Backtracking Search Optimization Algorithm and its Application to Roller Bearing Fault Diagnosis

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(Received 27 November 2014; accepted 10 June 2016)

It is clearly known that support vector machine (SVM) parameters have significant effects on the accurate rate of classification result. Adjusting the SVM parameters improves its effectiveness and accuracy, which is always a challenge. On the other font, the Backtracking Search Optimization Algorithm (BSOA), an evolutionary algorithm for solving optimization problems, is proposed and proven to be effective through various benchmark problems. This paper proposes an optimization method for the SVM parameters based on BSOA. For convenience, the proposed method has been named BSOA-SVM. This method is tested with some real-world benchmark data sets to verify its robustness and effectiveness. Then, BSOA-SVM is applied for diagnosing roller bearing fault, which is a real world problem. In this diagnosing process, the original acceleration vibration signals are first decomposed into product function (PFs) by using the local mean decomposition (LMD) method. Next, initial feature matrices are extracted from PFs by singular value decomposition (SVD) techniques to give single values. Finally, these values serve as input vectors for the BSOA-SVM classifier. The results from the problem show that the combination of the BSOA-SVM classifiers obtains higher classification accuracy with a lower cost time compared to other methods.

1. INTRODUCTION

Optimization of SVM parameters has always been a complex task for researchers since it was developed. In recent years, many algorithms were employed to handle this task, such as the trial and error procedures,[1] the grid algorithm,[2] the cross-validation method,[3] the generalization error estimation method,[4] the gradient descent method,[5] and so on. Unfortunately, these methods still contain some drawbacks that hamper the effectiveness of SVM. For example, the grid method requires complex computations and is time consuming while the cross-validation method also requires long and complicated calculations.[2] The heuristic algorithms, such as the genetic algorithm (GA), the particle swarm optimization (PSO),[6] and the ant colony optimization (ACO)[7] were also used to optimize SVM parameters. However, PSO is easily trapped into the local optimization areas[8] while GA has an expensive computational cost.[9]

Recently, Pinar Civicioglu developed the Backtracking Search Optimization Algorithm (BSOA), which is an evolutionary algorithm (EA) for solving optimization problems. The BSOA method could solve real-valued numerical optimization problems for a short time and the search result was better than other EAs.[10] Unlike other methods in the EA group, BSOA has only one control parameter in the algorithm. This makes the method much simpler to use. Therefore, in this paper, BSOA is combined with the SVM to give a so called BSOA-SVM for solving classification problems. BSOA-SVM was applied to diagnose the fault of roller bearing. In this diagnosing process, the original acceleration vibration signals were first decomposed into product function (PFs) by using the LMD method. Next, initial feature matrices were extracted from PFs by singular value decomposition (SVD) techniques to give single values. Finally, these values served as input vector for the BSOA-SVM classifier. The classification results of the proposed method show a higher accuracy and lower cost time compared with the GA-SVM, the PSO-SVM, and the CMAES-SVM methods.

The rest of this paper is organized as follows: in Section 2, the BSOA method is briefly reviewed. In Section 3, the parameter optimization algorithm based on the BSOA method is addressed. The fault diagnosis method based on LMD-SVD and BSOA-SVM, in which initial feature matrices extracted from a number of PFs are used as input vectors of BSOA-SVM, is presented in Section 4. In Section 5, the fault diagnosis method is used to diagnose the condition of actual roller bearings and is compared with the GA, the PSO, and the CMAES methods. Finally, the paper is concluded in Section 6.

2. BACKTRACKING SEARCH OPTIMIZATION ALGORITHM

BSOA is an adaptive search algorithm that uses three basis genetic operators including selection, mutation, and crossover to generate trial individuals. The principle of BSOA, which consists of six steps,[10] is presented in the flow chart in Fig. 1. More details of the steps are presented in following sections.

2.1. Define the Problem and Algorithm Parameter

The mathematical formulation of a typical optimization can be written as: