A novel method for eliminating rotation deviation in sequential images mosaic

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Abstract: To eliminate rotation deviation of sequential images mosaic when measuring linear dimensions of large scale parts with computer vision, a novel algorithm based on the chain code searching method is proposed. After image preprocessing, including image filtering, image segmentation, and edge detection, the chain code length of the contour line can be searched out by the proposed method. Then, the angle from the contour line to the coordinate axis is computed with the length of the contour line. After that, the sequence is rotated in the opposite direction and the rotation deviation is eliminated. It is prepared for the next mosaic of sequences in eliminating shifting deviation. Experiments are carried out on parts with a linear profile rotating angle from 0° to 9°. The results show that compared with the commonly used Hough transform, the new method has higher precision and faster speed, which is important in realizing online high precision measurements of large scale parts with a linear profile.

Key words: sequential images mosaic; linear profile; chain code; rotation deviation

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Computer vision measurement technology has been extensively studied in industry, agriculture, medicine, and other areas[1-3]. In the industrial sector, the visual measurement technology for small scale parts[4] is relatively mature. However, the technology on large scale parts (i.e., more than 50 mm) is not perfect. Hung et al.[5] proposed a three-dimensional technique for a full-field surface measurement system. Liu et al.[6] proposed a large scale measurement system. Although, these systems can be used to measure large scale parts, they are quite complex and need identification marks, which makes them difficult to be applied to the practical automatic production line.

In order to realize automatic measurement with computer vision for large scale parts on a production line, an easy-to-operate measurement system is designed and a sequential images mosaic method is established. Therefore, the fast and precision mosaic of sequential images is the key of measurement. A novel algorithm for eliminating rotation deviation of sequential images of large parts with the linear profile is proposed.

1 Measurement System

The computer measurement system as shown in Fig. 1 has four major modules: lighting, image acquisition, image processing, and conveyor. The lighting module contains red LED, and it is controlled by four switches separately. The image acquisition module equips an industrial CMOS camera (type MV-D1024-28-CL-10). The camera uses a global shutter, and it is suitable for production lines almost without moving distortion and image hysteresis. The X64-CL iPro capture card that supports area scan, line scan, black and white camera (8 to 64 bit), and color camera (up to 36 bit RGB) is used as the image acquisition card. The image processing module includes computer hardware and software. The software is programed by Matlab. The conveyor used to simulate the industrial product line is a common belt. Parts for testing are a series of standard gauge blocks, which can be easily calibrated and tested. The system realizes the automatic acquisition of sequential images and outputs final measurement results (cuboid parts) after series processing.

Fig. 1 Computer measurement system

2 Measurement Process

To obtain high-precision measurements of large scale parts, a high-resolution camera should be used because the imaging area is inversely proportional to the resolution of detection. For large scale parts, a single image just expresses a small area. Therefore, sequential images seam-

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less mosaic is used to acquire panorama. The measurement system works as follows: First, sequential images are captured. To reduce distortion, the camera and the large scale parts are adjusted to make the linear profile in the center of the camera lens. The light and the camera focal length are adjusted to make the image clear and of moderate brightness. Then the image distance, the object distance, and the focal length are made the same. The camera is automatically calibrated by Matlab[7]. After that, the conveyor and the measurement program are started. The camera continuously shoots to capture image sequences when the part passes a set position. It will not stop until the end of the part comes out of the range of vision. There is some overlap between two adjacent sequences. Secondly, the computer calculates the image mosaic, including image filtering, image segmentation, edge detection, eliminating rotation deviation, and shifting deviation. Finally, according to calibration and calculation, it outputs measurement results automatically.

In the above process, seamless mosaic technology of sequences directly affects the speed and accuracy of the measurement. The mosaic is completed by sequences matching. The existing methods of image matching can be divided into two categories: One is based on image gray values, such as the cross-correlation method, the projection method, the phase correlation method based on the Fourier transform or the fast Fourier transform[8], and the mutual information matching method depending on statistics by measuring two random variables[9]. The other is based on image features, such as matching based on edge features, profile characteristics, regional structural features, and feature points. These theories and methods are chosen by the specific characteristics of images. However, none does very well by itself on both efficiency and accuracy.

