A novel quality test method of electricity meter LCD Screen based on image processing

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Abstract. In order to solve the problem of incorrect test on the LCD screen quality of smart electricity meter and to make its visual inspection item perfect, a novel quality test method based on image processing is put forward in this paper. First, a novel algorithm of self-learning fast template matching based on the sequential similarity detection algorithm is proposed. Then, how to synthesize characteristics of many templates into a standard template and how to establish a real-time and self-learning template library are described in detail. Finally, the sequential similarity detection algorithm is improved with adaptive threshold. The experiment results show that the proposed test method has higher efficiency and accuracy for smart electricity meter LCD screen quality testing. Therefore, it has great practical applications.

1. Introduction

With the development of smart grid construction, the smart electricity meters which widely used have been unified designed according to the new smart electricity meter technical specification. In order to protect the economic interests of the power company and the power consumers, the new designed meters must past all function tests before used, according to the national verification regulations. LCD screen is the main meter reading device for the electricians and the power consumers. However, there are many LCD screen quality problems in the process of production, transportation and storage, such as broken screen, blurred screen, missing code and so on. So, it is necessary to test the quality of electricity meter LCD screen.

Many people have done plenty of research on the LCD screen test technology. Literature [1] has adopted PatMax and PatQuick algorithm to achieve automatic detection of the smart electricity meter LCD screen in flow line. Literature [2] has improved the template matching algorithm through the study of the basic algorithm of template matching on computer vision. Literature [3, 4] have adopted some methods such as wavelet transform and Hough transform, to research the LCD defect inspection. Literature [5-7] have improved the fast template matching algorithm and make it effective. The algorithms not only reduce computational costs, but also improve the quality of the approximated image. These studies have made a contribution to the development of LCD screen testing technology. But the smart electricity meter LCD screen quality test method in automatic testing system is imperfect. The matching accuracy is low and the miss ratio of visual inspection is high when some dust on LCD screen. And the testing efficiency is unable to keep pace with the high work rhythm of
the automatic testing system. Therefore, it is necessary to propose a novel quality test method of electricity meter LCD screen based on image processing.

2. Hardware structure and workflow

2.1. Hardware structure for testing

In large-scale smart electricity meters automatic testing system, the function of the hardware structure is to realize the appearance especially LCD screen quality testing [8, 9]. The hardware structure consists of industrial camera, light source, and retaining device, and electrical control unit, and image processing software, etc. The industrial camera is a kind of linear charge coupled device camera. And a special machine vision LED linear light source is used in the module. The programmable logic controller is adopted in the electrical control unit. Image processing soft and monitor unit run on an industrial computer. When electricity meters reach the hardware, the real-time online images are obtained through industrial camera. Then the images are transmitted to image processing software running on the industrial computer and template matching.

2.2. The workflow of LCD screen test

The workflow of LCD screen test is shown in figure 1. The whole process can be divided into two parts, standard template design and template matching [10]. Because of petty differences on content and fonts of the LCD screen, it needs to make the corresponding standard template respectively, according to the connection mode of electricity meter, vendors, and batch number, etc. And deposit the template to self-learning template library, so that it can be used at any time on LCD screen test. If the match is successful, the LCD screen of electricity meter is tested qualified. Otherwise, it is tested unqualified. And the electricity meter should be rechecked.

3. The novel quality test method

Due to the differences of manufacturing process, LCD screens have certain tolerance range. In addition, there are small changes in the image intensity which are caused by light conditions, dust in

![Workflow Diagram](image_url)
the air, and definition of LCD screen, etc. And the existing algorithms are generally based on a single template matching. To the electricity meters which are qualified but have certain differences from template, there will be some misjudgement phenomenon. The work rhythm of automatic testing system is decided by the matching efficiency. Therefore, from the perspective of reducing missing ratio and increasing the matching algorithm speed, this paper proposes a novel quality test method. In the method, the real-time and self-learning template library is established, and the sequential similarity detection algorithm (SSDA) is improved with adaptive threshold, and a novel algorithm of self-learning fast template matching based on SSDA is proposed.

