Research on Intelligent Recognition and Control Device of Aviation Line Number

Changfu Zhao\textsuperscript{1,a}, Guohua Cao\textsuperscript{1,2,b*}, Hongchang Ding\textsuperscript{1,2,c}, Ying Zhang\textsuperscript{1,d}, Han Hou\textsuperscript{1,e}

\textsuperscript{1}Mechanical Engineering, Changchun University of Science and Technology, Changchun, Jilin, China
\textsuperscript{2}Changchun University of Science and Technology Chongqing Research Institute, Chongqing, China
\textsuperscript{a}email: fuchangzhaocust@163.com, \textsuperscript{b}email: caogh@cust.edu.cn,
\textsuperscript{c}email: dinghc@cust.edu.cn,
\textsuperscript{d}email: 226490119@qq.com, \textsuperscript{e}email: 345094896@qq.com

\*

Abstract. In order to solve the problems such as low sorting efficiency, high error rate and inability to match the corresponding installation position on aviation wiring, we propose a machine vision line number recognition method, which is based on the threshold segmentation algorithm of gradation histogram to identify the line number and index the recognized results. The wire harness recognition system mainly includes three parts: wire number positioning, wire number character segmentation and character recognition. Experimental results show that the online detection speed of the vision system is 30m/min, the accuracy rate is higher than 98% and the average time is 0.04s. By matching the recognition results, index to the position where the wiring harness is to be installed to meet the requirements of aviation wiring.

1. Introduction

Machine vision is to realize the visual function of human beings, realize measurement and make judgments by machines instead of eyes\textsuperscript{[1]}. As a non-contact measurement method, machine vision measurement does not affect the motion characteristics of institutions and objects. Therefore, this technology is widely used in various fields, including semiconductor manufacturing, aviation/satellite image analysis, forensic science fingerprint recognition, security/monitoring, road traffic control and scientific research, physics, biology, astronomy, materials engineering\textsuperscript{[2]}.

Harness identification is an essential part of industrial production. Harness identification used to be manual inspection and classification. Relying on workers’ naked eyes to inspect the strings on the harness one by one to determine the application of the harness is labor-intensive and low-efficiency, which cannot fundamentally guarantee the quality of the inspection. Once the number of wire harness is misread by human eyes and applied to production, serious accidents will occur. As a non-destructive method, machine vision is used to identify the wire harness, which has the characteristics of accuracy, reliability and high efficiency. With the development of machine vision, this method can be used to achieve continuous and rapid non-destructive testing of harness characters, and due to the rapid development of machine vision, image processing, pattern recognition, and artificial intelligence, accurate detection using this method has become It is possible, but due to the impact of the site environment, the diameter of the wire harness, and the unfixed character size, it brings certain difficulties
to the positioning of the wire harness. At the same time, the pollution and defects of the wire harness itself will affect the character recognition rate. Therefore, the harness recognition system should have high adaptability and robustness, and can still correctly recognize characters with certain noise and distortion.

2. Full view mirror

Instead of the three cameras in the industry for full-view image acquisition, it is difficult to obtain synchronization, image fusion algorithms are complicated, and real-time performance is poor. Innovatively propose a full-view mirror, and determine the appropriate angle based on the refraction and reflection modeling analysis of light. As shown in Figure 1.

![Figure 1. Schematic diagram of the whole view mirror principle.](image)

2.1. Angular modeling of lenses

The principle of establishing the angle of the lens: modeling is based on geometric optics. It can be seen from the reflection theorem that an object formed by reflection can be equivalently regarded as a virtual image of the object directly imaging in the lens. Since the line diameter is small compared to the objective lens distance and lens size, and the image-to-lens distance is small compared to the image-to-optical axis distance, coaxial optics is used as the basic theory. The boundary conditions are established. The light passing through the first main focus of the lens on the virtual image is very close to the light directly passing through the optical center, so that the right tangent of the virtual image can be approximated as the right boundary of the imaging optical path. Similarly, the left side can be considered in the same way. But it is possible that the light reaching the lens is out of bounds when considering the boundary conditions.

