Study on the Technology of Digital Recognition in Verification Process of Mechanical and Electronic Anemometer

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Abstract

In order to solve the key technical problem in the verification process of mechanical and electrical coal mine anemometer, the paper presents digital recognition approach base on the characters of the anemometer image. First of all, collect the mirror images of the anemometer from a plain mirror which in the wind tunnels. And then we process the mirror images with secondary mirroring, grayscaling, denoising and binarization. Followed the location of the digital area can be determined and the incline distortion of the image can be adjusted. The final step is segmenting the single character in the digital character region and identify the corresponding number base on the characteristics of anemometer, which using the LED digital tube to display numbers. The experiments show that this method can accurately identify the numbers on the anemometer and has high recognition rate. The recognition time is able to meet the requirement for the verification of anemometer. Thus the method has high practical value.

Keywords: mechanical and electrical anemometer; anemometer verification; character segmentation; digital recognition

1. Introduction

The wind speed is one of the important parameters of coal mine safety, and has great significance for the security of production [1]. Now, anemometer is widely used in wind speed measurement [2]. According to the structure of anemometer, now commonly used anemometer can be divided into three types: mechanical type, electrical type, mechanical and electrical type [3]. The measuring department must do calibration for anemometer to make sure whether it is up to grade. Through the wind tunnel simulation, the verification and calibration of anemometers can be accomplished [4]. Because of the digital region of mechanical and electrical anemometer perpendicular to the observable window of wind tunnel in the verification process, it's hard to acquire the digital region image. At present, the researches about verification method of mechanical and electronic coal mine anemometer exist few.

In this article, digital image processing and recognition technology is applied in the verification process of mechanical and electrical coal mine anemometer. There are many recognition methods are proposed about digit recognition, such as template match method [5], statistical decision method [6], contour polygon method [7], neural network

approach [8], etc. Combing with practical project, this paper proposes a simple effective recognition method and a hardware and software implementation. The hardware system structure as the Figure 1 shows. In the wind tunnel, a plain mirror is placed in the position of 45 degrees from the digital region of anemometer. Through the observable window, camera aims at the mirror and collects the mirror image of anemometer. The camera is connected to the computer via data cable.
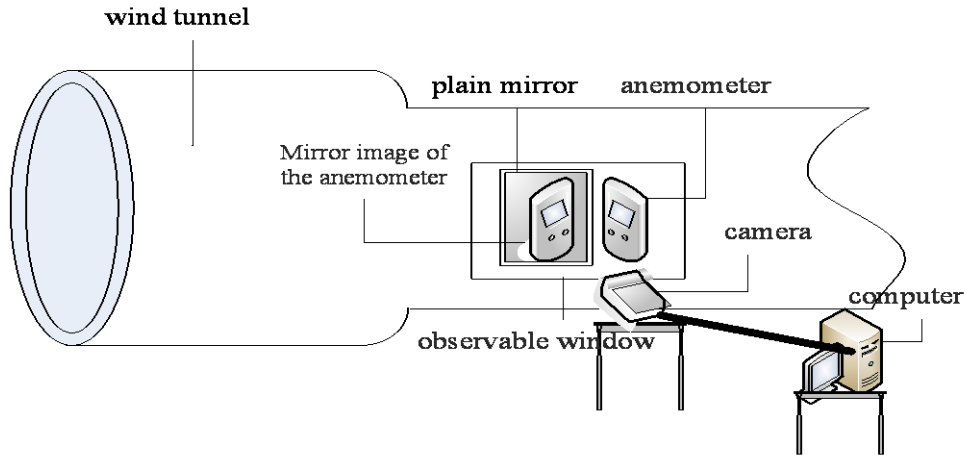

