

Study on Intelligent Image Recognition of Non-linear Short Pointer SF6 Meter Readings

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Abstract. Currently widely used SF6 inflatable equipment pressure gauge are short pointer and the pointer is not connected to the center of the dial (non-linear pointer), The position of the hands on this dial cannot be identified using traditional computer vision techniques. In order to solve the problem, This paper proposes a method for SF6 pressure gauge pointer and reading recognition based on digital image processing and Mask-RCNN neural network image segmentation technology. The method first pre-processes the SF6 pressure gauge image and Canny edge detection, while using Mask-RCNN network to extract the pointer feature information and scale feature information, and uses the SF6 pressure gauge pointer feature and scale feature to calculate the pressure gauge reading. The effectiveness of the algorithm is verified through the scale identification of 180 short pointer SF6 pressure meters actually operated in a 220kV substation with 100% accuracy.

1 Introduction

Due to the characteristics of SF6 pointer meter such as waterproof, anti-electromagnetic interference and oil resistance, the meter is widely used in substations. At present, most of the reading recognition for the pointer meter is judged by human eyes. The use of human eye judgment and manual recording will cause inefficiency, inaccurate reading data and other problems. Moreover, the widely used SF6 gas-filled equipment pressure gauges are short and the pointer is not connected to the center of the dial (non-linear pointer), and the pointer position of such dials cannot be identified by traditional computer vision techniques.[1-2]

To address the above problems, this paper proposes a digital image processing and Mask-RCNN neural network-based pointer reading recognition method for short pointer SF6 pressure gauges, which performs image pre-processing such as image filtering, image RGB binarization and Canny edge detection on the captured SF6 pointer gauge images, and uses Mask-RCNN network to segment the processed images in The pointer feature information and the scale dial feature information are used to obtain the meter pointer reading by angle calculation. The method overcomes the influence of SF6 pressure instrument level line interference, the pointer is too short and not connected to the center of

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the dial, and other factors that are unfavorable to the recognition of the reading, and achieves the accurate recognition of the pointer and the reading of this type of instrument.

The method is tested in a 220kV substation for 350 SF6 pressure gauges (180 of them are non-linear pointer) of bus bar, and the recognition accuracy reaches 100%, which successfully solves the problem that the scale readings of such gauges cannot be recognized at present.

The problem that the scale reading of this type of instrument cannot be identified has been successfully solved.

2 SF6 pressure gauge image pre-processing

The main evaluation criteria of Canny edge detection algorithm are to identify as many actual edges as possible and reduce false alarms generated by noise, and the identified edges are as close as possible to the actual edges of the image. The image to be recognized is obtained after Canny edge detection of the image, which improves the efficiency and accuracy of the neural network for pointer recognition.

2.1 Canny edge detection method

Before using Canny algorithm to do edge detection on the original image of SF6 pressure gauge, median filtering is needed to remove the noise in the image to make the edge details of the pressure gauge more obvious and improve the edge recognition rate of the pressure gauge dial, scale and pointer. And the image is binarized to separate the target to be recognized from the background in the SF6 pressure gauge image, so as to reduce the influence of irrelevant factors and background in the image on the recognition of gauge pointer, scale and reading. the steps of Canny edge detection algorithm include four steps of noise elimination, gradient amplitude and direction calculation, non-extreme value suppression and hysteresis threshold, as shown in figure 1.

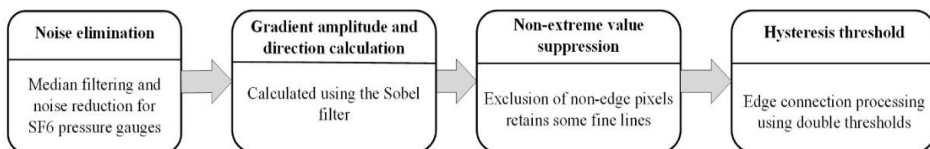


Fig. 1. Canny edge detection processing flow.

2.2 SF6 pressure gauge canny edge detection example

In this study, the median filtering process of the original image of the SF6 pressure instrument was performed by setting the filter matrix size respectively, Canny double thresholding using a high to low threshold ratio of 3:1, set to Min,Max(30, 90), Min,Max(40, 120), Min,Max(50, 150) and Min,Max(60, 180) respectively for image The effect is obtained from the edge detection test, as shown in figure 2.

From the experimental analysis, it can be obtained that according to the Canny edge detection evaluation criteria, the median filter matrix size is, the minimum threshold of Canny algorithm double threshold is 50, the maximum threshold is 150 when the SF6 pressure instrument image processing image dial outline is clear, the scale and pointer are clear outline, to achieve as much as possible to identify the actual edge and reduce the false alarm generated by noise, the edge of the logo and the image The goal is to identify as

many actual edges as possible and reduce the false alarm caused by noise, and the identified edges are as close as possible to the actual edges.

