 ©2018 IEEE

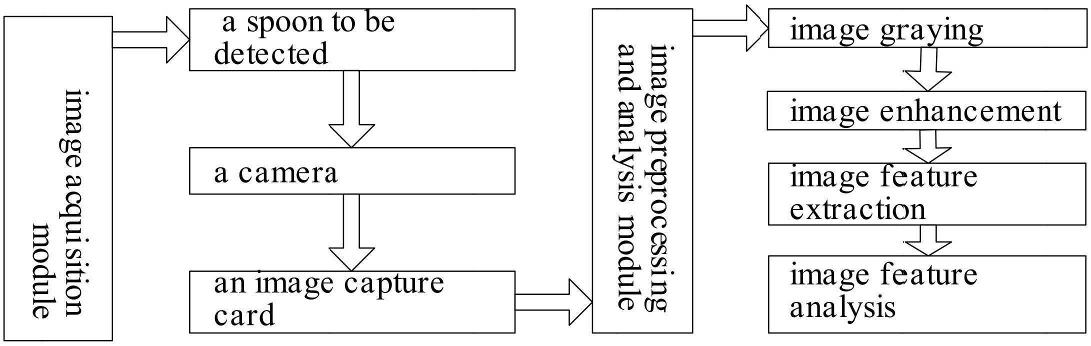


Fig.1. System block diagram.

B. *Image Acquisition*

The image acquisition module includes a spoon to be detected, a camera, an image capture card, etc. The overall process is to put the spoon to be tested into a designated position, provide enough light sources, and then use a camera to adjust the angle to shoot a spoon with the camera to get a clear image, send the captured image of the image acquisition card to the computer. Finally we use MATLAB software for image processing. The common defect is shown in Fig. 2, in which there are edge notches and wear in Fig. 2(a), there are irregularities in Fig. 2(b), irregular shapes and edges in Fig. 2(c), the wear of Fig. 2(d)

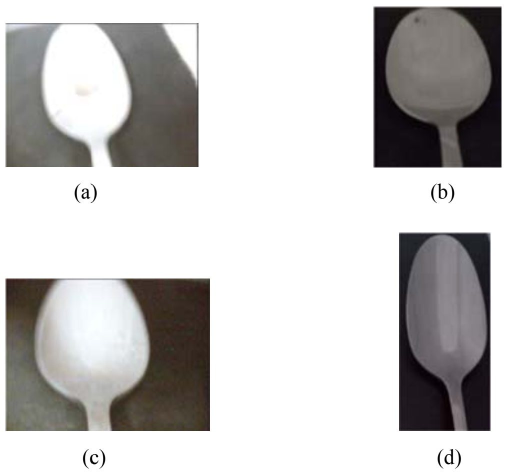


Fig.2. (a) Has edged notches and wear;(b) has partial bumps;(c) irregular shapes and edge gaps;(d) wear on the surface.

III. Image Preprocessing

A. *Image graying*

Because the image captured by the camera is an RGB image, in order to reduce the storage space of the image, the processing speed of the image is improved, at the same time, the function modules of each algorithm are satisfied to the greatest extent. Therefore, in the application of spoon surface defect detection, first, the collected image is subjected to grayscale processing[3-5]. As shown in Fig.3.This article uses the classic grayscale formula (1):

$$Gray = R \bullet 0.299 + G \bullet 0.587 + B \bullet 0.114 \quad (1)$$

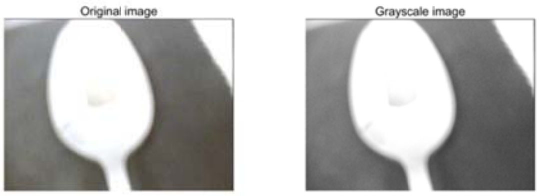


Fig.3. Before and after gray image.

B. *Image Enhancement*

Since the collected image contains various noises, the grayscale of the collected image is performed before the image analysis is performed, and noise reduction processing is performed. In this thesis, the noise characteristics of the surface image of the spoon were collected. Median filtering, histogram equalization, and sharpening filtering were used to denoise the acquired images. Its role is to enhance the image, highlighting useful information.

a) Median filtering

The median filter[1-4] is designed on the algorithm. Its purpose is to make the surrounding pixels' gray values close to each other, after processing the points where the gray values of the surrounding pixels are greatly different. Therefore, random noise can be attenuated, especially impulse noise, etc. The average is not simply taken in processing, and thus the blur produced is much less. Where the value is filtered, at the coordinate point (x, y), a window of size $m \times n$ is represented as S_{xy}, and its formula (2) is:

$$f(x, y) = \underset{(s,t)\in S_{xy}}{Median}[g(s, t)] \quad (2)$$

From the experimental observation, it can be seen that the median filter algorithm can not only eliminate the noise in the image, but also retain the details in the image to prevent edge blurring. As shown in Fig. 4.

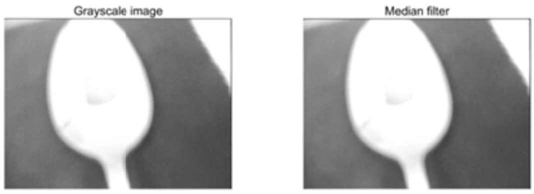


Fig.4. Median filter before and after image.

b) Histogram equalization

The grayscale histogram of the image represents the number of each grayscale pixel in the grayscale image, reflecting the frequency of occurrence of each grayscale in the image. After using the histogram equalization[3-5], the gray interval of the image can be pulled apart, or the gray scale can be evenly distributed, thereby increasing the contrast and clarifying the details of the image to achieve the purpose of enhancement. Its implementation is as follows:

(1) Calculate the grayscale histogram $p(r_k)$ of the original image. The formula (3) used is as follows:

$$p(r_k) = n_k / N \quad k = 0,1, \cdots ,255 \quad (3)$$

Where N is the total number of pixels in the original image and r_k is the kth gray level. n_k represents the number of pixels in the grayscale r_k appearing in the image, and $p(r_k)$ represents the probability of grayscale occurrence.

(2) Calculate the gradation cumulative distribution function s_k of the original image, and calculate the gradation conversion table according to formulas (4) and (5).

$$s_k = \sum_{j=0}^{k} p(r_j) = \sum_{j=0}^{k} \frac{n_j}{N} \quad k = 0,1,\cdots,255 \quad (4)$$

$$g_k = s_k \times 255/N + 0.5 \quad (5)$$

Among them, g_k is the gray value after the K-th gray level transformation, and the effect of 0.5 is rounding.

(3) According to the gradation conversion table, each gray level of the original image is mapped to a new gray level, and the histogram equalization can be completed. As shown in (a) and (b) of Fig. 5, depending on the defect images collected on the surface of the spoon, some grayscale images require histogram equalization enhancement, the effect is more obvious. However, when the difference in the gray level of some images is relatively obvious, using this method will make the effective area of the image less prominent.

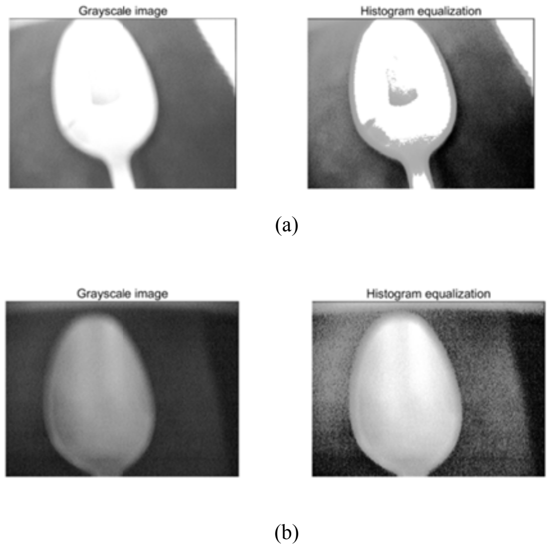


Fig.5. Histogram equalization: (a) ray difference is obvious; (b) gray scale difference is not obvious.