Figure 1. Hardware structure of the system

2. Image Collection and the Secondary Horizontal Mirror

In the verification system, the image of the anemometer was projected onto the plain mirror. The image collected by the camera is mirror. The mirror image needs secondary horizontal mirror and return to a normalized state. The secondary horizontal mirror operation is done by exchanging the position of the pixels with the vertical central axis as the center line. The principles are shown in Figure 2.
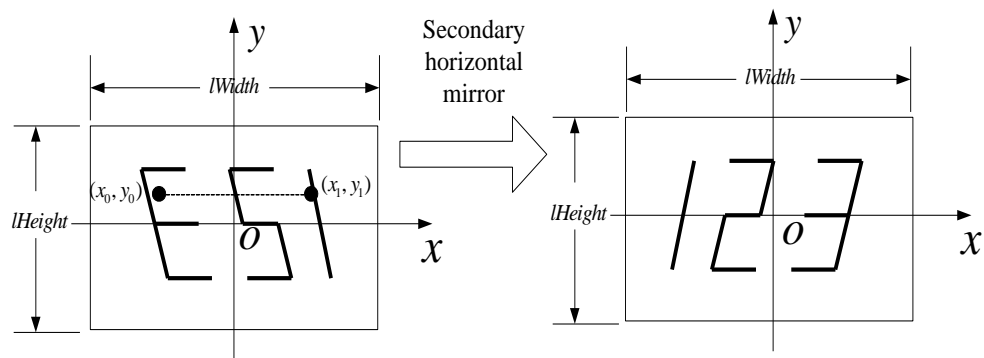

Figure 2. The principle of secondary horizontal mirror

The height of image is $lHeight$, the width of image is $lWidth$, the vertical axis of image is y. The pixel coordinate on the original image is (x_0, y_0), after the horizontal

mirror transformation, the new pixel coordinate is (x_1, y_1). After the secondary horizontal mirror transformation, the image returns to normalized state. The transformation formula is given as follow:

$$\begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} = \begin{bmatrix} -1 & 0 & lWidth \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} y_0 \\ x_0 \\ 1 \end{bmatrix} \tag{1}$$

3. Image Preprocessing

The image pretreatment stage mainly studies the image grayscale processing, denoising processing and the image binarization operation [9].

The images collected by the camera are color images. In order to locate and identify the digital region image, it needs us to convert the color images to gray scale image. The values of the three parameters of R, G, B are *R*, *G*, *B*, the transformed gray value is *Gray*, The transformation formula is given as follow:

$$Gray = 0.299 \times R + 0.587 \times G + 0.114 \times B \tag{2}$$

Because of the influence of the light and electromagnetic field, image acquisition process will inevitably produce image noise. In this article, the noises would be removed by medium filter, which can remove the isolated points effectively.

The OTUS method is used to convert the intensity image to a binary image.

4. Digital Region Location and Incline Distortion Adjustment

4.1. Anemometer's numerical region Location

As the digital instruments, the position of the digital region on the anemometer is fixed. There are two obvious characteristics of the digital region: one is the edge shape of the digital region, which is a closed quadrilateral; the other is the color of the digital region, which has great difference with the other regions in the threshold of the red, green, and blue (RGB) channels. Through image analysis all the regions can be found which edge is closed quadrilateral. Firstly, the edge information would be obtained by edge detection. The traditional methods of edge detection include Robert method, Sobel method, Prewitt method and Canny method [10]. Experimental results show that canny method has the good abilities of noise resisting and picture edge reserves. Canny method is used to detect the edge of the preprocessed anemometer image in the paper. The detection results are shown in Figure 3.
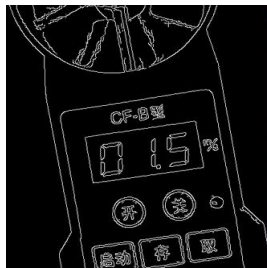

Figure 3. Edge detection by canny method Figure 4. The result of Location

Secondly, the closed curves in the edges-detected image can be obtained by using boundary tracking based on eight-neighbor model. Thirdly, the closed quadrilaterals can be obtained by specified accuracy approximation. Lastly, the digital region can be located by comparing the threshold of the red, green, and blue channels. Then the coordinates of the four corners of the digital region are recorded, and will be used in the next step. The result of location is shown in Figure 4.

4.2. Incline distortion adjustment

Because of the illumination and the angle of camera, the image photographed by the camera maybe produces distortion. The common types of distortions include incline distortion and perspective distortion. Through the experiment, we can find that the perspective distortion have little effect, so it only need to adjust the incline distortion. Incline distortion is adjusted by using the coordinates of the four corners which has obtained from the previous step. The principles are shown in Figure 5.
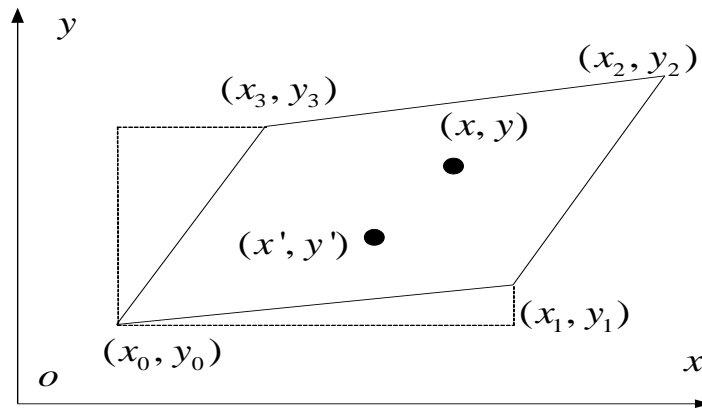

