JJMIE

Volume 8 Number 5, October 2014
ISSN 1995-6665
Pages 297 - 303

Jordan Journal of Mechanical and Industrial Engineering

Automobile Longitudinal Axis Detection Method Based on Image Segmentation and Preliminary Results

Peijiang Chen[a,b] and Yongjun Min[*,a]

[a] *College of Mechanical and Electronic Engineering, Nanjing Forestry University, Jiangsu, China*

[b] *School of Automobile, Linyi University, Shandong, China*

Received 27 Feb 2014 *Accepted 10 Oct 2014*

Abstract

With the growing number and high usage frequency, it was important for automobiles to test the performance. In order to detect automobiles effectively, the technologies of automobile contour detection and longitudinal axis extraction, based on digital image processing, were studied. The basic concepts of automobile testing technology were introduced, and several commonly used image segmentation methods were analyzed. Before image segmentation, the automobile image was preprocessed, including gray scale transformation, gray scale stretching and median filtering. According to the monotonicity of interclass variances to both sides of threshold, the rapid realization method of image segmentation based on OTSU was proposed. The extraction of automobile longitudinal axis was realized by using approximation method. The software running showed that it could effectively detect automobile contour and extract longitudinal axis, which laid foundation for subsequent automobile image analysis and feature extraction, and it had certain practical value.

Keywords: *: Automobile Contour; Longitudinal Axis; Image Segmentation; OTSU; Approximation Method.*

1. Introduction

Automobiles play important roles in our daily life and have greatly changed lifestyle. With the rapid progress of automobile technology and fast development of automobile industry, the automobile performance has been improved significantly [1]. At the same time, the automobile structure becomes more complex. With the increase of automobile travelling mileage, it is inevitable for some performance changes to take place, such as power declination, economic deterioration, reduction of safety and reliability, etc. [2]. These changes affect the normal operation and use of automobiles seriously, and they may even pose a threat to people’s lives. In order to protect the safety of automobiles and people, the automobiles’ technical states and usage performance should be known. Therefore, it is vital and necessary to identify and eliminate the faults in advance by detecting the vehicle performance.

The technologies of automobile detection are mainly concerned with the operation performance, which can identify the technical conditions without disassembling and providing a reliable basis for the fault detection and maintenance. With the advances of science and technology, especially the technologies of computer and communication, the traditional detection methods cannot meet the needs of modern automobile testing [3]. A variety of advanced equipment is used to make the automobile detecting process safer, faster and more accurate [4].

Automobile longitudinal axis, the center line or symmetrical line, is one of the basic characteristics of automobiles. In general, when an automobile moves along the road, the body sides are parallel with the road direction, and then the automobile's longitudinal axis is parallel with the road surface [5].

The extraction of automobile longitudinal axis is significant in automobile detection. For example, in the automobile headlamp detection, the longitudinal axis should be vertical with the pathway of headlamp tester, or the detection results may have errors. There are two general methods to resolve the measurement errors: a) using automobile adjusting device to alien the automobile, and b) using a certain technology to correct the detection results. For the first method, the instrument has a fixed length for the platforms of the front axle and the rear axle, which cannot adapt to the automobiles with different wheelbases; the adjusting time is long and the detection efficiency is low; due to this, then this method cannot meet the need of fast automatic detection in automobile testing stations. For the second method, a computer is used to process an automobile image; the first step is to extract the automobile contour and longitudinal axis, then to analyze the offset between the actual position and the ideal

[*] Corresponding author. e-mail: yjmin@njfu.edu.cn.

position of the automobile, and finally to correct the headlamp testing results according to the positional deviation. The second method is low-cost, and can obtain accurate measurement results. The correction of headlamp detection results can indirectly decrease the accidents caused by headlamp faults [6].

The detection of automobile longitudinal axis has mainly two methods: 1) a method based on machine vision, and 2) a method based on digital image processing. Lin [7] used the stereo vision technology to detect the longitudinal axis of an automobile which was parked on the automobile straightening apparatus. The two images of the automobile body were captured and the boundary lines, within certain slopes and lengths, were extracted, and, finally, their centerlines were gotten. This method has a good accuracy, but it needs a special straightening apparatus and two cameras; the system is very costing.

