Research on Auxiliary Detection Technology for Downlink Telemetry Parameter Anomaly Discovery

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Introduction

The design, development, manufacturing and delivery of carrier rocket have always been large-scale, multi-functional and complex systems engineering. With the increasing enrichment of functional objectives and tasks, the development complexity of carrier rocket has become higher and higher, and the resulting failure rate has also increased significantly. Therefore, the timely discovery, early warning and disposal of failure modes to avoid catastrophic consequences is of strategic significance.Therefore, the timely discovery, early warning and disposal of failure modes to avoid catastrophic consequences is of strategic significance.As we all know, the carrier rocket telemetry system monitors the operating parameters of each subsystem accurately and continuously, and transmits them to the ground monitoring center through the downlink channel.The purpose of abnormal detection of downlink telemetry parameters is to find abnormal points of working components or subsystems' working modes and laws in a series of acquired sequential parameter value information carriers. The interpretation results are an important basis to measure whether the component equipment or subsystems' working conditions are normal during the flight.

Aim

In order to solve the problem of efficient and automatic identification for the anomaly detection of carrier rocket downlink telemetry parameters, an automatic identification method based on the statistical characteristics of historical data is proposed for the slowly varying parameters.In this paper, the anomaly detection method of time series streaming telemetry data is studied. Based on Gaussian model, aiming at the problems of small probability of occurrence of abnormal samples, small number of samples, difficult to obtain class imbalance and high real-time requirements in parameter anomaly detection data set, a real-time anomaly detection algorithm based on GPR is proposed, so as to lay a foundation for automatic and intelligent parameter interpretation.

Method

Prediction of parameter value and fusion estimation:

Generally, the parameter values of telemetry targets are not only affected by the multidimensional parameter correlation, but also related to the change trend of time dimension. Based on the time dimension of Gaussian process and fuses the prediction results of historical samples of previous parameters is adopted realize the estimation correction of time dimension.

- Data preprocessing.

  The high dynamic, time-varying and nonlinear operating characteristics of the carrier rocket during flight will cause the rocket body vibration and strong nonstationarity. At the same time, the characteristic frequency of telemetry slowly varying parameters is mostly in low frequency, which is very easy to be polluted by environmental noise, causing dynamic changes of parameter characteristics, resulting in parameter characteristic information submerged in background noise. Finite Impulse Response (FIR) digital filter is used for data preprocessing for the collected telemetry slowly changing parameters.

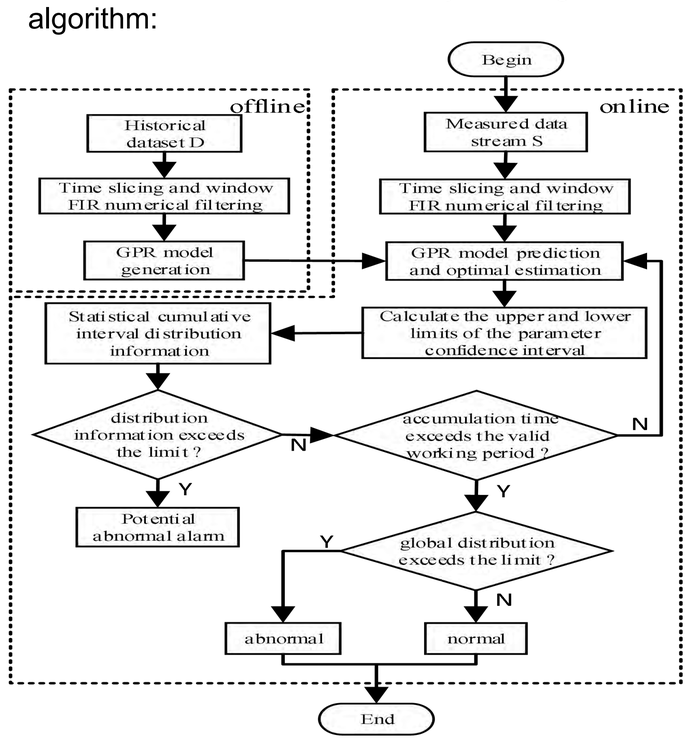
- Prediction of GPR.

  Gaussian process (GP) refers to a random process composed of a series of random variables that satisfy the Gaussian distribution in the continuous domain. It has good adaptability when dealing with complex problems such as high dimensions, small samples, and nonlinearity. GPR model is used in our paper to construct prediction algorithm.

