Lifetime Prediction Model of Cylinder Based on Genetic Support Vector Regression

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Abstract—In order to solve the problem of BP neural network, genetic support vector regression is presented to predict the lifetime of cylinder. Support vector regression (SVR) is a novel prediction algorithm based on structure risk minimization principles, which can lead to great generalization ability. In the genetic support vector regression model, the genetic algorithm is used to optimize the parameters of support vector regression. That’s because that the generalization ability of support vector regression is controlled by its parameters. The wear rate data of 20 mileages are employed to study the lifetime prediction of cylinder by the GSVR model. In order to prove the superiority of GSVR in lifetime prediction of cylinder, the RBF neural network and BP neural network are employed to compare with GSVR. The results of the experiments show that the lifetime prediction model of cylinder by the GSVR is better than that of RBF neural network, BP neural network.

Keywords- support vector regression; GSVR; lifetime prediction; generalization ability

I. INTRODUCTION

The using lifetime of car is determined by the lifetime of cylinder, and the lifetime of cylinder is determined by the wear rate of air cylinder[1,2]. Thus, the lifetime prediction of cylinder is the wear rate prediction of air cylinder. The common prediction technique of lifetime prediction of cylinder is BP neural network. However, the using results of BP neural network are unstable. In order to solve the problem of BP neural network, genetic support vector regression is presented to predict the lifetime of cylinder. Support vector regression (SVR) is a novel prediction algorithm based on structure risk minimization principles, which can lead to great generalization ability[3,4]. In the genetic support vector regression model, the genetic algorithm is used to optimize the parameters of support vector regression. That’s because that the generalization ability of support vector regression is controlled by its parameters. The wear rate data of 20 mileages are employed to study the lifetime prediction of cylinder by the GSVR model.

II. GENETIC SUPPORT VECTOR REGRESSION MODEL

A. Support Vector Regression

In regression formulation, the goal of support vector regression is to estimate an unknown function with continuous-valued. Assume that the regression formulation of support vector regression is defined as follows:

\[ y = w \cdot \theta(x) + b \] (1)

where \( w \) and \( b \) are the weight vector and the bias term.

The loss function \( L_x(f(x), y) \) is applied to measure the quality of estimation.

\[ L_x(f(x), y) = \begin{cases} |f(x) - y| - \varepsilon & \text{if } |f(x) - y| \geq \varepsilon \\ 0 & \text{if } |f(x) - y| < \varepsilon \end{cases} \] (2)

where \( \varepsilon \) is the insensitive loss parameter.

Two slack variables are introduced to minimize the following functional:

\[ \text{Min } \frac{1}{2} \|w\|^2 + C \sum_{i=1}^{n} (\xi_i^+ + \xi_i^-) \] (3)

Subject to

\[ y_i - f(x_i, w) \leq \varepsilon + \xi_i^+ \]
\[ f(x_i, w) - y_i \leq \varepsilon + \xi_i^- \]
\[ \xi_i^+, \xi_i^- \geq 0, i = 1, \cdots, n \]

where \( \xi_i^+, \xi_i^- \) are the slack variables, \( C \) is the regularization constant.

The Lagrange multipliers are introduced and the kernel function is defined as \( k(x, x_j) = \theta(x) \theta(x_j) \).

The solution of the optimization problem can be expressed by:

\[ f(x) = \sum_{i=1}^{n} (a_i - a_i^*) k(x, x_i) + b \] (4)

Subject to \( 0 \leq a_i \leq C, 0 \leq a_i^* \leq C \)

where \( a_i \) and \( a_i^* \) are Lagrange multipliers, \( n_{SVs} \) is the number of SVs.
The Gaussian kernel function is applied as the kernel function here, then the regression model in the study is expressed by:

\[ f(x) = \sum_{i=1}^{n} (\alpha_i - \alpha'_i) \exp \left( -\frac{|x-x'_i|^2}{2\sigma^2} \right) + b \]  

(5)

where \( \sigma \) is called the Gaussian kernel parameter.

**B. genetic support vector regression Model**

In the genetic support vector regression model, the genetic algorithm is used to optimize the parameters of support vector regression. The generalization ability of support vector regression is controlled by its parameters.

Therefore, the accuracy and generalization of support vector regression is improved. Genetic algorithm is a direct analogy to Darwinian natural selection, which is a promising alternative to conventional heuristic methods.

The basic process is described as: (1) The training parameters of support vector regression are represented by a chromosome; (2) Produce an initial population of chromosomes randomly; (3) The fitness function of chromosomes are calculated to seek the optimal values; (4) A new population of chromosomes in the next generation is produced by the three operations: selection, crossover, and mutation. Then, evolutionary process goes on until stop conditions are satisfied.

**III. RESEARCH AND ANALYSIS**

The wear rate of air cylinder is the important index to predict the lifetime of cylinder. The experimental data of the wear rate of air cylinder are shown in Fig.1. The wear rate data of 20 mileages are employed to study the lifetime prediction of cylinder by the GSVR model, where the wear rate data of 16–20 mileages are used as the testing data. In order to prove the superiority of GSVR in lifetime prediction of cylinder, the RBF neural network and BP neural network are employed to compare with GSVR. Fig.2 shows the prediction results of wear rate of air cylinder by GSVR; Fig.3 shows the prediction results of wear rate of air cylinder by RBF neural network; and Fig.4 shows the prediction results of wear rate of air cylinder by BP neural network. The comparison results between RBF neural network and BP neural network are given in Fig.5. The results of the experiments show that the lifetime prediction model of cylinder by the GSVR is better than that of RBF neural network, BP neural network.

![Figure 1. The experimental data of the wear rate of air cylinder](image)
Figure 2. The prediction results of wear rate of air cylinder by GSVR

Figure 3. The prediction results of wear rate of air cylinder by RBF neural network
Figure 4. The prediction results of wear rate of air cylinder by BP neural network.

Figure 5. The comparison results between RBF neural network and BP neural network.
IV. CONCLUSION

The genetic support vector regression is presented to predict the lifetime of cylinder. Support vector regression is a novel prediction algorithm based on structure risk minimization principles, which can lead to great generalization ability. In the genetic support vector regression model, the genetic algorithm is used to optimize the parameters of support vector regression. That’s because that the generalization ability of support vector regression is controlled by its parameters. The wear rate data of 20 mileages are employed to study the lifetime prediction of cylinder by the GSVR model. The results of the experiments show that the lifetime prediction model of cylinder by the GSVR is better than that of RBF neural network, BP neural network.

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