2.2. The constraint A

Ensure that at least one of the five images looks like a cable number, and that each one is complete. The following constraints are given. \( \theta_1 \): The first mirror and the perpendicular line of the axis of light lie in an Angle. \( \theta_2 \): the second mirror and the first one are in an Angle. \( \alpha_1 \): (first mirror) the Angle between the output ray of an object and its imaginary image. \( \alpha_2 \): same as the previous definition for the second mirror. \( \theta_0 \): the Angle of the middle line number in the section of the line.

\[
\begin{align*}
(\theta_1 + \theta_2) &< \theta_0 + 5 \times \pi/180 \\ 
\alpha_1 &> (\pi - \theta_1 - \theta_0/2 - 5 \times \pi/180) \\ 
\alpha_2 &< (10 \times \pi/180 - (\theta_1 + \theta_2) + \theta_0) \\ 
(\theta_2 + \alpha_2 + \alpha_1) &< \theta_0 \\ 
\theta_0 &= \frac{l}{r}
\end{align*}
\]

Where \( l \) is the arc length occupied by the character on the cylinder, \( r \) is the wire diameter

2.3. The constraint B

the object's imaginary image is only at the end of the mirror and within the mirror.

\[
\begin{align*}
(A_1x_1 + B_1y_1 + C_1) \times (A_1x_2 + B_1y_2 + C_2) &< 0 \\
(A_2x_1 + B_2y_1 + C_2) \times (A_2x_2 + B_2y_2 + C_2) &< 0
\end{align*}
\]
\[(A_3x_2 + B_3y_2 + C_3) * (A_3x_2 + B_3y_2 + C_3) < 0 \] \[(8)\]

\[(A_4x_2 + B_4y_2 + C_4) * (A_4x_2 + B_4y_2 + C_4) < 0 \] \[(9)\]

Where \(A_x + By + C_1\) is the equation of the boundary of the optical path of the virtual image. \(Ax + By + C_1\) are the endpoint coordinates of the mirror. And for the two mirrors on the left of the optical axis, the same is true on the right.

2.4. The constraint C

Ensure that the boundary of the exit path of the object's virtual image does not intersect with the object.

\[|A_2x_0 + By_0 + C_2| < r\] \[(10)\]

\[\sqrt{A_2^2 + B_2^2 + C_2^2}\]

\[|A_4x_0 + By_0 + C_4| < r\] \[(11)\]

Where \(Ax + By + C_1\) is the central coordinate of the object, and \(r\) is the radius.

2.5. The constraint D

Try to keep the five images on the same plane. And make the objective lens as short as possible to reduce the depth of field.

\[h_1 = \frac{f_1 * y_{0_1}}{y_{0_1} - f_1}\] \[(12)\]

\[h_2 = \frac{f_2 * y_{0_2}}{y_{0_2} - f_1}\] \[(13)\]

\[h_3 = \frac{f_3 * y_{0_3}}{f - y_{0_3}}\] \[(14)\]

\[h_2 = \frac{y_{0_2} * (y_{0_1} - f_1)}{y_{0_1} * (y_{0_2} - f_1)}\] \[(15)\]

\[h_2 = \frac{y_{0_3} * f_1}{y_{0_3} * (f - y_{0_3})}\] \[(16)\]

Note: \(\frac{h_1}{h_3}\) In the same way. Where \(y_{0_1}, y_{0_2}, y_{0_3}\) are the center coordinates of the imaginary image on the left of the optical axis respectively. \(h_1, h_2, h_3\) is the distance between the center of the circle through the lens and the line perpendicular to the optical axis. \(f_1, f\) is the first main focal length and focal length of the lens respectively. From the above two equations, it can be seen that when \(y_{0_1}, y_{0_2}\) increases, the above two equations tend to be one, that is the five image positions tend to be straight. So the objective lens is as far apart as possible.

