

Crimp Terminals Section Measurement and Analysis System Based on Partial Differential Equation

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Abstract: The method of the terminal section measurement and analysis which is based on image processing has been widely applied in the field of harness the quality detection, but it is still not satisfactory in automatic recognition of the terminal contour. The image segmentation technology which based on partial differential equations-C-V simplified segmentation model has been applied in automatic recognition and calculation of the terminal contour, on the basis of the technology, developed a system of crimp terminals section measurement and analysis, which has realized the automatic detection of the quality, analysis and report output. The application of this system not only reduces the labor intensity of testing personnel, but has important implications for improving the level of testing technology of harness crimping terminal quality in automotive industry, electronics, electrical, machine and so on.

Keywords: automotive wiring harness, automatic contour extraction, crimp terminal, partial differential equation.

1. INTRODUCTION

With the increasing of requirements in comfort, economy, safety, Automobile electronic product types are increasing, automobile wiring harness is becoming more and more complex, The failure rate of the wire harness also increases accordingly, which requires improving the performance of wire harness in reliability and durability. Judging from the crimping terminal quality in four aspects, mainly in the appearance, cross-sectional tensile resistance of standard and the crimp height, width standard. The traditional of terminal crimping quality detection relies mainly on visual staff, not only time-consuming, low accuracy of measurement, but also the observation data cannot be preserved well. Crimp terminals measurement and analysis base on microscopic image analysis become a trend in recent years, but the current system cannot realize the function of automatic measurement and analysis.

The method of image processing which based on partial differential equation is become a hot research topic in recent years [1, 2], the theory has been affirmed by many research results in the accuracy and stability of image segmentation. In the wiring harness terminal profile analysis and measurement system, the theory can be divided accurately section contour of the wiring harness terminal. This paper uses technology of partial differential equations of image segmentation to automatic segmentation of the internal and external contours of the terminal section image. Through the

MATLAB environment to verify the effect of the automatic detection contour, and then developed a system of terminals section measurement and analysis in accuracy and stability, the system has realized the automatic output results, reduced the labor intensity of testing personnel and improved work efficiency.

2. THE COMPOSITION AND WORKING PRINCIPLE OF THE SYSTEM

2.1. The Composition of the System's Hardware

According to the specific object of our research, the main hardware devices: host computer, display, image acquisition card, microscope, CCD camera, output device (printer and CD-R), network servers and storage devices etc, the hardware structure of the single machine system as shown in Fig. (1).

2.2. The Structure of the System's Software

The software of the system mainly includes: system platform module, image acquisition module and profile image analysis.

(1) System platform module: Complete user interface design of the client and research & development of common color image processing, such as image display, image file input and etc.

(2) Image acquisition module: Capture terminal section image from the microscope through the camera, or capture section image directly by the camera or capture a video and then save it to a specified folder.



Fig. (1). The composition of the system's hardware.

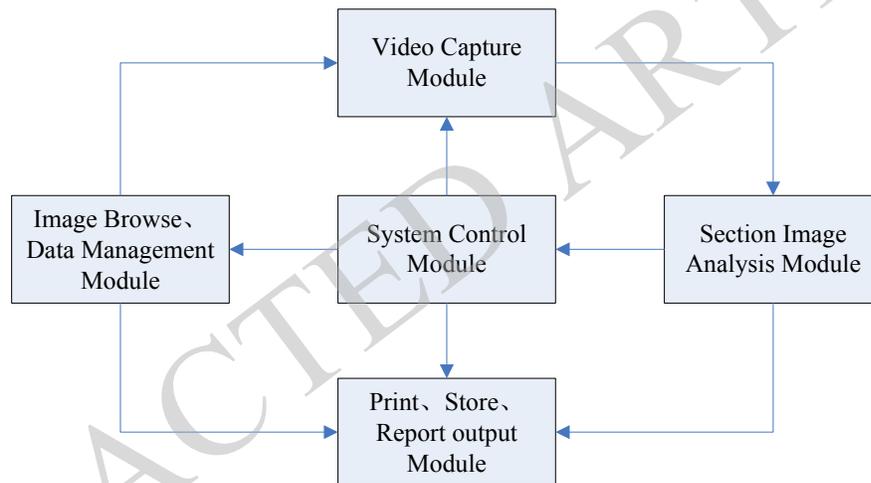


Fig. (2). The function chart of system.

(3) Section image analysis module: Complete the measurement and calculation of area, height, width and rate of deformation parameters of the terminal section image. At the same time, store data, generate a report data, and then send it to the control module and print. The function chart of system of terminals section measurement and analysis as shown in Fig. (2).