c) Sharpen filtering

For blurred images, through sharpening filter compensates for the outline of the image and makes the image clearer. Sharpening filters are commonly used Laplace operators. Laplace operators are more suitable for improving image blur due to diffuse reflection of light. The Laplace operators formula (6) for the discrete function is:

$$\nabla^2 f(i, j) = f(i+1, j) + f(i-1, j) + f(i, j+1) + f(i, j-1) + -4f(i, j) \quad (6)$$

The corresponding filter template (7) is as follows. After filtering, as shown in Fig. 6.

$$H = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad (7)$$

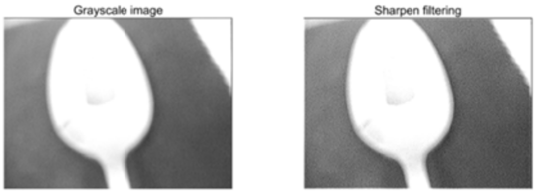


Fig.6. Sharpen filtering before and after image.

Through the enhancement of the image, median filtering, histogram equalization, and sharpening filtering are respectively used. According to the different grayscale images we have acquired, we choose appropriate methods to enhance the image. In summary, as shown in Fig. 7. Sharpening filter can better compensate the image's outline and filter out noise. Therefore, the paper chooses sharpening filtering to enhance the image.

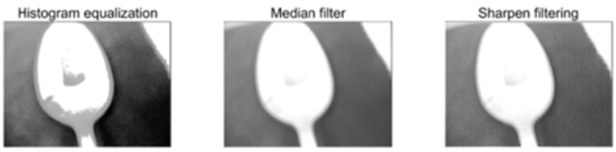


Fig.7. Three image contrast enhancement method.

IV. Image Feature Extraction

A. Basic Definition of Image Feature Extraction

For the extraction of image features, the image segmentation technique is described. There are many methods and types of image segmentation. There are generally two types of image segmentation algorithms, which are based on the discontinuity of the gray value of the image or its similarity. The discontinuity is based on discrete changes in the image grayscale segmentation of the image. Such as edge detection, boundary tracking, and Hough transforms. Similarity, dividing the image into similar areas based on pre-established guidelines. Such as regional division, regional growth, regional merger. Edge detection algorithms discussed in this paper are first-order differential operators, Sobel operators, Prewitt operators, Roberts operators and Canny operators[1-4], second-order differential operators, Log operators.

B. First-order differential operators

Edge detection is achieved using differences in the image characteristics of the object and the background. For the Roberts operator, there are mainly two following 2*2 templates (8):

$$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \quad \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \quad (8)$$

The Prewitt operator consists mainly of the following two 3*3 templates (9):

$$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad (9)$$

The Sobel operator is mainly composed of the following two 3*3 templates (10):

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (10)$$

The Canny operator has the advantages of low bit error rate, high positioning accuracy, and suppression of false edges. The edge of the detection, as shown in Fig. 8.

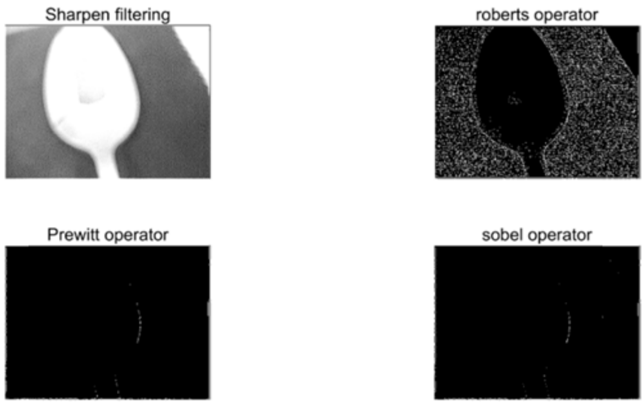


Fig.8. Edge detection of first order differential operators.

C. Second-order differential operator

The Laplace operator is a second-order differential operator that does not depend on the edge direction. It is a scalar quantity rather than a vector, and it has a rotation-invariant property. It is often used in image processing to extract image edges, and its expression. The formula (11) is

$$\nabla^2 f = \frac{\partial^2 f}{\partial^2 x} + \frac{\partial^2 f}{\partial^2 y} \tag{11}$$

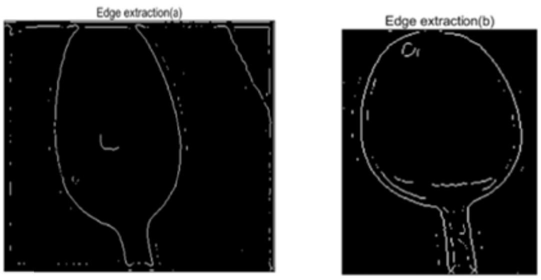
The test results are shown in Fig. 9.

Fig.9. Canny operator and Log operator edge detection.

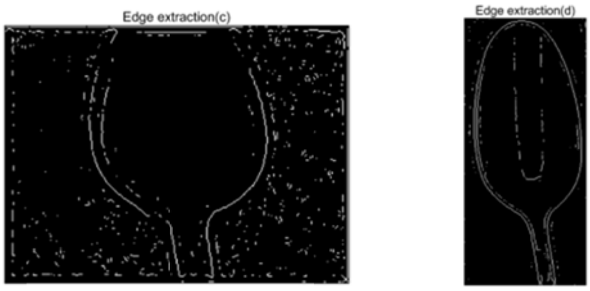
Through the extraction of image features, this paper uses a variety of methods for image edge extraction, which are first-order differential operator, Sobel operator, Prewitt operator and Roberts operator, and the Canny operator, second-order differential operator, Log operator. Finally, we can see from Fig.8 and Fig.9 that the Canny and Log operators can better detect the surface defects of the spoon with the same image. Therefore, this paper chooses the Canny operator and Log operator to extract the features of the image.

D. Application of defect detection algorithm

Through the Canny operator and Log operator selected in this paper, the image feature extraction[6-8], as shown in Fig.10. Above, can be accurately detected on the surface of the spoon, as well as clear outline detection, and the recognition rate is high.



（a） (b)



(c) (d)

Fig.10. (a) Edge extraction of Fig. 2(a); (b) Edge extraction of Fig. 2(b); (c) Edge extraction of Fig. 2(c); (d) Edge extraction of Fig. 2(d).

V. Image Feature Analysis

A. Basic Definition of Image Feature Analysis

For the feature analysis of images, this paper mainly describes the description of texture features. The texture feature describes the surface property of the scene corresponding to the image or image region and is a value calculated from the image. It quantifies the characteristics of the change in the gray level within the region. The texture features of an image are often periodic, reflecting the texture of the item, such as roughness, smoothness, graininess, randomness, and regularity. Texture analysis extracts texture features through certain image processing techniques to obtain a quantitative or qualitative description of the texture.

Several commonly used methods, such as gray-scale differential statistics, autocorrelation functions, gray-level co-occurrence matrix, and spectral feature-based analysis methods. This article mainly describes the gray difference statistics method.

B. Gray Difference Statistical Method

The gray-scale histogram of the texture region is used as a texture feature. Using the image histogram, we can get these information about the texture, such as the mean, variance, energy, and entropy. Let (x, y) be the point in the image, and the different gray value of the point $(x + \Delta x, y + \Delta y)$, which is only slightly different from the formulas (12) is:

$$g_\Delta(x, y) = g(x, y) - g(x + \Delta x, y + \Delta y) \tag{12}$$

The probability $p(k)$ of the value of g_Δ can be obtained from the histogram, when the frequency $p(k)$ taking the smaller difference K is larger, it reflects the rough texture. When the histogram is flat, it indicates that the texture is fine. Related texture feature formulas (13), (14), (15) are:

$$mean = \frac{1}{m}\sum_{i} ip(i) \tag{13}$$

$$con = \sum_{i} i^2 p(i) \tag{14}$$

$$Entropy = -\sum_{i} p(i)\log_2[p(i)] \tag{15}$$

The texture analysis data for the surface of the 10 sample spoons are shown in Table (1):