The image is the main source of information acquisition and exchange [8]. In recent years, the methods of image acquisition, processing, and non-contact measurement are widely used in many fields, such as traffic monitoring, automobile headlamp detection, automatic identification of automobile license, shape measurements of the automobile body, smart identification of automobile type, etc. [9]. In the process of automobile detection based on image processing technology, there are other objects and background besides the vehicles in the image. In order to further extract, analyze and process the automobile characteristics, the key step is to separate the automobile from the complex scene of the original image and obtain the automobile contour.

Based on image processing, the technologies of image segmentation and contour detection of automobiles are discussed and the longitudinal axis of automobile is extracted in this study. Since the method uses one camera only, it can reduce the system cost. Besides, it is a noncontact measurement method; the system is suited for online application in vehicle detection station.

The remainder parts of this paper are as follows: the second section analyzes the commonly used methods of image segmentation; the third part gives the system design of automobile longitudinal axis detection based on image segmentation; section four analyzes the main idea of image segmentation based on maximum interclass variance, puts forward the quick achievement process of OTSU, and discusses the realization process of automobile longitudinal axis extrication; section five concludes the paper to show that the automobile longitudinal axis extraction mthod based on image processing has practical value in automobile detection.

2. Image Segmentation Methods

Image segmentation is a key technology in digital image processing, which occupies important position in the image engineering. On the one hand, image segmentation is the basis of target expression and it has an important impact on the characteristic measurement. On the other hand, image segmentation and segmentation-based technologies including target expression, feature extraction and parameter measurement convert the original image into more abstract and compact form, and then the higher level of image analyzing and understanding become possible [10].

Simply, image segmentation refers to the fact that different regions, with special meanings in an image, are distinguished, and each region meets the consistency of a specific area. Image segmentation can also extract interesting targets, including gray scale of pixel, color, texture, etc. [11]. There are many ways to segment images, the most classic methods include threshold-based segmentation [12], edge detection, region extraction, and so on.

2.1. Threshold Segmentation Method

The threshold-based method is the most common way to segment images [13]. This method can directly process gray scale information in a binary or a multi-valued way. Firstly, one or several thresholds are selected. Then, the gray scale value of each pixel in the image is compared with the threshold to classify the corresponding pixels according to the comparison results and classify the pixels within the same gray scale interval as the same area. It is obvious that the threshold determination is a key factor that has a direct impact on the segmentation result.

This segmentation method has a simple process, low cost and strong practicality. However, when the difference of image gray scales is not obvious, or the most of gray scales are overlapped, it is often difficult to get an accurate segmentation result and many over-segmentation or under-segmentation errors occur [14]. The basic threshold segmentation methods include histogram twin peaks method, iterative method, OSTU method, etc.

2.2. Edge Detection Method

Edge detection is an important way to achieve image segmentation by detecting the place where the gray scale or structure has mutation, which indicates the end of an area and the start of another area. At the edge of an image, the gray scales are not continuous which can be detected by derivative operation [15]. The position of step edge corresponds to the extreme points of the first order derivative and the zero crossing points of the second derivative. Therefore, the basic image edge detection technologies are mostly realized based on a differential operation. The edge detection operator can extract image boundary by checking the neighborhood of each pixel and quantify the changes of gray scales. Because edge and noise are not consecutive points, it is difficult to overcome the effects of noise for using direct differential operation. In general, the images are smoothed by filters before edge detection.

The commonly used first-order differential operators include Roberts, Prewitt and Sobel. The second-order differential operators have Laplace, Log and Canny. In practice, the variety of differential operators are usually expressed by small region templates. Each operator is best suited to a certain application field. This feature has superiority in application because it can help accomplish specific edge detection. But it is limited due to the fact that the predefined edge detection method may not achieve the best results for other application or unknown circumstances.