2.3. System Working Theory

The harness terminals after slicing has been put on the countertop of industrial microscope, the image is blown up to a certain multiple by the microscope, and then capture the video signal through the camera, observe on the screen, grab and save the image which is to be analyzed. And image pre-treatment, eliminate noise or enhance the contour. And then calibrate the images analysis module, that's to say, confirm

the actual percentage of image, After that, use the image analysis tool to extract automatically image of the internal and external contour, and realize the automatic measurement of contour area, height, width and other parameters. Save the result of image measurement and analysis to file or output to custom Excel or custom file of .doc. If necessary, print it. A flow of system as shown in Fig. (3).

3. AN IMAGE SEGMENTATION TECHNIQUE BASED ON PARTIAL DIFFERENTIAL EQUATIONS

3.1. Level Set Method for Image Segmentation

The basic idea of image segmentation method based on partial differential equations is to construct the corresponding differential model according to the requirements of

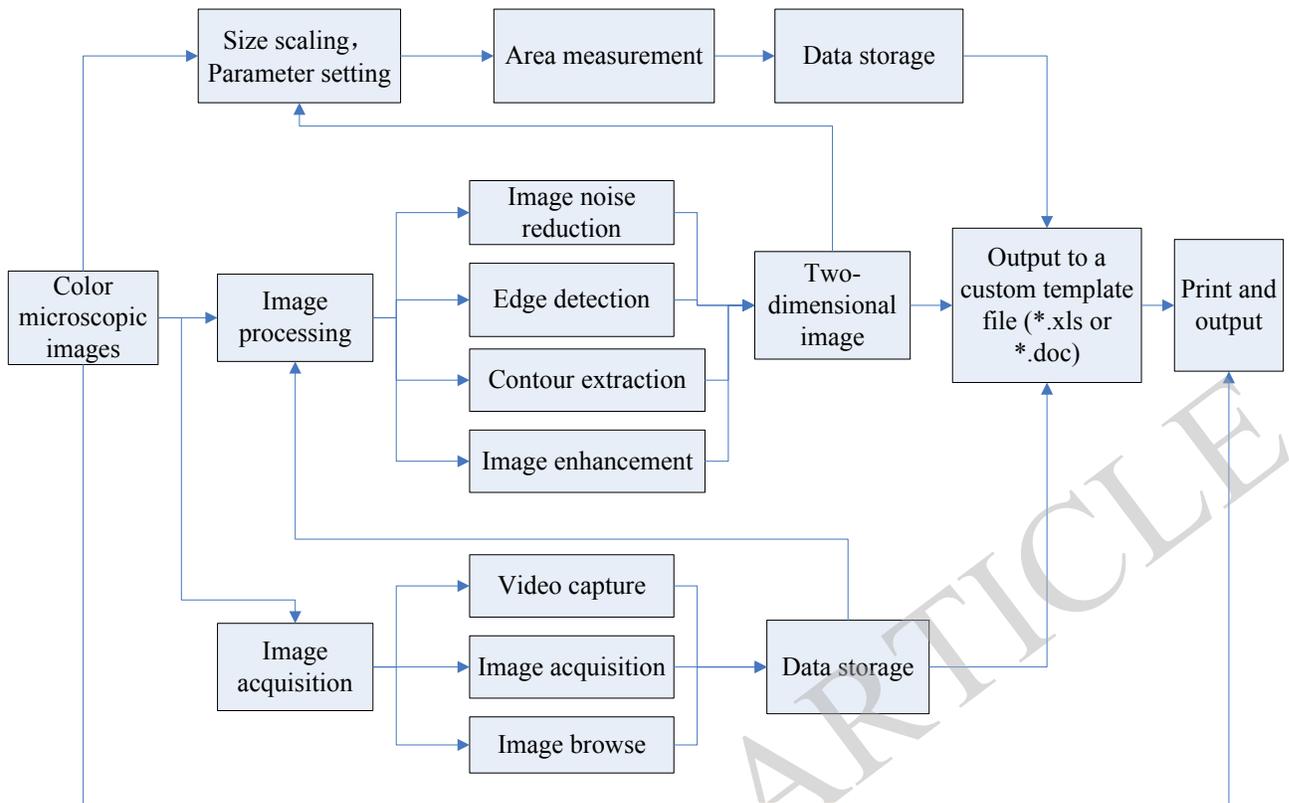


Fig. (3). A flow of system.

