Abnormal Detection of Vibrating Sinking Pipe Gravel Pile Machines Based On Support Vector Machine Model

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Abstract. The intelligent monitoring system automatically collects the current value, drilling depth and drilling verticality and other parameter data of the equipment during the operation of the vibrating sinking pipe gravel pile machines. When the pile driver works normally, the parameter data meet certain distribution characteristics. In the work of the vibrating sinking pipe gravel pile machines, Parameter data are used for data mining, and one class support vector machine is used to learn the boundary of data. Once the equipment works abnormally, it can be detected in time to reduce the loss. Experiments show that the method has a high detection rate and is easy to be extended to other engineering equipment.

Keywords: Vibration Sinking Gravel Piles, Support Vector Machine, One Class SVM

1. Introduction
In 1995, Coretes et proposed the support vector machine (SVM) model. Aiming at maximizing the geometric interval between heterogeneous data, the SVM model obtains the classification of hyperplane by solving a convex quadratic programming problem. Support vector machine (SVM) is an important machine learning method based on statistical learning theory. In the research of existing achievements, support vector machine (SVM) has been widely used in the field of data mining because it can get better classification results in small sample problems and can solve the classification of high-dimensional data [1-3].

The intelligent monitoring system of vibration driven gravel pile machine is mainly to install sensors on the traditional gravel pile machines. Real-time data of construction parameters of gravel piles are collected by sensors, and the collected data are uploaded to an embedded computer system for analysis and visual processing. The real-time visualization display of construction parameters such as total current value of pile driver, the current value of exciting hammer. Therefore, in a certain period time, the intelligent monitoring system can accurately record the working state and the main working parameter data of the vibratory immersed tube gravel pile machine[8-10]. This provides the necessary data environment for the vector machine model to analyze whether the pile machine operates normally.

SVM is a kind of machine classification model based on small-scale training samples. Its algorithm and model only involve statistical learning theory, applied mathematics and data mining. Under the
condition of limited training samples, statistical learning theory provides a basic theoretical framework for the theory of SVM [4].

Support vector machine is a kind of machine classification model based on small-scale training samples. Its algorithm and model only involve statistical learning theory, applied mathematics and data mining. In the case of limited training samples, statistical learning theory provides a basic theoretical framework for support vector machine theory. In 1995, Vapnik first proposed support vector machine (SVM) and proposed that the structural risk minimization should be one of the basic principles when building models and algorithms using its basic theory. The structural risk minimization principle (SRM) reduces the VC dimension of the learning machine and controls the expected risk of the learning machine on the whole sample set. The function set is constructed as a sequence of function subsets that are arranged according to the size of VC dimension. The minimum empirical risk is found in each subset, and the empirical risk and confidence range is considered between subsets to obtain the minimum actual risk.

2. Support Vector Machine

2.1 Soft Interval Linear Separable Support Vector Machine (SVM)

On a given training sample set, the basic idea of a soft interval linear separable support vector machine is to find a positive middle partition hyperplane in the sample space based on the training set to separate different classes of samples. Let \( X \) be the training sample set

\[
T = \{(x_1, y_1), (x_2, y_2), \ldots, (x_N, y_N)\}
\]

where \( x_j = (x_{j1}, x_{j2}, x_{j3}) \) is working parameter data of the vibrating sinking pipe gravel pile machine (the current value, the depth of drill pipe and the perpendicularity of drill pipe), \( y_i \in \{-1, +1\} \) is the detection label at the time \( i \). The following is the hyperplane \((W, b)\) equation in the training sample set

\[
w^T x_i + b = 0
\]

where the normal vector \( w = (w_1, w_2, w_3) \), the dimension \( b = 3 \). Then we have the distance from any point \( x \) to the hyperplane \((W, b)\) in the training sample space

\[
r = \frac{|w^T x + b|}{||w||}
\]

where the constraint condition

\[
y_i (w^T x_i + b) \geq 1
\]

For the whole sample training set, if there is the parameters \((W, b)\) that satisfy the constraint conditions such that \( r \) is the maximum, the model is called hard interval. If the model can maximize the interval and minimize the number of training samples that do not meet the constraints, it is called soft interval. In this paper, we give the "soft interval" method.