2.3. *Region Segmentation Method*

The essence of image segmentation method based on region is to connect the pixels of the same nature together to constitute the final divided regions. It utilizes local space information of the image and can effectively overcome some shortcomings of other ways. The method is characterized by dividing the segmentation process into several sequential steps, in which the subsequent steps should be judged according to the results of the previous steps.

There are two major implementation ways: a) region growing, and b) region splitting and merging. The basic idea of the region growing method is to aggregate the pixels or sub-regions of a similar nature to form a larger area. The key point of this method is to select a suitable growth or similar criteria. The growth guidelines can be generally divided into three kinds: 1) rule based on regional gray difference, 2) rule based on gray scale distribution statistical properties, and 3) rule based on region shape [16]. The method of splitting and merging is to divide the image into many small regions with strong consistency, to combine them into a large region, and finally the image segmentation is achieved [17].

2.4. *Segmentation Method Combined with Specific Theory*

In recent years, with the appearance of many new theories and methods, there have been many segmentation techniques combining with certain theories, including mathematical morphology [18], genetic algorithm, wavelet transformation, neural network, etc.

3. Design of Automobile Longitudinal Axis Detection System

When detecting automobile headlamps in vehicle testing stations, and because of the misalignment between the tested automobile and headlamp tester, there may be errors in detecting results. The errors can be corrected by analyzing the deviation of automobile parking location [19]. In this application, the extraction of automobile longitudinal axis is a critical step.

In order to reduce the system cost, a single camera is applied to capture the automobile images. Firstly, the automobile is parked in predetermined position in the vehicle testing station. The camera is set just above the automobile [20], and the image plane is aligned with the testing field by camera calibration. Then, the automobile overlooking image is captured, and it is processed by the computer to obtain the automobile outline by image segmentation technology. Finally, the longitudinal axis of the automobile can be extracted.

The process of system implementation of automobile longitudinal axis detection is shown in Figure 1.

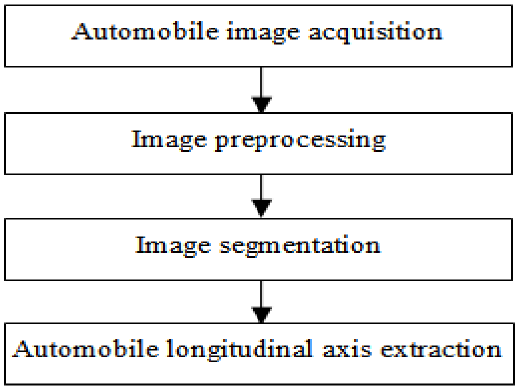


Figure 1. Implementation process of automobile longitudinal axis detection system

4. Realization of Automobile Longitudinal Axis Extraction

In order to test the effectiveness of this algorithm preliminary, a longitudinal axis detection system of automobile is designed. Due to the limitations of the experimental conditions, only two images of different types of automobiles are used to test the algorithm.

4.1. *Preprocessing of Automobile Image*

After acquiring the automobile image, the preprocessing is necessary, including gray scale conversion, gray scale stretching and image smoothing.

In the case of low light condition, the clarity of the gray scale image is greater than that of the color image. In order to adapt to different lighting conditions, the color automobile images are converted to gray scale images. Moreover, the process can reduce the complexity of information computation.

The gray scale stretching method is used to manipulate the image to enhance the variation range of image gray scale, rich gray scale levels and enhance contrast and resolution of the image. The commonly used gray scale stretching function is given, as shown in Eq. 1:

$$f(x)=\begin{cases}\dfrac{y_1}{x_1}x & x<x_1\\[2mm] \dfrac{y_2-y_1}{x_2-x_1}(x-x_1)+y_1 & x_1\le x<x_2\\[2mm] \dfrac{255-y_2}{255-x_2}(x-x_2)+y_2 & x_2\le x\end{cases} \quad (1)$$

Where, x_1, x_2 are gray scale values of turning points of the original image; y_1, y_2 are gray scale values used for the transformed image.