3. Image Acquisition And Preprocessing

The image acquisition part is generally composed of light source, lens, digital camera and image acquisition card. At present, CCD cameras are widely used in machine vision systems due to their small size, reliable performance, and high definition[3-5]. In machine vision lighting application systems, two illumination methods are generally used: transmitted light and reflected light. The reflected light should fully consider the relative position of the light source and the optical lens, the texture of the surface of the object, the geometric shape of the object, and the background. The selection of the light source must conform to the required geometry, lighting brightness, uniformity, and spectral characteristics of the light. At the same time, the luminous efficiency and service life of the light source must be considered. Because the LED light source has good color rendering, wide spectral range, and energy covers the entire range of visible light, with high luminous intensity and long stabilization time. Therefore, the light source in this paper is an LED semi-transmissive light source, placed in front of the lens, and a black screen is used as the camera background.

For the image acquired by machine vision, the target is preprocessed by gray-scale correction and noise filtering, so that the useful information in the image target can be extracted more easily[6]. In the process of image acquisition and transmission, due to various reasons, it is inevitably affected by noise.
In order to accurately extract the characters on the image, the image should be denoised. The removal of noise largely depends on the type of noise. Common noises are divided into additive noise, quantization noise, and salt and pepper noise. Common image denoising methods are divided into two categories, namely spatial domain method and frequency domain method. This article uses spatial domain mean filtering to remove noise in the image and lay a good foundation for subsequent edge extraction.

Set a graphic $f(x, y)$ as the matrix of $N*N$, after processing of graphics for $g(x, y)$, through the establishment of a suitable template for convolution operation, so as to achieve the aim of image smooth, median filter in the specific calculation formula is as follows:

$$g(x, y) = \frac{1}{M} \sum_{(i, j) \in S} f(i, j)$$  \hspace{1cm} (17)

Where $x, y = 0,1,2...N -1$, $S$ is the set of neighborhood centered at the point $(x, y)$; $M$ is the total number of coordinate points in the neighborhood $S$, that is the total number of pixel points. $f(i, j)$ is the grayscale value at the position $(i, j)$ in the neighborhood $S$.

4. Image Segmentation

Image segmentation is an important issue to realize automatic recognition and analysis of machine vision images, and its segmentation quality has an important impact on subsequent image analysis\[7-8\]. Fast and accurate segmentation of feature targets from complex images has always been the research focus of scholars at home and abroad. Image segmentation can use three ways, namely, region segmentation, boundary segmentation and boundary formation segmentation. There are many methods of image segmentation. The image segmentation method used in this article is threshold segmentation. Threshold segmentation is a relatively primitive, simple, but very common image segmentation technique.

When the image is composed of different parts, usually the image shows different peaks in the gray histogram, and we select the area we need from them, as shown in Figure 2.

![Figure 2. Gray histogram.](image)

In order to detect the edge of the image object, the histogram was divided into two parts by threshold $T$, and then the following operations were performed on image $f(i, j)$\[9-11\] :

1. scan every line of the image $f(i, j)$, and $g1(i, j)$ is obtained by comparing the grayscale of each pixel point in the scanned row with that of $T$.
2. scan each column of image $f(i, j)$ again, and $g2(i, j)$ is obtained after comparing the grayscale of each pixel point in the scanned column with $T$.
3. combine $g1(i, j)$ with $g2(i, j)$, that is, get the boundary image $g(I, j)$ of the object.

$$g(i, j) = \begin{cases} f(i, j) > T \\ 0 \text{ if } f(i, j) < T \end{cases}$$  \hspace{1cm} (18)

The obtained boundary image $g(i, j)$ is divided into target area (black) and background area (white), as shown in Figure 3.

![Figure 3. Threshold segmentation diagram.](image)

In this way, a grayscale image is turned into a binary image, the area where the cable is located is
determined, and then character extraction and character recognition are performed on the image.