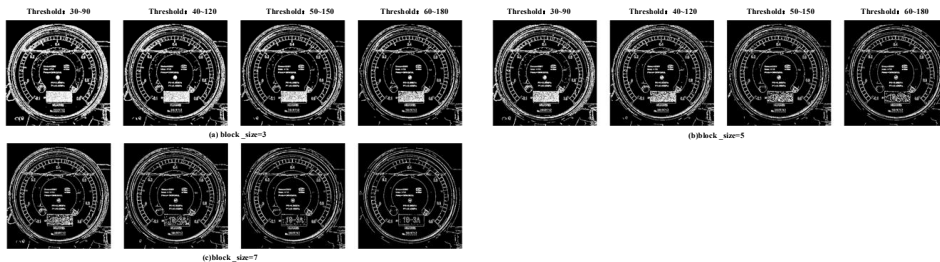


Fig. 2. Comparative analysis of median filtering effect of SF6 pressure instrument.

3 SF6 pressure gauge pointer characteristics identification

3.1 Mask-RCNN Artificial Neural Network

The Mask-RCNN is used to extract and identify SF6 pressure gauge pointer features. The Mask R-CNN network structure includes Mask branches that employ layers that are independent of the quantization results. The fully connected network acting on each RoIAlign region predicts the segmentation mask in a pixel-to-pixel manner for semantic prediction and segmentation of binary classification. Target detection and image segmentation are done simultaneously in the target region, and the bypass branch can be executed in parallel with the prediction branch for classification and target detection frame regression. [3-4] Advantages of Mask-RCNN for SF6 meter pointer feature extraction:

- Mask-RCNN is a high-speed and high-accuracy network by using ROIAlign strategy and MASK, which makes it more accurate in segmenting SF6 dial scale features and short pointers.
- The algorithm is scalable and easy to use. It is flexible and can be used to accomplish a variety of tasks, including meter classification, target detection, and pointer instance segmentation.
- The Mask R-CNN network processing preserves the accurate pixel and spatial location of SF6 images, and can improve the output accuracy of the Mask layer of the network by 10% to 50%.

Mask-RCNN adds a bypass branch network to the Faster-RCNN. It can achieve segmentation of pressure gauge pointer from the original image, reduce the difficulty of pointer recognition and improve the accuracy. A simple schematic diagram for instance segmentation is shown in figure 3.

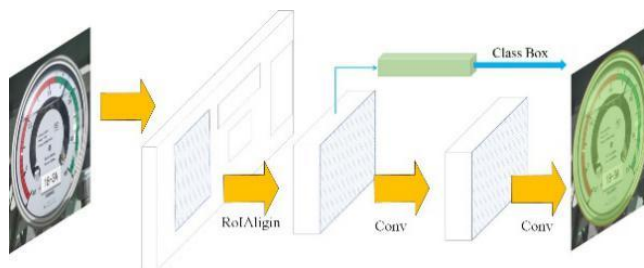


Fig. 3. Mask-RCNN framework based on target segmentation.

3.2 SF6 pressure gauge pointer identification example

In order to speed up the convergence speed of training and solve the problem of small sample size of training set, this paper adopts the ResNet50_vd training model obtained by ImageNet dataset training as the initial model for the experiments in this paper, and carries out migration learning on the basis of this model to obtain the SF6 pressure gauge pointer recognition model.

In the training and recognition process of the Mask-RCNN SF6 pressure gauge pointer recognition model, the Mask network gets the set of Mask pixels that meet the threshold requirements and the classification labels and confidence levels of the FC layer output; the average of the confidence levels of the three channel FC layer outputs is obtained, and the feature information such as the position, length, and width of the pointer at the maximum confidence level is obtained according to the Mask network. The training and recognition flow chart, as shown in figure 4.

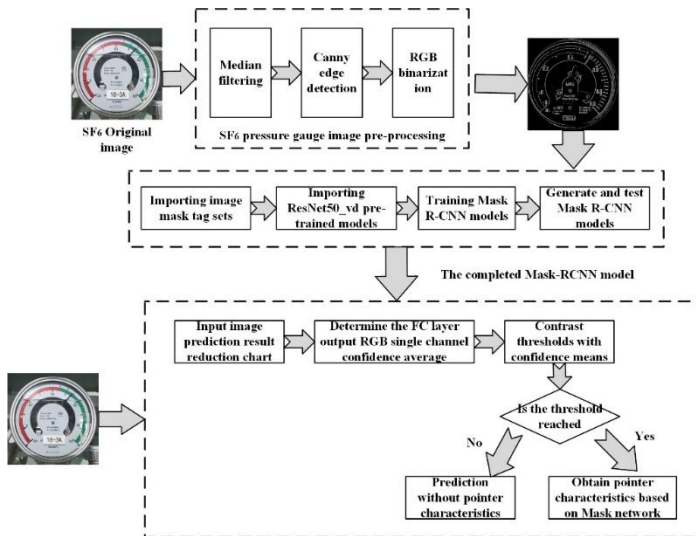


Fig. 4. Network model training and SF6 pointer image recognition flow chart.

