Automatic calibration of dial gauges based on computer vision

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ABSTRACT

Against the image characteristics of dial gauges, an automatic detection system of dial gauges is designed and implemented by using the technology of computer vision technology and digital image processing methods. Improved image subtraction method and adaptive threshold segmentation method is used for previous processing; a new method named as region-segmentation is proposed to partition the dial image, only the useful blocks of the dial image is processed no the other area, this method reduces the computation amount greatly, and improves the processing speed effectively. This method has been applied in the automatic detection system of dial gauges, which makes it possible for the detection of dial gauges to be finished intelligent, automatically and rapidly.

Keywords: Computer vision, region-segmentation method, central projection, least squares analysis, dial gauges

1. INTRODUCTION

Dial gauges have characters of simple structure, easy using, and are widely used in scientific experiments and production line. Our country manufactures tens of thousands of dial gauges per year. To periodically calibrate these dial gauge, manufacturers and users usually do it by manual and by eyes. This method depends on detectors' operation experiences, operation habits, mental status and other subjective factors, which have problems such as high intensity, low efficiency, calibration errors, poor reliability, etc. In order to improve detection effect, calibration precision, automatic detection is necessary.

Because of the calibration of dial gauges is a high-volume, repetitive procedure. Its operation is simple, standardized, and not influenced by external environment; these provide conditions for automatic detection. In recent years, computer vision and digital image processing technology have continuous developed, making these requirements possible.

Camera is used to acquire the dial images and background images, and then convert the analog signals to digital signals which can be received by computer. The digital image processing technology is used to complete image storage, scale identification, pointer location and recognition, determine instrument accuracy rating, and error analysis, and other key operations. For the purpose of getting higher detection accuracy than human detection, increasing productivity, reducing product costs, achieving automatic calibration of dial gauges is significance. This paper sets dial test indicator as an example to achieve an automatic detecting system of dial gauges.

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2. AUTOMATIC IDENTIFICATION PRINCIPLES OF INSTRUMENTS

In order to get the readings of dial gauges, several main parameters should be identified as follows: the dial center and coordinate of the gyration center, locations of all scale marks, the dial pointer's location. Normally, we can consider that the dial center and the gyration center are coincidence. There are 100 scale marks totally, which are uniformly distributed in the concentric circles with the dial center as their center point.

After the above analysis, the automatic identification of instruments can be divided into the following steps: distinguish the dial center, distinguish the scale marks, interpretation of indicating values.

2.1 Distinguish the dial center

In the calibration of dial gauges, only the pointer is changing, therefore, we can adopt image subtraction method [1~3]. Subtract the corresponding pixel values of two images which pointers are in different positions. Because in these two images, the pixel values are basically same except the dial pointers. After subtraction, the pixel values are close to zero except the dial pointers.

According the image histogram after subtraction, a fixed threshold is used for binary process [1~3], because the impact of external factors such as light while acquiring images, the binary image will have some isolated points, so the characteristics that we need will not be distinguished accurately. If want to obtain specifically area and information, it must predigest and divide the image [4]. This paper use the adaptive threshold segmentation method in the binary image process [1~3, 5]. Using this method in binary image process can resolve the impact of isolated points and distinguish the pointer characteristics much better. In order to identify the dial center accurately, we use three images which pointers have an interval of 120 degree. Apply this method to extract pointers, and their endpoints are used to fit the center point, that is the dial center.

2.2 Distinguish the scale marks

It is an important step to get dial scales for identifying the indicator of a dial gauge. Because the dial scales are located on a circle which has the same center with dial center. Therefore if treat the whole image in the identification of dial scales will take up great amount of computing time. In order to reduce the computing time, region-segmentation method is proposed to divide a dial image according to the dial radius, take the image block which has the scales to process. The scale identification has two steps, first define the position of every scale mark. Specific methods are as follows: according to pointer's position of the collected picture, in accordance with the dial center and dial radius can define a circle area intersecting with all scale marks. Then record the pixel position of all scale marks in this area of the image, use central projection method to compute the position of every scale mark pixel on the dial circle. These projection position values distributes in the 0~359 degree range. According to the distribution of these points on the circle we can accurately define the position of every scale mark. Second define the position of 0 scale. While the scale identification, the first image collected is an image which pointer is in the 0 place. Through subtraction method can get image which the pointer position is at 0. The pointer position on the dial circle can be computed by using the central projection method , and the scale if coincident with this position is the 0 scale position.

