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Parameter Prediction Model for Signal Reconstruction Fluctuating Operation State of Chemical Machinery Equipment Based on Ant Colony Algorithm

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Exploring structure of parameter prediction model for signal reconstruction fluctuating operation state of chemical machinery equipment based on ant colony algorithm, and optimizing the global performance. After analyzing the process itself and establishing a list of all variables, to construct optimization mathematical model and obtain the problem solution, and then to analyze and verify the optimization result. Continuous multiple ant colony algorithm can be applied to continuous optimization problems, and it also has good global optimization performance. The pheromone distribution model is a key factor affecting the ant colony algorithm. To improve the accuracy of the ant colony algorithm's parameter prediction, a good pheromone distribution model should be designed.

1. Introduction

Chemical companies are faced with the issues of energy, environment and economy. In particular, the rapid development of information technology in modern society has enabled chemical companies to develop toward the direction of digitization and intelligence. Computer signal systems based on manufacturing processes are also developing toward automation, which will inevitably bring about changes in production methods. Therefore, the chemical industry needs to pay more attention to the role of process system engineering, and make full use of system engineering to achieve the optimal design of the system. From the point of view of monitoring the operation state of equipment signals, the purpose is to guarantee the stable operation of chemical machinery equipment, and to manage and control the design and operation, as well as to exert its value-added properties.

Therefore, this paper also proposes the continuous multiple ant colony algorithm based on pheromone distribution, and applies it to the equipment signal management of chemical machinery, and gives the standard test system and structure of the test algorithm. The ant colony algorithm derives from the characteristics of biological intelligence, and it is a simulated evolutionary algorithm. Preliminary research shows that the algorithm has many excellent properties. Through the problem of PID controller parameter optimization design, it makes contrast between the result of ant colony algorithm design and the result of genetic algorithm design. The numerical simulation results show that the ant colony algorithm is a new optimization method of simulation evolution, and displaying that it is suitable for the superior characteristics of its solution to combinatorial optimization problems.

2. Literature review

An important link in the predictive maintenance is to predict the state of the equipment. Only a more scientific prediction of the future state of the equipment can be used to better understand the running state of the equipment and its future running trend, so that the gradual failure of the equipment can be found in time. The occurrence of a general fault is a gradual process, which requires that we can monitor the running state of the equipment in real time and make the correct state prediction in time. Accurate state prediction can help us make reasonable maintenance plans, achieve efficient maintenance, and ensure the smooth progress of the production process. Therefore, the prediction of equipment failure has increasingly become a topic attracting many experts and scholars to study and explore.

Fault prediction technology is a more advanced and more scientific way to ensure maintenance, which is a multidisciplinary subject. The fault prediction technology is based on the running state of the current equipment as the starting point, combining the historical data, the environmental impact and the structure characteristics of the research object to predict the future operation state of the equipment, and analyze and judge the possible failures in the future by predicting the possible failures. It also determines the cause, the specific location and the severity of the possible failure and predicts the development trend of the fault and the impact of the failure, so that the failure can be eliminated before the failure, and the safety of the equipment as well as the smooth operation of the production can be ensured. At present, there are many experts and scholars at home and abroad engaged in the research on fault prediction. The methods are different, but mainly starting from the point of view of data, to establish the mathematical models to predict. The real prediction based on mathematical model began in 1927. Yule proposed the autoregressive (AR) prediction model, and Slutsky proposed a moving average (MA) prediction model. Thereafter, in 1933, Kolmogorov put forward stochastic process and the estimation theory based on the probability. The researches made by the pioneers provided the idea and direction for the development of the prediction technology and laid the theoretical foundation.

