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ORIGINAL ARTICLE

Fault Diagnosis Method of Section Track Circuit Based on Support Vector Machine

Pengrui Liu ,Wenchang Li

China AcademyRAilway Sciences Corporation Limited standards&MetroologyRSearch Institute,Beijing,100081,China

Abstract: Support Vector Machines(SVM)Is a Machine Learning AlgorithmWhich. Based. statistical Learning Theory.This algorithm accomplishes. structural risk-minimization principle.. Most predominance. SVM. proper. limited samples decision.. Nature. algorithm. acquiring connotative class information. great extent form limited samples.This article will support vector machine

Keywords: support;diagnosis;cross-subject

1. An overview

The most in recent years China of Railway career development quickly.Thanks to Sensing Technology,Big Data Analysis Technology,Cloud computing and cross-subject of development, The intelligence level of Railway Signal Monitoring System is not high at present.,Low troubleshooting and set maintenance efficiency,Rely heavily on artificial experience, Support Vector Machine (SVM)Artificial intelligence algorithmZPW-2000Intelligent Diagnosis of track circuit, and the reliability and feasibility of the scheme are verified by experiments..

2. What is support vector machine?

The problem of machine learning is mainly solved by the traditional statistics based on the asymptotic theory, that is, when there are infinite training samples, the optimization of learning machine parameters is made use of the principle of empirical risk minimization..However, due to the differences between the empirical risk and the actual risk, and in the case of small samples, this difference is particularly obvious..In practical engineering, due to the fuzzy signal and fault relationship and other factors, the number of typical fault samples in fault diagnosis is limited..Like the artificial neural network based on the principle of empirical minimization, the problem to be solved is how to get the decision function with strong generalization ability from less fault samples, for small sample problem, the result of fault diagnosis is not ideal, and it is difficult to get valuable application..Therefore, in practical engineering, there is an urgent need to solve the small sample problem..

Century90In the middle of the decade, the theory of machine learning for small sample processing gradually matured, forming a more perfect theoretical system..1992Year to year1995A new learning machine Support Vector Machine (SVM) based on Statistical Learning Theory (Support vectormachine,SVM)Came into being.Compared with the artificial neural network, SVM has several advantages.,Can solve the small sample problem; second,Solving High Dimension and local extremum problems.

In addition,SVMIt has a very simple structure and is an effective tool to apply statistical learning theory..

In low-dimensional space, for hard-to-classify data,SVMIt can be mapped into a high-dimensional space by some kind of mapping, making it classification..This machine learning algorithm is based on statistical learning theory.VCDimensional theory (Vapnik-Chervonenkis dimension)And structural risk minimization

StructuralRISK Mining,SRM)Based on the training principle, it has stronger generalization ability than neural network, can do the best tradeoff between model complexity and learning ability, and requires small sample training data..Therefore, this studySVMBasic Algorithms for Diagnosis.The basic principles are as follows:

FunctionφAs a nonlinear mapping function, the vectorXFrom the original data collection space to the high-dimensional feature space,<A,B>Operator representation variableAWithBThe Inner Product.After the above parameter mapping, the original data which can not be classified in the low dimensional original space can be divided into high dimensional feature space..Classification hyperplane in upper-type high-dimension space by weight parameterOmegaAnd offset ParametersBFunctional Theory shows that the optimal classification hyperplane must satisfy the formula (5.)Qualifying condition.

Can be understood as between two classification plane"Functional distance".Therefore, an appropriate transformation of the above problems can be expressed as follows (6.),Type(7.)Optimization Problem.

$_I$For Lagrange Operator.FunctionLRespectively onOmegaAndBPlease partial-make it zero and solving the can get its extreme value.Such (9),(10).

CorrespondingB*Also can be accordingly derived by the classification super flat of decision-making function can be said such (12):

$F(X) = Sign[_{Sigma}{}^{L}Y_I\alpha^*_I \langle X_I\varphi(X)\rangle B^*]$

I = 1

Will monitoring VectorXOf value into the-accordingF(X)Of output results can be the input sample to classification.However actual data collection,Transmission and process will not avoid to make monitoring VectorXMixed with certain of noise makes data difficult to completely the linear methods the classification then can through and relaxation ParametersZeta(Zeta>0)The methods of the original methods the correction the original problem override such (13):

$_I(\langle Omega\varphi(X_I)\rangle B)\geq 1-\xi I$ =12...L

At this time of classification problem can describe for such (14)Or (15)Shown in the Optimization Problem

Which,CFor punishment Parameters,ξFor relaxation variable.

According to the similar of analysis solving process at this time of decision-making function can be said for such (16)The form:

$F(X) = Sign[_{Sigma}\alpha^*_IY_IK(XX_I)B^*]$

I SVS

Which,CFor punishment Parameters,ξFor relaxation variable,$K(XX_I) = \langle\varphi(X)\varphi(X_I)\rangle$ For nuclear Function.

The above mathematical model have many kinds of solving methods this paper the classic of order sequential minimum optimization (SMO)Algorithm to solve.

