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METHODS FOR MODELING CONTACT DYNAMICS OF CAPTURE MECHANISMS

Philip Williams, Pat Tobbe and John Glaese: Logicon Control Dynamics Co.
600 Boulevard South, Suite 304
Huntsville, AL 35802
(205) 882-2650
FAX: (205) 882-2683

In this paper, an analytical approach for studying the contact dynamics of space-based vehicles during docking/berthing maneuvers is presented. Methods for modeling physical contact between docking/berthing mechanisms, examples of how these models have been used to evaluate the dynamic behavior of automated capture mechanisms, and experimental verification of predicted results are shown.

Contact force models have been developed for space vehicles using a technique known as the Method of Soft Constraints. In this method, contact forces are computed for any physical contact between capture mechanism surfaces (i.e., docking rings, alignment guides, capture latches, etc...). The docking/berthing ports are defined as an assemblage of surfaces where each surface is considered a geometric constraint with respect to other port surfaces. Contact force calculations are done in 3-dimensional space when any defined surface attempts to pass through another surface. The generated force is mutually normal to the surfaces in contact and its magnitude is proportional to the depth of penetration. These forces are then used to drive the equations-of-motion of the docking/berthing vehicles.

The Method-of-Soft-Constraints has been applied to the following mechanisms: Apollo Probe-Drogue, RMS End-Effector, Orbital Maneuvering Vehicle Three Point Docking Mechanism (OMV TPDM), and Space Station Docking and Berthing Mechanisms. Models for these mechanisms have been used to predict capture envelopes, contact forces, system dynamic response, and vehicle/manipulator control system performance in the presence of contact forces. Hardware-in-the-loop simulation results have been generated at the MSFC Six DOF Motion Facility for the RMS End-Effector, OMV TPDM, and Space Station Docking Mechanism. These results compared favorably with those predicted by the analytical model. Results from a hardware test of a single latch version of the OMV TPDM on the MSFC Flight Robotics Laboratory air-bearing floor have also correlated well with analytical and hardware-in-the-loop simulation data.

This paper will describe applications of the Method of Soft Constraints to docking/berthing mechanisms, explain the benefits of an analytical model, and present results from past test programs.

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