- Parameter Fusion Estimation.

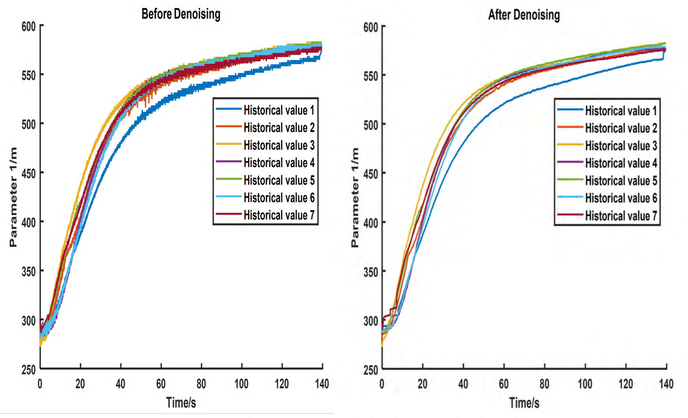
  In this paper, dynamic Gauss-Markov fusion estimation is performed on the prediction output of the sub-model based on each historical sample data to obtain the global prediction.

- Implementation of real-time early warning algorithm:

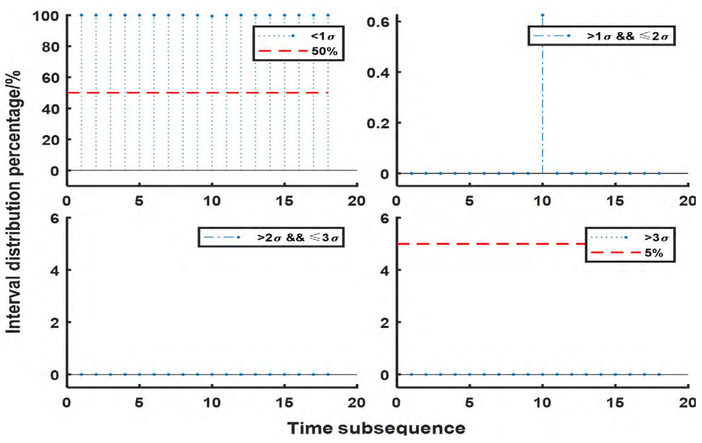


Results

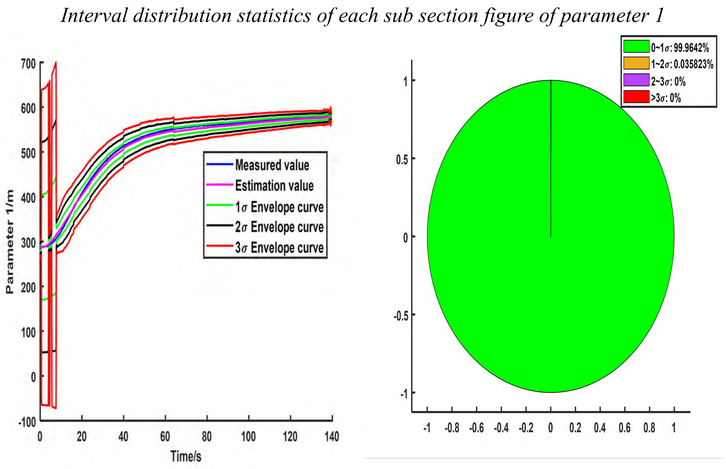
The telemetry slowly varying parameters recorded in the previous complete flight tests of a certain type of carrier rocket is taken as an example.



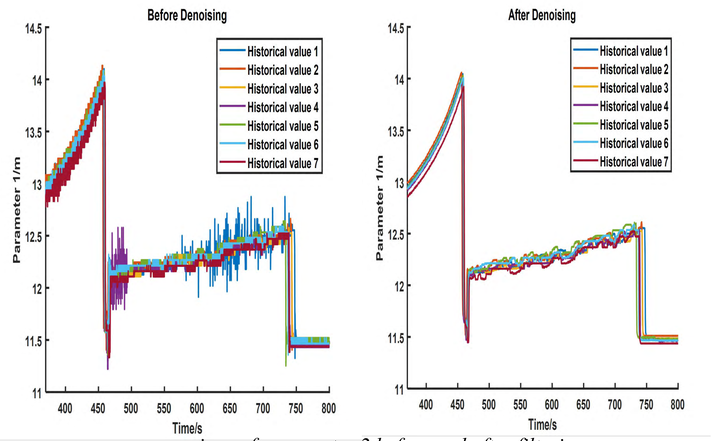
comparison of parameter 1 before and after filtering