3. Model Establishment

This research based on support vector machine the algorithm Modeling.The model is divided into data read,Training Model and diagnosis three part.First import training diagnosis model used of training data set in import training data set after on its the training get to Fault Diagnosis Model.Training Before the model required of punishment ParametersCAnd Nuclear ParametersGammaThe estimation.

3.1 Data get

In order to make research object simplified this project only study track circuit adjustment state under the monitoring data.Data divided into training set

Traindata)And Test Set (Testdata)Two part training set used to training diagnosis model test set that is for diagnosis of actual

Table1 Indoor monitoring data list

Serial number	Monitoring of name	Serial number	Monitoring of name
1	Work the voltage	14	By end cable side small system Carrier Frequency
2	Work the current	15	By end cable side small system Low Frequency
3	Work the carrier frequency	16	By end equipment side main system voltage
4	Work the low frequency	17	By end equipment side main system Carrier Frequency
5	Send end cable Side Voltage	18	By end equipment side main system Low Frequency
6	Send end cable side current	19	By end equipment side small system voltage
7/	Send end cable side Carrier Frequency	Natural 20	Receive entrance main system voltage
8	Send end cable side Low-Frequency	21	Receive entrance main system Carrier Frequency
9	Ballast Resistance	22	Receive entrance main system Low Frequency
10	By end cable side main system voltage	23	Receive entrance small system voltage
11	By end cable side main system Carrier Frequency	24	Receive entrance small system Carrier Frequency
12	By end cable side main system Low Frequency	25	Receive entrance small system Low Frequency
13	By end cable side small system voltage		

Data.Training set data and test set data points two kind of situation:

(1)Existing signal Centralized Monitoring System of indoor monitoring data (25Monitoring)

2)In addition to the above25A data the increase outdoor monitoring device after the data11The total36The.

2Outdoor monitoring data list

Serial number	Monitoring of name	Serial number	Monitoring of name
1	Send end cable side current	7/	By end lead wire long die of wiring current
2	Send end lead wire long die of wiring current	8	By end lead wire long introduced wiring current
3	Send end lead wire long introduced wiring current	9	By end lead wire short die of wiring current
4	Send end lead wire short die of wiring current	10	By end lead wire short introduced wiring current
5	Send end lead wire short introduced wiring current	11	Protection box temperature
6	By end cable side current		

Taking into account the track circuit actual fault data difficult to get so first the mathematical modeling of methods established track circuit of Mathematical Model, and then in Model of based on the need for a diagnosis of all kinds of fault simulation to get corresponding data.Track circuit equivalent circuit model as shown in Figure1Shown in the province went to the little track part.

Use uniform transmission line theory can be the track circuit the accurate modeling in modeling process in each unit module of four end network coefficient can be (17),(18)Calculation get.

According to each module of actual circuit structure can get track circuit the module of four end network parameters.Track Circuit of fault simulation can be by in Fault Location access resistance of style implementation change access resistance of resistance can be simulation fault of serious degree resistance infinite when equivalent to break resistance for Zero Equivalent to short-circuit.Figure2,3Shown in for use track circuit mathematical model simulation get of fault influence Curve.Limited to space only given part curve results by the curve can see different of fault on different of monitoring of has a different of influence this also show that for actual application process in May multi-fault situation.

(1)RCSaid connection resistance by changeRCSimulation fault serious degree.

2)RGSaid ballast resistance simulation in Set1<RG<Natural 20OMEGAIn km(According to the field situation adjustment) when Ballast resistance belongs to normal state;RG>Natural 20OMEGAIn kmBelongs to ballast resistance increased;RG<1OMEGAIn kmBelongs to ballast resistance reduce.

(3)By parameters is set assurance training set data and test set data of different.

Actual when data format in will add sample collection of time a bar in to training add new fault sample when algorithm will according to the fault mode and sample collection of time will new sample. Appropriate location.

Due to system equipment physical topology on the connectivity and equipment of each other influence indoor Device25A monitoring of and outdoor Device

A monitoring measuring tools have is high correlation and coupling.

3.3 Training Model

Based on the above equipment system and fault characteristics of describe this section will based on support vector machine methods to establishZPW-2000Track Circuit of intelligent fault diagnosis model;In model in two stay Optimization of parameters the Weight ParametersCAnd Radial-based nuclear function of parametersSigmaWhich punishment parameters Main Influence"An interval maximum of hyperplane"And"Assurance data point deviation minimum"Between the weight;Radial-based nuclear ParametersSigmaMain Influence mapping after the data sample in high-dimensional space in the complex degree this two parameters of select will directly influence diagnosis model of generalization ability.