3.1. Establish the self-learning template library
To reduce the miss ratio, this paper synthesizes characteristics of many templates into a standard template and establishes the self-learning template, other than using a single template. The principle:
1) Store some images which are qualified but have certain differences from each other;
2) Establish limits of tolerance according to the characteristics of images;
3) So if the characteristics of detected images are in the tolerance range, the image matching is successful. Otherwise, the matching is failed.

The key point of a standard template is to establish limits of tolerance. Here the process of mathematical modelling is introduced. In order to guarantee the accuracy, images in the template library will be divided into small area, which is 100 × 100. And each small area does a projection in the vector direction. Then select the maximum and minimum values of projection in the vector direction which is the same small area in each image. Set up the maximum and minimum value curves in the vector direction. So a tolerance range is established according to the two curves. The model of every small area is described as follow:

\[
\begin{align*}
    f_{m,\text{max}}(\gamma) &= \max_{1 \leq k \leq n} \left[ g_{m,k}(\gamma) \right] \\
    f_{m,\text{min}}(\gamma) &= \min_{1 \leq k \leq n} \left[ g_{m,k}(\gamma) \right]
\end{align*}
\]

(1)

where \( f_{m,\text{max}}(\gamma) \) and \( f_{m,\text{min}}(\gamma) \) are the maximum and minimum value curves in the vector \( \gamma \) direction respectively, and \( m \) is the small area number, and \( n \) is the number of templates in the template library, and \( g_{m,k}(\gamma) \) is the grey value of \( \gamma \) point, and \( k \) is the image template number.

In order to reach the goal of self-learning, select a few qualified images and add to the template library after a certain detected images. Then adjust the established tolerance range according to the characteristics of the added image. Also the standard template in the library is adjusted.

3.2. The improved SSDA with adaptive threshold
The traditional SSDA through calculating the error value between matching image and template gets the match points. First set a threshold. Then calculate the corresponding point error point by point. When the cumulative value exceeds the threshold, stop accumulating, and record the cumulative number. The accumulative error calculation formula is shown as follow:

\[
E(\gamma) = \sum_{m=1}^{M} \sum_{n=1}^{N} |S^\gamma(m, n) - T(m, n)|
\]

(2)

where \( S^\gamma(m, n) \) is the grey value of \( \gamma \) point in real-time images, \( T(m, n) \) is the grey value of the standard template, \( m \times n \) is the divided small area.

As the traditional SSDA adopts fixed threshold, there are a vast number of calculations on the non-matching points. So the efficiency of the algorithm is low. The threshold of the improved SSDA is adaptive and not fixed which will discard the non-matching points with less calculation. And the matching point needs more error accumulation to reach the threshold. The implementation method:
1) Take the tolerance range of the standard template as the initial threshold;
2) Calculate error accumulated value of each image;
3) If the error accumulation value of subsequent points is greater than or equal to the threshold, the threshold remains the same; otherwise, reset the threshold according to the formula 3. So image matching related calculations are accomplished in the process of continuously adjusting the threshold.

$$\text{TH}(\gamma) = K\Delta \varepsilon + V(m, n)$$

(3)

where \( \text{TH}(\gamma) \) is the threshold of \( \gamma \) point, \( K \) is the scaling factor, \( \Delta \varepsilon \) is the error accumulated value, \( V(m, n) \) is the tolerance range of the small area \( m \times n \).

The curves of accumulative error of the improved SSDA are shown in figure 2. A is non-matching point, and B is matching point. Compared with the traditional algorithm, the amount of calculations on non-matching points is reduced. Therefore, the matching speed of the improved SSDA with threshold self-adjusting is faster.

![Figure 2 Curves of accumulative error of the improved SSDA.](image)

3.3. The novel algorithm of self-learning fast template matching based on SSDA with self-adjusting threshold

Based on the previous discussion, the novel algorithm of self-learning fast template matching based on SSDA with self-adjusting threshold is shown in figure 3.

