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FEASIBILITY OF INNOVATIVE FAULT DETECTION, ISOLATION AND RECOVERY ON-BOARD SPACECRAFT USING COGNITIVE AUTOMATION

Abstract

Fault detection and diagnosis is a crucial aspect in spacecraft operations and on-board software with respect to safety, reliability and performance. The success of a space mission depends on the adequate and timely system reaction to unexpected environmental changes and fault or failure of components or subsystems.

The traditional spacecraft fault detection, isolation and recovery (FDIR) approach involves pre-flight analysis of fault and failure scenarios that result in corresponding (often hard-coded) routines on-board the spacecraft as well as around-the-clock monitoring, threshold checking, and trend analysis of a large amount of telemetry data by human operators on ground. In case a fault is detected, the spacecraft is put into a known safe configuration and control is transferred to the ground in order to diagnose the fault and recover the system. These classical FDIR techniques have multiple shortcomings such as increasing time delay between commands sent and received concerning large distance interplanetary spacecraft. Often, unnecessary safe mode events are triggered since knowledge about the system, its operational capabilities and impact of environmental interaction is usually not represented on-board.

Today's rapid progress in increasing computing power enables the transfer of fault detection functionality from the ground to the spacecraft itself to ensure safe and high-performance operation with less intervention by human operators. Consequently, increasing spacecraft autonomy offers also the prospect of reducing overall operational cost. This paper introduces an innovative fault diagnosis methodology using cognitive automation and Cognitive System Architecture (COSA) on spacecraft system level FDIR while integrating conventional well-proven FDIR approaches on component and subsystem levels. The cognitive automation technology was developed by the Institute of Flight Systems of the University of German Armed Forces Munich.

The objective of the presented study is the proof-of-concept of cognitive automation being also suitable on enhancing spacecraft on-board autonomy. Context sensitive reactions of the spacecraft in case of unexpected failure are enabled by implementing knowledge about the current system and environmental state, system operational capabilities and the impact of faults and recovery actions on the system and system performance. A case study that applies the cognitive automation concept to the power subsystem of an interplanetary spacecraft is performed: relevant spacecraft system and subsystem models, applicable boundary conditions and environmental models are identified. The obtained simulation results are presented and discussed.