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UPDATING SUBSYSTEM-LEVEL FAULT-SYMPTOM RELATIONSHIPS FOR TEMPERATURE AND HUMIDITY CONTROL SYSTEMS WITH REDUNDANT FUNCTIONS

Abstract

As we aim for deep space exploration, supporting vital functions, such as the Temperature and Humidity Control System (THCS) in the Environmental Control and Life Support System (ECLSS), through timely onboard fault detection and diagnosis becomes paramount for mission success. Many prior fault diagnosis approaches are based on previously experienced faults and faults envisioned during system design and assume that the function that models the relationship between faults and associated symptoms (fault-symptom relationships) will remain constant throughout the THCS' lifetime. However, many of these diagnosis methods are not robust to automatically accounting for changes in fault-symptom relationships as a result of redundant functions introduced via the subsystem operating in the context of system-of-systems or unplanned habitat reconfiguration. Fault diagnosis is only as effective as its understanding of the fault-symptom relationships, and if this relationship is incorrect, then the results generated by fault diagnosis will suffer. We motivate the need to revise fault-symptom relationships with a case study in which redundant heating functions are introduced in a system-of-systems operation in an earth-based THCS analog, the Heating, Ventilation, and Air Conditioning (HVAC) system, and the original fault-symptom relationship is revealed to be no longer accurate. We identify current fault-symptom relationship generation methods that account for redundancy within subsystems, such as Model-Based Dependability Analysis (MBDA) methods and data-driven causal discovery methods, and apply them to the analog scenario above. Through this analysis, we detail our procedure in: (i) identifying relevant fault-free system information, such as redundancy, to revise fault-symptom relationships used in fault diagnosis and (ii) empirically evaluating the fault diagnosis performance in a THCS with the original and revised fault-symptom relationship. Our contribution lies in identifying gaps between the current fault-symptom generation methods and the one we envision for deep space travel that accounts for redundancies introduced in system-of-systems operation and unplanned habitat reconfiguration. We found that although the MBDA methods can automatically generate fault-symptom relationships given system flow information and fault mode of components, they also required manual revision of the aforementioned information to create fault-symptom relationships that reflect redundancies that exist in our analog scenario. On the other hand, we concluded that the causal discovery methods can detect redundancies in system-of-systems operation that may help us revise fault-symptom relationships, but suspect variables that contribute to redundancies may have to be hand-picked.