5. Image Recognition

The image segmented by threshold value requires that the original character can be reproduced exactly. (1) there is no white space in the characters. (2) the characters after segmentation keep the characteristics of the original characters basically.[12-15]

After threshold segmentation, the character image is a whole, including the space between characters and characters. Therefore, to identify a single character, the first step is to separate a single character from the whole, and through the analysis of the connected domain, the segmentation between characters can be achieved. Will get the characters of morphology segmentation after corrosion expansion after first operation, dilation is all vector plus and collection of vector addition of two operands from X and B respectively, and take to any possible combinations.

\[ X \smallcirc B = \{ p \in \epsilon^2 : p = x + b, x \in X \text{ and } b \in B \} \]  

Erosion is a vector subtraction of the set elements to merge the two sets.

\[ X \smallcirc - B = \{ p \in \epsilon^2 : x + b \in X, \forall b \in B \} \]

The closed operation is:

\[ X \cdot B = (X \smallcirc B) \smallcirc - B \]

Get the character area shown in figure 4.

Figure 4. Character area diagram.

The purpose of character recognition is achieved through character comparison between the segmented characters and the classifiers learned and trained from a large number of images.

6. Experiment And Analysis

In order to complete the on-line detection of wire bundles, the detection experiment is designed according to the principle and method described above. The identification system includes an industrial CCD camera, a light source, a wire beam clamp, a full-angle reflector, a wire beam, a lifting platform and an optical platform. The experimental device is shown in figure 5.

Figure 5. Schematic diagram of the experimental device.

Design and selection of the line beam recognition device: the center of the camera, lens, light source and total reflector is located on the same line to form a coaxial optical system. Because the full-view mirror and cable are black and white, the working wavelength of the system can be defined as visible light region, so the camera can choose black and white camera. Since the cross-section of the total reflector is a 92*40mm rectangular surface, and the target surface of the sensor is usually a 4:3 rectangle,
the short edge length of the target surface should be taken as reference in order to absorb all the objects into the target surface. Due to restrictions on the size of factory environment as well as to the unit, a single camera view all line number identification equipment should be miniaturization, as far as possible on the premise of guarantee the camera function, choose the small size, reliable performance, high resolution it company mercury MER-1070-10GM subminiature industrial camera, target surface size of 1/2.3 of an inch, and a resolution of 3843*2748, pixel size 1.67um×1.67 um, \( \beta = \frac{4.62}{92} = 0.05 \), distinguish the scenery accuracy is: Pixel size/magnification ratio \( = \frac{0.00167}{0.05} = 0.033 \text{mm} \), so the resolution of the existing system can reach 0.03mm.

Due to the total reflection mirror is 277 mm, the distance to the lens to the focal length of the object lens for \( f' = \frac{1}{1+\frac{1}{\beta}} = \frac{277/(1+\frac{1}{0.05})}{13.2 \text{ mm}} \), the system as the resolution is greater than 1/(2*0.1*0.05)=100 (lp/mm), so choose Computar M3Z1228C-MP lens, the target surface size for: 2/3 inch, 12-36 mm focal length, aperture range F2.8-F16C.

Analysis of the existing way of lighting, as well as the demand for light source selection, in meet the geometry shape, lighting brightness, uniformity, light spectrum characteristics and luminous efficiency and service life conditions, such as using forward coaxial illumination will be directly in front of the light source for the lens, choose d depending on the AFT-RC series coaxial light source lighting (white light) system, its appearance size is 95*70*70.

In the control of total reflection mirror, reoccupy hand three-dimensional console (X axis and Z axis translational and angular displacement), select Zolix company NFP-1462 translation units (travel 25 mm, sensitivity<0.001 mm) and KSMG10 swing-65 angular displacement (travel+10 mm Swing<40 um), the rotation can be achieved with the manual of 3d console for each position control of the whole Angle of mirror.