Figure 5. Incline distortion adjustment principle

Firstly, select the bottom-most pixel position of the image as datum and draw a horizontal line. Then move the pixels of bottom edge down to the datum line. The other pixels would be moved down by the same proportion. Secondly, select the left-most pixel position of image as datum and draw a vertical line. Then move the pixels of left edge to the datum line. The other pixels would be moved to the left by the same proportion. The coordinates of the four corners are (x_0, y_0), (x_1, y_1), (x_2, y_2), (x_3, y_3). The coordinate of any point on original image is (x, y), after adjustment, the new coordinate is (x, y). The transformation formula is given as follow:

$$\begin{cases} x' = x + (y - y_0)(x_0 - x_1) / (y_1 - y_0) \\ y' = y + (x - x_0)(y_0 - y_3) / (x_3 - x_0) \end{cases} \tag{3}$$

After adjustment, the located region turns to a rectangle. The adjustment result is shown in Figure 6.
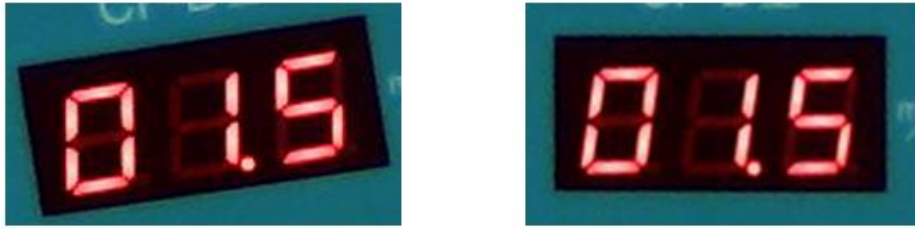
Figure 6. The image before and after incline distortion adjustment

5. Digital Region Segmentation

When the region of the digital characters is extracted, it needs to accurately segment the single digital character. The methods of character segmentation include clustering method, projection method and template matching method. For the advantages of running speed and program structure, the vertical and horizontal projection segmentation method is used to segment the Characters in the paper. The projection segmentation needs to use the binarization image. The horizontal projection can be achieved through accumulating the pixels value from column's vertical direction. The vertical projection can be achieved through accumulating the pure gray value from row's horizontal direction. The results of projection are shown in Figure 7.

Figure 7. Horizontal and vertical projection image

There are two valleys on the horizontal projection image. The lower edge of the valley on the top of image is the upper boundary of character segmentation. The upper edge of the valley on the bottom of image is the bottom of character segmentation. There are four valleys on the vertical projection image. The right edge of the three preceding valleys can be selected as the left boundary of every character. The left edge of the last three valleys is selected as the right boundary of every character. Set these boundaries as the positions of character segmentation. Then complete the character segmentation. After the above processing, three binarization images of the characters are separated out. The pixel color of the characters is black; the color of the background is white. The results of characters segmentation are shown in Figure 8.

Figure 8. The results of characters segmentation

6. Character Recognition

The character recognition in this paper includes two parts: digit recognition and decimal point recognition.

6.1. Digit recognition

The mechanical and electronic coal mine anemometer uses the seven-segment LED to display the number. According to the position of the digital tube, the image can be divided into seven regions. The numbers can be recognized by scanning these regions and comparing with code tables.