In the application of automobile longitudinal axis detection, the image is smoothed to reduce noise. The median filter is used to realize this function in this study. The gray scale images of the tested automobiles after preprocessing are shown in Figure 2:

(a) Automobile 1

(b) Automobile 2

Figure 2. The gray scale images of the tested automobiles

4.2. Image Segmentation Based on Maximum Interclass Variance

A maximum interclass variance, a dynamic threshold method, was brought out by Nobuyuki Otsu [21], which is simply called OTSU. The basic idea is to find a threshold value through a gray histogram of the image. The value makes the interclass variance get the maximum and divides the image into two parts: target and background [22].

Supposing that the number of image pixels is N, the gray scale range is [0, K-1], the number of pixels corresponding to the gray level i is n_i, the probability is $p_i = n_i / N$, and $\sum_{i=0}^{K-1} p_i = 1$.

According to gray scales, a certain threshold T divides the image pixels into two categories: C_0 and C_1. The former contains the pixels which gray scale belongs to [0, T]; the latter includes the pixels which gray scale range is [T+1, K-1].

The means of C_0 and C_1 are given respectively, as shown in Eq. 2:

$$u_0 = \sum_{i=0}^{T} iP_i / w_0 \text{, } u_1 = \sum_{i=T+1}^{K-1} iP_i / w_1 \tag{2}$$

Where, $w_0 = \sum_{i=0}^{T} p_i$, $w_1 = \sum_{i=T+1}^{K-1} p_i = 1 - w_0$.

The mean of the total image is gotten, as shown in Eq. 3:

$$u_T = \sum_{i=0}^{K-1} iP_i = w_0 u_0 + w_1 u_1 \tag{3}$$

The interclass variance is defined, as shown in Eq. 4:

$$\begin{aligned}\sigma^2 &= w_0 (u_0 - u_T)^2 + w_1 (u_1 - u_T)^2 \\ &= w_0 w_1 (u_0 - u_1)^2\end{aligned} \tag{4}$$

The largest value of T can be gotten when the interclass variance gets the maximum. The value is the best segmentation threshold for OTSU segmentation method.

4.3. Quick Achievement of Automobile Image Segmentation Algorithm

The basic idea of the OTSU algorithm is to select a certain gray scale as the threshold value which divides the image into two groups and calculates the interclass variance of the two groups. When the interclass variance is maximal, the threshold is used to segment the image.

It is obvious that the main calculation amount of this algorithm lies in computing the interclass variance. The method is simple in idea, but the computation amount is large, which hiders the rapid implementation of image segmentation. As for the standard 256 level grayscale image, in general, it needs 256 calculations to get the maximum variance [23]. In order to improve the operating speed, a rapid implementation method of OTSU is proposed in this study.

In order to find out how to segment the automobile gray scale image quickly, the interclass variance for each gray scale value of the automobile image, shown in Figure 2 (a), is given, as shown in Figure 3.

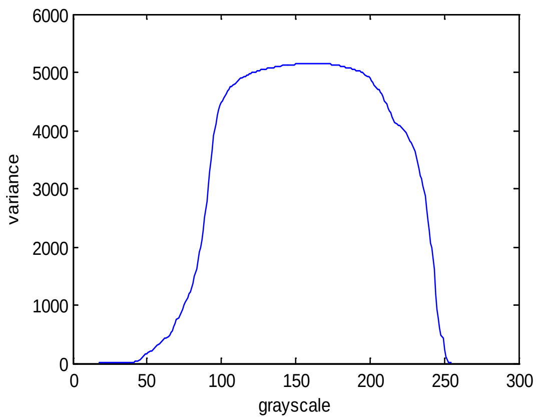


Figure 3. Interclass variances of image pixels

It can be seen that the maximum of interclass variance corresponds to the best segmentation threshold value. The interclass variance monotonically decreases when the gray scale is less than the threshold and the interclass variance monotonically increases when the gray scale is greater than the value. This feature can provide convenience to quickly calculate the optimal segmentation threshold value. The rapid calculation process is given, as shown in Figure 4.

For the given automobile image, shown in Figure 2 (a), the gray scale threshold value, using conventional OTSU algorithm, is 159, and the value with the rapid method is 160. The difference is very small, but the analyzing speed is greatly enhanced. In this case, the threshold can be obtained by 40 calculations in the rapid method, which is much smaller compared with the 256 calculations in the conventional method.