image segmentation. And then solve the differential equation. The solution of equation is the expected result [3, 4]. Image segmentation based on partial differential equations mainly uses the active contour model to achieve for now. The traditional active contour models are divided into parameters active contour model and geometric active contour model. The feature of parameters active contour model is to place the virgin curve near the target area without setting the evolution of the curve is contraction or expansion artificially. But the disadvantage is that it is difficult to handle the topology's transformation of the model, such as merging or splitting of the curve and so on. However the geometric active contour model can improve and mend the parameters active contour model's weakness [5]. Its biggest advantage is that it does not depend on the parameter settings of the original argument's deformation, but to evolve automatically the target curve according to the topology of digital images. In the process of the development, the appearance of the Level Set method plays a crucial role.

The main idea of the level set method is to make the moving interface as the level set function which the zero level set is embedded in the high one-dimensional. By evolving the closed hypersurface to get the evolution equation of the level set function, and the closed hypersurface is always the zero level set. So make sure the zero level set repeatedly, you will get the final evolution result. The mathematical definition of the level set function as follows:

Assuming the implicit function at time t of the closed curve $C(p, t): 0 \leq p \leq 1$ is $\phi(x, y, t)$, that is to say, at time t , the zero level set of $C(p, t)$ as follows:

$$\begin{cases} c(p, 0) = \{(x, y) | \phi(x, y, 0) = 0\} \\ c(p, t) = \{(x, y) | \phi(x, y, t) = 0\} \end{cases} \quad (1)$$

Partial differential equation of geometric active contour model, represented by level set method:

$$\begin{cases} \frac{\partial \phi}{\partial t} = g[|\nabla I(C)|](k + v) \nabla \phi \\ \phi(x, 0) = \phi_0(x) \end{cases} \quad (2)$$

Active contour lines of this model are disturbed by noise. If the image noise is very loud, and you need a higher variance gaussian filter, which often blurs the image, influences the evolution of active contour lines, or produces inaccurate positioning.

3.2. C-V Simplify Segmentation Model

In order to improve the above problems and to solve which depends only on the edge gradient information, Chan and Vese proposed a simplified segmentation model based on M-S[6]. Firstly, suppose the gray part of each equivalence of the image is constant. To find the original and to be

segmented images which have the smallest differences for the purpose of minimizing the energy function F^{MS} .

$$I(R_i) \approx \begin{cases} C_0, & \text{if } R_i \in \text{inside}C \\ C_b, & \text{if } R_i \in \text{outside}C \end{cases} \quad (3)$$

Suppose the original image $I(x, y)$ is divided into two regions by active contour lines C which includes the object and the background. Each equivalent average gray part is c_0 and c_b . Chan and Vese proposed a simplified energy function [7, 8] based on MS image segmentation model is as follows:

$$F(C, c_0, c_b) = \mu L(C) + vS_0(C) + \lambda_0 \int_{\text{inside}(C)} |I - c_0|^2 dx dy + \lambda_b \int_{\text{outside}(C)} |I - c_b|^2 dx dy \quad (4)$$

The advantages of MS simplified segmentation model with respect to the original level set segmentation method is: (1) no longer rely on the image gradient information, but take advantage of the full energy information; (2) no need to be too concerned about the initial curve position; (3) is not very sensitive to noise. Finally, to solve the segmentation model MS by level set methods: firstly, suppose the signed distance function based on the initial active contour line C_0 is ϕ , $\{C_0 \mid \phi_0(x, y) = 0\}$, and $\phi[\text{inside}(C)] > 0$, $\phi[\text{outside}(C)] < 0$, then we can get:

$$L(C) = \int_{\Omega} |\nabla H| dx dy = \int_{\Omega} \delta(\phi) |\phi| dx dy$$

$$S[\text{inside}(C)] = \int_{\Omega} H(\phi) dx dy \quad (5)$$

Formulating (5) into (4), we can be pushed out:

$$F(C, c_0, c_b) = \mu \int_{\Omega} \delta(\phi) |\nabla \phi| dx dy + v \int_{\Omega} H(\phi) dx dy + \lambda_0 \int_{\text{inside}(C)} |I - c_0|^2 dx dy + \lambda_b \int_{\text{outside}(C)} |I - c_b|^2 dx dy \quad (6)$$

