Research on Visual Inspection System of Waterproof Breathable Membrane Based on HALCON

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Abstract. Aiming at the needs for high-efficiency, high-precision and stable detection of waterproof and breathable membranes, a waterproof and breathable membrane quality detection system with burrs, filaments, spots and uniformity as the detection indicators has been designed based on HALCON. The upper computer system is developed based on C# and the lower computer is developed based on PLC. The upper computer system analyzes and processes the images collected by the industrial camera, which is the core of the entire detection system. The lower computer communicates with the upper computer through industrial Ethernet, and sends motion instructions to the servo system through the Ethernet bus. Tests show that the system can perform high-efficiency, high-precision and stable detection of the quality of waterproof and breathable membranes.

1. Introduction

With the development of machine vision technology, more and more measurement and inspection schemes choose machine vision technology. In those environments that are not suitable for human work, machine vision has gradually replaced human vision. In addition, in mass production, the non-contact measurement method of machine vision is an excellent solution both in reliability and stability.

Waterproof and breathable membranes are widely used in waterproof solutions for electronic products such as mobile phones and tablets due to their good waterproofness and breathability. The market demand and the demand for electronic products have increased simultaneously. In the production process of waterproof breathable membranes, there are three major failures: oversize, oversize foreign objects, and over level uniformity. The traditional detection scheme is mainly manual spot inspection. The workers place the waterproof breathable membrane under an optical magnifier for visual inspection. The accuracy and precision cannot be guaranteed. Especially under the demand of high-intensity detection, the traditional detection scheme cannot meet the demand. Aiming at the problem of traditional solutions in the detection of waterproof and breathable membranes, machine vision was selected here as the detection scheme of waterproof and breathable membranes to solve the problems of low manual efficiency, low accuracy, and poor accuracy, while taking into account the functions of data analysis and processing.

In this article, HALCON is used as the image processing library, Visual Studio is used as the development platform, C# is used as the programming language. The quality inspection of waterproof and breathable membrane is realized by HALCON, C#, industrial area scan cameras, PLCs, industrial Ethernet, servo motors, profinet communication protocols, GigE Vision protocol, etc.
2. Construction of Vision System
The design is a typical distributed control system, which consists of upper computer, lower computer, actuator, detection device and so on. The lower computer system uses Siemens S1200PLC as the core controller, and is connected to the upper computer through industrial Ethernet. After power-on, the program is downloaded through Ethernet. After the system is running, the PLC externally triggers the industrial camera through the relay. The upper computer receives the image information of the industrial camera and performs image processing. The PLC sends motion instructions to the servo driver V90 through industrial Ethernet, and changes the product through the movement of the X and Y axes. The position enables each product to be detected, and at the same time, the servo driver sends the data read from the incremental encoder to the PLC, and finally the PLC sends it to the host computer. The structural diagram of the vision system is shown in Figure 1, the waterproof and breathable membrane is shown in Figure 2, and the white round hole surrounded by the black frame is the part to be detected.

3. Control Principle of System
The PLC triggers the industrial camera to take pictures through the rising edge signal. The industrial camera sends the graphic information to the upper computer through industrial Ethernet. The upper computer performs image processing by calling the assembly named halcondotnet. After the image processing is completed, the upper computer communicates with the PLC via the Sharp7 Data interaction, sending motion instructions to the PLC, the PLC will analyze the instructions of the upper computer to control the servo system action via Ethernet, the control principle can be simplified as shown in Figure 3.
4. Design of Detection Algorithm
The foreign body detection in this system consists of four parts: burr detection, speckle detection, filament detection, and uniformity detection. The detection flow chart of the system is shown in Figure 4, where product positioning is achieved through template matching.

4.1 Detection of burr
The burr is a thorny object at the edge of the white film, which can be extracted by threshold segmentation and feature extraction of the edge portion.

4.2 Detection of speckle
The spots are divided into two parts, dark spots and bright spots. The grayscale value at the dark spots is small and the grayscale value at the bright spots is large. After detection, it is found that the grayscale characteristics of the dark spots satisfy equation (1), and the grayscale characteristics of the bright spots satisfy equation (2).

\[
\text{grayOrigin} \leq \text{grayMean} - \text{offsetNegative} \quad (1)
\]

\[
\text{grayOrigin} \leq \text{grayMean} + \text{offsetPositive} \quad (2)
\]

In the equation: \( \text{gray Origin} \) is the original grayscale value of the spot position, \( \text{grayMean} \) is the grayscale value after the average of the spot position is filtered, \( \text{offset Negative} \) is the defined grayscale value of the dark spot, and \( \text{offset Positive} \) is the grayscale defined value of the bright spot.

4.3 Detection of filament
The wool is a filamentous foreign substance on the surface of the white film, and its grayscale characteristics are not obvious. The main detection is divided into two parts, the first part is the
frequency domain bandpass filter filtering, and the second part is the spatial domain feature extraction. The processing results are shown in Figures 5, 6, and 7.

