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MULTI-LEVEL FAULT DIAGNOSIS FOR LASER RANGING SYSTEM IN GRAVITATIONAL WAVE DETECTION

Abstract

The deep space gravitational wave detection mission uses laser to measure the change of the distance between the test masses of three formation satellites to detect gravitational waves. The long distance of several million kilometers between spacecrafts and the accuracy of laser ranging at nano-radian level put forward high requirements for the control system of laser link. In the gravitational wave detection mission, the inter satellite laser link is affected by the telescopes, the test masses and the spacecrafts, and the dimension of the system is high. The stable control of these objects is necessary to maintain accurate laser links, any one-dimensional control failure may lead to system link interruption and mission failure. In the actual mission, satellites need to perform accurate fault diagnosis by monitoring the quadrantal photodiode in real time to ensure the stability of the system. Traditional fault diagnosis methods can be divided into two categories, qualitative analysis method and quantitative analysis method. For the high-dimensional complex control system of deep space gravitational wave detection, the qualitative analysis method has high accuracy and efficiency, but it can't identify specific fault parameters and is mainly used to diagnose the types of fault; the quantitative analysis method has high calculation accuracy, but it needs a large amount of calculation, the limited calculation capacity on the satellite makes it difficult to achieve accurate fault diagnosis. In order to overcome the above difficulties, this paper combines quantitative and qualitative analysis methods to provide a fast, accurate and robust fault diagnosis method for the gravitational wave detection control system. Due to the high-dimensional and complex characteristics of the gravitational wave detection system, it is difficult to directly use quantitative analysis method to diagnose the fault of the system. Therefore, this paper uses qualitative analysis method to quickly determine the fault type and components. To ensure the efficiency of fault identification, this paper uses machine learning to determine the specific parameters of the fault. For the gravitational wave detection system, the most common fault type is the control data stuck. The identification of the specific parameters of this fault type using machine learning is difficult to meet the need for high precision. Therefore, this paper uses the branch and bound to search the accurate value around the machine learning diagnosis result to improve the accuracy. Finally, the effectiveness and feasibility of the method are verified by simulation results.