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SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Space Technology and System Management Practices and Tools (4)

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AN INTELLIGENT MODEL-BASED DIAGNOSING ENGINE USING CONSTRAINT PROGRAMMING

Abstract

Spacecraft health management system requires the ability of sensing self-states and adjusting to environment variation automatically. As model-based reasoning use the knowledge abstracted from the physical principles, rather than expert empiric or testing cases, it is more robust for complex system to handle new events. Such intelligent systems had been demonstrated in spacecraft, like L2 in DS-1 and EO-1, and HyDE in SSWG, but the contradiction between efficiency and accuracy is still the obstacle for application. In this paper, we developed a model-based diagnosing engine using constraint programming (CP) technology, which could diagnose quality and quantity hybrid models efficiently and accurately. Since spacecraft is composed of multi-components, its behavior is the integration of all component behaviors and their relations. For models, we use discrete and continuous variables and constraints to describe component behaviors, and use shared variables to establish component relations. As normal mode switching or fault occurring in components could lead to huge number of cases of system behavior, reasoning is to find the cases which are consistency with observations. The intelligent diagnosing engine is composed of two main modules: 1) reasoning module, for possible conflicts and candidate generation, as well as data management; 2) general CP solver—Choco, for consistency checking of candidate (CCC). As cost of CCC is high, the goal of reasoning module is to sort high possible and eliminate impossible candidates. The primary diagnosing steps are similar to classical model-based reasoning, including fault detection, conflicts searching, candidate generation and CCC. We improved reasoning intelligence through following approaches. Firstly, qualitative constraint propagation was used to split large-scale system into a set of local sub-systems, which could check consistency independently. Therefore, fault detection started reasoning from the observations, and only needs to check the consistency of small-scale sub-systems, rather than comparing all predictions and observations in classical model-based approach. Secondly, we developed a local reasoning algorithm which could re-reason the system quickly. It only changed a few sub-systems when some modes or constraints changed. Thirdly, since CCC is on sub-systems, different candidates may share some identical sub-systems. Establishing a database of them would greatly reduce duplicate CCC. Fourthly, hitting sets were generated using CP solver efficiently. We demonstrated the diagnosing in a semi-physical avionic platform of micro-satellite, which showed that single and double faults in components or observations could be diagnosed efficiently and accurately, while 3 or 4 faults could also be diagnosed correctly but exhausting more time.