It mainly includes the flow of self-learning template built and the process of template matching. Firstly, a self-learning template library is established in the algorithm. And record the number of smart electricity meter in the process of detection. If quantity is more than 100, choose a real-time qualified image to the self-learning template library. And adjust the established tolerance range according to the characteristics of the added image. Also the standard template in the library is adjusted. Secondly, adopt the improved algorithm of SSDA with threshold self-adjusting. As the threshold is adaptive and not fixed which will discard the non-matching points with less calculation, it improves the matching efficiency. Finally, take the real-time online image to match the standard template. And the match result is disposed accordingly.
Select more qualified and petty different images
Pre-process the real-time image S
Synthesize characteristics of many templates into a standard template T
Call the standard template, and match the real-time image
Call the improved algorithm of SSDA with threshold self-adjusting
Save the matching results
Whether to end?
\( Y \)
\( N \)
Take one qualified image added into the template library, \( N = 0 \)
Adjust the limits of tolerance and the standard template
Continue to collect real-time images S, \( N = N + 1 \)
End

**Figure 3** The algorithm of self-learning fast template matching based on SSDA with self-adjusting threshold

### 4. Experimental results

To examine the efficiency of the novel quality test method of electricity meter LCD screen, it was compared to the traditional SSDA and the Image segmentation techniques and LCD localization algorithm (IST-LLA). Different strategies were employed to accelerate template matching in these algorithm respectively. All the compared algorithms had been implemented in an industrial computer with Windows XP.

**4.1. Matching accuracy and processing time**

Twenty thousand images of smart electricity meters were taken at the production floor. The execution time and missing ratio for the proposed algorithm, the traditional SSDA and the Image segmentation techniques and LCD localization algorithm are shown in table 1.

| Algorithm      | Time(s) | Correct Decisions | Incorrect Decisions | Missing Ratio |
|----------------|---------|-------------------|---------------------|---------------|
| Proposed Algorithm | 0.057   | 19954             | 46                  | 0.0023        |
| Traditional SSDA   | 0.579   | 19906             | 94                  | 0.0047        |
| IST-LLA            | 0.137   | 19572             | 428                 | 0.0214        |
According to the experimental results, the average time of the matching algorithm spent is less than 0.06 seconds and the missing ratio is lower. It shows that the proposed matching algorithm greatly improves the speed of template matching without any lower accuracy. The method discards the non-matching points with less calculation, which improves the matching efficiency.

4.2. Matching robustness
The experiments on the standard template library and on matching between the template and the tested sample are added. The qualified smart electricity meter and its matching picture of LCD screen testing are shown in figure 4 and figure 5. The matching successful characters are marked with green boxes. As shown in figure 5, the matching accuracy is very high.

![Figure 4](image1.png) The qualified LCD screen.

![Figure 5](image2.png) The matching picture.

![Figure 6](image3.png) The meter with missing code.

![Figure 7](image4.png) Matching picture with missing code.

The electricity meter with missing code and its matching picture of testing are shown in figure 6 and figure 7. The number “8” is missing and the LCD screen is unqualified. The test method works well and the missing “8” with red box is shown in figure 7.

![Figure 8](image5.png) The qualified smart meter with dust.

![Figure 9](image6.png) The matching picture with dust.

The qualified smart electricity meter with dust and its matching picture of detection are shown in figure 8 and figure 9. Even though there are dusts on the LCD screen, the characters are matching successful, which shows that the method has good robustness. In the new method, the standard template can be adjusted through continuous learning. Besides, image grey value varies with the outside conditions, such as light, dust in the air and so on. But the new method can overcome it and reduce misjudgement rate effectively.
The smart electricity meter with cracks and its matching picture of detection are shown in figure 10 and figure 11. The characters are matching unsuccessful as shown in figure 11. The method can detect unqualified electricity meter and it works well.

Figure 10 The qualified smart meter with cracks. Figure 11 The matching picture with cracks.

5. Conclusion
A novel quality test method of smart electricity meter LCD screen is proposed in this paper, in order to realize the function of on-line detection and solve the problem of incorrect detection. First it synthesizes characteristics of many templates into a standard template and establishes the self-learning template, other than using a single template. Then it improves the SSDA and reduces lots of calculations on non-matching points which dramatically increases matching speed. Finally, the experimental results show that the new method not only has high detection efficiency and matching accuracy, and low missing ratio, but also has great application value of engineering for the LCD manufacturers, smart electricity meter manufacturers and meter testing organizations.

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