Fast-axis collimating lens recognition algorithm based on machine vision

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Abstract: In order to solve the problem of low efficiency and low accuracy of manually picked fast shaft collimation lens in actual production, the method of recognition of fast shaft collimation lens based on machine vision is studied. Using industrial camera to achieve image acquisition, using HALCON software to pre-process the image of fast-axis collimated lens, edge detection and other aspects of research, through the platform verification, the results show that the processed image is clear and easy to identify. In the lens placement is not accurate, the background is dirty can still ensure a better positioning effect, This study has some reference significance for visual recognition in the actual production of fast-axis collimation lens.

1. introduction
Fast-axis collimated lens (FAC) is a compact, high-performance aspheric cylindrical lens. The fast-axis collimating lens used in this article is applied to the beam shaping of high-power semiconductor fiber lasers. The correct placement of its position will determine the transmit power of the fiber laser. FAC is mostly mass-produced, and the FAC is placed in a 10×8 array in the box when it leaves the factory, and is positioned by the adhesive film. In the actual production of the laser, due to the deviation of the FAC factory placement position, the lens itself is not easy to identify and other issues, it is often used to manually pick and place the FAC into a specific fixture before proceeding to the next step.

Machine vision is a comprehensive subject in multiple fields. First, a computer is used to obtain image information using an optical system, processed, and then the obtained data is applied to system control. In recent years, with the continuous development of image processing technology, the application of machine vision in actual production has also expanded from the original electronic semiconductor industry to other industries[1]. Foreign inspection systems based on machine vision have played an important role in optical device production and mechanical processing. Machine vision technology has good flexibility, high degree of automation and no contact. It is suitable for the positioning and recognition of precision lenses. Compared with artificial vision, machine vision has the advantages of no fatigue, high efficiency and strong adaptability to the working environment. Applying the machine vision system to the recognition and positioning of FAC can greatly improve the production efficiency, and it also has higher accuracy and stability. Taking a certain model of FAC as the research object, the paper proposes a machine vision-based FAC recognition method, and designs an image processing program based on HALCON, and finally completes the verification through experiments.
2. Image processing algorithm

2.1 Image Acquisition

The illuminating light source used in this article is a point light source. The illuminating beam can be approximated as a parallel light. The light path is shown in the figure. The spherical part on the left (red in the figure) and the rounded part on the right (blue in the figure) are refracted by the lens. After reflecting with the material box at the bottom of the lens, not all return to the camera, so two dark stripes appear in the field of view. The middle plane part (green in the picture) does not refract, so most of the light returns to the camera, and the field of view shows almost Transparent. This paper designs a method for identifying the FAC lens: extracting two dark stripes dividing a single FAC lens, connecting the two stripes to form a rectangle, and completing the identification of the target lens by measuring the relevant data of the rectangle.

2.2 Image Processing

This article uses an industrial black-and-white camera and does not need to perform grayscale processing on the camera, so this article mainly studies image filtering, image segmentation and feature extraction. Image filtering is to suppress the noise of the target image while preserving the details of the original image as much as possible, so that the image can be clearer, and subsequent analysis of the image can be performed efficiently and reliably. Therefore, it is an indispensable operation in image preprocessing. This paper mainly studies the three algorithms of median filter, mean filter and Gaussian filter, and selects the most suitable algorithm through experimental analysis[2].

Mean filtering is a typical linear filtering algorithm, which replaces the pixel value of the target pixel with the average value of the pixel in a certain area S. The size and shape of the field depends on the nature of the processed image. For the area with a size of 5×5 and the center of the target pixel, the operation expression is:

$$G(x, y) = \frac{1}{25} \sum_{s=-2}^{2} \sum_{t=-2}^{2} f(x+s, y+t)$$

Gaussian filtering is essentially a signal filter, and its principle is similar to that of mean filtering. Its template coefficients obey Gaussian distribution. By increasing the gray weight of the center point, the blur problem in filtering can be reduced. The two-dimensional Gaussian distribution is as follows:
Median filtering is a non-linear signal processing technology based on the sorting theory, which can remove noise more effectively without changing the topological structure of the image while retaining the details of the image [6]. The working principle is to use a window to scan on the target image, arrange the pixels in the window image according to the gray scale size, and finally take the middle gray value to replace the center gray value of the window. The output formula is:

\[ G(x, y) = \text{Med} \{ f(x - a, y - b), (a, b) \in \Theta \} \]  

Among them, Med means to take the middle value of the target window, \( f(x,y) \) is the original image, \( G(x,y) \) is the processed image, which is the two-dimensional window template, usually a 3×3, 5×5 area is taken as a guarantee To effectively remove isolated noise points, this paper selects a 3×3 area.

\[ G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \]  

2.3 Image enhancement

Affected by internal and external factors such as light source and environment, the gray-scale contrast between the lens and the background is not enough, which will affect the subsequent image segmentation and edge detection [3]. Therefore, it is necessary to enhance the image and improve the contrast of the image. Gray transformation is an important means of image enhancement. Its principle is to transform the original image \( G(x,y) \) into a new image through a mapping function, namely:

\[ G(x, y) = T[G(x, y)] \]  

According to the different mapping functions, gray scale transformation can be divided into linear transformation and nonlinear transformation.

