

## Insulator Recognition Based on Moments Invariant Features and Cascade AdaBoost Classifier

Siyuan He<sup>1, 2, 3, a</sup>, Ling Wang<sup>4, b</sup>, Yong Xia<sup>4, c</sup> and Yandong Tang<sup>1, d\*</sup>

<sup>1</sup>State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang, Liaoning, 110016, China

<sup>2</sup>University of Chinese Academy of Sciences, Beijing, 100049, China

<sup>3</sup>School of Automation, Shenyang Institute of Engineering, Shenyang, Liaoning, 110136, China

<sup>4</sup>Benxi Power Supply Company, Liaoning Electric Power Company Limited, Benxi, Liaoning, 117000, China

<sup>a</sup>hesiyuan@sia.cn, <sup>b</sup>bxwl\_650928@126.com, <sup>c</sup>sum18@163.com, <sup>d</sup>ytang@sia.cn

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**Abstract.** A method based on moments invariant features and cascade AdaBoost classifier for insulator recognition is put forward to solve the problem of poor performance of insulator recognition. At first, the insulator image is preprocessed by median filtering, dilating, eroding and Otsu thresholding. Then, for the better extraction of moments invariant features, the preprocessed insulator image is tilted correctly based on PCA (Principal Component Analysis). Next, the moments invariant features are extracted and chosen to compose complex classifier in the process of training AdaBoost. Finally, the complex AdaBoost classifiers are combined in a cascade method for insulator recognition. The results of experiments demonstrate that the proposed method can recognize the insulator from complex background in the mountainous area, and it has better robustness, accuracy and validity.

### Introduction

With the development of society, the power demand is larger and larger, and the power industry is facing huge opportunity and challenge. The power transmission line and equipments are often under the attack of rain and wind, and the power transmission system often has the fault, so they must be patrolled for the reliability of power transmission.

Among the power transmission equipments, the insulator is very important for the power transmission system, and it supports and separates electrical conductors without allowing current through itself. Because of the development of extra-high-voltage and ultra-high-voltage power transmission line, a large number of insulators are used. For the reliability of power transmission, the insulator must work well. However, the insulator is frequently broken, for power transmission line is vulnerable to attacks from high wind and hailstone, such as string dropping and fracture. According to statistics, the damaged insulator occupies 81.3% in all fault diagnosis [1]. Therefore, the insulator must be inspected, and it has the profound impact on the safe operation of power transmission line.

Nowadays, manual inspection has been the main way of power transmission line and equipments inspection. However, this method not only expends a mass of human and material resources, but also cannot realize the real-time supervision. In recent years, the use of UAV (Unmanned Aerial Vehicle) for power transmission line and equipments inspection is a hot technology, and it can detect the power transmission line and equipments, and discriminate the failure under no power cut. A lot of research on power transmission line and equipments inspection based on UAV has been carried out. However, the performance of published inspecting method for power transmission line and equipments inspection is not very well, especially the insulator inspection.

In this paper, a method based on moments invariant features and cascade AdaBoost classifier for insulator recognition embedded onto a UAV is proposed, and it is the first step for insulator inspection. The results of experiments demonstrate that the proposed method can recognize the

insulator from complex background in the mountainous area, and it lays the foundation for insulator fault diagnosis.

The rest of this paper is organized as follows. In the next section, the insulator recognition algorithm is described. In Sect. 3, the preprocessing method of insulator is presented. In Sect. 4, the tilt correction method of insulator based on PCA is presented. In Sect. 5, moments invariant features extraction is introduced. In Sect. 6, cascade AdaBoost classifier is introduced. In Sect. 7, experiment results and analysis are presented. Finally, Sect. 8 concludes this paper with some remarks.

### Insulator Recognition Algorithm

Insulator recognition process is divided into two steps as follows. The first step is to determine the coarse location of insulator, and that is searching for the insulator candidate region from the input image. The second step is to recognize the insulator, and that is to determine whether the insulator exists in the candidate region.

#### Insulator Coarse Location Algorithm.

The insulator coarse location algorithm and some experiment results are shown in Fig. 1. At first, the power transmission tower is detected from the input image using the method which is proposed in [2], and marked with a bounding box. Then, the power transmission lines are detected in the left and right regions of the power transmission tower using the method which is proposed in [3]. Finally, the insulator candidate regions are marked with bounding boxes, according to the collinearity of insulator and power transmission line, and the location of insulator next to the power transmission tower.

The power transmission tower detection method is as follows. At first, the linear object is extracted from the input image using LSD (Line Segment Detector) method [4]. Then, the position of power transmission tower is detected using the statistical projection method.

The power transmission line detection method is as follows. At first, according to the eigenvector direction of Hessian matrix, the direction of linear object is extracted from the input image. Then, the point of approximate eigenvector direction is extracted to compose the line segment using the region growing method. Finally, the linear object is extracted from these line segments using the statistical method to make the line segment most and longest along the linear object, and the power transmission line is detected.

#### Insulator Recognition Algorithm.

The insulator recognition algorithm is shown in Fig. 2, and it is divided into training process and recognition process. In the training process, the insulator sample image and non-insulator sample image are preprocessed by median filtering, dilating, eroding and Otsu thresholding. Then, the sample image is tilted correctly based on PCA. Next, the moments invariant features are extracted and chosen to compose complex classifier. Finally, the complex AdaBoost classifiers are combined in a cascade method for insulator recognition. In the recognition process, the image of insulator candidate region is processed as the procedure of training process, and then, recognized by the complex AdaBoost classifiers.

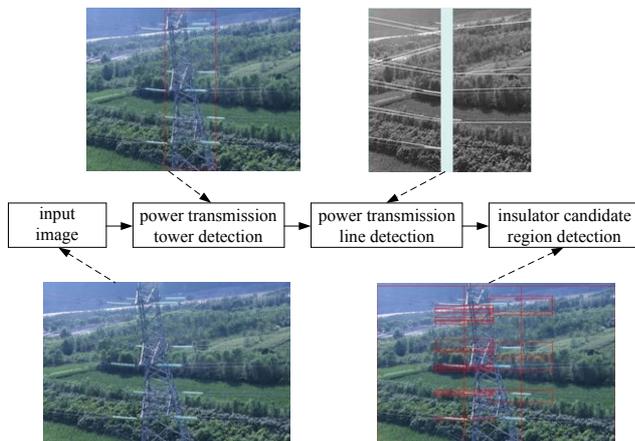


Fig. 1 Insulator coarse location algorithm flowchart

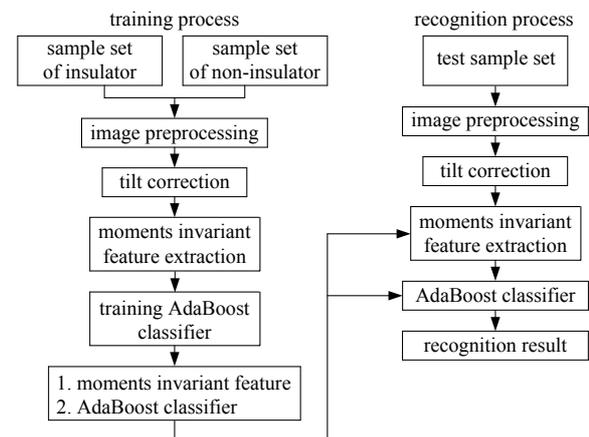


Fig. 2 Insulator recognition algorithm flowchart

### Image Preprocessing

The insulator image which is acquired by UAV is not very well, and its quality degenerates. In order to improve the accuracy of recognition and reduce the amount of computation, the insulator image is processed by median filtering, dilating, eroding and graying [5]. As shown in Fig. 3 (a), it reduces the noise interference, smooths the highlight point, and the difference among the pixel values is reduced. For the better extraction of moments invariant features, the gray image is converted into the binary image with Otsu algorithm. The binary image is shown in Fig. 3 (b).



Fig. 3 Preprocessed images

### Tilt Correction

As shown in Fig. 1, a tilt angle exists between insulator main direction and horizontal direction, and this has negative effect on the extraction of moments invariant features. In this paper, PCA is used to tilt the insulator correctly. This method rotates the initial coordinate to the main direction of the target by coordinate transformation, and maximizes the variance of projection onto the main direction [6]. The specific steps are as follows.

(a) Establish the matrix of insulator image.

The number of pixel which value is 1 in the insulator image is  $N$ , and the binary image of insulator can be represented by matrix  $A_{2 \times N}$ .

(b) Centralize the matrix of insulator image.

Transform each row of the matrix  $A_{2 \times N}$  from  $a = [x_i, y_i]^T$  to  $a' = [x_i - \bar{x}, y_i - \bar{y}]^T$ . Where  $[\bar{x}, \bar{y}]^T$  is the mean vector of  $A_{2 \times N}$ , and that is the central coordinate value of insulator image. The standard matrix of  $A_{2 \times N}$  is  $\bar{A}$ .

(c) Solve the covariance matrix  $C_A$ .

$C_A = \bar{A}\bar{A}^T / N$ . Where  $C_A$  is the  $2 \times 2$  matrix.

(d) Solve the eigenvalues ( $\lambda_1, \lambda_2$ ) and eigenvectors ( $\xi_1, \xi_2$ ) of  $C_A$ .

If  $\lambda_1 > \lambda_2$ ,  $Q = [\xi_1, \xi_2]$ .

If  $\lambda_1 < \lambda_2$ ,  $Q = [\xi_2, \xi_1]$ .

(e) Transform the coordinate.

$B_{2 \times N} = Q^T A_{2 \times N}$ , and create a binary image with  $B_{2 \times N}$ .

### Feature Extraction

Because the distance between camera and insulator is changed in the use of UAV for power transmission line inspection, the insulator in the image is different, such as the position, direction and size. Therefore, the chosen feature must have the characteristics of invariance in translation, rotation and scale. Invariant moments have the characteristics mentioned above, so moments invariant features are extracted for insulator recognition [7].

#### Basic Theory of Invariant Moments.

(a) Origin moment

The origin moment is defined as:

$$m_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x^p y^q \rho(x, y) dx dy \quad p, q = 0, 1, 2, \dots \quad (1)$$

Where  $\rho(x, y)$  is the continuous distribution function.

## (b) Central moment

The central moment is defined as:

$$u_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} (x - \bar{x})^p (y - \bar{y})^q \rho(x, y) d(x - \bar{x}) d(y - \bar{y}) \quad (2)$$

Where  $\bar{x} = m_{10} / m_{00}$ ,  $\bar{y} = m_{01} / m_{00}$ .

## (c) Moment invariant

The moment invariant is defined as:

$$M(u, v) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \exp(ux + vy) \rho(x, y) dx dy \quad (3)$$

## (d) Image moment invariant

The image is a discrete function, so the definition of image moment invariant is a little different from the above.

The image origin moment is defined as:

$$m_{pq} = \sum_x \sum_y x^p y^q f(x, y) \quad p, q = 0, 1, 2, \dots \quad (4)$$

Where  $f(x, y)$  is the discrete distribution function.

The image central moment is defined as:

$$u_{pq} = \sum_x \sum_y (x - \bar{x})^p (y - \bar{y})^q f(x, y) \quad (5)$$

Where  $\bar{x} = m_{10} / m_{00}$ ,  $\bar{y} = m_{01} / m_{00}$ .

The image normalized central moment is represented as:

$$\eta_{pq} = \frac{u_{pq}}{u_{00}^\gamma} \quad (6)$$

Where  $\gamma = \frac{p+q}{2} + 1$ ,  $p+q = 2, 3, \dots$ .

