ADAPTIVE KALMAN FILTERS FOR ORBIT ESTIMATION OF NAVIGATION SATELLITES FOR DGPS APPLICATIONS

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Abstract

- Differential Global Position System (DGPS) is a GPS mode that uses a reference station at a known location to calculate and broadcast pseudo range corrections.
- Major contribution is due to orbit errors which are be estimated by nonlinear Kalman like filters.

Introduction

- Motivation
- Interoperable Differential SAT NAV systems
- Using GPS, GLONASS, GALILEO or other future satellites
- Several Aspects to Interoperability of Differential systems
- Estimation of Errors
- Focus on Orbit errors
- Orbit Estimation

Kalman Filtering

Kalman filter is a sequential estimation problem normally based on the Innovations approach. The problem is normally stated as:

Given a sequence of noisy observations to estimate the sequence of state vectors of a linear system driven by noise.

Orbit Model

Dynamic model in orbiting Cartesian frame:

\[ \begin{align*}
\dot{x} &= \frac{1}{m} (F - m \omega^2 x) + w_x, \\
\dot{y} &= \frac{1}{m} (G - m \omega^2 y) + w_y, \\
\dot{z} &= \frac{1}{m} (H - m \omega^2 z) + w_z,
\end{align*} \]

Modified UKF

- Key to the UKF are the calculation of the:
  - Sigma Points & Weights
  - for estimating the state vector’s mean and covariance from those of the sigma points
  - Uses Cholesky Decomposition of Covariance matrix
- A numerically superior approach is to use SVD

Estimate Errors

- With the UKF the maximum predicted error in the pseudo-range is thus less than 10m relative to the data generated for the GLONASS satellite.
- With the modified UKF the maximum predicted error in the pseudo-range is now reduced to less than 1mm relative to the data generated for the GLONASS satellite.
- This corresponds to an improvement by factor of 10000
- Moreover the predicted error is now uniform.

Adaptive UKF Filtering

- Covariance matrices of the state and observation noises were assumed constant
- Noise Statistics may be UNKNOWN
- Adaptive Kalman Filtering facilitates real time estimation of Noise Statistics
- Suitable for Orbit Estimation
- Only the process noise covariance is recursively updated

Discussion

- The main reason for the better performance of the UKF is that the UT approximates the mean and the covariance to third order which is better than linearization.
- SVD improves performance of the UKF significantly

Conclusions

The modified and adaptive UKF facilitate the use of arbitrary realistic models of the process and measurement noise statistics and thus give very good estimates of a navigation satellite’s pseudo-range.

Main References


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