In recent years, many experts and scholars at home and abroad have studied the prediction technology, and built different forecasting models for different objects. Shao and others set up a new model combining gray GM (1,1) and LRM based on the validity principle in terms of the difficulty of equipment fault prediction. Through the simulation and prediction of the original data of the equivalent interval measurement, it is estimated when the system can reach the upper limit of the fault data and deduce the fault time of the system according to the results. At the same time, the metabolic method is introduced to improve the prediction accuracy. Finally, taking the output voltage of a certain radar transmitter data as an example, the validity and practicability of the model in fault prediction are verified (Shao et al., 2015). Song and others used rough set theory and grey theory with the advantage of dealing with imprecise data, and proposed a fusion algorithm based on them. The attribute reduction algorithm of rough set theory can reduce the decision table of fault diagnosis, and the grey theory can predict faults based on the new reduction decision table. Through the verification of a certain type of aeronautical radio equipment, the results show that the accuracy of the fault prediction is high, thus providing a basis for improving the reliability and maintainability of the equipment (Song et al., 2014). Jin and others aimed at the problems of complex equipment failure information and difficult to predict faults, applied support vector machine (SVM) to establish the fault prediction model. On the basis of the analysis of support vector machine regression algorithm, the fault prediction model was built by least squares support vector machine (LS-SVM). LS-SVM can effectively reduce the complexity of the model. By choosing the appropriate parameters, the model can predict the fault data better and has higher prediction accuracy (Jin et al., 2013). In order to solve the problem that complex electronic equipment structure, lack of fault information, unpredictable faults and the existing fault prediction methods can not directly predict the state of electronic equipment, Tian and so on put forward a combined fault prediction method. The method is based on least squares support vector machine (LS-SVM) and hidden Markov model (HMM) of condition-based maintenance (CBM). First of all, the circuit that the circuit element should be changed by the sensitivity analysis is determined by changing the degenerate state parameters of different components; secondly, the combined failure prediction model is established; finally, the circuit state is predicted. The results show that the proposed method can directly predict the different states of the circuit, so that the fault state of the electronic equipment can be predicted directly, and the prediction accuracy is up to 93.3% (Tian et al., 2014). In order to ensure the safe operation and improve the intelligent level of the early fault prediction of the key mechanical equipment group, Xu and others put forward Internet of things fault prediction and health management based on three-layer structure to realize the comprehensive perception, reliable transmission and intelligent processing of the fault information of the mechanical equipment group. The two key technologies of state monitoring and fault prediction are analyzed, and the application prospect of fault prediction and health management based on the Internet of things is proposed (Xu et al., 2012). Li and Li established BP neural network to accurately predict the state of the device. This network can be used to accurately predict the system state and residual life of the space equipment, so that it can provide maintenance in time, reduce the loss of failure and improve the reliability (Li and Li, 2012). Zhou et al. proposed an improved GM (1,1) model for the defects of the general GM (1,1) model. The optimal prediction dimension was obtained by particle swarm optimization (PSO), and the model parameters were adaptively changed by metabolism. Finally, the improved grey model was applied to the fault prediction of a high voltage power supply circuit of modern airborne radar. The calculation and simulation results of Matlab software showed that the prediction accuracy of the improved grey model was higher than that of the original grey model (Zhou et al., 2013). Henriques et al. proposed a system that supported maintenance analysis, in which temperature, water level and vibration

sensors could provide real-time data to analyze the isolation conditions of transformers and switches in the basement, and a new kind of neural network alarm partial discharge (PD) activity was proposed (Henriques et al., 2016).
To sum up, there are few studies on the prediction of equipment state using ant colony algorithm in the above research. Therefore, this paper uses ant colony algorithm to study the state prediction model of chemical machinery and equipment, which provides more information for the engineer to judge the state of the equipment, making the result more scientific and more credible.

3. Method

3.1 Optimization algorithm

The chemical process optimization is to find out the equipment parameters or process variables that make the performance index or the objective function of the process system reach the maximum or minimum under the constraint conditions given by the chemical process performance and characteristics. In general, it is reflected in the following aspects: The optimization of the undetermined parameters in the mathematical model, the optimization of process operating conditions, the optimization of process input variables and other parameters, the optimal control of dynamic systems, the optimization of process architecture variables, and the optimization of production plans. Regardless of which of the above problems, it still includes the three elements of the objective function, decision variables, and constraints condition. And its general form is:

$$\min f(x)$$
$$s.t. x \in D$$

Specific algorithm process as shown in Figure. 1:

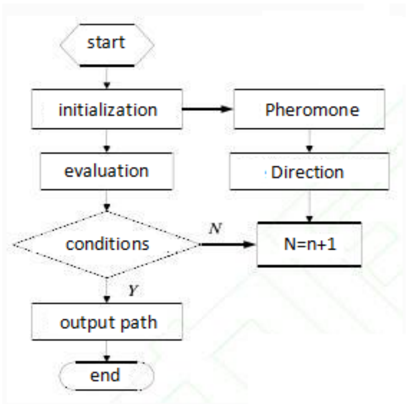

Figure 1: Ant Colony Algorithm Flow Chart

The optimization problem can usually be divided into such two types of continuous optimization problem and discrete optimization problem. The object of the discrete optimization problem is the discrete state solution space, while the optimized object is the continuous solution space within a certain interval. Since this paper focuses on the continuous multiple ant colony algorithm and applies it to the continuous optimization problem in chemical engineering. Therefore, the following only introduces several problems in continuous optimization.
Classical optimization methods are usually divided into linear programming, nonlinear programming, and stochastic programming, non-smooth planning, multi-objective programming, geometric programming, integer programming, etc., based on the different nature of the problem. Correspondingly, there are some more mature conventional algorithms, such as the simplex algorithm applied to the linear programming problem, applied to nonlinear programming method, conjugate gradient method, sequential quadratic programming method, and the branch and bound, cutting -plane method and dynamic programming applied to integer programming problems . These methods generally have more rigorous mathematical theory, but when the model is complex, such as when the variable has many dimensions, the number of constraint equations is more, and the nonlinearity is strong, or the model structure is complex and it cannot be expressed by explicit equations, these methods can not be effectively solved, or the solution time is too long, for example, combinatorial explosion in combinatorial optimization problems or bad solution results, or such as trapping into local extremum, the initial value directly affecting the result of optimization.

3.2 Ant colony algorithm

Although the individual behavior of ants is relatively simple, the entire ant colony appears as a highly institutionalized social organization. By releasing the pheromone on the foraging path as a medium for ant communication, the ants cooperate with each other to form an autocatalytic process and eventually find the shortest path for foraging. Graphically speaking, supposed that there are two paths leading from the anthill to the food. At the beginning, there are as many ants as the number in the two paths, and the ant will return immediately after reaching the destination along a road. Like this, on the short path, the time for ants to travel back and forth is short, which also means that their frequency of repetition is faster. Therefore, the number of ants that pass through a unit of time is more, and the number of pheromone released is also more. After that, more ants are attracted to release more pheromones, but the situation of the long road is on the contrary. Therefore, as time goes by, more and more ants will gather in shorter path, which approximates the shortest path.
Ant colony algorithm has the characteristics of strong global optimization ability, high efficiency of searching optimization and easy construction. And it has been widely concerned by researchers in the field of chemical process optimization, and its application in chemical process optimization has gradually become popular. The ant colony algorithm test function as shown in Figure. 2.

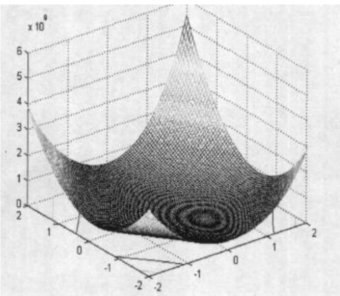

Figure 2: Function Graphic

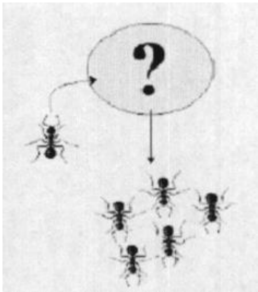

Figure 3: Mobilization

In the process of constructing the algorithm path, the path probability selection mechanism is used to guide the ant to select the path, and the tectonics solution not only increases the pheromone density for more potential pathways in the pheromone update process, but also constructs the pheromone volatility rules. In this way, positive feedback narrows the search scope, ensures that the algorithm is optimized towards the optimal solution, as well as negative feedback maintains the search scope, avoiding premature convergence of the algorithm to local optimal results. Under the combined action between the positive feedback and negative feedback, ant colony algorithm can be self-organized evolution to obtain a certain degree of satisfactory solution to the problem. The ant recruitment process as shown in Figure. 3.
The idea of combining strategy with evolutionary algorithms is adopted by many researchers of continuous ant colony optimization. Such algorithms usually divide the continuous space into several discrete small regions with limited number. The ant moves these small regions through the operator of the evolutionary algorithm, and selects according to the pheromone in the region, and randomly adjusts the position of the selected small region in a local range or adds superior strategies to conduct local excavation. Due to the full use of the research results of evolutionary algorithms and local optimization algorithms, the hybrid algorithm shows an excellent optimization. Especially in the solution of high-dimensional problems, the optimization performance is better. Its disadvantage is that the parameter determination of the algorithm is more complicated. In particular, it should be noted that although the pheromone remains in the "small region" and the object of the operation is also the "small region", in the implementation of algorithm, the "small region" corresponds to the path of the ant and represents a point feasible solution.

