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Automatic Verification of Intelligent Electricity Meter with Image Processing and Digit Recognition

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Abstract. The intelligent electricity meter is adopted widely in the power system. To improve the verification efficiency and decrease the artificial error, realizing automatic verification of the intelligent electricity meter is necessary. The image of the intelligent electricity meter is collected with the camera, and the image processing is conducted, including region positioning and segmentation, tilt correction, gray scale, smoothing, binarization, sharpening, discrete point removal and edge detection. After the image processing, the decimal point is positioned, the negative sign is judged, and the digit recognition is conducted. The results show that the verification efficiency is improved greatly than the manual operation.

Keywords. Intelligent electricity meter; Automatic verification; Image processing; Digit recognition

1. Introduction

To maintain the safe and stable operation of the power system, the intelligent electricity meter is adopted widely. To measure the electric quantities accurately, it is necessary to verify the intelligent electricity meter regularly. The verification of the intelligent electricity meter includes two parts, namely, error verification and account parameter verification. The error verification is to check whether the background record data is correct. The account parameter verification is to record and analyse the parameters of the intelligent electricity meter. The traditional verification process relies on the manual operation extensively, the appearance of the artificial error is inevitable, including reading deviation and miscalculation. Besides, the efficiency of the manual verification is low, which is difficult to meet the rapid development of the power system. To improve the verification efficiency and decrease the artificial error, realizing automatic verification of the intelligent electricity meter is necessary.

With the rapid development of the image processing and digit recognition, lots of progress is made in the field[1-14]. Zhang et al. explored a novel neural network-based nonlinear filter, which was able to remove mixed noises and sharpen the edges in noise-corrupted digital images[1]. Simulation results showed that the proposed filter was able

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to effectively remove the mixed Gaussian and impulsive noises and sharpen the edges. Wang et al. presented a method of automatic indication recognizing for a multi-pointer meter by image processing and recognizing[2]. The result indicated that the method was reasonable and applicable. Duan et al. proposed a fast meter digits recognition method based on fuzzy theory[3]. A fuzzy digit recognizer was constructed based on the maximum membership principle of fuzzy theory. The results showed that the recognition rate was higher than 99% and the recognition time of 7 digits was less than 30 ms for digital meters. Vlach et al. adopted fuzzy methods and image fusion for image processing with LabVIEW tools for quality management[8]. Ma et al. analyzed the recognition methods for digital images, and proposed an edge-tracking method, a distance feature information method and a feature information extraction method for recognizing digital images[9]. Khandual et al. developed an objective and reliable evaluation method for the efficiency of singeing process with digital image processing[10]. The imaging system ensured controlled, diffused and uniform illumination across the samples, and the proposed evaluation method was suitable and economic for analysis of singeing efficiency.

To improve the verification efficiency and decrease the artificial error, adopting the digit recognition and image processing, developing automatic verification of the intelligent electricity meter is necessary, which is the purpose of the present work. The present work is organized as follows. Firstly, the shortcomings of the traditional verification process are pointed out, and the overall design principles of the automatic verification system is put forward. Then, the image processing methods are introduced, including region positioning and segmentation, tilt correction, gray scale, smoothing, binarization, sharpening, discrete point removal and edge detection. Lastly, the software implementation of the automatic verification system is introduced, and the performance of the automatic verification system is tested.

2. Shortcomings of the Traditional Verification Process

The traditional verification process relies on the manual operation extensively, the appearance of the artificial error is inevitable, including reading deviation and miscalculation. To improve the verification efficiency and decrease the artificial error, realizing automatic verification of the intelligent electricity meter is necessary.

3. Overall Design Principles of the Automatic Verification System

To realize automatic verification of the intelligent electricity meter, the digit recognition and image processing are adopted, and the following principles are obeyed.

3.1 Verification Accuracy

Developing the automatic verification system of the intelligent electricity meter, the verification accuracy is very important. The automatic verification system is designed to work without the manual operation, thus, the verification accuracy should exceed the accuracy of the manual operation.

3.2 Verification Efficiency

Besides the verification accuracy, the other purpose to develop the automatic verification system is to improve the verification efficiency, and the effective way is to decrease and remove the manual operation during the verification process. Usually, the verification efficiency is limited by two aspects, namely, reading of the display value of the intelligent electricity meter and processing of verification data, thus, these two aspects should be focused to improve the verification efficiency.

3.3 Economy

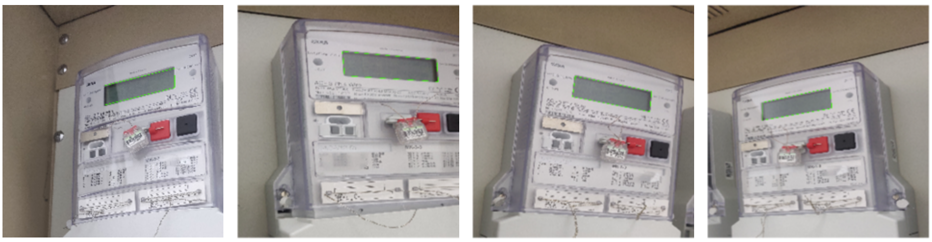
The economy is another key index. To save the cost of the automatic verification system, optimizing the software algorithm is an effective way.