\[
\min \frac{1}{2} ||w||^2 + C \sum_{i=1}^{N} \xi_i
\]

where penalty coefficient \( C > 0 \), relaxation variable \( \xi_i \geq 0 \) and satisfy the following requirements

\[
y_i (w^T x_i + b) \geq 1 - \xi_i
\]

Since the maximum interval is a convex quadratic programming problem, it can be directly solved by the ready-made optimization package, but here we use Lagrange multiplier method.
\[ L(w, b, \xi, \alpha, \mu) = \frac{1}{2}||w||^2 + C \sum_{i=1}^{N} \xi_i - \sum_{i=1}^{N} \alpha_i (y_i(w^Tx_i + b) - 1 + \xi_i) - \sum_{i=1}^{N} \mu_i \xi_i \]

where \( \alpha_i \) is the Lagrangian extremum, and \( \alpha_i \geq 0, \mu_i \geq 0 \). The partial derivative of the equation is obtained by gradient descent method

\[ \nabla_w L = w - \sum_{i=1}^{N} \alpha_i y_i x_i = 0, \nabla_b L = - \sum_{i=1}^{N} \alpha_i y_i = 0, \nabla_\xi L = C - \alpha_i - \mu_i = 0 \]

so

\[ w = \sum_{i=1}^{N} \alpha_i y_i x_i, \sum_{i=1}^{N} \alpha_i y_i = 0, C - \alpha_i - \mu_i = 0 \]

The final convex optimization model of dual algorithm is obtained as follows

\[ \min \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i \alpha_j y_i y_j (x_i \cdot x_j) - \sum_{i=1}^{N} \alpha_i, \ s.t. \sum_{i=1}^{N} \alpha_i y_i = 0 \]

\[ 0 \leq \alpha_i \leq C, i = 1, \ldots, N \]

Therefore, the two optimal parameters in the hyperplane with the largest interval required in the support vector machine is obtained as follows

\[ w^* = \sum_{i=1}^{N} \alpha_i^* y_i x_i, b^* = y_k - \sum_{i=1}^{N} \alpha_i^* y_i (x_i \cdot x_k) \]

After the solution of the hyperplane with the largest interval, the sign function of the hyperplane after the sample points are brought into the sample point can only be used to determine whether it belongs to the positive or negative class. The schematic diagram of the data is as follows the figure 1.

![Figure 1. Soft interval linear separable SVM](image)

### 2.2 One Class SVM and Anomaly Detection

One class SVM is an unsupervised algorithm. It classifies new data into similar data or different data from the training set. One class SVM regards all the data which are different from the normal data as novel data. By the boundary according to the actual needs, we consider the data beyond the boundary as abnormal data. The principle and mathematical model of one class SVM algorithm and SVM algorithm are basically the same [5-6]. One class SVM is based on a class of data (normal data) to find the hyperplane, to solve the maximum interval of negative samples in SVM algorithm, and then completes the anomaly detection under unsupervised learning [7]. The maximum model is as follows
\[
\min_{r, O} V(r) + C \sum_{i=1}^{N} \xi_i
\]

where \( V(r) \) is a sphere with the center \( O \) and the radius \( r \), penalty coefficient \( C > 0 \), relaxation variable \( \xi_i \geq 0 \) and satisfy the following conditions

\[
\|x_i - O\|_2 \leq r + \xi_i, y_i(w^T x_i + b) \geq 1 - \xi_i
\]

Solving one class SVM algorithm, we use SVDD method.

\[
F(R, a, \xi_i) = r^2 + C \sum_{i=1}^{N} \xi_i
\]

where

\[
(x_i - a)^T (x_i - a) \leq r^2 + \xi_i
\]

The schematic diagram of the data is as follows the figure 2.

![Figure 2. One class SVM](image)

### 3. Conclusion

In this paper, through the intelligent monitoring system of the vibrating sinking pipe gravel pile machine, the working parameter data of the pile machine are collected, and the training sample set of the normal operation of pile machine is obtained. According to the classification method of support vector machine, the boundary of the training sample set is found. The boundary is used to judge whether the operation parameters of the vibrating sinking pipe gravel pile machine are normal. If it is normal within the boundary, if it is abnormal outside the boundary. Experiments show that the method has a high detection rate and is easy to be extended to other engineering equipment.

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