2.3 Interpretation of indicating values

Same as the scale identification, the indications identification only need to process the current pointer position, then the pointer's pointing can be obtained. Therefore the images are divided by angles after the circle is identified by scale. Only the arc area which contains pointer is processed and projection method is used to project pointer onto the dial circle. By comparing the pointer projection value and the scale projection value, the pointer position can be obtained.

3. TEST EXPERIMENTS AND RESULTS

A high resolution, black-white camera is used to collect dial images which manufactured by All-time corporation, AT-Snap 100M model. This kind of camera has a USB 2.0 interface. It can capture real-time, uncompressed video data and image and not need extra collection instruments. In order to obtain higher resolution, when detecting different dial test indicators, it requests the dial obtained by image acquisition system should fill of the image window as possible as it can. As shown in Fig.1, they are a group of dial images collected by this camera.

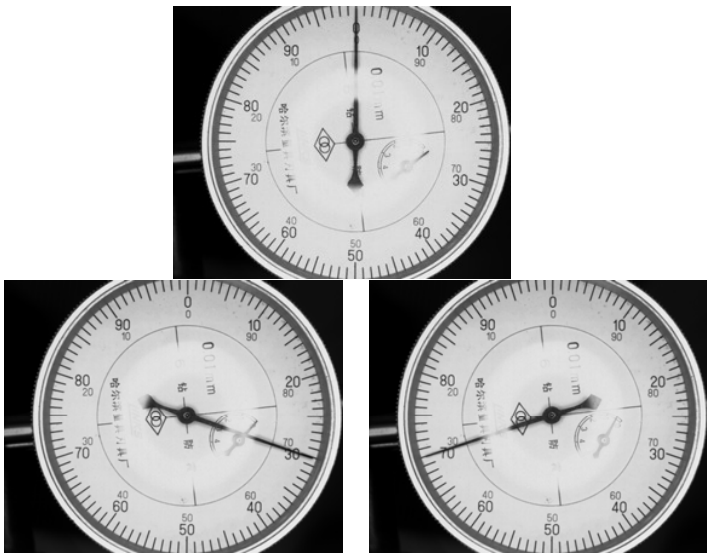

Fig.1. the Dial Image of a Dial Gauge

After processing the images of Fig.1 using the image subtraction method, as shown in Fig.2.

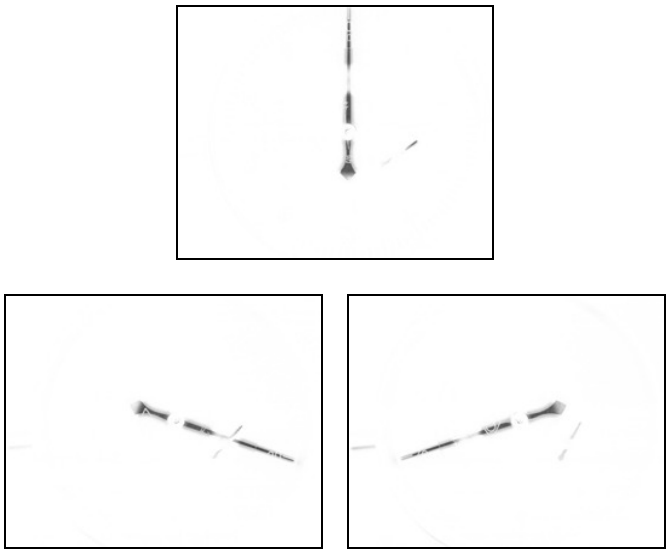

Fig.2. the Image Using Subtraction Method

These images which pointers have an interval of 120 degree are used to fit the center point, the dial center is located at pixel (691,506), and the scale projections on the circle is obtained by scale identification . As shown in Fig.3