Line number identification equipment structure design, install the camera in optical recognition, install the base coaxial light illumination way, black baffle as background of cable, according to the size of the object distance, the cable to the distance of the object lens, then the cable on the total reflection mirror imaging, as well as the distance cable movable cables to the mirror in the view of the whole distance, through the three dimensional position and posture of the turntable adjust the Angle of the reflector, the camera can get clear image of cable, the specific device is shown in figure 6.Open the light source, adjust the appropriate focal length, run the program, identify the characters on the wire harness online, and write all the characters read to the file.

![Figure 6. Assembly drawing.](image_url)
programming language is Halcon language combined with C# programming environment. The detection result accuracy rate is >98%, the detection speed is 30m/min, and the average time is 0.04s. By indexing the detection results, the location where the wiring harness needs to be installed is found to meet the wiring requirements of large aircraft.

7. Conclusion
Through the above analysis, based on theoretical research, our team has developed a set of line number intelligent identification and matching device. This device satisfies the real-time requirements of aviation automatic wiring and has been put into production. When the device encounters line number defect, CCD camera noise interference, light source instability, wiring harness jitter, etc, it will have a certain impact on the recognition result. Therefore, there are still many difficulties in the research of aviation line number intelligent identification control device.

Acknowledgments
The author is grateful to the national key research and development plan (development of major scientific instruments and equipment) for financial support during the course of this research.

References
[1] S Guo, J Zhang, X Jiang, Y Peng, L WangMini Milling Cutter Measurement Based on Machine Vision Procedia Engineering,2011,15(1):1807-1811.
[2] YJ Shin, JB LeeMachine vision for digital microfluidics Review of Scientific Instruments,2010,81(1):014302.
[3] Xiang-Yang T, Yong Z, Jiang-You L I , et al. Present Situation and Applications of Machine Vision's Key Techniques[J]. Journal of Kunming University of ence & Technology, 2004.
[4] Lanterman A D, Miller M I , Snyder D L . Automatic Target Recognition via the Simulation of Infrared Scenes[J]. Proc of Annual Ground Target Modeling & Validation Conf, 1995:195-203.
[5] Marques, Oge. Image Processing Basics[J]. 2011, 10.1002/9781118093467:21-34.
[6] Li H, Doermann D , Kia O . Text Extraction, Enhancement and OCR in Digital Video[C]. Selected Papers from the Third IAPR Workshop on Document Analysis Systems: Theory and Practice. 1999.
[7] Masoud O, Panpanikolopoulos N.A novel method for tracking and counting pedestrians in real-time using as a single camera[J]. IEEE Transactions on Vehicular Technology,2001,50(5):1267 -1278.
[8] Huang S M, Lo H C, Wang P, Yuen K. A game theory based exit selection model for evacuation[J]. Fire Safety Jounal ,2006,41(13):364-369.
[9] Tian S, Jian-yi K, Xing-dong W, et al. Improved Sobel algorithm for defect detection of rail surfaces with enhanced efficiency and accuracy[J].Journal of Central South University,2016,11(23) :2867-2875.
[10] Zhang Q, Liu M, Wu C, et al. A stranded-crowd model(SCM)for performance-based design of stadium egress[J].BUILD ENVIRON,2007,42(7):2630-2636.
[11] Collins R T, Lipton A J, Kanade T. Introduction to the special section on video surveillance[J]. IEEE Transactions on Pattern Analysis & Machine Intelligence,2000,22(22):745-746.
[12] Henein C M, White T. Macroscopic effects of microscopic forces between agents in crowd models[J]. Physcial Statistical Mechanics & Its Applications,2007,36(347):144-148.
[13] Teknomo K. Microscopic Pedestrian Flow Characteristics: Development of an Image Processing Data Collection and Simulation Model[D].Tohoku University Japan,2002.
[14] Y.H. Liang, et al. A skew detecton method for 2D bar code images based on the least square method. Proceedings of the Fifth International Conference on Machine Learning and Cybernetics,2006:13-16.
[15] N.M. Ralevic, S. Drazic, R. Obradovic. The Hough Transformation of Rectangle.6th International Symposium on Intelligent Systems and Informatics, 2008:1-4.