3.3 Parameters prediction for operation state of chemical machinery equipment

The calculation process of the algorithm will be performed iteratively. It usually takes the maximum iteration round or the algebra of the search stall as the termination condition of the algorithm. The main steps of the algorithm are as the following.
Setting the parameter values, generating the initial values of the distribution center and width of the pheromone density function corresponding to each subgroup, determining the initial size of each subgroup, and setting the round counter t=1.

Each subgroup is sampled according to its corresponding pheromone density distribution function, generating new locations for its ants and completing state transference, conducting the evaluation of the food sources found by the ants, determining the optimal ants for the head ant and populations of each subgroup.
Selecting collaborative methods of multiple groups to determine the new location of head ant, and determining the size of each subgroup in the next iteration based on the selected subgroup size calculation rules.
Calculating the distribution width of the pheromone density function, and each subgroup shares this information.

4. Result and discussion

Since there is an important concept of pheromone concentration in the ant colony algorithm, and every time an ant passes, the pheromone concentration will be updated once. According to this idea, when the data is predicted, the sample data should be trained first. Each time the data changes represent an ant selection. In this way, according to the different data, ants also have different choices. In the face of each selection, the different pheromone concentrations on each road will have a direct impact on the choice of ants. As shown in Figure. 4. In the future, the state in which it may be developed is related to the concentration of "pheromone" through the training of the state in history. In this way, it is possible to predict the state of development of the equipment that is theoretically closest to the actual situation at the next moment.

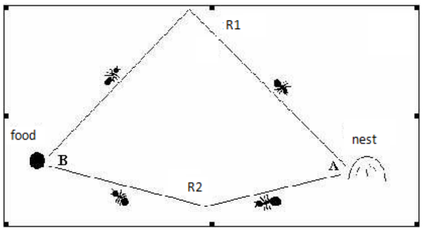

Figure 4: Algorithm Results

Aimed at the constantly fluctuating rising data, first of all, through the idea of signal reconstruction, it is treated as a graph that fluctuates within a certain range, that is, similar to sine wave patterns and linearly increasing patterns. Through this process, the data that fluctuate within a certain range is more regular, which makes it possible to conduct ant colony algorithm prediction research on a certain range fluctuating patterns, and which also makes it easier to find the regularity of data in the training of samples to make the prediction result more accurate and have higher credibility. So the signal reconstruction, fluctuation data as shown in Figure. 5

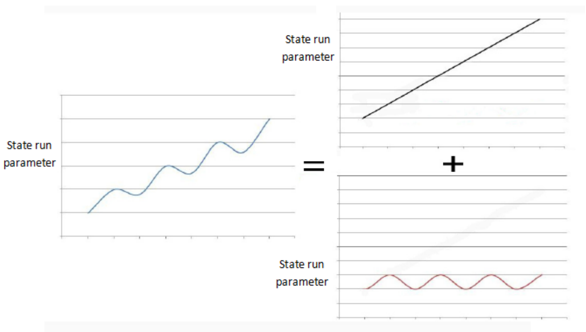

Figure 5: Fluctuating Upward Data Graph

After completing the prediction, the pheromone is continuously updated, and the actual state value at this time can continue to train and update the pheromone so that a new pheromone can be obtained. And when the state value at the next moment is predicted, there are more samples to support the prediction of the data, so that the prediction is more reliable and the results are closer and closer to the actual situation. The intra-system prediction flow chart as shown in Figure. 6.

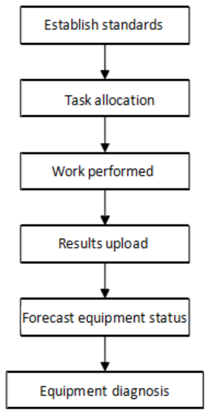

Figure 6: System Internal Prediction Flow Chart

5. Conclusion

The chemical industry faces various challenges. How to deal with these challenges should begin with the optimization of technologies. The chemical system itself is relatively complex, and the design of the model structure is also more complicated. At this time, the traditional optimization method is no longer suitable. As a new heuristic algorithm, ant colony algorithm effectively makes solutions to the problem quickly and combines the feasibility in a short time. In essence, the research on the parameters prediction model for the operation state of chemical machinery and equipment has important significance for the optimization algorithm of spatial problems. But to determine the global optimization algorithm has high requirements for mathematical analysis. In the future, it still needs a complete ant colony algorithm theoretical model to be scientific and rational in parameter selection and optimization strategies. Although the idea has some problems in the implementation process, it provides new and feasible ideas for future continuation research. Its aim is to have a complete set of point inspection standard processes in the system. Moreover, in the system, it is also possible to predict the quantitative state parameters of the equipment.

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