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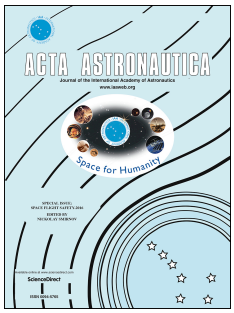

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Observability of satellite launcher navigation with INS, GPS, attitude sensors and reference trajectory

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Abstract

The navigation system of a satellite launcher is of paramount importance. In order to correct the trajectory of the launcher, the position, velocity and attitude must be known with the best possible precision. In this paper, the observability of four navigation solutions is investigated. The first one is the INS/GPS couple. Then, attitude reference sensors, such as magnetometers, are added to the INS/GPS solution. The authors have already demonstrated that the reference trajectory could be used to improve the navigation performance. This approach is added to the two previously mentioned navigation systems. For each navigation solution, the observability is analyzed with different sensor error models. First, sensor biases are neglected. Then, sensor biases are modelled as random walks and as first order Markov processes.

The observability is tested with the rank and condition number of the observability matrix, the time evolution of the covariance matrix and sensitivity to measurement outlier tests. The covariance matrix is exploited to evaluate the correlation between states in order to detect structural unobservability problems. Finally, when an unobservable subspace is detected, the result is verified with theoretical analysis of the navigation equations.

The results show that evaluating only the observability of a model does not guarantee the ability of the aiding sensors to correct the INS estimates within the mission time. The analysis of the covariance matrix time evolution could be a powerful tool to detect this situation, however in some cases, the problem is only revealed with a sensitivity to measurement outlier test. None of the tested solutions provide GPS position bias observability. For the considered mission, the modelling of the sensor biases as random walks or Markov processes gives equivalent results. Relying on the reference trajectory can improve the precision of the roll estimates. But, in the context of a satellite launcher, the roll estimation error and gyroscope bias are only observable if attitude reference sensors are present.

Keywords: Observability, INS, GPS, reference trajectory

Notation

Latines letters

0_i	$i \times i$ zero matrix
$0_{i\times j}$	$i \times j$ zero matrix
A	state matrix

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