ABSTRACT

AUTONOMOUS LANDMARK TRACKING ORBIT DETERMINATION STRATEGY

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Condensed Abstract

Determination of the orbit of a spacecraft about an asteroid or comet presents many challenges relating to the dynamic environment and introduction of new data types. Optical tracking of craters on the surface of a central body was first used operationally for navigation by the Near Earth Asteroid Rendezvous (NEAR) mission to the asteroid Eros. The NEAR navigation system relied on a manual system of landmark detection and identification. Development of an autonomous navigation system would require orbit determination to be performed on the spacecraft computer with no human intervention. In this paper, an orbit determination strategy is described that is fully autonomous and relies on a computer-based crater detection and identification algorithm that is suitable for both automation of the ground based navigation system and autonomous spacecraft based navigation.

Extended Abstract

Determination of the orbit of a spacecraft about an asteroid or comet presents many challenges relating to the dynamic environment and introduction of new data types. Optical tracking of craters on the surface of a central body was first used operationally for navigation by the Near Earth Asteroid Rendezvous (NEAR) mission to the asteroid Eros. The landmark tracking data was integrated with Doppler and range radiometric data and laser altimeter data to determine the orbit of the NEAR spacecraft in conjunction with the physical properties of Eros that are needed for orbit determination and navigation. The NEAR operational orbit determination strategy involved solving for hundreds of parameters that were updated daily as additional measurements were obtained. These parameters included spacecraft state and other parameters related to the spacecraft orbit such as solar pressure and propulsive maneuvers in addition to Eros physical parameters that included gravity harmonic coefficients, pole and prime meridian, inertia tensor, landmark locations and ephemeris. The initial orbit determination emphasis upon arrival at Eros was to physically characterize Eros. The pole, prime meridian, inertia tensor and gravity field were first determined. The principal data type

used for this determination was optical tracking of landmarks. The landmarks are craters on the surface of Eros and thousands are identified and catalogued for this purpose. After the physical characterization of Eros was completed to an accuracy necessary to sustain orbit determination, the identification and processing of landmark data became routine but remained time consuming and tedious to the end of the mission.

The development of a totally autonomous navigation system for application to a spacecraft in orbit about an asteroid or comet is far from being realized. The major obstacle is the need for a computer-based algorithm for identification of craters to replace the current manual identification. An evolutionary development is envisioned that will achieve full autonomy in stages. The first stage would be an autonomous system that would determine the spacecraft orbit and point science instruments at features on the asteroid or comet that are of interest. The second stage would execute propulsive maneuvers to control the orbit and automatically execute a mission plan. The third and final stage would be initiated on approach to an asteroid and would characterize the asteroid, acquire science data and completely execute the mission plan. The first two stages are well within the current capability of computer systems and algorithms. Since the initial characterization of the asteroid or comet would require algorithms that must anticipate a wide variety of asteroids and comets, it is expected that the third stage would require artificial intelligence and will not be developed in the immediate future.

In this paper, algorithms are described for achieving the first two stages of autonomy. The initial characterization of the body is performed on the ground and the results uploaded to the spacecraft. The autonomous navigation is initialized with a high precision spacecraft state vector and asteroid or comet model. Additional data is acquired and processed to maintain the orbit. The centerpiece of this autonomous system is an algorithm for detection and identification of landmarks. This automatic landmark tracking system is designed for both ground based and space based application and performs the entire spacecraft orbit determination without human intervention. Segments of the NEAR orbit are determined using the new automatic landmark tracking and compared with the convention orbit determination obtained during NEAR mission operations. An algorithm is also analyzed that would function autonomously.