3 Principle of the Proposed Method

On machine vision measurement technique of large scale parts with the fixed overlap, the longer the parts, the more the sequential images and the larger the computation of sequences matching. The matching method directly determines whether it can be used on a practical production line or not. During the measuring process, the zoom and other deviations of the sequential images are ignored, because the object distance and the focal length are fixed. Then the essence of the image mosaic is to eliminate the rotation deviation and shifting deviation of adjacent images. On the basis of the linear profile, this paper presents a high-speed and stable algorithm of eliminating rotation deviation. Fig. 2 shows a sequential image. The novel technology for eliminating rotation deviation is performed as follows. First, median filtering is used to eliminate salt and pepper noise and impulse noise. Consequently, more useful image edge and details are preserved. Secondly, images are segmented to separate the objective from the background. Half of the objective gray value plus half of the background is selected to be the threshold because the difference between the background and the foreground is significant. When the gray value is more than the threshold, it is assigned zero; otherwise, it is assigned 255. Then all the gray values of the image are converted to zero or 255, and the goal is extracted as shown in Fig. 3. Thirdly, the Robert operator with a good accuracy is used in image edge detection, and the linear profile is identified as shown in Fig. 4.

Fig. 2 An image of mechanical parts

Fig. 3 The foreground of the image

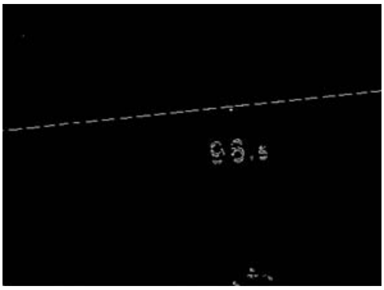

Fig. 4 The detected contour

After the contour line is detected, it is tested using the new method and the Hough transform, respectively. There are mainly two well-known algorithms. One is the Hough transform with large calculations. The other is the Freeman chain code with 8-connected paths tracking from one contour pixel to the next, which has less calculation than the Hough transform. Due to the detected linear profile of sequences, the chain code method only follows the track in one direction, which not only saves memory space but also greatly decreases the amount of computation. Fig. 5 shows the part of an ideal line rotating angle of 10° from the horizontal direction. Cot(10°) equals 5.67 and the length of each horizontal chain code is almost the cotangent of the angle, because each step is one unit in the vertical direction. The error is less than one unit.

Therefore, the average length value of all the horizontal chain codes is just the cotangent in principle. Then the rotating angle can be obtained by the inverse cotangent.

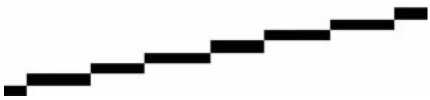

Fig. 5 Binary image of a line rotating angle of 10° from horizontal direction

According to the above principle, the chain code method searches the line along the horizontal direction to obtain the length of each section chain code along the horizontal row. Fig. 6 shows the magnified linear profile shown in Fig. 4, which is waiting for measurement. Due to the noise in the image, codes belonging to the same section may be divided into two or more breaking codes. Therefore, when tracing the chain code, if the present pixel does not belong to the edge, the following m (m usually equals 3) pixels are used to judge whether the pixel belongs to the edge or not.

Fig. 6 A binary image of the contour line

If all the pixels are not on the edge, the chain code searching of that section is finished and a new chain code searching begins on the next pixel of the row. Finally, the longest chain code is selected as the row chain code. The other rows are searched in the same way. The flowchart of the searching chain code algorithm is shown in Fig. 7.