The parametersCAndSigmaThe correction and optimization can be divided into artificial style and automatic adjustment of style.If the artificial correction style the first training set data of diagnosis model the test if Model Diagnosis performance does not meet the requirements again on the above calculation get of parametersCAndGammaThe appropriate artificial correction after again re-training model;General for parametersCTo in ParametersGammaTo minor.But in actual test in artificial Correction Adjustment of errors of up30%There error big,Trouble effort and difficult to meet the actual demand and Problems.Therefore, this paper based on genetic algorithm of parameters Regulation.Genetic algorithm is AmericanJ.HollandProfessor put forward of a kind of by simulation natural evolution theory of optimization methods according to survival of the fittest and the principle of survival of the fittest-by-s evolution the more and more accurate of approximate solution final implementation Optimal Solution.Main including3A basic of operation:Select,Cross and Variation.First,"Select"Of Process main is individual string in accordance with their respective of adaptation value to select copy adaptation value equivalent to various biological In order to survival the necessary of ability decided to the individual string of select or not;"Cross-"This a operation main can be divided into two steps:The first step is will select operation of individual random of two combined with the second step is the cross-and reproductive its results is constantly to recombinant to generate new of individual; finally,"Variation"Said random of to small of probability change a string of value and generate new of individual and take population of scale sizeNatural 20Cross-probability0.9Evolution of algebra100.Its algorithm process as shown in Figure4Shown in:

The Genetic Algorithm of Support Vector Machine Parameters Optimization get optimal CValue 2018Optimal

GammaValue1.

Particle Group algorithm also known as birds foraging algorithm is a kind of new of evolution algorithm from random solutions to the by iterative evolution search optimal solution.Figure5Is based on particle group algorithmSVMParameters Optimization process.

Which PiFor ParticleI After the history best location,PGGroup in all particle the experience of best location the Genetic Algorithm of Support Vector Machine Parameters Optimization get optimalCValue 1987 Optimal Gamma Value0.84.

3.4 Diagnosis test and Results Analysis

This system prototype diagnosis divided into two kind of mode: Off-line Diagnosis and real-time diagnosis.Off-line diagnosis is the record of history data the diagnosis.Real-time diagnosis is the Monitoring System Real-time Monitoring data the diagnosis model of signal centralized monitoring and transmission of monitoring data the diagnosis and have to visits

Broken results.

In the diagnosis when can according to need to select previous training save of diagnosis model (whether contains probability output) such as select probability output of Form, diagnosis results also given each group sample belongs to the fault category of probability value in"Off-line Diagnosis"Mode under, in view of historical data sample quantity huge of reason don't will each sample of probability output value the graphics display user can according to own of interest select a sample the probability display.

In"Real-time diagnosis"Mode under diagnosis model will real-time display each monitoring sample diagnosis results of probability output, taking into account the diagnosis system without also no necessary to Monitoring System of sampling rate of Signal Monitoring System of each sampling data sample the diagnosis so can is set time window such1Minutes on the time window in the sample values average after again the diagnosis.

This research in the field to complete the no insulation Track CircuitZPW-2000AOf the parts connection loose fault mode under monitoring points signal of test to analysis verify Track Circuit Theory Model of accuracy and the fault mode of the monitoring signal of Influence Law.By in different fault location access variable rheostat of Methods simulation fault its fault of degree by change resistance of size to Simulation.Experimental measured of monitoring data in244Group (2928A sample points)Which including different of fault mode and different fault of serious degree.The fault mode of the sample under the data are shown in the following table which ballast resistance including3OMEGAIn kmAnd4OMEGAIn kmTwo.

Table6 Based on track circuit simulating board of experimental data information

Fault mode	F1F2F4F6F7F9F10F11F13	F5F8	F3F12F14F15	F16
Serious degree	[550]OMEGA	[0.11]OMEGA	/	Break
Sample quantity	Each fault modeNatural 20Group in220Group		0	24

According to field-proven most situation under the measurement results and theory calculation results very close to which based on genetic algorithm and particle swarm optimizationSVMDiagnosis accuracy respectively as shown in Figure6And figure7/Shown in.

Average error of difference not very individual situation under Genetic Algorithm of maximum error is big but its in run time has the absolute advantage; in addition this experimental data total contains2928A sample points however taking into account system equipment performance with time will happen migration in actual test in reduce training sample40%When particle group algorithm of diagnosis accuracy quickly decreased47%And genetic algorithm still keep81%The diagnosis accuracy show the genetic algorithm in processing small sample when the high precision characteristics.Therefore priority select Based on Genetic AlgorithmSVMParameters Optimization.

In addition in actual fault diagnosis process in on Data"To mean"And processing operation can get data of evolution trend further eliminate measured data and calculation data between the error.

4. Conclusion

This paper use Support Vector Machine onZPW-2000Track Circuit Equipment The the Fault Diagnosis Analysis and use genetic algorithm to the Optimization get optimalCValue2018OptimalGammaValue1.Use particle group algorithm get of get optimalCValue1987OptimalGammaValue0.84For actual application system of development and development lay the foundation.ZPW-2000Fault Diagnosis of Track Circuit Equipment.The main content of the follow-up research is to extend the research on Fault Diagnosis of other equipment of station signal, and then develop the practical application system..

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