Figure 5 Original image  Figure 6 Filtered image  Figure 7 Result image

4.4 Detection of uniformity
This detection is to detect the uniformity of the white film, and the uniformity discriminant $J_c (k)$ is obtained by improving Otsu, as shown in Equation 3-3. The maximum value of $J_c (k)$ is the uniformity index.

$$J_c (k) = \left( \frac{P_2 (k)}{P_1 (k)} \right)^{0.5} \cdot \frac{\sum_{(r,c)\in\alpha} \left[ (f(r,c) - m)^2 + (g(r,c) - m)^2 \right]}{\sum_{(r,c)\in\alpha} \left[ (f(r,c) - m)^2 + (g(r,c) - m)^2 \right]}$$

Where $P_2 (k)$ is the probability that the grayscale value is less than $k$, $P_1 (k)$ is the probability that the grayscale value is greater than or equal to $k$, $o$ is the pixel whose grayscale value is greater than $k$, and $f (r, c)$ is The grayscale value of the pixel $(r, c)$, $m$ is the average grayscale value, and $g (r, c)$ is the average grayscale value in the pixel $(r, c)$ area.

Since the area of the white film is small, the equation (4) can be obtained.

$$f(r,c) \approx g(r,c) \quad (4)$$

Substituting Equation (3) into Equation (4) gives Equation (5).

$$J_c (k) = \left( \frac{P_2 (k)}{P_1 (k)} \right)^{0.5} \cdot \frac{\sum_{(r,c)\in\alpha} (f(r,c) - m)^2}{\sum_{(r,c)\in\alpha} (f(r,c) - m)^2}$$

After analysis, we can get Equation (6), Equation (7) and Equation (8).

$$\frac{P_2 (k)}{P_1 (k)} = \frac{\text{area}_2}{\text{area}_1} \quad (6)$$

$$\sum_{(r,c)\in\alpha} (f(r,c) - m)^2 = \text{area}_1 \cdot \delta_1^2 \quad (7)$$

$$\sum_{(r,c)\in\alpha} (f(r,c) - m)^2 = \text{area}_2 \cdot \delta_2^2 \quad (8)$$

Where $\text{area}_2$ is the total area of pixels with grayscale value less than $k$, $\text{area}_1$ is the total area of pixels with grayscale value greater than or equal to $k$, $\delta_1^2$ is the variance of pixels with grayscale value less than $k$, and $\delta_2^2$ is the variance of pixels with grayscale value greater than or equal to $k$.

Substituting Equation (6), (7), (8) into Equation (5) gives Equation (9).

$$J_c (k) = \left( \frac{\text{area}_2}{\text{area}_1} \right)^{0.5} \cdot \frac{\text{area}_1 \cdot \delta_1^2}{\text{area}_2 \cdot \delta_2^2}$$

(9)
5. Design of Software

5.1 Configuration of host computer program
The upper computer has been developed with Visual Studio 2019 as a development platform. When the program is running, the upper computer executes the image processing algorithm and sends motion instructions to the PLC according to the processing results. The instructions are written to the DB data block of the PLC. The code looks like this:

```csharp
public S7Client s7Client = new S7Client();
byte[] dbBufferWrite = new byte[WriteSize];
intWriteSize = 22;
intDBNumberWrite = 2;
s7Client.ConnectTo("192.168.0.1", 0, 1);
s7Client.DBWrite(dbBufferWrite, WriteSize, DBNumberWrite);
```

5.2 Configuration of PLC program
The PLC uses Tia Portal V14 as the platform to develop the ladder diagram. The program is divided into two categories, one is the data interaction part and the other is the servo motion control part.

6. Analysis of operating results
287 products were selected for testing, and burrs, speckle, filaments, and uniformity were used as the evaluation indicators of eligibility. The test results are shown in Table 1. After analysing the testing results, it was found that the false detection was mainly caused by spot and filament. By analysing the program configuration parameters, it was found that the false detection rate can be decreased by adjusting some parameters of program.

| Detection Items   | Sample Size | False Number | False Detection Rate |
|-------------------|-------------|--------------|----------------------|
| Burr              | 287         | 0            | 0                    |
| Speckle&Filament  | 287         | 4            | 1.39%                |
| Uniformity        | 287         | 0            | 0                    |
| Summary           | 287         | 4            | 1.39%                |

7. Conclusion
For waterproof breathable membranes, the traditional manual sampling inspection scheme not only has the disadvantages of low efficiency, high cost, and low accuracy, but also the test results of this scheme cannot guarantee the pass rate of the entire product. The author of this article has designed a waterproof breathable film detection system based on HALCON, which uses machine vision instead of human eyes to carry out a full inspection of the size and foreign objects of the waterproof breathable film to greatly improve the detection efficiency and the reliability of the detection results. This system provides a brand-new, efficient and reliable automatic detection scheme for the detection of high-precision membrane materials represented by waterproof and breathable membranes.

References
[1] Liao P S, Chen T S, et al. A fast algorithm for multilevel thresholding[J]. Journal of Information Science and Engineering, 2001, 170(5): 713-727.
[2] Villacorte M, Suzuki K, et al. Visual detection of air-to-air refueling drogue[C]. 2015 International Conference on Unmanned Aircraft Systems, ICUAS 2015 2015:416-425.
[3] Frosinuk A, Kolchanov D S, et al. Optical Interference-Based Sensors for Visual Detection of Nano-Scale Objects[J]. Nanoscale, 2019,11(13):6343-6351.
[4] Singh W P, Singh R S. Gelation-based visual detection of analytes[J]. Soft Materials, 2019, 17(1):93-118.
[5] Ma Li-Hong, Wang Hai-Bo, et al. Visual detection of trace lead ion based on aptamer and silver
staining nano-metal composite[J]. Colloids and Surfaces B: Biointerfaces, 2018, 162: 415-419.