4. Image Processing Methods

The image processing and digit recognition are essential to realize the automatic verification system of the intelligent electricity meter. Thus, the image processing methods are introduced, including region positioning and segmentation, tilt correction, gray scale, smoothing, binarization, sharpening, discrete point removal and edge detection.

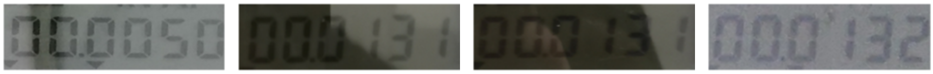
4.1 Region Positioning and Segmentation

During the verification process, the size and shape of the meters are different. To collect the image of the meters effectively, the region positioning is necessary. Figure 1 shows several different positions of the intelligent electricity meter. It is observed that the angle and orientation of the display screen region are various, thus, to recognize the digits effectively, the region positioning and segmentation is important. Figure 2 shows the results of the region positioning and segmentation of the intelligent electricity meter. It is observed that the display screen region of the intelligent electricity meter is positioned and segmented accurately.



(a) (b) (c) (d)

Figure 1. Several different positions of the intelligent electricity meter



(a) (b) (c) (d)

Figure 2. Results of the region positioning and segmentation of the intelligent electricity meter

4.2 Tilt Correction

The collected image is usually declining, to make the digit recognition and image processing convenient, it is needed to conduct the tilt correction. Usually, the top and bottom edges of the display screen region are parallel lines, the Hough transformation is adopted, namely, measuring the declining angle of parallel lines and correcting the display screen region. The Hough transformation is the most commonly used method to check whether there are parallel lines. Set the equation of the line is $y = kx + b$, conduct the transformation $\rho = x\cos\theta + y\sin\theta$, where ρ is the distance from the line to the coordinate origin, and θ is the orientation angle between the normal of the line and x-axis. After the Hough transformation, each point of the line (x_i, y_i) represents a curve in the Hough plane $\rho = x_i\cos\theta + y_i\sin\theta$, and the line $y = kx + b$ is converted to a series of curves in the Hough plane, and they cross the point (ρ, θ).

During the verification process, the real-time requirement is important. The traditional Hough transformation calculates each pixel point of the image to check whether there are parallel lines, which is very expensive and difficult to satisfy the real-time requirement. To decrease the computation cost, the traditional Hough transformation is modified, namely, only calculating the top and bottom edges of the display screen region, where parallel lines are checked with the most possibility.

4.3 Gray Scale

The colors of the image are composed of three primary colors, namely, red, green and blue. To eliminate the difference of the color of the image, the gray scale process is to make the gray level of the three colors equal. Usually, the gray scale process is to convert colorful images to gray images. Gray images save less information and are easier to be processed than colorful images, for example, the black-while photos are typical gray images. To process gray images, it is needed to quantify the brightness levels of gray images. Usually, the brightness levels of gray images are divided into 256 levels, among them, 0 is the darkest, and 255 is the brightest. To convert colorful images to gray images, the weight coefficient method is adopted, namely, the conversion relation is

$$I = 0.299R + 0.587G + 0.144B \tag{1}$$

where I is the brightness level of the gray image, and R, G, B represent red, green, blue.

4.4 Smoothing

The collected image is inevitably polluted by the environment noise, which makes digit recognition and image processing difficult. To improve the image quality, it is needed to smooth the image. The image smoothing can be conducted in the space domain, and also can be done in the frequency domain. At the same time, the edges and details of the original images should not be destroyed after the image smoothing.

4.5 Binarization

The image binarization is the threshold treatment, namely, the gray level of the gray image is less or more than a critical value, the pixel point is set to be black or white. The essence of the image binarization is to convert 256 gray levels of the gray image to only two levels, 0 or 1. The image binarization is to save the data size greatly, which brings a faster processing speed. The image binarization is a key part, which affects the quality of the digit recognition. The choice of the critical value is essential. If the critical value is too large, some of the important objects are removed, while some background noises are selected if the critical value is too small. Usually, two main methods are adopted, namely, global critical value method and local critical value method.

4.6 Sharpening

The image sharpening is important to digit recognition and image processing. Firstly, the image sharpening can enhance the edges of the image, which makes fuzzy images clear and improves the quality of the images. Secondly, the image sharpening can select the edges of the image and segment the images, which is helpful to the following image processing. The essence of the image becoming fuzzy is the average and integral calculation, thus, to make fuzzy images clear, the inverse calculation is taken, namely, the differential operation can make images clear. The two main methods of the image sharpening are the high pass filtering and the differential method. In the present work, the Roberts gradient operator is adopted. Set the point of the original image is $f(x, y)$, and the gradient vector at (x, y) is

$$G[f(i,j)] = |f(i,j) - f(i+1,j)| + |f(i,j) - f(i,j+1)| \quad (2)$$

The critical value is set to be Δ, after the transformation, the point $g(x, y)$ is

