Autonomous Sequencing and Model-based Fault Protection for Space Interferometry

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The Remote Agent is a software set for sophisticated monitoring and control of complex systems. Flight validated as an experiment on the Deep Space One spacecraft [1], it has been repackaged as the foundation for process control in space-based optical interferometry applications. Two main elements of the Remote Agent autonomy architecture, Livingstone [2] and the Smart Executive [3], are being integrated with the Real-Time Control software controlling interferometry testbeds at the Jet Propulsion Laboratory. The application of these technologies to robust autonomous sequencing, model-based fault protection and control of a ground-based interferometer has been demonstrated, in the context of a representative observation scenario. This paper describes the functionality of the software elements, provides an overview of the system models developed for this task, and discusses the demonstrated capabilities of the integrated system. The goal of this paper is to provide an example of how state-of-the-art model-based autonomy technology is integrated with a complex aerospace system, and to highlight the lessons learned from the integration process.

An optical interferometer instrument consists of numerous components, with significant component interaction. Each component can have multiple possible failure modes, often involving multi-step recovery procedures. When dealing with such a complex system, integrated pre-flight testing is essential. A successful demonstration on a ground testbed is the first step toward broader acceptance of autonomy technology in the aerospace community, and possible adoption in future missions. A successful demonstration consists of performing monitored execution of complex sequences during nominal interferometer operations, and providing robust recovery capability in the face of potentially subtle failures.

Livingstone - Livingstone is a model-based monitoring, diagnosis and reconfiguration engine that performs significant deduction in the sense/response loop. It uses common-sense qualitative models of spacecraft components and subsystems, expressed in a transition system formulation. Livingstone models built for this task represent the subsystem responsible for linear metrology and fringe tracking on a single interferometer baseline.

Smart Executive (EXEC) - The EXEC is a robust, event-driven, goal-oriented and multi-threaded plan execution system. The EXEC code incorporates constructs for exception handling, timeouts, concurrent thread spawning, event synchronization, goal achievement, and resource management.

Demonstrated Capabilities - A variety of features were successfully implemented, ranging from basic interactive commanding of testbed components to more complex constructs for state achievement and maintenance, with autonomous recoveries. The demonstrated scenario consisted of bringing the interferometer instrument online from an idle state, achieving internal metrology lock, and acquiring the science fringe. Robustness of the system was tested by causing the internal metrology to lose lock during fringe tracking. The Remote Agent system correctly diagnosed the fault and initiated a recovery sequence, resulting in re-acquisition of internal metrology lock and fringe tracking.

References

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