4.4. Implementation of Automobile Longitudinal Axis Extraction

According to the symmetrical characteristics of the outline of automobile overlooking image, the approximation method is used to detect the automobile longitudinal axis after getting the automobile outline [24]. The analyzing method of automobile longitudinal axis extraction is shown in Figure 5.

The extraction process of automobile longitudinal axis, based on approximation method, is as follows:

1. Set the error threshold ε according to the measurement accuracy requirement and camera resolution.
2. Select the starting positions by drawing two lines, get four points a_1, b_1, c_1, d_1, and then obtain two midpoints m_1 and n_1 according to the lines a_1b_1 and c_1d_1 , respectively.
3. Analyze the angle between the two lines a_1b_1 and m_1n_1, as shown in Eq. 5:

$$\theta_1 = \arctan(-\frac{1}{k_1}) \tag{5}$$

where, $k_1 = \frac{(y_{a_1} + y_{b_1}) - (y_{c_1} + y_{d_1})}{2(x_{a_1} - x_{c_1})}$

If $|\theta_1 - 90| \geq \varepsilon$, draw the vertical line of m_1n_1, and obtain the edge points a_2, b_2, c_2, d_2.

4. Analyze the angle between the two lines a_2b_2 and m_2n_2, as shown in Eq. 6:

$$\theta_2 = \arctan(-\frac{1+k_1k_2}{k_1 - k_2}) \tag{6}$$

The process is repeated until $|\theta_2 - 90| < \varepsilon$, finally the automobile longitudinal axis is acquired. The extraction results of longitudinal axis for the tested automobiles are shown in Figure 6:

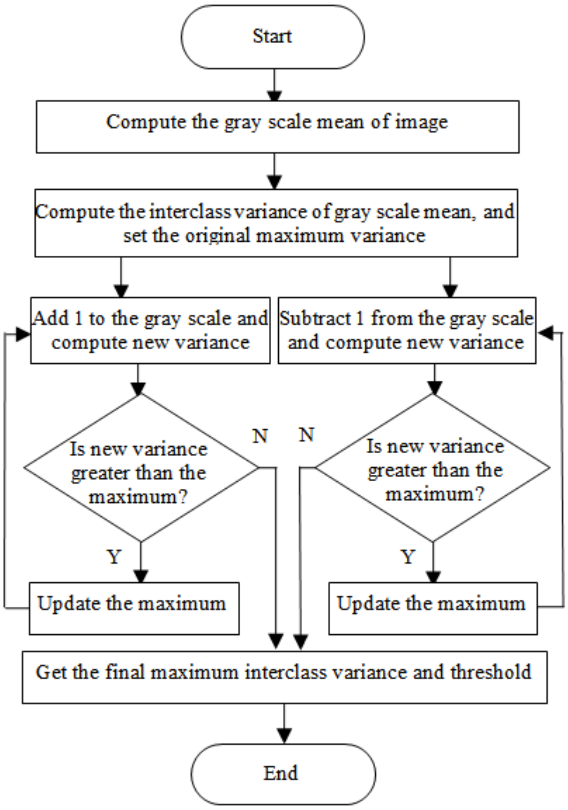


Figure 4. Rapid calculation process of OTSU

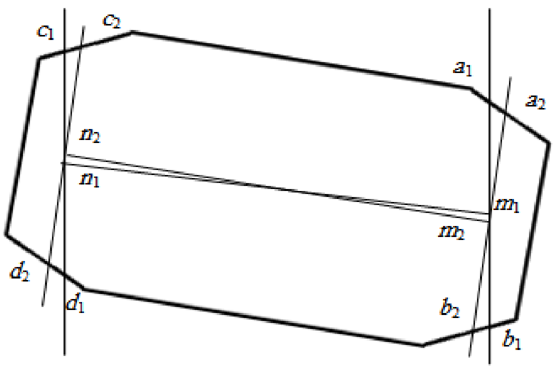
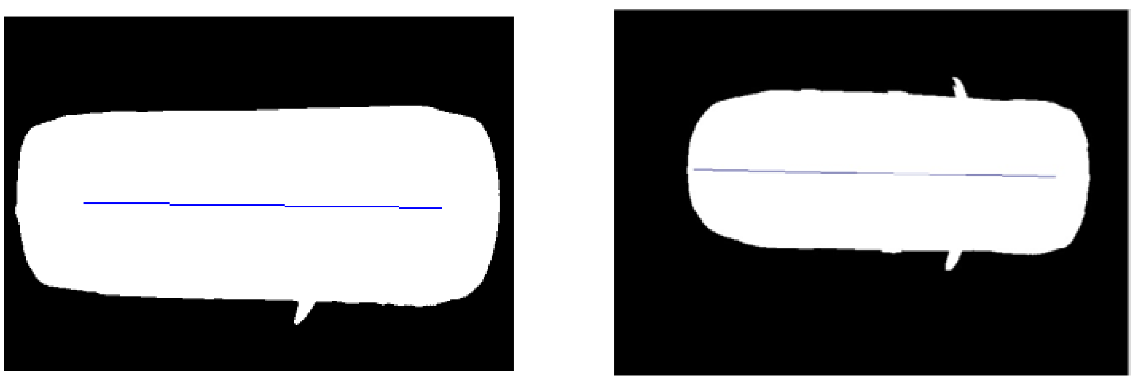


Figure 5. Analyzing method of detecting automobile longitudinal axis based on approximation method



(a) Automobile 1

(b) Automobile 2

Figure 6. Detection results of the automobile longitudinal axis

As can be seen from Figure 6, the algorithm proposed in this study can effectively extract the longitudinal axes of the two tested automobiles in different backgrounds. And from the extraction process, the angle between the longitudinal axis and the horizontal axis of the image coordinate system can be obtained. After camera calibration, the image plane is aligned with the testing field, then the parking deviation angle of the automobile is obtained, which can be used to correct the measurement data of the headlamp tester and improve the measurement accuracy in automobile headlamp testing. In addition, the measurement precision of automobile longitudinal axis is affected by the color difference between the automobile body and background, camera resolution, field lighting, etc.

5. Conclusions

On the basis of analyzing several commonly used image segmentation methods, the system of automobile contour detection and longitudinal axis extraction is designed and implemented. The experiment results show that the quick realization of image segmentation, based on OTSU, can effectively detect the outline of the automobile image and can greatly improve the detection speed. The automobile longitudinal axis can be extracted through approximation method. Compared with other methods, it has low cost and real time. It can lay a good foundation for the subsequent analysis and feature extraction of the automobile image, and the automobile longitudinal axis method has a certain application value.

It is important to note that this method needs a high demand for image segmentation; then a more accurate image segmentation method should be developed to achieve a better extraction result of the automobile longitudinal axis in future research. Furthermore, due to the limitations of the experimental conditions of this study, only two automobiles are selected to detect longitudinal axes, more experiments need to be carried out to test the algorithm. In addition, considering that the method is mainly used in a vehicle test station, only cars are selected for the test. In order to widen the application scope, the method should be improved to test other type of vehicles in our future studies.

Acknowledgements

This study is supported by the Graduate Student Research and Innovation Program of Jiangsu Province (No. CXLX13_513) and the Science and Technology Development Planning Project of Shandong Province (No. 2013YD05004), P. R. China.

References

[1] N. S. Asad, Y. S. Ge, H. Zhao, "Aldehyde and BTX Emissions from a Light Duty Vehicle Fueled on Gasoline and Ethanol-Gasoline Blend, Operating with a Three-Way Catalytic Converter". Jordan Journal of Mechanical and Industrial Engineering, Vol. 4 (2010) No. 3, 340-345.

[2] P. Wu, "Study on Correction Method of Parking Error in Automobile Headlamp Testing". Master Thesis, Changchun, China: Jilin University; 2009.

[3] J. Wei, "Development of Automobile Detection Technology". Technology and Life, (2011) No. 9, 217-217.