We use the traditional Faster-RCNN and Mask-RCNN to perform recognition experiments on SF6 meter pointers respectively. The training dataset is 5000 SF6 meter images, the batch_size is 5, the initial learning rate is 0.2, and the number of iterations is 30. The Faster-RCNN and Mask-RCNN models were finally obtained and calibrated for testing. the accuracy and loss function change curves during the training of Mask-RCNN are shown in figure 5.

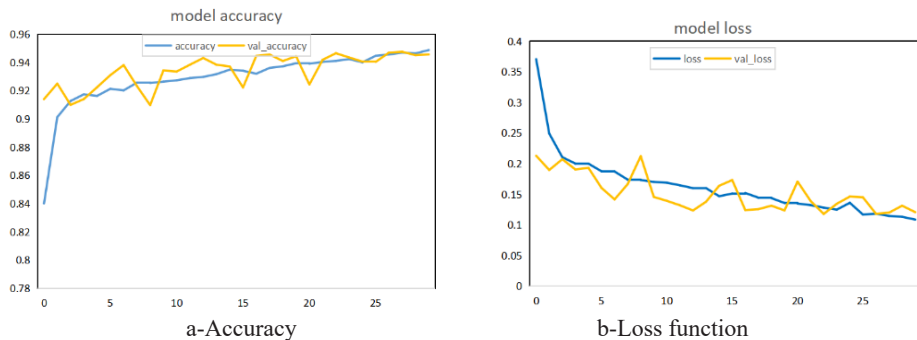


Fig. 5. Mask-RCNN Accuracy and Loss Function.

The accuracy and loss function variation curves during Faster-RCNN training are shown in figure 6.

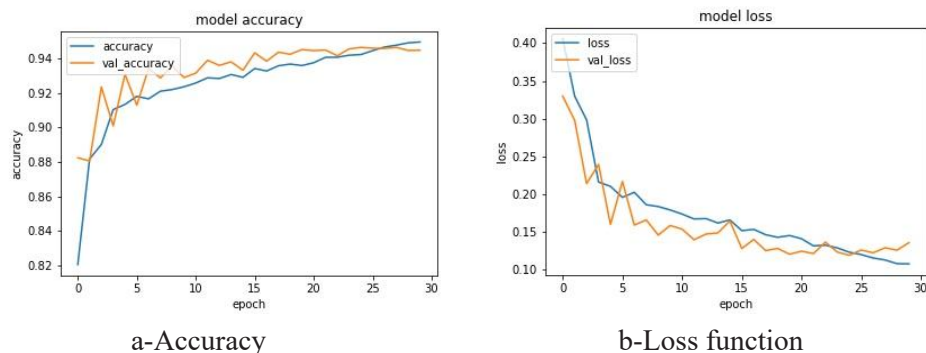


Fig. 6. Faster-RCNN Accuracy and Loss Function.

After experimental tests, the recognition accuracy of Faster-RCNN and Mask-RCNN is summarized, as shown in Table 1.

Table 1. Comparison table of recognition accuracy between Faster-RCNN and Mask-RCNN

Algorithm	Accuracy(%)	Calibration Accuracy(%)	Training time(s)
Faster-RCNN	65.8	63.6	86,406
Methodology of this article	98.7	97.8	66,422

From the above experimental data analysis, it can be concluded that Faster-RCNN has a certain gap with Mask-RCNN in terms of accuracy and training speed. the Mask-RCNN network model is more suitable for SF6 gauge pointer recognition application scenario.

The results of SF6 pressure gauge recognition using Mask-RCNN network are shown in figure 7.

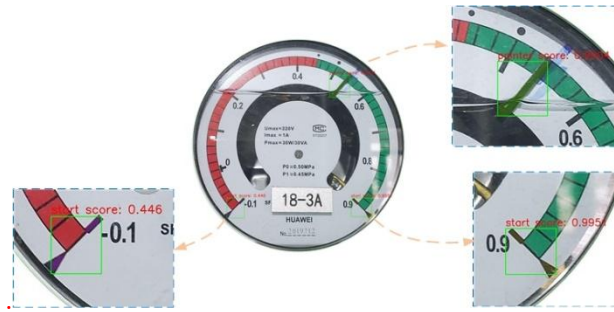


Fig. 7. Mask-RCNN Sulfur hexafluoride pressure gauge pointer split

From Figure 7, the dark green and purple parts are the Mask pixel regions predicted by the network, and the green boxes are the corresponding bounding box regions. The confidence level of meter pointer recognition is 0.9, and the confidence level of scale end mark recognition is 0.99. Thus, it can be concluded that the network model based on Mask R-CNN has high accuracy and effectiveness when applied to the recognition of sulfur hexafluoride meter pointer.

