A Modified Adaptive Chaotic Binary Ant System and Its Application in Chemical Process Fault Diagnosis

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Abstract. Fault diagnosis is a small sample problem as fault data are absent in the real production process. To tackle it, Support Vector Machines (SVM) is adopted to diagnose the chemical process steady faults in this paper. Considering the high data dimensionality in the large-scaled chemical industry seriously spoil classification capability of SVM, a modified adaptive chaotic binary ant system (ACBAS) is proposed and combined with SVM for fault feature selection to remove the irrelevant variables and ensure SVM classifying correctly. Simulation results and comparisons of Tennessee Eastman Process show the developed ACBAS can find the essential fault feature variables effectively and exactly, and the SVM fault diagnosis method combined with ACBAS-based feature selection greatly improve the diagnosing performance as unnecessary variables are eliminated properly.

1 Introduction

Fault diagnosis, which can provide early warning for process upset and reduce loss, plays an important role in industry process. But it is a challenge to apply fault diagnosis to modern complex and large-scaled chemical process because there are large amounts of variables with noise monitored. When all collected variables are taken as the inputs to discriminate faults, high dimension of data greatly reduces the performance of diagnosing because of the disturbances of too much irrelevant variables and noises, and badly spoil the real-time capability due to the increased complexity of computation. Especially, fault diagnosis is a small samples problem as the fault data are deficient in the really production process, which make some classification algorithms not suitable for fault diagnosis.

In this paper, we use the SVM as classifier to diagnose the chemical process steady faults as it can tackle the small sample problem. As mentioned above, high dimension of data will impair the classification capability of SVM. So it is essential to preprocess the sampled data to reduce the data dimension.

There have been several approaches to preprocess data developed, applied and widely researched in fault diagnosis applications, such as Principal Component Analysis (PCA) [1] and Kernel PCA [2], which are well-known methods for feature
extraction. The large sets of process monitored variables data in the chemical industry are often highly correlated and as a result are generally good candidates for PCA and KPCA. As feature extraction methods can produce lower-dimensional representations of the data which better generalize to data independent of the training set than using the entire dimensionality of the observation space, and therefore, improve the proficiency of detecting and diagnosing fault.

But the extracted information by feature extraction methods is not directly related to the objective of fault diagnosis. So the number of retained components maybe is still large in order to contain enough information for diagnosing. Sometimes, even worse, the extracted data is not exactly acceptable for fault diagnosis because the resulting lower dimensional space may contain little of the required faults information, which makes the feature extraction invalid for fault diagnosis in some conditions.

To make up for this shortage, feature selection method was proposed as an alternative to preprocess the collected data [3]. In the process of fault diagnosis, feature selection is operated to directly search and find the essential fault variables. Only the selected variables will be retained and used as inputs for fault diagnosis. As the irrelative variables are all removed, the real-time capability and correct rates of fault diagnosis will be greatly improved. In order to find the fault feature variables effectively and properly, a modified adaptive chaotic binary ant system is proposed and combined with SVM to realize fault feature selection in the paper.

The reminder of the paper is organized as follows. Section 2 presents the ACBAS algorithm and the feature selection method based on ACBAS combined with SVM in detail. The setup of simulations is introduced in Section 3. Section 4 describes the performances and comparisons of developed ACBAS algorithm and fault diagnosis method based on feature selection. Section 5 concludes the results of simulations.

2 Theory

2.1 Ant Colony Optimization (ACO)

ACO algorithm inspired by colonies of real ants has been successful employed to solve various optimization problems. It is an evolutionary approach where several generations of artificial agents in a cooperative way search for good solutions. Agents are initially randomly generated on nodes, and then stochastically move from a start node to feasible neighbor nodes. Agents collect and store information in pheromone trails during the process of finding feasible solutions. Agents can online release pheromones while building solutions. In addition, the pheromones will be evaporated in the search process to avoid local convergence and to explore more search spaces. Thereafter, additional pheromone is deposited to update pheromone trail offline so as to bias the search process in favor of the currently path.

The pseudo code of the classical ACO algorithm [4] can be described as:

Procedure: Ant colony optimization
Begin
    While (ACO has not been stopped) do
        Agents_generation_and_activity();