**Hu Invariant Moments.**

Using the image normalized central moment, Hu invariant moment is defined as:

$$h_1 = \eta_{20} + \eta_{02} \quad (7)$$

$$h_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2 \quad (8)$$

$$h_3 = (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} + \eta_{03})^2 \quad (9)$$

$$h_4 = (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2 \quad (10)$$

$$h_5 = (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{12} + \eta_{03})^2] + (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{12} + \eta_{03})^2] \quad (11)$$

$$h_6 = (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}) \quad (12)$$

$$h_7 = (3\eta_{12} - \eta_{30})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + (3\eta_{11} - \eta_{03})(\eta_{30} + \eta_{03})[3(\eta_{03} + \eta_{12})^2 - (\eta_{12} + \eta_{03})^2] \quad (13)$$

In the insulator recognition, Hu invariant moments are extracted as features, and chosen to compose complex classifier.

**Cascade AdaBoost Classifier**

In the power transmission line inspection, the insulator recognition can be considered as two-class object recognition. One is the insulator class, and the other is the non-insulator class. Therefore, machine learning method can be used to recognize the insulator. In 1996, Freund and Schapire proposed the AdaBoost algorithm, and they used it in the face detection [8]. In 2001, Viola and Jones proposed the concept of integral graph and cascade classifier based on the AdaBoost algorithm, and they made face detection achieve real time at high detection rate, and promoted the face detection technology greatly [9].

In this paper, cascade AdaBoost classifier which was proposed by Viola and Jones are chosen to recognize the insulator. In cascade AdaBoost classifier, each classifier is trained by AdaBoost algorithm. If the sample is recognized as the positive sample by the previous classifier, it can be put

into the next classifier. If not, it is recognized as the negative sample and output directly. The sample output by the last classifier is the positive sample recognized by each classifier. The scheme is shown in Fig. 4.

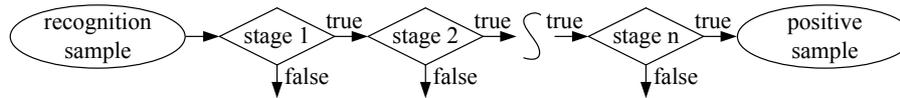


Fig. 4 Schematic of cascade AdaBoost classifier

### Experiment Results and Analysis

In the experiment, the number of training sample set is 1887 including 669 insulator samples and 1218 non-insulator samples, and the number of test sample set is 80. The non-insulator samples include power transmission line, vibration damper, power transmission tower, and so on. The number of insulator in each test sample is unknown. The background of sample is the mountainous area. In the acquisition of insulator image, the power transmission tower is detected using the method which is proposed in [2], and then high definition camera is used to take the photo of insulator. Besides, if UAV comes across the weak air current during image acquisition, the system of stability of aerial camera platform can compensate the shake.

In the training process, the number of convergence level is 15. In the recognition process, 467 insulators are recognized in 80 test samples, 38 insulators are missed, and 7 non-insulators are recognized as insulator. The recognition result is shown in Fig. 5. The true positive rate  $t_P$  and the false recognition rate  $f_R$  are as follows [10].

$$t_P = \frac{n_{TP}}{n_{TP} + n_{FN}} = \frac{467}{467 + 38} = 0.92475$$

$$f_R = \frac{n_{FP}}{n_{TP} + n_{FP}} = \frac{7}{467 + 7} = 0.01477$$

Where  $n_{TP}$  is the number of insulator when it is the insulator,  $n_{FN}$  is the number of non-insulator when it is the insulator, and  $n_{FP}$  is the number of insulator when it is the non-insulator.