1. Linear transformation

Linear transformation changes the contrast of the image by adjusting the overall gray value distribution of the image, so it can effectively improve the problem of image underexposure or overexposure. The formula for linear transformation of gray value is as follows:

\[ G(x, y)' = \frac{d-c}{b-a} [G(x, y) - a] + c \]  

Is the current gray value, is the gray field, is the target gray field, is the output gray value. It can be seen from this formula that the linear change can increase the gray difference of the image, and the contrast between the dark part and the bright part can be more obvious from the image.

2. Nonlinear transformation

Non-linear transformations mainly include Gamma transformation, Log transformation and Pow transformation.

Gamma transformation is used for image correction to correct images with too high or too low gray levels to enhance contrast. Its expression is:

\[ G(x, y)' = [G(x, y) + \text{esp}]' \]  

\text{esp} is the compensation coefficient and is the Gamma coefficient. When =1, it is linear transformation; when >1, the contrast of the high gray area of the image is enhanced; when <1, the contrast of the bottom gray area of the image is enhanced.

Log transformation is logarithmic transformation, and its transformation principles are as follows:
Among them, B generally takes e, 2, 10, etc., and c is a constant of proportionality. The logarithmic transformation can highlight the darker details in the image and compress the image with high gray levels.

The pow transformation is the exponential transformation, which is used to correct bleached pictures or over-black pictures. The transformation principles are as follows:

\[ G(x, y)' = cG(x, y) \]  
(7)

It is the transformation coefficient. When it is >1, it performs gray-scale compression; when it is <1, it performs contrast enhancement.

Comparing the processed pictures, it can be seen that the Log transformation reduces the image contrast, which does not meet the requirements. The image is blurred after Pow transformation, which is not convenient for subsequent processing. Gamma transformation can only enhance the high grayscale area or the bottom grayscale area, and its applicability is not high. After the linear gray scale transformation, the image contrast is better, which is convenient for subsequent image processing, and the linear transformation can be applied to different environments by setting the parameters, and the robustness is good. Therefore, the linear enhancement algorithm is selected for image enhancement in this paper.

2.4 Image segmentation

Image segmentation is a key step from image processing to image analysis. The basic principle is to use certain characteristics of the image (such as gray level) to divide the image into specific areas with unique properties. The effect of image segmentation directly determines the results of machine vision. Commonly used image segmentation methods mainly include threshold segmentation, region segmentation and edge segmentation. Threshold segmentation has the advantages of simple calculation, higher computational efficiency, and fast speed. Therefore, the threshold segmentation method is selected for image segmentation in this article[4].

Because there are multiple lenses in the camera field of view, and only one lens can be picked up in actual production, it is easy to produce, and identify one lens at a time. After the positioning is successful, the next lens can be identified after the coupling is completed. Select the lens in the first row and the third column for processing, and use the built-in select_shape operator to perform the segmentation of area’, ‘row’, and ‘column’ in turn to obtain the image of the target lens.
After image segmentation, two shadow area images of the target lens are obtained. The union1 operator is used to turn the two areas into a connected domain, and the shape_trans operator is used to connect the area into a rectangle with angle characteristics. The operator area_center (RegionTrans, Area, Row, Column) get the area of the above rectangle and the coordinates of the center of the rectangle, and use the operator orientation_region (RegionTrans1, Phi) to get the inclination angle of the rectangle. This method can save tedious steps, shorten the calculation time, and is convenient and quick.

3. Instance verification
The object of the implementation example is a box of complete FAC, the maximum size of the material box is 51mm×51mm, the main hardware equipment of the experiment is: a USB3.0 interface CMOS industrial camera-MV-CE060-10UM, the resolution is 3072×2048, the maximum frame rate is 42.7 fps, the target surface size is 1/1.8", the pixel size is 2.4 µm×2.4 µm; a telecentric lens of MVL-HY-05-180C model with a magnification of 0.5 and a working distance of 180mm. A computer equipped with Windows system and HALCON software. The recognition effect of the target lens is as follows:

![Fig.6 Xld image of target lens](image)

| Area | Row    | Column | Phi   |
|------|--------|--------|-------|
| 4177 | 157.299| 485.955| 1.56815|

In order to test the recognition rate of the algorithm in this paper for FAC lens, 100 tests were carried out. The results show that the recognition rate of the algorithm in this paper reaches 96%, and the average recognition time is 0.52s. Compared with manual recognition, the cost is greatly reduced and the efficiency is significantly improved.

Analysis of the causes of the 4 unrecognized experimental results showed that the two were caused by the FAC lens placed in the opposite position at the factory, and the remaining 4 were caused by the interference of objective factors such as stains in the lens cartridge, so follow-up Research also needs to strengthen the robustness of the system.

4. conclusions
This article draws two conclusions:

(1) A fast-axis collimating lens recognition algorithm based on machine vision is proposed: After reading the picture with an industrial black-and-white camera, it is processed by the two image preprocessing algorithms of median filtering and linear gray transformation enhancement. The noise and dirt marks of the image are processed, and the image quality is improved; the two shadows formed by a single lens in the picture are recognized, and the two shadows formed by a single lens in the picture are connected to form a rectangle with angular characteristics, and the center position and tilt angle of the rectangle are obtained.
(2) The image processing method studied in the article can realize the accurate positioning of FAC lens and real-time data measurement, and provide technical support for the automatic pickup of FAC lens device, which greatly reduces actual production costs and improves efficiency.

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