ABSTRACT

STABILIZING AND SPECIFYING MOTION RELATIVE TO UNSTABLE TRAJECTORIES: APPLICATIONS TO SPACECRAFT FORMATION FLIGHT

by

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This dissertation studies formation flight in the unstable environment about the Earth-Sun halo orbits, with specific applications to interferometric imaging. These dynamical systems are unstable and time varying in general. The approach taken in this research is to create "artificial" center manifolds by applying a single control law to a spacecraft formation. The methodology for controller design was chosen to maintain the Hamiltonian structure of the problem. Using this approach, simple feedback control laws can be designed that will force a formation of spacecraft to perform coordinated maneuvers corresponding to motion in the center manifold of a stabilized periodic orbit. As part of this research a refined notion of stability based on the 2-norm of the state transition matrix has been developed. Using this approach formation control laws are developed that minimize the inter-spacecraft drift.

The main contributions of this dissertation are as follows. First a class of control laws are derived and analyzed that stabilize a class of unstable periodic orbits in the Hill restricted three-body problem. The control laws are derived by stabilizing the short-time dynamics of motion about a trajectory by the use of a feedback law. The monodromy matrix of the resulting orbit has all of its eigenvalues on the unit circle with non-zero imaginary parts except when certain resonances exist. By adjusting the feedback control gain it is possible to induce large winding numbers, which correspond to formation revolutions about the nominal trajectory. To describe the motion we approximate the time-varying linear dynamics with a “local” time-invariant system. The “orbital elements” of these linear solutions are defined and used to describe the possible motions for a formation of spacecraft. Based on this work, various approaches to design a formation of spacecraft are developed. With position-and-velocity feedback control laws, the entire constellation can be forced to follow an arbitrary path and carry out a trajectory plane re-orientation with respect to the rotational or inertial frame. The evaluation and analysis of the cost of these maneuvers show the feasibility of our algorithm. Third, the transient stability of relative motion is investigated. First the notion of transient stability and instability using the Krein Signature of the state transition matrix is defined for the relative motion. Examples of stable relative motion with and without transient stability are provided. This approach is also used to prove the robustness of a class of control laws.