INSTITUTO TECNOLÓGICO DE AERONÁUTICA
MP-208: Optimal Filtering with Aerospace Applications
Exame

Prof. Davi Antônio dos Santos

November 20, 2020

In this work, the students will design, implement, and evaluate two attitude determination algorithms suitable for drones. One of the algorithms is a CDEKF, while the other one is a CDUKF. The underlying problem is formulated in Chapter 8 (see the slides of the course), considering three triaxial navigation sensors: a rate gyro, an accelerometer, and a magnetometer. Briefly, the problem is defined as the estimation of the platform attitude Euler angles (in the 1-2-3 sequence) jointly with the biases of the rate gyro. For simplicity, the accelerometer and magnetometer are assumed to be bias-free. Regarding the sensor roles, the magnetometer and the accelerometer provide what we call the "vector measurements", while the rate-gyro data are used as a known forcing input of the attitude kinematic equation.

Table 1 presents the system parameters to be adopted in this assignment.

Table 1: System parameters.

Description	**Value**
Initial conditions of the plant	$\begin{bmatrix} \boldsymbol{\alpha}^{b/g}(0) \\ \boldsymbol{\beta}_b^{gy}(0) \end{bmatrix} \sim \mathrm{N}(\mathbf{0}_{6\times1}, \mathrm{diag}((\pi/9)^2\mathbf{I}_3, 10^{-1}\mathbf{I}_3))$
Rate-gyro noise	$\mathbf{Q}^{gy} = 2.5 \times 10^{-7}\mathbf{I}_3$
Rate-gyro drift	$\mathbf{Q}^{d,gy} = 1.0 \times 10^{-12}\mathbf{I}_3$
Accelerometer noise	$\mathbf{Q}^{ac} = 1.5 \times 10^{-5}\mathbf{I}_3$
Magnetometer noise	$\mathbf{Q}^{mg} = 0.02\ \mathbf{I}_3\ \mu\mathrm{T}$
Local magnetic field	$\mathbf{m}_g = [13.7\ \ -4.6\ \ -10.9]^{\mathrm{T}}\ \mu\mathrm{T}$
Gravity acceleration	$g = 9.81\ \mathrm{m/s^2}$
Sampling time	$T_s = 0.01$ s

To generate the system trajectory for the study below, let us adopt the following angular velocity signal as a forcing function of the attitude kinematic equation (see equation (1) in the slides of Chapter 8):

$$\boldsymbol{\omega}_b^{b/g}(k) = \frac{2\pi}{3}\begin{bmatrix} \sin(0.5\pi T_s k) \\ \sin(0.5\pi T_s k + 0.5\pi) \\ \sin(0.5\pi T_s k + \pi) \end{bmatrix} \ \mathrm{rad/s}.$$

Question 1. Obtain the Jacobian matrices for the implementation of the CDEKF.

Question 2. Write a MATLAB script to simulate the afore-described system and implement the designed CDEKF. The script must contain an outer loop for the Monte Carlo iterations.

Question 3. Write a MATLAB script to simulate the afore-described system and implement the designed CDUKF. This script either must contain an outer loop for the Monte Carlo iterations.

Question 4. Using the scripts implemented in Question 2 and Question 3, conduct a simulation study to evaluate the performance of the attitude determination algorithms (the CDEKF and the CDUKF) over 100 Monte Carlo realizations, in a simulation period of 10 s. For each of the six state components (say, the ith component), this study must include one graphic containing:

- ten realizations of $\{\tilde{X}_{i,k|k}\}$ vs time; and
- the respective diagonal element of the matrix square root of $\mathbf{P}_{k|k}$ vs time.

Question 5. Write a report to objectively present the obtained results, together with the respective analysis.