Euler - Lagrangian method for solving equation (6) can be obtained:

$$\begin{cases} C_0(\phi) = \frac{\int_{\Omega} I(x, y) H_{\varepsilon}(\phi) dx dy}{\int_{\Omega} H_{\varepsilon}(\phi) dx dy} \\ C_b(\phi) = \frac{\int_{\Omega} I(x, y) [1 - H_{\varepsilon}(\phi)] dx dy}{\int_{\Omega} [1 - H_{\varepsilon}(\phi)] dx dy} \\ \frac{\partial \phi}{\partial t} = \delta_{\varepsilon}(\phi) \left[\mu \frac{\nabla \phi}{|\nabla \phi|} - v - \lambda_0 [I(x, y) - c_0]^2 + \lambda_b [I(x, y) - c_b]^2 \right] \\ \phi(0, x, y) = \phi_0(x, y) \end{cases} \quad (7)$$

Take the approximation of the Heaviside function:

$$H_{\varepsilon}(z) = \frac{1}{2} \left[1 + \frac{2}{\pi} \arctan\left(\frac{z}{\varepsilon}\right) \right], \quad (8)$$

$$\delta_{\varepsilon}(z) = \frac{1}{\pi} \frac{\varepsilon}{\varepsilon^2 + z^2}$$

By numerically solving equation (7), you can calculate the value of each point in the images, updating the level set. Finally evolve the curve to the edge of the object so as to achieve segmentation purposes.

3.3. C-V Simplified Segmentation Methods Used in the Detection of the Terminal Image

As can be seen from the above analysis: C-V method is affected by noise relatively small [9, 10], is less influenced by initial position and relationship of the shape, and it can get better results without manual intervention, it also can get better effect in the noise image and a discontinuous border, as well as a weak image edge. Its ideas and steps are as follows: (1) According to image position, Gray level and gradient information to judge the approximate location of the edge, and then detect the image filtering and its edge. (2) During the process of image filtering, according to pixel distribution, using the weighted average method of the gray level to eliminate the noise [11]. (3) In the edge detection, use active contour model to extract the object boundary. its mainly idea to use curve evolution to find object boundary.

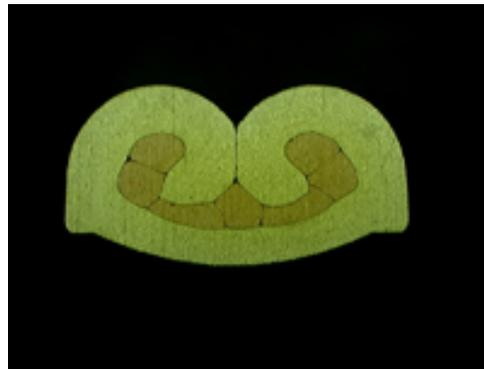
The following Figs. (4, 5 and 6) are the experimental results for the above method in MATLAB. There are three sub-figures in Fig. (4, 5 and 6). (a) is the original image through a microscope images plus camera to capture; (b) using the above method automatically identify is the line core of the internal contour; (c) is the terminal external contour which is identified automatically. According to the result of the analysis, use the technology of the partial differential equations to achieve the satisfactory results in the automatic identification of inside and outside contours of the wiring harness terminal.

4. THE REALIZATION OF THE SYSTEM

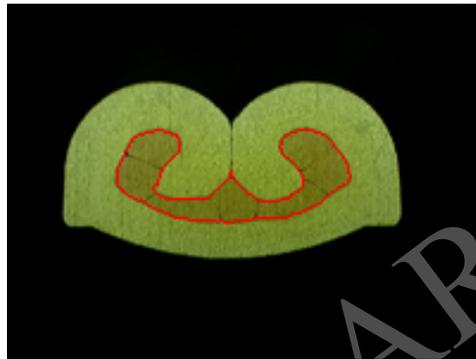
On the basis of the above research, with based on .Net development platform, we use C# and OpenGL as the main development tool, in the windows platform system has developed the system of wiring harness terminal section measurement and analysis which based on partial differential equation. System development reference to the national standard and German standard of harness the quality detection, custom a kind of report template of wire harness quality detection, and then realize the automatic measurement of terminal contour, analysis and automatic output report of quality testing. Fig. (7) is the main interface of the terminal section measurement and analysis system.