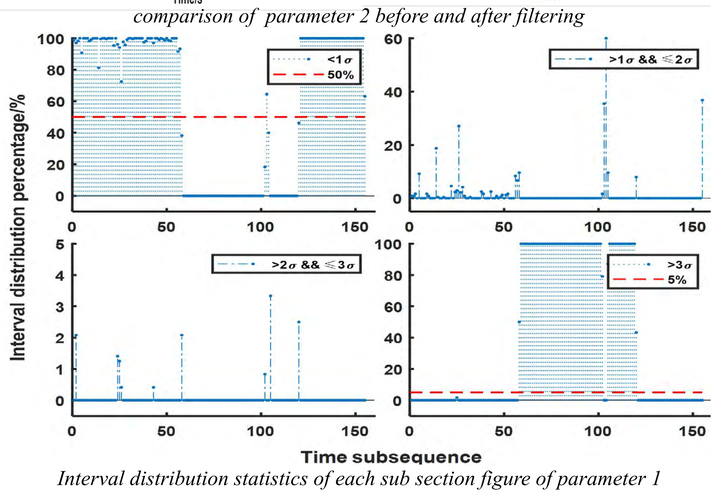
Interval distribution statistics of each sub section figure of parameter 1



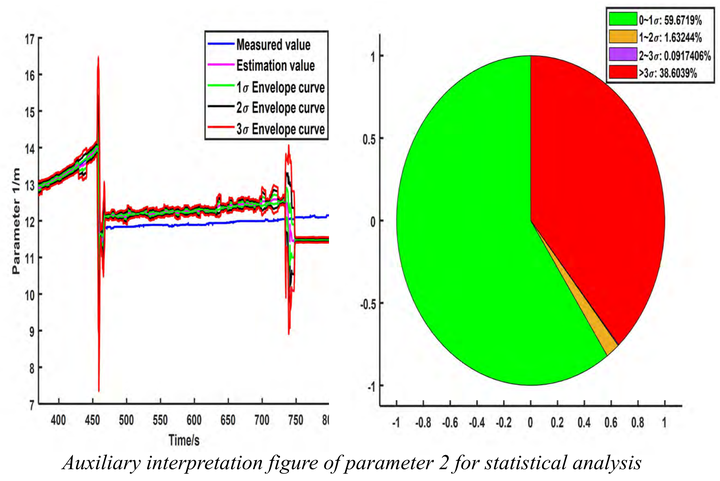
Auxiliary interpretation figure of parameter 1 for statistical analysis



comparison of parameter 2 before and after filtering



Interval distribution statistics of each sub section figure of parameter 1



Auxiliary interpretation figure of parameter 2 for statistical analysis

Comparison of Regression evaluation Indexes with different parameters

Methods	Arguments	MAE	MAPE	RMSE
Ref	*PARA_1*	2.818	1.553%	5.529
	PARA_2	0.003	0.964%	0.011
	PARA_3	1.923	0.557%	2.713
	PARA_4	1.728×10^5	32.036%	1.924×10^5
Ours	*PARA_1*	1.992	1.108%	2.254
	PARA_2	0.0028	0.756%	0.0035
	PARA_3	1.841	0.539%	2.646
	PARA_4	2.796×10^4	3.254%	3.872×10^4

K-sigma principle can be used to count the probability distribution of the measured values of the target data. When exceeds the limit error is greater than 5% or lower than is less than 50% , it will be characterized as a potential abnormal parameter, and abnormal alarm will be carried out. we can also see that our method is superior than other's in terms of evaluation indicators.

Conclusion

The method integrates time slicing, FIR numerical filtering, Gaussian Process Regression and dynamic Gauss-Markov estimation to construct parameter discrimination interval for real-time alarm. Simulation results show that it can effectively identify parameter abnormal with inconsistent statistical characteristics under the condition of ensuring certain accuracy. Finally, our method is completely based on the statistical characteristics of historical measured data, so the consistency of the normal mode of the parameters is relatively high, and the detection algorithm for multi-mode conditions is a direction worthy of further research.