Feature Extraction Method based on AIC-Fisher Application in Ultrasonic Testing

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Abstract. In ultrasonic testing, the feature extraction of ultrasonic signal is equivalent to defect feature extraction. How to extract the effective signal features is the key to the defect identification. Traditional of ultrasonic signal features (echo time and peak value) insufficient to reflected defects characteristics. Commonly use features extraction and has supervision of discriminant method to optimization signal features. Fisher linear discriminant is to reduce the high-dimensional features to one-dimensional space, and to calculate the feature projection matrix according to the sample point distribution in one dimensional space. But the sample point distribution misclassification rate of one-dimensional feature is not optimal. So paper proposed a feature extraction method based on AIC-Fisher. The dimension of dimensionality reduction and dimensionality reduction are determined by Fisher criterion, sample point distribution error rate and AIC criterion. Then, the optimal feature set is used to quantify the defect depth. Finally, the experimental results show that this method can obtain the effective features, and has a high accuracy in the identification of defect depth.

1. Introduction

Ultrasonic testing is a common method of non-destructive testing. It has the advantages of accurate positioning, high sensitivity and fast response. And it is widely used in industrial, medical, military, agriculture, biotechnology and other fields. Defect detection is one of the main functions of ultrasonic testing. Due to the complex relationship between the ultrasonic signal and the defect reflection surface, it is difficult to find the effective feature in the practical application. Therefore, the feature extraction of the ultrasonic echo is the difficulty of the defect identification [5]. The traditional feature extraction is to extract the signal waveform or energy distribution in time-frequency domain. It cannot fully describe the characteristics of defects, especially it is not aware of the defect characteristics, and cannot directly select the effective signal features. So, many scholars often use multi feature framework to select more common features and combine supervised feature extraction methods. In order to extract the effective features adaptively. Linear discriminant analysis (Fisher) is the most commonly used supervised feature extraction method, but it has the problem of high false recognition rate after dimensionality reduction.

This paper proposed a feature extraction method based on AIC-Fisher, considering the distribution of the sample points of the Fisher linear discriminant, raises each kind of fault sample point error rate as dimensionality reduction index were constructed to determine the number of dimensionality reduction based on dimension reduction model AIC criterion. Finally, the defect depth recognition experiment is designed to verify the effectiveness of feature extraction. This method can obtain the effective defect feature, and has high accuracy in defect recognition. Compared with traditional feature extraction methods such as PCA and ICA, it has a great advantage.
2. Feature Extraction Method Based on AIC-Fisher

Feature extraction based on AIC-Fisher method proposed in this paper, the diagram is as follows:

As shown in Figure 1, proposed a feature extraction method based on AIC-Fisher, which is used in ultrasonic detection of defects depth recognition. Firstly, collecting the ultrasonic flaw signals and the ultrasonic signal is divided and de-noised. Then, the feature extraction and optimization of the processed signal, including three steps: multi feature extraction, feature vector selection based on Fisher and feature dimension optimization based on AIC-Fisher. Multi feature extraction includes time domain envelope spectrum feature extraction, frequency domain amplitude spectrum feature extraction and wavelet decomposition energy distribution feature extraction. Feature vector selection based on Fisher is to select the dimension reduction feature according to the change of Fisher criterion value. Feature extraction method based on AIC-Fisher is based on the sample point error rate as the index to calculate the AIC value, AIC value to determine the minimum dimension is used to obtain the optimal feature subset. Finally, neural network is used to identify the defect depth.

2.1 Fisher-Based Feature Selection

This paper proposed a feature vector selection method based on Fisher, the specific method is: Searching the Fisher criterion function value of the largest combination of different dimensions, and drawing the \( J \) curve under different dimensions. The Fisher criterion function is the trace of the discrete matrix ratio, the expression is as follows:

\[
J(a) = \frac{a^T S_w a}{a^T S_b a}
\]

\( J(a) \) is the criterion value. \( S_w \) is the within-class scatter matrix. \( S_b \) is the between-class scatter matrix. \( a \) is a vector map.

\[
S_w = \sum_{i=1}^{c} S_i = \sum_{i=1}^{c} \sum_{x \in C_i} (x_i - \mu_i)(x_i - \mu_i)^T
\]

\[
S_b = \sum_{i=1}^{c} P_i(\mu_i - \mu)(\mu_i - \mu)^T
\]
$X$ is a feature set, a total of $N$ samples belong to the $C$ category. Each class contains $n$ samples. $\mu$ is the mean value of each category; $\mu$ is class center; $P_i$ is a priori probability of class $i$. The feature of large contribution to the growth of the curve in the $J$ value growth curve is selected as the feature set used to reduce the dimension.