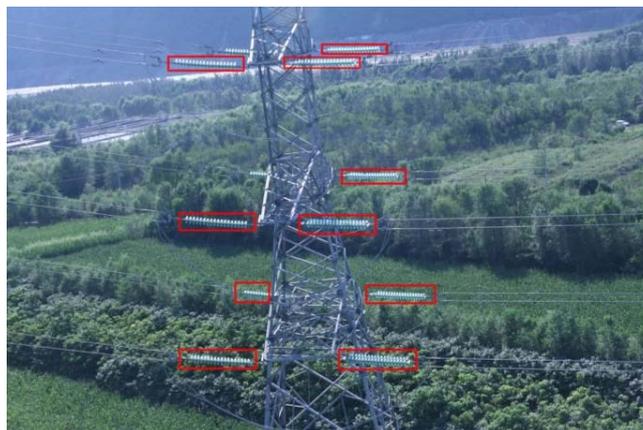


Fig. 5 Illustration of recognition result

The experiment results show that the true positive rate is 92.475% and the false recognition rate is 1.477%, and the results satisfy the application requirement. The main reasons for missed recognition and false recognition are as follows.

(a) Some power transmission line is not detected accurately, this causes the wrong candidate region of insulator, and leads to the missed recognition or false recognition.

(b) Some insulator candidate region is large, this improves the complexity of candidate region of insulator, and leads to the missed recognition or false recognition.

(c) The background of some insulator is so complex, and this improves the rate of missed recognition and false recognition.

## Conclusions

A method based on moments invariant features and cascade AdaBoost classifier for insulator recognition is put forward to solve the problem of poor performance of insulator recognition. The results of experiments demonstrate that the proposed method can recognize the insulator from complex background in the mountainous area, and it has better robustness, accuracy and validity.

In the future work, the insulator recognition algorithm will be improved in order to improve the insulator detection rate and reduce execution time, and ultimately to achieve the insulator inspection and fault diagnosis using a real UAV.

## Acknowledgement

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## References

- [1] Y. Liu, Z.D. Qian and K.Q. Xia, "Transient Response of High Voltage Transmission Lines with Drum Type Towers Based on Insulator Rupture", *Journal of Vibration Engineering*, Vol. 22, No. 1, pp. 6-12, 2009 (In Chinese).
- [2] S.Y. He, L. Lin and Y.D. Tang, "The Research of Power Transmission Tower Detection Method Based on UAV", *Chinese Journal of Scientific Instrument*, Vol. 33, No. 8, pp. 270-275, 2012 (In Chinese).
- [3] W.T. Li, H.J. Fan and Y.D. Tang, "Detection Algorithm of High-Voltage Line Based on Hessian Matrix", *Chinese Journal of Scientific Instrument*, Vol. 33, No. 8, pp. 243-246, 2012 (In Chinese).
- [4] Rafael Grompone von Gioi, Jérémie Jakubowicz and Jean-Michel Morel, "LSD: A Fast Line Segment Detector with a False Detection Control", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 32, No. 4, pp. 722-732, 2010.
- [5] J. Zhao and C. Feng, "Moving Object Detection and Segmentation Based on Adaptive Frame Difference and Level Set", *Information and Control*, Vol. 41, No. 2, pp. 153-158, 2012 (In Chinese).
- [6] D.H. Wu and C.H. Zhu, "A Novel License Plate Slant Correction Method Based on Principal Component Analysis", *Journal of Highway and Transportation Research and Development*, Vol. 23, No. 8, pp. 143-146, 2006 (In Chinese).
- [7] G.H. Liu, "Recognition of Porcelain Bottle Crack Based on Modified ART-2 Network and Invariant Moment", *Chinese Journal of Scientific Instrument*, Vol. 30, No. 7, pp. 1420-1425, 2009 (In Chinese).
- [8] Yoav Freund and Robert E. Schapire, "Experiments with a New Boosting Algorithm", In *Proceedings of the 13th Conference on Machine Learning*, pp. 148-156, 1996.
- [9] Paul Viola and Michael Jones, "Rapid Object Detection Using a Boosted Cascade of Simple Features", *International Conference on Computer Vision and Pattern Recognition*, pp. 511-518, 2001.
- [10] X.M. Tao and P.D. Cao, "The Semi-Supervised SVM Classification Algorithm Based on Two-Stage Learning", *Information and Control*, Vol. 41, No. 1, pp. 7-13, 2012 (In Chinese).

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