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TOOLS FOR RECONFIGURABLE CONTROL SYSTEM COMPARISONS FOR AUTONOMOUS ASSEMBLY APPLICATIONS

Abstract

Reconfigurable control systems are a key enabling technology for autonomous assembly, allowing for a single control system to maintain performance despite large mass property variations that occur from docking and undocking during assembly. There is a wide range of reconfigurable control systems that can be implemented, based on the amount of apriori information known to the designer. The range spans from gain scheduling, where most all the information about the transitions are known, to online system identification, where no information is known. However, little to no techniques currently exist to compare these methods to determine which reconfigurable control system design is the appropriate design for the given assembly scenario. This paper offers two methods to enable the comparison which aids in the selection of a control system for assembly. The first method is a set of metrics to enable a quantitative comparison between reconfigurable control systems on a number of different aspects, such as mass, power, development time, and flexibility. The second method is a simulation that utilizes the set of metrics, a detailed characterization of the scenario, and full control system design to execute a time simulation of the assembly. The time simulation allows for detailed calculation of system level performance of the assembly, such as total time for assembly and fuel used.

Results are presented for sixteen reconfigurable control systems designs, with four main components: gain scheduling, multiple model control, online model calculation, and system identification. Each of the sixteen designs is tested on two scenarios: ACRRES and ALMOST. ACRRES (Autonomous Control Reconfiguration for Robotic Exploration Systems) is a set of three autonomous vehicles, each starting at an initial random location that self-assembles into a triangle configuration. ALMOST (Assembly of a Large Modular Optical Space Telescope) consists of a single tug assembling six mirror pieces from an initial stack configuration to a hexagonal ring formation. The vehicles in both scenarios are based on the SPHERES testbed (Synchronized Position Hold Engage Reorient Experimental Satellites), while the payload in ALMOST is a scaled version of the SPOT mirror developed at NASA Goddard Space Flight Center. Results of the 32 test cases (16 methods, 2 scenarios) are expected to show a trend in the performance of the control system design, based on the architecture parameters. Sensitivity analysis is also performed to confirm the trends by varying the scenario architecture parameters, such as number of payload, number of tugs, and size of payload with respect to tug, and comparing the corresponding results to that of the baseline cases. In general, the simulation and incorporated metrics will allow engineers to select the appropriate control system design in a more quantitative fashion, based on the particulars of their given assembly application. The results for these particular studies can provide novel insight into the influences of the control system design on the performance of the assembly.