深蓝学院

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惯性器件误差分析及标定作业分享

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纲要

第一部分：理论

- ➢第二部分：实验

理论部分

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Errors come from 3 parts：bias, scale and misaligned errors.

1. Bias:

$$b^a = \begin{bmatrix} b_x^a \\ b_y^a \\ b_z^a \end{bmatrix}, b^g = \begin{bmatrix} b_x^g \\ b_y^g \\ b_z^g \end{bmatrix}$$

2. Scale

$$K^a = \begin{bmatrix} s_x^a & 0 & 0 \\ 0 & s_y^a & 0 \\ 0 & 0 & s_z^a \end{bmatrix}, K^g = \begin{bmatrix} s_x^g & 0 & 0 \\ 0 & s_y^g & 0 \\ 0 & 0 & s_z^g \end{bmatrix}$$

理论部分

3. Misaligned errors:

$$\mathbf{T} = \begin{bmatrix} 1 & -\beta_{yz} & \beta_{zy} \\ \beta_{xz} & 1 & -\beta_{zx} \\ -\beta_{xy} & \beta_{yx} & 1 \end{bmatrix} \longrightarrow$$

$$T^a = \begin{bmatrix} 1 & -\alpha_{yz} & \alpha_{zy} \\ 0 & 1 & -\alpha_{zx} \\ 0 & 0 & 1 \end{bmatrix}$$

$$T^g = \begin{bmatrix} 1 & -\gamma_{yz} & \gamma_{zy} \\ \gamma_{xz} & 1 & -\gamma_{zx} \\ -\gamma_{xy} & \gamma_{yx} & 1 \end{bmatrix}$$

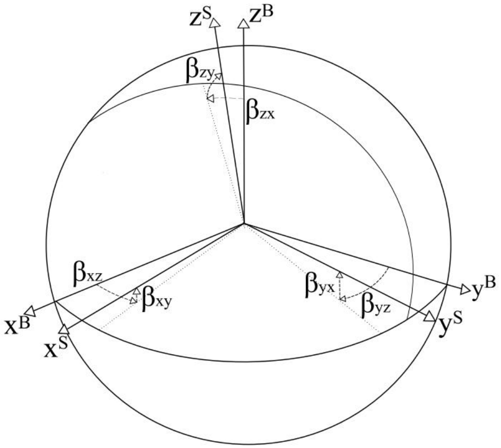

Fig. 2. Non-orthogonal sensor (accelerometers or gyroscopes) axes (x^S, y^S, z^S), and body frame axes (x^B, y^B, z^B).

So the final error model:

The complete sensor error model is

$$\mathbf{a}^O = \mathbf{T}^a \mathbf{K}^a (\mathbf{a}^S + \mathbf{b}^a + \boldsymbol{\nu}^a)$$

for the accelerometers, and

$$\boldsymbol{\omega}^O = \mathbf{T}^g \mathbf{K}^g (\boldsymbol{\omega}^S + \mathbf{b}^g + \boldsymbol{\nu}^g)$$

理论部分

Derivatives

$$|A| = |T + K(x - B)| = \sqrt{A_x^2 + A_y^2 + A_z^2}$$，x为测量值

$$\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ S_a & 1 & 0 \\ -S_b & S_c & 1 \end{bmatrix} \begin{bmatrix} k_x & & \\ & k_y & \\ & & k_z \end{bmatrix} \begin{bmatrix} x - b_x \\ y - b_y \\ z - b_z \end{bmatrix}$$

$$= \begin{bmatrix} k_x \cdot (x - b_x) \\ S_a \cdot k_x (x - b_x) + k_y (y - b_y) \\ -S_b \cdot k_x (x - b_x) + S_c \cdot k_y (y - b_y) + k_z (z - b_z) \end{bmatrix}$$

$$\frac{\partial |A|}{\partial S_a} = \frac{\partial |A|}{\partial A_y} \cdot \frac{\partial A_y}{\partial S_a} = \frac{A_y}{|A|} \cdot k_x (x - b_x)$$

$$\frac{\partial |A|}{\partial S_b} = -\frac{A_z}{|A|} \cdot k_x (x - b_x)$$

$$\frac{\partial |A|}{\partial S_c} = \frac{A_z}{|A|} \cdot k_y (y - b_y)$$

$$\frac{\partial |A|}{\partial k_x} = \left(\frac{A_x}{|A|} + S_a \frac{A_y}{|A|} - S_b \cdot \frac{A_z}{|A|}\right) \cdot (x - b_x)$$

$$\frac{\partial |A|}{\partial k_y} = (y - b_y)\left(\frac{A_y}{|A|} + \frac{A_z}{|A|} S_c\right)$$

$$\frac{\partial |A|}{\partial k_z} = \frac{A_z}{|A|}(z - b_z)$$

$$\frac{\partial |A|}{\partial b_x} = -\frac{A_x}{|A|} k_x - \frac{A_y}{|A|} S_a k_x + \frac{A_z}{|A|} \cdot S_b \cdot k_x .$$

$$\frac{\partial |A|}{\partial b_y} = -\frac{A_y}{|A|} k_y - \frac{A_z}{|A|} \cdot S_c \cdot k_y$$

$$\frac{\partial |A|}{\partial b_z} = -\frac{A_z}{|A|} k_z .$$

纲要

- 第一部分：概述
- 第二部分：实验

实验部分

实验部分换成下三角模型，本质上是选择加速度frame和body frame的哪一个轴对齐，todo部分填充好，解析求导参考之前的作业，通过验证源码标定结果与下三角标定结果是否一致即可。

课程中提到使用近似方法求解：

$$(I + S_a)^{-1} \approx I - S_a$$

$$\begin{aligned} a &= (I - S_a)\, K_a' \,(A - b_a) \\ &\approx (I - S_a)\, K_a' A - b_a \end{aligned}$$

实验部分

- 这里需要描述一下关于xsens_xxx.mat的数据格式,读取的数值并不是角速度或加速度,而是16位带符号数作为陀螺仪测量数据输出,即数据类型是int16,需要根据传感器的量程转换计算,加速度计也一样,具体可以参考博客:
- https://blog.csdn.net/lgcjlu/article/details/88536094

Ref

- https://blog.csdn.net/lgcjlu/article/details/88536094
- https://github.com/Kyle-ak/imu_tk
- https://github.com/Neil-Oyoung/imu_tk
- Calibration and performance evaluation of low-cost IMUs
- A Robust and Easy to Implement Method for IMU Calibration

在线问答

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Q&A

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感谢各位聆听!

Thanks for Listening