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AUTOMATED RELATIVE STATE DETERMINATION IN A MULTI-SATELLITE ARRAY USING GPS WITH NO GROUND STATIONS

Abstract

Multi-satellite systems have been considered for a variety of purposes from space weather monitoring to interferometry. One of the reasons why autonomous multi-satellite arrays are so popular for space exploration is that they enable the simultaneous collection of data from different locations by the same system. Also, large constellations with $n>>2$ agents often have a high level of redundancy; that is, the functionalities of individual satellites are interchangeable. From a purely kinematic standpoint, having thousands of satellite members can be a trivial problem. However, when GPS signal transmission between constellation members is considered, a solution that incorporates transmission time and quality must be considered. In light of using GPS for relative positioning in multi-satellite arrays, large constellations pose a problem because many previous solutions that use the well-known GPS technique of carrier phase differencing have occurred between at most two satellites and/or ground stations.

As a step toward large constellations, the goal of this work is to achieve position and velocity consensus in a six-satellite array using GPS signals to estimate satellite states; all of this is done in the absence of ground stations. A leader satellite uses a double-differencing GPS estimation scheme to determine the follower satellites' relative states. For the purpose of improving inter-satellite communication, a minimum satellite-to-satellite distance is maintained, and the spacecraft are constrained to communicate only with their closest neighbors. The positions estimated using GPS are validated by comparison to both a truth model and the estimated positions found using an Extended Kalman Filter.

Simulations of the signal transmission process and resulting formation flight are performed using Matlab. The effects of time-delay determination and integer ambiguity resolution on the position and attitude convergence time are recorded. Initial results show that the quality of the double-differenced solution is dependent upon the inter-satellite distances, and specifically that the signal quality and baseline distances are inversely proportional.

Previously, GPS could only be considered in a near-Earth environment due to the dependence on ground stations. However, not only will these results render a broader understanding of the communication tools available for multi-satellite systems both close to and far from Earth, but it will also eliminate the problems present in transmission of signals between earth-bound and space-bound receivers such as loss-of-signal periods and signal transmission delays due to the ionosphere.