CONCLUSION

Quality detection of crimping quality automotive wiring harness terminals is one of the key factors which are to ensure the vehicle safety, reliability and improve vehicle quality. The research which base on partial differential equations of simplified C-V method has realized automatic recognition of the terminal section of inner and outer contour, and automatic calculation of height, width, core number and cross section area or perimeter parameters. Compared parameters which is measured and standard, and then judge the terminal



(a)



(b)



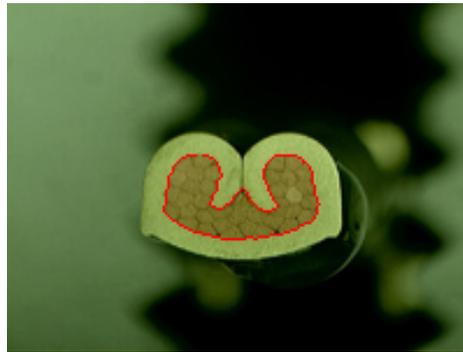
(c)

Fig. (4). In the case of idea contrast.



(a)

Fig. (5). Contd...



(b)

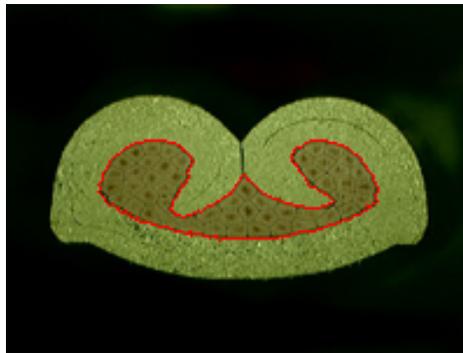


(c)

Fig. (5). In the case of fuzzy boundaries.

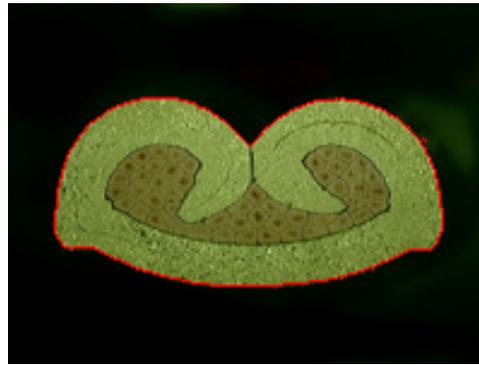


(a)



(b)

Fig. (6). Contd...



(c)

Fig. (6). Terminal image contour by interference.

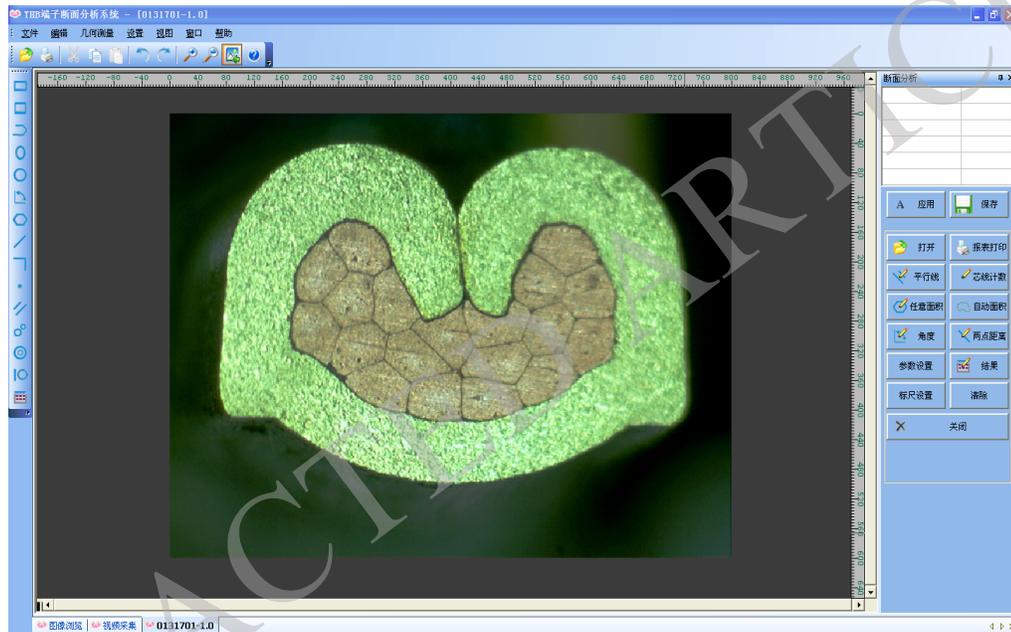


Fig. (7). The main interface of system.

crimping quality is eligible, and automatically output the test result. the system meets the needs of terminal crimping quality detection in manufacturing industry of wiring harness , it can greatly reduce the labor intensity of the testing personnel, improve work efficiency, and ensure the quality of products.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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