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FAULT DIAGNOSIS OF GRAVITATIONAL WAVE DETECTION SYSTEM OPERATION WITH LIMITED COMPUTING RESOURCES USING SYMBOLIC DIRECTED GRAPH TECHNIQUES

Abstract

Recently, research on the direction of gravitational wave detection is in full swing. China plans to launch Taiji II in 2024 to set up a multi-spacecraft exploration system in a predetermined orbit, and the LISA project from the United States will also complete the scientific research and development of the three-spacecraft system in recent years. However, due to the special detection environment, serious electromagnetic interference and other uncertain factors, detection system failures occur from time to time, and gravitational wave detection missions will also be affected or even interrupted. Therefore, under the condition of long communication time with the ground and limited on-board resources, it is necessary for the system to discover and diagnose the source of faults in time, so as to ensure the safe operation of the system. In this paper, a fault diagnosis method is proposed. Firstly, a qualitative model of a single spacecraft for gravitational wave detection is built based on the improved symbolic directed graph method. By defining nodes of different stages, more information is given to the directed graph of the system and the quantitative information of the system is transformed into different stages of the qualitative model, thus improving the shortcoming of too much information missing in the process of qualitative model modeling. Then, combined with the qualitative model information of a single spacecraft, the multi-spacecraft collaborative fault-diagnosis model under the condition of limited computing resources is established. By adding the single spacecraft computational constraints, inter-spacecraft constraints and different fault modes, the prerequisite requirements of the gravitational wave detection system diagnosis are ensured. Finally, according to the qualitative constraints between the nodes of system model, the incompatible branches are searched by the integration of forward propagation and backward tracking to find the set of fault sources, and the fault possibility ranking of the possible fault sources is completed. The integration of forward propagation and backward tracking solves the limitation problem of single search of minimum diagnosis set by traditional diagnostic methods and deletes the redundant and incorrect incompatible branches from the qualitative logic perspective, which can effectively improve the accuracy of the final diagnostic solution. The simulation results also show that by injecting different faulty modes, the proposed method can quickly respond to the gravitational wave detection system fault and diagnose the fault source under the condition of limited computing resources, which improves the diagnosis efficiency compared with the traditional model-based method.