$$g(x,y) = G[f(x,y)], G[f(x,y)] \geq \Delta \quad (3)$$

$$g(x,y) = f(x,y), G[f(x,y)] \leq \Delta \quad (4)$$

4.7 Discrete Point Removal

After the above procedures, some noises still exist with the discrete points, which should be removed to improve the image quality. The commonly used methods to remove discrete points include the mean filter and median filter. However, these methods are not suitable to recognize the narrow digits, since they may remove the digit pixel. In the present work, the noise is removed by removing the impurities. Scan the whole image, find a black point, calculate the number of the black points connecting to the black point directly or indirectly. If the number is larger than a critical value, it is not a discrete point, otherwise, it is a discrete point, which should be removed.

4.8 Edge Detection

The edges are the obvious characteristics of the images. The edge detection is the basis of the image segmentation and object region recognition[15,16], which is one of the most active fields in the computer vision. The edges of the image are the places where the gray levels are discontinuous, for example, the sudden change of the colors. The edges of the image have two main characteristics, one is the direction, and the other is the amplitude. The gray levels perpendicular to the edge change rapidly, while the gray levels along the edge change smoothly, thus, the edge is detected by calculating the gradient of the pixels. The Prewitt operator is adopted in the present work, whose stencils are

$$E_h = \begin{pmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix} \tag{5}$$

$$E_v = \begin{pmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{pmatrix} \tag{6}$$

where E_h and E_v are the horizontal and vertical detection operators, respectively.

5. Software Implementation of Automatic Verification System

The software design of the automatic verification system is significant, and figure 3 shows the flow chart of the software implementation. Before the image collection, the intelligent electricity meter should be set. After the meter setting, the image is collected with the camera. Firstly, the display screen region is positioned, and the original image is segmented. Next, the image processing is started, including tilt correction, gray scale, smoothing, binarization, sharpening, discrete point removal and edge detection. Then, the decimal point is positioned, and the sign of the value is judged. If the above procedures are conducted correctly, the digit recognition is finished, otherwise, the whole process is started anew.

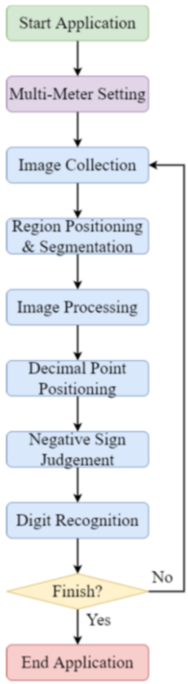


Figure 3. Flow chart of the software implementation of the automatic verification system

Figure 4 shows the iteration of the train process of the automatic verification system. It is observed that the accuracy of the automatic verification system increases with the increase of the iteration number, which is close to 100%, more than the accuracy of the manual operation. Figure 5 shows the verification results of the intelligent electric meter. The parameters of the meter can be recognized accurately and effectively, which is helpful to improve the automatic level of the power system.

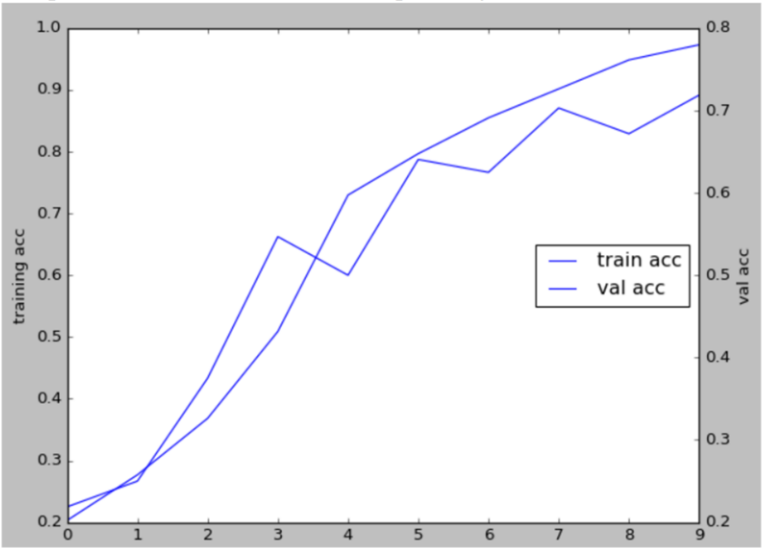


Figure 4. Iteration of the train process of the automatic verification system

Figure 5. Verification results of the intelligent electric meter

6. Conclusion

To improve the verification efficiency and decrease the artificial error, the automatic verification system of the intelligent electricity meter is designed based on the image processing and digit recognition. The image of the meter is collected with the camera, and the image processing is conducted, including region positioning and segmentation, tilt correction, gray scale, smoothing, binarization, sharpening, discrete point removal and edge detection. After the image processing, the decimal point is positioned, the negative sign is judged, and the digit recognition is finished, which is the overall idea of the automatic verification system. The automatic verification system is tested, and the results show that it improves the verification efficiency greatly than the manual operation.

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