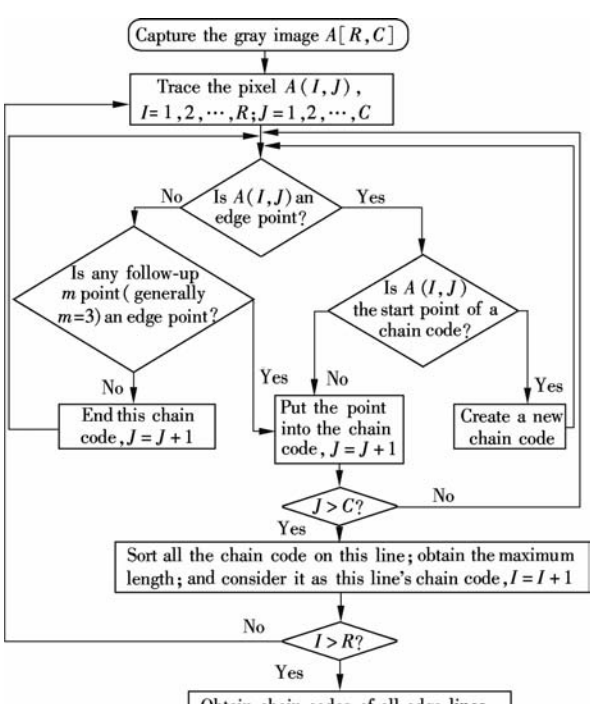

Fig. 7 Flowchart of searching chain code

Finally, the chain length data is sorted to obtain the longest chain code which is denoted as max L. The maximum length may be broken due to the noise interference even if the deflection angle is 0°. Hence, an upper threshold T_1 (e. g., $T_1 = 195$) is set. When the maximum length of a chain code is larger than T_1, the deflection angle is 0° by default. When the deflection angle is smaller, the average length of the horizontal chain code is larger in theory, such as cot(1.5°) = 38.188 5. However, it is difficult to search a chain code with a length greater than a certain threshold because of the noise. Consequently, another threshold T_2 (e. g., $T_2 = 40$) is introduced. When max L is greater than T_2, the value of max L is regarded as the cotangent of the deflection angle. When the deflection angle is larger, the theoretical mean value of the horizontal length of the chain code is shorter. To exclude the influence of noise, the lengths of the chain code are arranged in an ascending order and the data column is divided into three parts on average. The average value of the middle part is adopted as the average length of the chain code. The formula which is used to compute the deflection angle is

$$\alpha = \begin{cases} 0 & \text{if} \quad \max L > T_1 \\ \operatorname{arc\,cot}(\max L) & \text{if} \quad T_2 < \max L \leqslant T_1 \\ \operatorname{arc\,cot}(\text{avg}) & \text{if} \quad \max L \leqslant T_2 \end{cases} \quad (1)$$

where α denotes the deflection angle, and avg is the average value of the middle part of data after sorting. The flowchart of obtaining the average chain code is shown in Fig. 8.

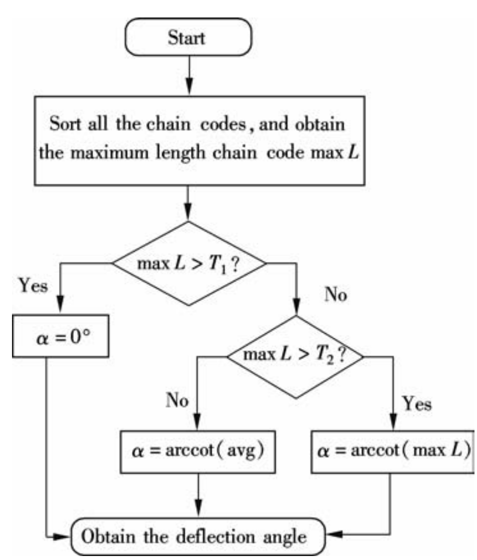

Fig. 8 Flowchart of obtaining average chain code

4 Experiments and Results

After image filtering, image segmentation, and edge detection, contrast experiments are performed between the proposed method and the Hough algorithm with ten 160 × 640 pixel images. The algorithm is run on a laptop computer with the Intel Core2 Duo T6670 (2.2 GHz) processor and 2.93 GB memory. The measurement value of the rotation angle and the computation time are given in Tab. 1. The experimental results show that compared with the Hough algorithm, the accuracy of the proposed algorithm is improved and the speed is considerably faster.

Tab. 1 Angle calibration

Rotation angle/(°)	Proposed algorithm		Hough algorithm	
	Measurement/(°)	Time/s	Measurement/(°)	Time/s
0	0	0.064	0	2.156
1	1.133	0.064	1.265	2.172
2	2.089	0.063	2.336	2.255
3	3.014	0.062	3.271	2.283
4	3.970	0.061	4.335	2.306
5	4.761	0.059	5.282	2.322
6	6.048	0.057	6.355	2.376
7	7.163	0.055	7.323	2.404
8	7.692	0.051	8.415	2.438
9	8.782	0.048	9.374	2.479

5 Conclusion

Compared with the commonly used Hough transform, the proposed method has ideal results both in calculating speed and precision when eliminating rotation deviation. It provides the probability of online measurements for large scale parts with linear profile. Moreover, it is prepared for the next mosaic of sequences in eliminating shifting deviation.

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消除序列图像拼接中旋转偏差的新方法

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摘要:在用机器视觉在线自动测量大尺寸零件的直线轮廓尺寸时,为了消除序列图像拼接中的旋转偏差,提出了一种基于链码搜索的新算法.将序列图进行滤波、分割、边缘提取预处理后,搜索边缘轮廓线的链码长度,根据链码长度求出轮廓线与坐标轴间的夹角,将序列图反向旋转这一角度,使序列图中直线轮廓方向与坐标方向一致,从而消除了序列图的旋转偏差,为后续拼接中消除平移偏差做好准备.对旋转偏差为0°~9°的线性轮廓零件进行了实验,结果表明:与经典的Hough变换相比,新方法精度更高,速度更快,这对实现大尺寸直线轮廓零件在线高精度测量具有重要实用价值.

关键词:序列图像拼接;直线轮廓;链码;旋转偏差

中图分类号:TP394.1