4 Pointer scale calculation

The SF6 meter pointer recognition is performed using the network obtained from 2.2 training completion, and the meter recognition result image is obtained, and the result image is processed by OpenCV to obtain the meter center coordinates, pointer Mask pixel region center point coordinates, meter scale start Mask pixel region center coordinates, meter scale end Mask pixel region center coordinates, and draw the horizontal line through the center of the circle, vertical line, the straight line from the pointer Mask pixel region to the center of the circle, the straight line from the scale start Mask pixel region to the center of the circle, and the straight line from the scale end Mask pixel region to the center of the circle, as shown in figure 8.



Fig. 8. Pointer scale calculation.

In Figure 8, according to the fitted straight line, the angle between the pointer straight line and the horizontal can be calculated by summing the coordinates of the two endpoints of the pointer Mask pixel region to the circle center straight line, where is the meter circle center coordinates, which can be obtained by the Hoff circle detection method. The contour information can be extracted from the contour information obtained by processing the bounding box area through the edge detection method. The contour information of the bounding box area image contains the center point coordinate information of the rectangular shape, the height and width information and the rotation angle information. The

angle between the instrument pointer and the horizontal line is calculated as shown in equation (1). [5]

$$\theta = \tan^{-1} \left| \frac{y_1 - y_0}{x_1 - x_0} \right| \times \frac{180}{\pi} \tag{1}$$

Calculated from Figure 6 $\theta=53^\circ$. Similarly, one can calculate $\varphi_1=40^\circ$, $\varphi_2=40$.

Based on the calculated angle θ , φ_1 and φ_2 , Summarize the formula to calculate the SF6 pressure gauge pointer reading, as shown in equation (2).

$$M = \min R + \frac{\max R - \min R}{180 + \varphi_1 + \varphi_2} \times (180 - \theta + \varphi_1) \tag{2}$$

In the formula, M is the pointer reading, $\min R$ is the instrument dial start scale value, $\max R$ is the instrument dial maximum scale value, θ is the angle between the pointer and the circle center line and the horizontal line, φ_1 is the angle between the start scale and the circle center line and the horizontal line, φ_2 is the angle between the maximum scale and the circle center line and the horizontal line.

Calculated according to equation (1) obtained from θ , φ_1 and φ_2 and equation (2), Calculate the sulphur hexafluoride pressure gauge pointer readings as described below:

$$M = -0.1 + \frac{0.9 - (-0.1)}{180 + 40 + 40} \times (180 - 53 + 40) \approx 0.5423 \tag{3}$$

Through the calculation can be obtained at this time the sulfur hexafluoride instrument pointer reading is about 0.5423, compared with the picture instrument actual pointer indication, the accuracy of 100%.

From the above experimental results, it can be seen that the algorithm proposed in this paper can identify the indication of the meter pointed by the pointer more accurately, and then can determine whether the pointer is in the red area indicating the lack of gas. At the same time, this algorithm has a small error rate, simple process implementation and good visual effect, which is very suitable for practical application.

In a 220kV substation, 350 SF6 pressure gauges (180 of which are non-linear pointer gauges) of busbar cutters were tested for reading recognition, and the recognition accuracy rate reached 100%, which successfully solved the current problem that the scale readings of such gauges could not be recognized.

5 Conclusion

(1) Image pre-processing such as image filtering, image RGB binarization and Canny edge detection are performed on the SF6 pointer meter image by using digital image processing technology to make both the scale and pointer contours clearer, reduce noise and reduce the influence of complex environment.

(2) Mask-RCNN neural network is used to segment the pointer feature information and the scale feature information, and by using the pointer feature information and the minimum scale and maximum scale feature information of the dial, the angle calculation is carried out, and finally the meter pointer reading is obtained with an accuracy of 100%.

(3) The proposed method in this paper has the characteristics of high real-time, high efficiency and low cost, and the recognition rate can be maintained at 100% even in complex environments such as when the pointer is relatively short, when the pointer is not directly connected to the center of the meter, and when it is affected by the level line.

(4) Through the reading recognition test of 350 SF6 pressure gauges in a 220kV substation bus bar, the results show that the proposed method can accurately recognize the

readings of 180 non-linear pointer pressure gauges, and the recognition accuracy rate reaches 100%.

(5) The proposed method of using Mask-RCNN is very effective for the scale and reading recognition of SF6 pressure gauge images.

References

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