SIMULATING THE LIAISON NAVIGATION CONCEPT IN A GEO + EARTH-MOON HALO CONSTELLATION

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ABSTRACT

Linked Autonomous Interplanetary Satellite Orbit Navigation, or LiAISON, is a novel satellite navigation technique where relative range and range-rate measurements between two or more spacecraft in a constellation are processed to obtain the absolute state of all spacecraft [1–5]. No ground-based measurements are required. The method leverages the asymmetry of the gravity field that the constellation exists in allowing a unique configuration to exist. Previous research has focused on lunar constellations with at least one satellite in an Earth-Moon libration point orbit; LiAISON, however, is not confined to this particular set up, and could be of use in other navigation scenarios, as suggested by Hill [1]. One scenario of interest is to apply LiAISON to GEO satellites, as traditional ground-based orbit determination in this orbit regime is often difficult due to a lack of relative motion and conventional GPS receivers are ineffective at such high altitudes. This configuration would extend a GPS-like navigation capability to any Earth orbiting satellite as well as those at the Moon. This work focuses on the tracking of a GEO satellite, but has implications for other Earth or Moon orbits.

In particular, this paper describes the technical details of developing a high fidelity navigation simulation for the LiAISON concept in an Earth-Moon constellation, with one satellite in GEO orbit and another in a halo orbit about the Earth-Moon L_1 point. Again, only relative range measurements between the two satellites are processed as observations. The filter simulation will include the effects of dynamical modeling errors from unmodeled third-body forces (JPL DE405 ephemeris), mismodeled Earth potential and mismodeled solar radiation pressure, as well as random measurement errors, measurement biases, and measurement gaps. A variety of filtering schemes will be investigated, such as the conventional and extended Kalman filters (CKF and EKF) with state noise compensation (SNC), and the consider covariance filter. Filter convergence characteristics for varying levels of initial uncertainty will be examined as well as the estimation of measurement biases, the effects of large measurement gaps, and dynamic model compensation (DMC) to recover un-modeled or mismodeled forces or parameters.

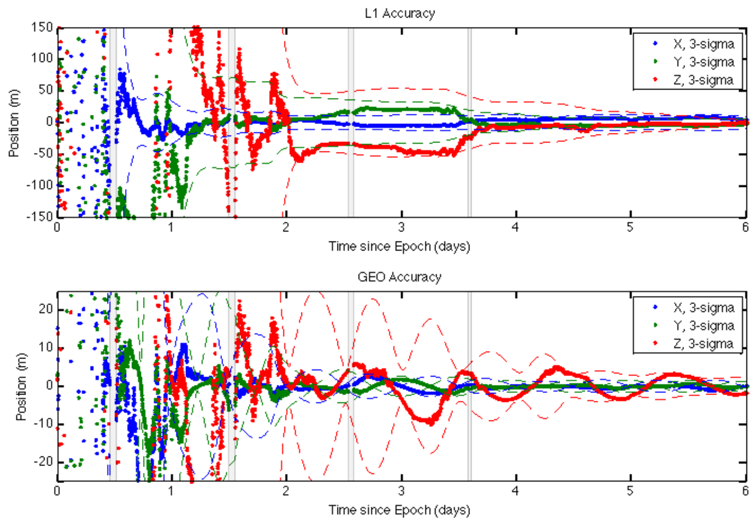

Figure 1. Estimated L_1 halo (top) and GEO (bottom) satellite position accuracy (i.e. filtered solution $-$ truth) from an EKF plotted over time. Bold lines indicate accuracy and the dashed lines indicate the associated 3-σ uncertainty from the covariance. Plot has been clipped for clarity.

Preliminary work has shown that an EKF can accurately recover the states of the Lunar L_1 and GEO satellites taking into account both measurement noise and bias. Starting with no certainty of the satellites positions and no dynamical modeling errors, the filter converges to meter-level accuracy in position and 10^{-5} m/s-level accuracy for velocity for both satellites; refer to Figure 1. Here, the data track spanned 6 days with observations every 90 minutes. By better quantifying the uncertainty of the initial state, we expect that the solution accuracy will be maintained, if not further improved, in the presence of dynamical modeling errors.

1. References

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