AUTONOMOUS RECONFIGURABLE GPS/INS NAVIGATION AND POINTING SYSTEM FOR RENDEZVOUS AND DOCKING

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ABSTRACT

This paper describes the results of an integrated navigation and pointing system software development effort sponsored by the NASA Marshall Space Flight Center through a SBIR Phase II Program. The integrated Global Positioning System (GPS)/Inertial Navigation System (INS) implements an autonomous navigation filter that is reconfigurable in real-time to accommodate mission contingencies. An onboard expert system monitors the spacecraft status and reconfigures the navigation filter accordingly to optimize the system performance. The navigation filter is a multi-mode Kalman filter to estimate the spacecraft position, velocity and attitude. Three different GPS-based attitude determination techniques, namely, velocity vector matching, attitude vector matching, and interferometric processing, are implemented to encompass different mission contingencies. The integrated GPS/INS navigation filter will use any of these techniques depending on the mission phase and the state of the sensors. The first technique, velocity vector matching, uses the GPS velocity measurement to estimate the INS velocity errors and exploits the correlation between INS velocity and attitude errors to estimate the attitude. The second technique, attitude vector matching, uses INS gyro measurements and GPS carrier phase (integrated Doppler) measurements during a spacecraft rotation maneuver to determine the attitude. Both of these techniques require only one GPS antenna onboard to determine the spacecraft attitude. The third technique, interferometric processing, requires use of multiple GPS antennae. In order to determine 3-axis body attitude, three GPS antennae (2 no-coplanor baselines) are required.

In the current implementation, the above three techniques are implemented in a multi-mode filter. The software implementation is chosen such that additional new filter modes and processing techniques can be added easily. One addition to the present configuration modes is in the incorporation of relative navigation mode between two spacecraft - a target and a chaser spacecraft - to demonstrate the

capability of GPS to support autonomous rendezvous and docking.

The navigation and attitude determination filter is implemented in Ada programming language. Object oriented software design is used to lay the foundation for the development of a highly reconfigurable embedded Kalman filter software. The software architecture implements two separate software functions: (1) multi-mode navigation Kalman filter, and (2) knowledge-based contingency mission planner. The reconfigurable feature of the software is derived from the use of a real-time interpretive mechanism to execute code threads stored in linked lists. Each code thread defines a navigation filter mode. An embedded expert system stores and executes the knowledge base in real-time. Facts are stored in a network of cross-referenced lists which connect facts to decision modules.

The paper also presents simulation results of the integrated GPS/INS navigation filter for two filter configurations and predicts the spacecraft navigation and attitude determination performance.