Electric Equipment Image Recognition Based on Decision Fusion of Multiple Classifiers for Electric Safety

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\textbf{Abstract.} This paper proposes an electric equipment image recognition algorithm based on decision fusion of multiple classifiers. Considering the drawbacks of a single classifier, three classifiers, i.e., K-nearest neighbor (KNN), support vector machine (SVM), and sparse representation-based classification (SRC) are jointly used in the classification stage. The decision values from the three classifiers are linearly combined using a weighting strategy. So, the merits of different classifiers can be fused to enhance the recognition performance. Finally, based on the fused decision values, the object label of the test sample can be decided. To validate the effectiveness of the proposed method, images of three electrical equipments (insulators, power transformers, and breakers) are classified and compared with some other methods.

1. Introduction

Electric equipments play an important role in modern life and it is necessary to maintain that they work smoothly. In this case, it is desired that the working states of these equipments can be checked in time. Electric equipment image recognition provides a good way to achieve such objective, which could recognize the object labels of different electrical equipments through specifically designed algorithms. Previously, some methods were developed in this field [1-5]. In general, the features of the image are first extracted such as geometrical features or projection features. Afterwards, different kinds of classifiers like K-nearest neighbour (KNN), support vector machine (SVM), sparse representation-based classification (SRC), and neural networks (NN) are used to classify these features. Based on the decision values from these classifiers, the object label in an unknown image can be decided.

However, it should be noted that a single classifier could hardly handle all the situations occurred in the real-world scenarios. So, it is promising that the combination of different classifiers could enhance the final recognition performance. In the previous works, decision fusion of multiple classifiers was validated to be notably effective for pattern recognition problems [6-8]. Therefore, this study applies multi-classifier decision fusion to the problem of electrical equipment image recognition. KNN, SVM, and SRC are adopted as the basic classifiers. For a test sample, its features are first extracted by principal component analysis (PCA). Then, the feature vector is input into the three
classifiers simultaneously. The decision values from the three classifiers (e.g., distances, probabilities, and reconstruction errors) are fused via linear weights. Finally, based on the fused decision values, the object label of the unknown test sample can be decided. Experiments are conducted based on images of three electrical equipments (insulators, power transformers, and breakers). And the results validate the effectiveness of the proposed method.

2. Method Description

2.1 Basics of Different Classifiers

This study chooses KNN, SVM, and SRC as the basic classifiers for the following decision fusion. KNN is a classic classifier by modifying the conventional nearest neighbour. The KNNs of the test sample are first found from all the training samples. Afterwards, these neighbours are analysed to find the best matching for the test sample so the object label can be determined.

SVM is an advanced classifier to minimize the structural risk. Through the training process by all the training samples, some hyperplanes can be parametrized in the high-dimension space, which could separate different kinds of objects. Then, by comparing the test sample to the hyperplanes of different training classes, the object label can be obtained.

SRC is a recently proposed classifier based on the compressive sensing theory. The test sample is first represented over the global dictionary formed by all the training samples. Based on the solved sparse coefficients, the reconstruction errors of different classes can be calculated to decide the object label.

2.2 Multi-classifier Decision Fusion

As analysed in the former subsection, different classifiers have different principles and they have different advantages as for the recognition of electrical equipments. Therefore, this study tends to combines their merits to enhance the recognition performance. Denote the decision values from the three classifiers as \( s_1 \), \( s_2 \), and \( s_3 \), respectively. All the three decision values are pre-processed to share same meanings, such as probabilities. Then, a linear fusion strategy is conducted as follow:

\[
fs(i) = w_1s_1(i) + w_2s_2(i) + w_3s_3(i)
\]

In equation (1), \( w_1, w_2, w_3 \) denotes the corresponding weights of different classifiers. With little prior information, this study assumes \( w_1 = w_2 = w_3 = 1/3 \). Based on the fused decision values, the object label of the test sample can be determined. Specifically, this study uses the probabilities in the fusion, so the class with the maximum fused decision value is the correct object label.

2.3 Recognition Procedure

The proposed method in this paper can be illustrated as Fig. 1 and the detailed implementation steps are as follows:

Step 1: Extract the features of all the training samples by PCA to form the training database for different classifiers;
Step 2: Extract the PCA feature vector of the test sample;
Step 3: Classify the PCA feature vector of the test sample using KNN, SVM, and SRC simultaneously;
Step 4: Fuse the decision values of different classifiers based on equation (1);
Step 5: Determine the object label of the test sample based on the maximum fused decision value.
Fig. 1 Procedure of electric equipment image recognition based on multi-classifier decision fusion.

3. Experiments

3.1 Three Electric Equipments for Recognition
Images of three typical electric equipments (insulators, power transformers, and breakers) are used for experimental validation. For each equipment, there are 2000 real-measured images, among which 1400 are randomly selected for training and the remaining ones are tested. All the images have the sizes of 400 pixels × 400 pixels. Meanwhile, Method 1 from [1], Method 2 from [2], and Method 3 from [3] are simultaneously compared.

3.2 Results and Analysis
First, the proposed method is tested on the three electrical equipments based on the original samples. Table 1 displays the detailed recognition results of the proposed method. Each of the three equipments can be correctly classified with accuracy over 92% and the average recognition rate is 94.67%. Table 2 further compares the average recognition rates of different methods. The proposed method outperforms the remaining ones significantly. According to all these results, the effectiveness of the proposed method can be quantitatively validated.

A further experiment is conducted under noise corruption. By adding different levels of noises in the original test samples, the performance of different methods at different signal-to-noise (SNRs) can be plotted as Fig. 2. As shown, the average recognition rate of the proposed method tops at each noise level so it has the best robust to noise corruption.

Table 1. Recognition results of the proposed method.

| Test samples    | Classification result | Recognition rate (%) |
|-----------------|------------------------|----------------------|
|                 | Insulator | Power transformer | Breaker  |
| Insulator       | 552       | 18                  | 30       | 92.00 |
| Power transformer| 8         | 586                 | 6        | 97.67 |
| Breaker         | 13        | 11                  | 566      | 94.33 |
| Average recognition rate (%) | 94.67 |

Table 2. Performance comparison of different methods.

| Method       | Proposed | Method 1 | Method 2 | Method 3 |
|--------------|----------|----------|----------|----------|
| Average recognition rate (%) | 94.67    | 91.17    | 91.86    | 92.24    |
4. Conclusion
An electrical equipment image recognition method is proposed method via multi-classifier decision fusion. The decision values from KNN, SVM, and SRC are combined using a linear fusion strategy. Based on the fused decision value, a more robust decision can be formed. So, the proposed method could achieve better recognition performance by combining the merits of different classifiers. By testing the proposed method on the images of three typical electrical equipments, its effectiveness and robustness are validated.

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