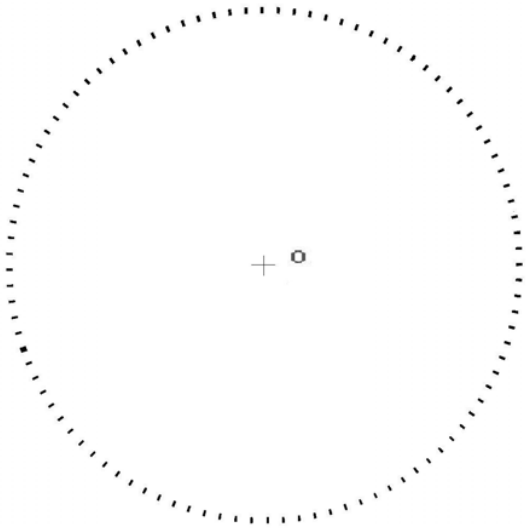

Fig.3. the Calibration Image of Dial Gauge

In which the “O” is the center point of dial gauge.

When the pointer at the 10 scale, the segmentation image after processing by the detecting system, as shown in Fig.4

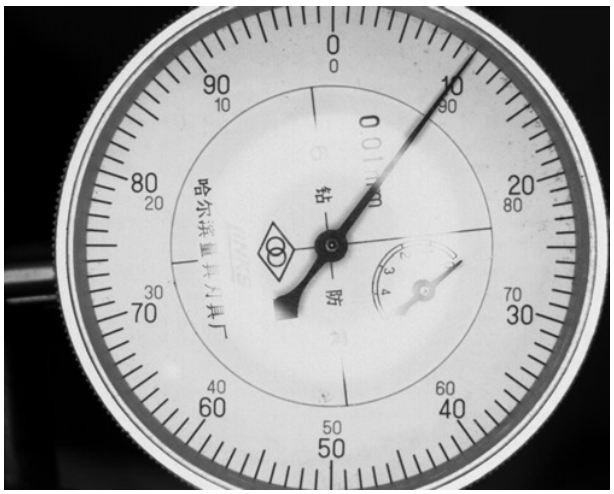

Fig.4. the Segmentation Image while Pointer at the 10 Scale

In which the "O" is the center point of dial gauge.

The indicating value of this position obtained by using projection method is 100.0745um. The indication error at this position is 0.0754um.

In order to verify the accuracy of dial identification based on computer vision, the dial gauge calibrator in the experiments obtain one test point at dial gauge every 10 scales, then compare the measurement values with human eyes' readings. 4 experiments are carried out, and the error table as shown in Tab.1 the indication error curves are shown in Fig.5.

Table.1 the comparison error table between Computer Vision measurement and the human eye readings (μm)

Detection number	0	10	20	30	40	50	60	70	80	90	0
1	-0.045	0.036	0.054	0.065	-0.012	0.009	-0.083	-0.044	-0.048	0.070	-0.052
2	-0.039	-0.071	-0.051	-0.069	-0.042	0.004	0.055	0.020	0.010	-0.066	0.064
3	-0.048	0.035	0.022	0.080	0.031	0.036	0.041	0.015	0.021	0.056	-0.048
4	0.048	-0.077	-0.008	-0.023	-0.088	-0.026	0.026	0.013	0.030	-0.045	0.049

From the above table and figure, it can be obtained that the maximum error of dial identification using computer vision and human eyes test is 0.088um. According to the long-term staff experiences of detectors, who are engaged in dial gauges calibration test by their eyes for long time, the identification error is about 0.2um. Therefore it is feasible to automatically identify dial gauges using computer vision.

In order to speed up image processing, to make it identify the indicators in real-time, the region-segmentation method is used to deal with the pointer image. The original image is 1024×768, each pixel of the image should be processed 8 times in image processing, which is more than ten million times in total. And after using the region-segmentation method, there is only one hundred thousand pixels need to process in identifying every indicator. The runtime is 0.1% of the

original which great reduced the running time of program. The detecting speed of each indicator is 0.2182 seconds by using the system, while the speed of SJ2000 Indicator Automated Inspecting Instrument is 0.5 seconds developed by the ShenZhen Metrology and Quality Inspecting Research Institute [7].