[4] L. Liu, C. Deng, S. Wang, "Overview on Development of Vehicle Detecting Technology". Special Purpose Vehicle, (2008) No. 7, 46-49.

[5] J. Peng, "Research on Measurement of Vehicle Size Based on Digital Image Processing". Master Thesis, Hefei, China: Hefei University of Technology; 2008.

[6] H. Zhu, "Research on the Image Processing Technology for Automobile Headlamp Testing". Master Thesis, Nanjing, China: Nanjing Forestry University; 2007.

[7] H. Lin, "Study on Testing System of the Position Deviation of Vehicle-body and Axle Based on Stereo Vision". Master Thesis, Changchun, China: Jilin University; 2008.

[8] X. Zhao, C. Lin, L. Huang, Y. Yang, "Vehicle Detection and Recognition of MATLAB-Based Image Processing Method". Journal of Data Acquisition & Processing, Vol. 24 (2009) No. S, 141-143.

[9] Y. Lu, C. Yang, T. Zhang, X. Yan, "Application of Image processing technology in motor vehicle testing industry". China Measurement Technology, (2003) No. 6, 36-37.

[10] F. Li, "Research and Implementation of Image Segmentation Algorithm in Vehicle Detection System". Master Thesis, Shenyang, China: Northeastern University; 2005.

[11] X. Luo, J. Tian, Y. Zhu, J. Wang, R. Dai, "A Survey on Image Segmentation Methods", Pattern Recognition and Artificial Intelligence. Vol. 12 (1999) No. 3, 301-312.

[12] A. B. Adnan, A. N. Bassam, "A Fusion Technique Based on Image-Statistical Analysis for Detection of Throat Cancer Types". Jordan Journal of Mechanical and Industrial Engineering, Vol. 4 (2010) No. 6, 677-684.

[13] H. Hou, M. Wang, S. Ren, "An Improved Ray Casting Algorithm Based on 2D Maximum Entropy Threshold Segmentation". Journal of Convergence Information Technology, Vol. 7 (2012) No. 17, 243-250.

[14] R. Xu, "An Overview of Image Segmentation Technique and Performance Evaluation". Journal of Ningbo University of Technology, Vol. 23 (2011) No. 3, 76-79.

[15] G. Zhang, "Machine Vision". Beijing, China: Science Press; 2005.

[16] S. Le, H. Wu, Y. Fu, "Research and Prospect on Image Segmental Methods". Journal of Nanchang College of Water Conservancy and Hydroelectric Power, Vol. 23 (2004) No. 2, 15-20.

[17] W. Yang, Z. Li, Y. Wang, P. Lv, "Survey of Image Segmentation Method Based on Region". Journal of Electronic Measurement and Instrument, (2007) No. S, 278-281.

[18] P. Chen, "Study on Medical Image Processing Technologies Based on DICOM", Journal of Computers, Vol. 7 (2012) No. 10, 2354-2361.

[19] Y. Min, Y. Zhai, "Direction Detection for Automobile Headlamp Beam Based on Digital Computer Image Processing". Journal of Southeast University (Natural Science Edition), Vol. 31 (2001) No. 6, 1-4.

[20] L. Zhu, "Research on the Test Technology of Automobile Headlamp based On Image Processing". Master Thesis, Nanjing, China: Nanjing Forestry University; 2005.

[21] N. Otsu, "A threshold selection method from gray-level histograms". IEEE Transactions on Systems, Man, and Cybernetics, Vol. 9 (1979) No. 1, 62-66.
[22] D. Zhang, Detailed Notes to MATLAB Digital Image Processing, Beijing, China: Publishing House of Electronics Industry; 2010.
[23] S. Zhou, P. Yang, W. Xie, "Infrared image segmentation based on Otsu and genetic algorithm". International Conference on Multimedia Technology, Hangzhou, China, 2011.
[24] Y. Min, L. Zhu, H. Zhu, Z. Xu, "Design and implementation of correction system for measuring error of automobile headlamp beam". Journal of Nanjing Forestry University (Natural Science Edition), Vol. 34 (2010) No. 2, 107-110.