2.2 Feature Extraction Method based on AIC-Fisher

In this paper, feature extraction method based on AIC-Fisher is proposed, which combines the AIC criterion and the Fisher criterion to further eliminate the redundant vectors in the feature set:

**Step1:** According to the distribution of mapping matrix of sample points by Fisher pre reduction, if the category of the sample point and the center distance is greater than other types of center distance, the point is considered as a miscarriage of justice, the calculation of different dimensions of the error rate.

$$P = \frac{D_w}{Q}$$  \hspace{1cm} (4)

**Step2:** According to the AIC criterion to calculate the AIC value of the dimension reduction matrix of different dimensions:

For the $K$ dimension of the sample data includes $N$ categories, each class contains a $Q$ sample, $D$ is the sample point error of different categories.

$$AIC = -2 \sum_{m=1}^{N} \ln \left( \frac{N}{K} \right) \cdot \frac{Q(m)}{D_{max} - D_{min}} + 2K$$  \hspace{1cm} (5)

**Step3:** Drawing the change curve of AIC value, the lowest point of the curve corresponds to the best dimension reduction.

3. Experimental design and analysis

3.1 Experimental Design

In the experiment, ten kinds of defects with the same shape but different depth were identified. In a uniform thickness of the steel plate, there are ten kinds of defects of aperture 1.00mm, depth of 0.5mm~5mm, each defect difference between 0.5mm. Each defect was scanned 30 times, and a total of 30*10 ultrasonic echo signals were collected. The schematic diagram of the test piece and the defect is shown in figure 2:

![Figure 2 The specimen and sketch of defects](image)

3.2 Result analysis

According to the above, the experiment according to the different dimensions of the Fisher criterion value change, make the $J$ value curve as shown in figure 3:

It can be seen from Figure 3 that the contribution of the first 8 dimensions to the growth of the $J$ value is large, so choose the feature of the 8 dimension as the feature set for AIC-Fisher optimization. AIC value curves are obtained by the AIC-Fisher method, as shown in Figure 4:
From the above diagram, reduced to 3 dimensional minimum AIC value can be obtained. In order to compare the superiority of this method, the 7 dimension, the 8 dimension, the 9 dimension and the 24 dimension are taken as examples to reduce the dimension distribution map, as shown in figure 5–8:

Finally, the 3D feature set is used as the sample set of neural network recognition. There are ten kinds of defects in the sample set, each group has 30 sets of data, and the 20 sets of data is used as the training set, and the 10 sets of data is used as the test set for the quantitative identification of neural network. Specific results are shown in table 1:

It can be seen from the above table that the accuracy of Fisher method is higher than that of PCA and ICA. And in the multidimensional Fisher method, the recognition effect of the sample to the 1 dimension is not good and the false alarm rate is high. According to the overall data, the recognition
The rate of the Fisher criterion is improved, and the optimal feature obtained by the AIC-Fisher method has the highest recognition rate.

**Figure 5** 24D-Fisher map

**Table 1** Results of neural network analysis

| Optimization method | false positive(%) | Correct recognition rate(%) |
|---------------------|-------------------|----------------------------|
| PCA                 | 44.0              | 68.3                       |
| ICA                 | 42.3              | 69.8                       |
| Fisher              | 40.0              | 70.3                       |
| AIC-Fisher          | 12.3              | 93.6                       |
| 5D-Fisher           | 36.7              | 73.0                       |
| 6D-Fisher           | 35.0              | 75.6                       |
| 7D-Fisher           | 34.7              | 74.9                       |
| 8D-Fisher(1D)       | 35.3              | 74.9                       |
| 8D-Fisher(2D)       | 26.3              | 80.2                       |
| 8D-Fisher(4D)       | 14.0              | 91.3                       |
| 8D-Fisher(5D)       | 21.6              | 87.4                       |
| 8D-Fisher(6D)       | 22.3              | 85.3                       |
| 8D-Fisher(7D)       | 24.7              | 82.7                       |
| 9D-Fisher           | 36.3              | 75.1                       |
Figure 6 7D-Fisher map

Figure 7 9D-Fisher map
4. Conclusion
In this paper, according to the limitation of the feature extraction of ultrasonic signal and the limitation of Fisher dimension reduction method, a method of ultrasonic signal feature extraction based on AIC-Fisher is proposed. In this method, according to the change curve of the Fisher criterion value in different dimensions to select a reasonable feature set. According to the distribution of known sample points, the paper points out the error rate index of the sample points, and combine the AIC criterion to determine the dimension of the dimension reduction of the feature set. Finally, the calculation of RBF neural network identification is reduced, and the accuracy of quantitative recognition of defect depth is improved.

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