TABLE1. Texture analysis of spoon surface

Feature / Image	Mean	Con	Entropy
X1	0.0285	297.2290	3.6873
X2	0.0564	382.1922	4.4914
X3	0.0425	581.7349	2.7577
X4	0.0268	252.6182	2.0654
X5	0.0431	270.1998	4.4307
X6	0.0421	259.0418	4.2234
X7	0.0199	205.2581	3.1393
X8	0.0798	788.1756	4.4773
X9	0.0818	820.6432	4.5632
X10	0.0620	464.1085	4.5029

C. *Analysis of experimental results*

For the data of the table, this paper statistics the three texture features of the image, which are the Mean, Con, Entropy images, as shown in Fig.11, Fig.12, and Fig. 13.

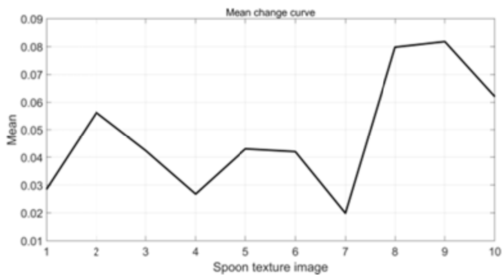


Fig.11. Mean statistics.

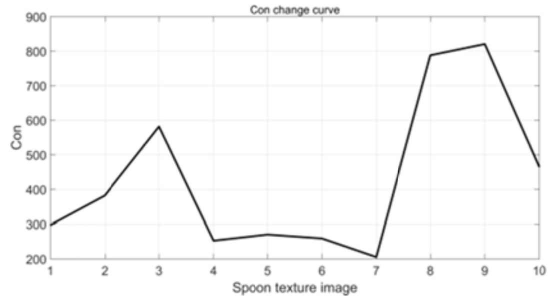


Fig.12. Con statistics.

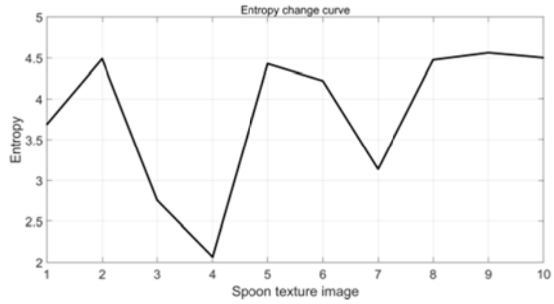
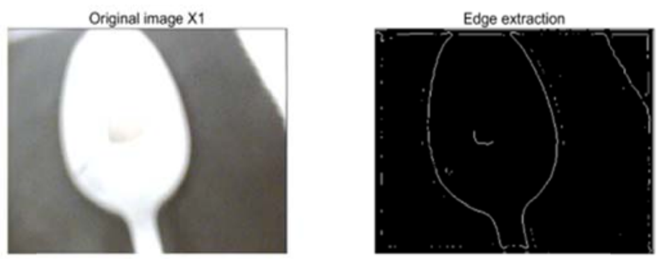


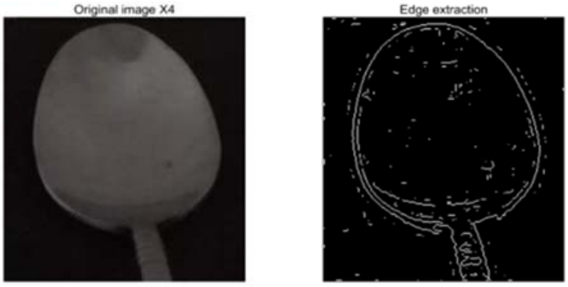
Fig.13. Entropy statistics.