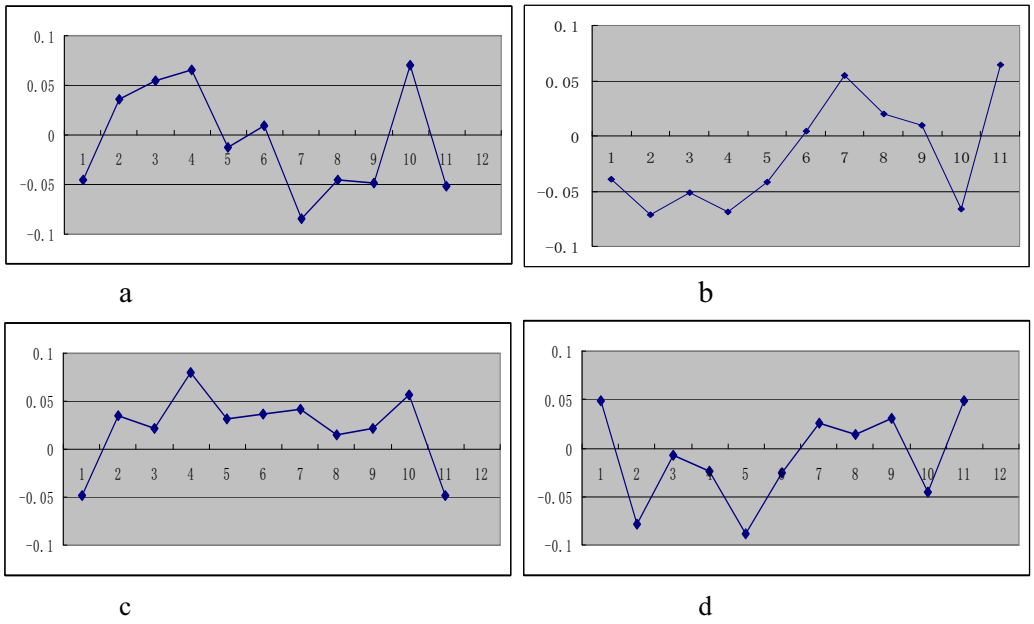

Fig.5. Indication Error Curve

4. CONCLUSIONS

The region-segmentation method proposed in this paper saved a large amount of computing time, laid the foundation for dial gauges real-time identification application.

In this paper through comparing the computer vision test result errors with human eyes reading errors, it is indicated that using computer vision and digital image processing technology method to complete dial gauges identification can obtain higher accuracy, and can replace the human test method. Repeated experiments show this automatic detection system can meet the industrial needs of dial gauges automatically detect. It has a good prospect. Especially for peculiar environment which can not be tested by human eyes, this system has more superiority.

REFERENCES

[1] He Bin, Ma TianYu, Etc. Visual C++ Digital Image Processing. Beijing: People's Posts and Telecommunications Publishing House, 56-74, (2002)

[2] Zhou ChangFa. Proficient Visual C++ Image Processing Programming (second edition). Beijing: Electronics Industry Publishing House, 34-39, (2004)

[3] (United States) Rafael C .Gonzalez, (United States) Richard E .Woods. Digital Image Processing. Beijing: Electronics Industry Publishing House, 46-53, (2007)

[4] Yang Musheng, Chen Rong, Zhang Yu. "An automatic test instrument for dial gauge based on computer image process," IEEE International Conference on Automation and Logistics, 1320-1324, (2007)

[5] Wen He, Teng ZhaoSheng, Etc. "Intelligent reading method for analog meter based on computer vision," Chinese Journal of Scientific Instrument, 1234-1239, (2007)

[6] Sun FengJie, Etc. "Studies of the Recognition of Pointer Angle of Dial Based on Image Processing," Proceedings of the Csee, 73-78, (2005)

[7] global trade connects world, http://www.sjgc360.com/tradeinfo/offerdetail/31-704-0-61930.html