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Master Thesis (Year 2014)

Evaluation of Different State-Transition and Estimation Approaches in Multi-Sensor Multi-Platform Navigation with respect to varying types of trajectories using MATLAB

Referee

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Key Words

Navigation, Parameter Estimation Process, GNSS, INS, Gauss-Markov Model, Prediction, Least Mean Square Adjustment, Condition Equations.

Summary

This Master thesis describes the theoretical and practical development of a parameter estimation process (figure 1) to be applied in navigation applications. A MATLAB code is implemented and a software system that simulates the output data from a Global Navigation Satellite System (GNSS) and Inertial Navigation Systems (INS) is used in order to test the implemented algorithm. This simulation software will provide reference and observation data, therefore the resulting adjusted data can be compared with the reference data. Furthermore, different simulated theoretical trajectories i.e., straight line, circle, helix and spline, are tested in order to study the behavior of the obtained parameter values in each case, since they have different characteristics and settings, e.g., constant velocity, with/without acceleration, wrong initial orientation etc. Finally, the algorithm is applied to an actual case using simulated data. The situation chosen is the tracking of running trains.

A state estimation process is applied to tracking cases, where the transition model will be the one that has a full 3D model with 16 parameters: position $(u_x{}^e, u_y{}^e, u_z{}^e)$, velocity $(\dot{u}_x{}^e, \dot{u}_y{}^e, \dot{u}_z{}^e)$, acceleration $(\ddot{u}_x{}^e,\ \ddot{u}_y{}^e, \ddot{u}_z{}^e)$, orientation $(q_{0_b}^{\ e},\ q_{1_b}^{\ e}, q_{2_b}^{\ e},\ q_{3_b}^{\ e})$ and angular rate $(\omega_{x_{eb}}^{\ b},\ \omega_{y_{eb}}^{\ b},\ \omega_{z_{eb}}^{\ b})$. Firstly, a prediction of the parameters in the state vector is computed using a specific transition model. These predicted values are combined with observation data obtained from different sensors, i.e., GNSS and INS. To constrain the solution and reach more accurate results, condition equations can be added to the state estimation process. Here, the quaternion condition (1) and the automotive condition – both first (2) and second (3) derivatives- have been implemented in order to attain an improved solution.

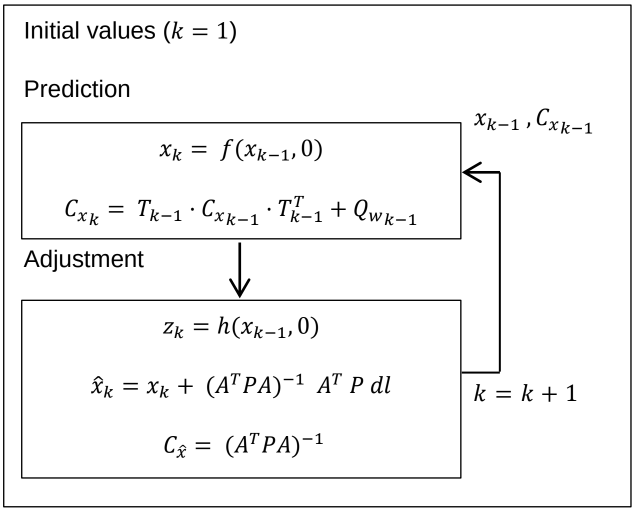

Figure 1. Parameter estimation process.

$$q_0{}^2 + q_1{}^2 + q_2{}^2 + q_3{}^2 = 1 \tag{1}$$

$$\begin{bmatrix} \dot{u}_x \\ \dot{u}_y \\ \dot{u}_z \end{bmatrix}^e = R_b^e \begin{bmatrix} |\dot{u}^e| \\ 0 \\ 0 \end{bmatrix}^b \qquad (2)$$

$$\frac{\delta}{\delta t}\dot{u}^e = \dot{R}_b^e \begin{bmatrix} |\dot{u}^e| \\ 0 \\ 0 \end{bmatrix}^b + R_b^e \begin{bmatrix} \frac{\delta}{\delta t}|\dot{u}^e| \\ 0 \\ 0 \end{bmatrix}^b \qquad (3)$$

After multiple tests, it has been demonstrated that the introduction of conditions helps to correct the obtained parameters' values in general. The automotive condition is needed in order to correct orientation, confirming its usefulness and need in navigation applications.

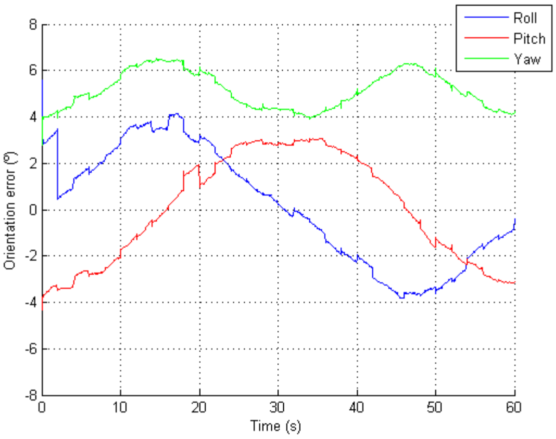

Figure 2. Adjustment without conditions.

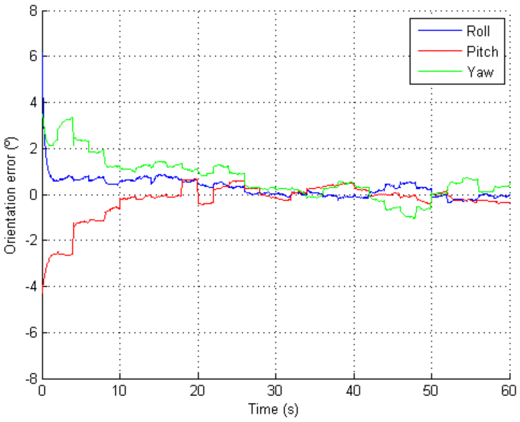

Figure 3. Adjustment with conditions.

Figure 2 and figure 3 show the orientation error in a circular trajectory after applying an adjustment process without conditions and with conditions, respectively. Further investigations were dealing with the integration of odometry as further sensor observation type.