By using the gray-scale difference method for defect detection on the surface of the spoon, we can find four pictures X1, X4, X7, and X9 from the figure and the table, which have obvious characteristics, and we can in the above picture. By analyzing the mean, variance, energy, and entropy, it can be known that when $p(k)$ is flat, the entropy is larger and the energy is smaller. When $p(k)$ is distributed near the origin, the average value is smaller. The more the distribution is near the origin, the smaller the average value.

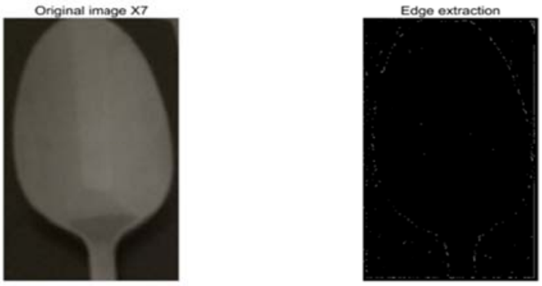
The four edges of the X1, X4, X7, and X9 images are detected as shown in (a), (b), (c), and (d) of Fig.14:



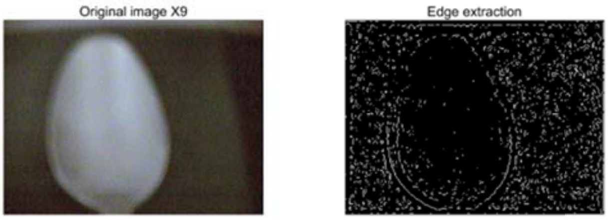
(a)



(b)



(c)



(d)

Fig.14. Edge detection of images: (a)image X1; (b)image X4; (c)image X7; (d)image X9.

VI. Conclusion

In this paper, the detection of metal surface defects is mainly focused on the detection of surface defects of spoons commonly used in restaurants. This article in each part of the implementation, after repeated measurements and method verification, especially in the image preprocessing, I have chosen multiple solutions, namely median filtering, histogram equalization, and sharpening filtering. For image feature extraction, I have chosen several schemes, namely, first-order differential operator, Sobel operator, Prewitt operator and Roberts operator, and the Canny operator, second-order differential operator, and Log operator. In the end, I chose sharpening filtering, Canny operator, Log operator for image processing. And the defect detection system has a good stability, and it has a higher recognition rate for the more common spoon surface defect images.

ACKNOWLEDGMENT

Thanks to Teacher Zhang for his guidance, as well as the lab's brother and brother's advice. A deep understanding of the flaw detection on the spoon surface. Through the rational use of MATLAB, the processing of the image makes the detection system designed in this thesis have a higher recognition rate for the more common spoon surface defect images. Therefore, once again thank the teachers and classmates for their help.

REFERENCES

[1] A.L. Wang, Research on Surface Defect Detection Based on Digital Image Processing. Harbin: Harbin Institute of Technology, 2014.

[2] J. Jiang, Research on Optical Detection Algorithm for Container Surface Damage. Harbin: Harbin Institute of Technology, 2009.

[3] W.D. Chen, Research and development of surface flaw detection technology for metal workpieces. Wuxi: Jiangnan University, 2013.

[4] Z.F. Long, Research on Bottle Cap Defect Detection Algorithm Design and Reconfigurable Scheme Based on Machine Vision. Hangzhou: Hangzhou University of Electronic Science and Technology, 2011.

[5] L. Luo, E.H. Zhang, “Research and implementation of inspection system to paper surface defect based on image analysis,” Journal of Xi’an University of Technology, vol.30, issue 2, pp.187-192, 2014.

[6] Z.M. Li, H. Li and J. Sun, “Printed circuit board defect detection based on digital image processing,” Instrument Technology and Sensors, issue 8,pp.87-89,2012.

[7] J. Wang, Y.X. Zhou and B.Q. Xu, “Application of Image Processing in Detection of Capsule Shape Defects,” Journal of China Jiliang University, vol.23, issue 3, pp.239-245, 2012.

[8] R.X. Gao, X.D. Ren and X.Wu, “Research on Mobile Phone Screen Defect Detection System Based on Image Processing,” Measurement and Control Technology, vol.36, issue 4, pp.26-30, 2017.