The procedure of recognition algorithm is as follow:

1）Region division: First, we set the preprocessed binary image background pixels equal to1 (white) and object pixels equal to0 (black).According to the position of the digital tube, the single character image can be divided into seven parts. These regions correspond to seven digital tubes respectively, and were marked as A, B, C, D, E, F, and G. Seven Boolean type variables which correspond to the seven regions would be chosen to mark the states of the individual diodes. The results of region division are shown in Figure 9.
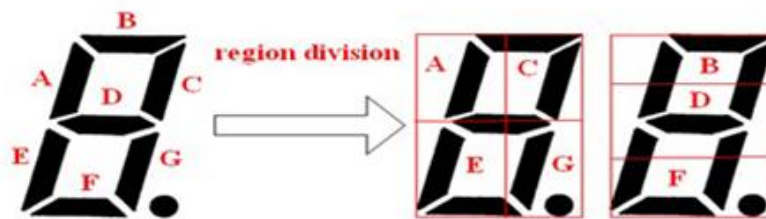

Figure 9. The results of the digital tube region division

2）Threshold determination: According to the prior knowledge, the maximum width and the maximum height of the single character image would be obtained and marked as $MaxWith$ and $MaxLength$. The threshold values of the vertical and horizontal digital tube are $Threshold1$ and $Threshold2$ respectively. The sum of the black pixels in each column can be counted from area A and area C, the maximum value is $Threshold1$. The sum of the black pixels in each row can be counted from area B and area D, the maximum value is $Threshold2$.

3）Digtal recognition: Firstly, if $MaxLength > 3 MaxWith$, the character will be recognized as the number 1. Secondly, the sum of the black pixels in each column can be counted respectively from area A, area C, area E and area G. if the maximum value close to $Threshold1$.The Boolean type variable of the corresponding region would be set to 1, otherwise it would be set to 0. The sum of the black pixels in each row is counted respectively from area B, area D and area F. If the maximum value close to $Threshold2$, the Boolean type variable of the corresponding region would be set to 1, otherwise it would be set to 0. Lastly, the value of the single character can be recognized by comparison with the truth table. The truth table is listed in Table 1.

Table 1. Truth table of the digital tube

The value of the character	the area of the digital tube						
	A	B	C	D	E	F	G
0	1	1	1	0	1	1	1
2	0	1	1	1	1	1	0
3	0	1	1	1	0	1	1
4	1	0	1	1	0	0	1
5	1	1	0	1	0	1	1
6	1	1	0	1	1	1	1
7	0	1	1	0	0	0	1
8	1	1	1	1	1	1	1
9	1	1	1	1	0	1	1

6.2. Decimal point recognition

Because of inclined font, it's difficult to separate decimal point from the character image. The decimal point is located within a particular region in the bottom right corner. Although there are many skew correction methods of the image, it also needs thinning and normalization after calibration. In the paper, the particular region scanning and comparison method is used to recognize decimal point. The minimum external rectangles of the connecting areas in the bottom right corner would be obtained by scanning. The length and width ratio of minimum external rectangle and the area ratio between connecting area and external rectangle are calculated in order to judge whether the decimal point exist or not. If the formula 4 and formula 5 are satisfied, the decimal point exists.

$$\varepsilon_1 \leq \frac{lheight}{lwidth} \leq \varepsilon_2 \tag{4}$$

$$\frac{\sum_A S(x,y)}{lheight \times lwidth} \times 100\% \geq \varepsilon_3 \tag{5}$$

In the formulas, A is the minimum external rectangle. *lheight* is the length of minimum external rectangle, *lwidth* is the width of minimum external rectangle . $S(x,y)$ is the pixel value of coordinate point (x,y).the upper and lower bound of length width ratio are ε_1 and ε_2 , the lower bound of the area ratio is ε_3 .

7. Experimental Results

We choose one hundred real images which contain three hundred characters to carry on the experiment. The results of these experiments are listed in Table 2. The recognition rate of characters is at least 97%. A single test run time is 180ms, which and can completely meet the practical need.

Table 2. The results of these experiments

Type	Symbol sum	number of correctly recognized	number of can not recognized	recognition rate
Character'1' (Without a decimal point)	46	46	0	100%
Character with a decimal point	100	97	3	97%
Character without a decimal point(except'1')	154	153	1	99%

8. Conclusions

The digital recognition in the verification process of mechanical and electronic coal mine anemometer is worth to study. The digital region location method base on the shape and color, which is not influenced by camera position, is feasible and effective. We present a new region segmentation and scanning method for digital recognition. There is no need of the thinning and the normalization in this new segmentation and scanning method and it has small amount of calculation and higher recognition rate. The digital image processing and recognition technology is applied to solve the key problems in the verification process of anemometer, and has practical application value.

Acknowledgements

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