The Navigation Research Center,NUAA,PRC

A CONING COMPENSATION ALGORITHM WITH PURE FILTERED ANGLE RATE INPUT

Qinghua Zeng1, Jianye Liu1, Andrew. H. Kemp2, Wei Zhao1

1 Navigation research center, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, P.R.China.

2 School of Electronic and Electrical Engineering, University of Leeds, LS2 9JT, UK.

Brief Biography

Dr Qinghua Zeng is with the Navigation Research Centre, College of Automation Engineering, NUAA, Nanjing, PR.China. Tel: +86(0)25-84895889, E-Mail: zengqh@nuaa.edu.cn

The Navigation Research Center (NRC), College of Automation Engineering ,Nanjing University of Aeronautics and Astronautics, is engaged in the research of navigation and traffic technology.

In the Strapdown Inertial Navigation System (SINS), the coning error of the inertial measurement unit (IMU) is one of the major factors affecting SINS accuracy, especially for high precision units.

Assuming in coning motion, the motion equation along corresponding axis is

$$\Phi = \left[0, \quad a\cos(\Omega t), \quad a\sin(\Omega t)\right]^T$$

Classical coning motion :

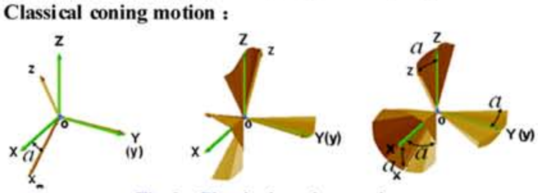

Fig 0. Classical coning motion

Substituting the filtered angular rate into the coning algorithm with ideal angular increments is unable to realize an excellent coning error compensation effect.

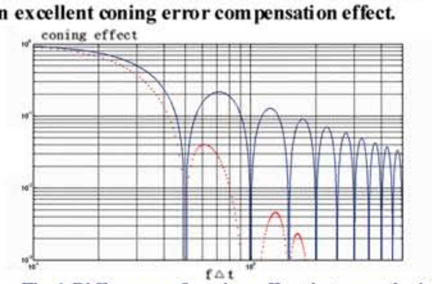

Fig 1.Difference of coning effect between the ideal physical quantity (continuous line) and project filtered one (dotted line)

Gyro angular rate can be expressed

$$\omega(t+\tau) = g_0 + g_1\tau + g_2\tau^2 + \cdots + g_M\tau^M$$

The inner integration angle

$$\hat\theta(h) = \int_0^h \omega(t+\tau)d\tau$$
$$= g_0 h + \frac{1}{2}g_1 h^2 + \frac{1}{3}g_2 h^3 + \cdots + \frac{1}{M+1}g_M h^{M+1} = HGh$$

The formula for fitting angular increment is

$$\hat\theta(h) = HGh = (HC^{-1})Wh = SWh = \left(s_0\omega_0 + s_1\omega_1 + \cdots + s_M\omega_M\right)h$$

The axis X correction of rotation vector can be expressed as:

$$\delta\Phi_x = \sum_{p=1}^{M} C_{px}x_p \qquad \sum_{p=1}^{M} C_{px}x_p = \Phi_{cx}$$

The components of angular increment and rotation vector along axis Y and Z change periodically, which will not cause the unlimited volatility of attitude angle.

The constant component along the X axis directly causes the attitude angle error, the error principle can be defined as

$$\varepsilon = \boldsymbol{\Phi}_x - \hat{\boldsymbol{\theta}}_x - \delta\hat{\boldsymbol{\Phi}}_x$$

We can get

$$\sin^2 a\sum_{p=1}^{M}\{\sum_{k=1}^{\infty}\frac{(-1)^{k+1}\lambda^{2k+1}}{(2k+1)!}[(p-1)^{2k+1} - 2p^{2k+1} + (p+1)^{2k+1}]\}x_p$$
$$= 2\lambda\sin^2(a/2)\left\{\sum_{k=1}^{\infty}\frac{(-1)^{k+1}\lambda^{2k}}{(2k+3)!}[(M-1)^{2k+3} - 2M^{2k+3} + (M+1)^{2k+3}]\right\}$$

The correction coefficients of compensation algorithm

$$X_{M\times 1} = [x_1, x_2, \cdots, x_M]^T = A^{-1}B$$

The dominant term of residual error in X axis is as follows

$$\delta\tilde\phi = \Phi_{cx} - \delta\hat\Phi_x$$
$$= 2\sin^2(a/2)\left\{\frac{(-1)^M\lambda^{2M+3}}{(2M+5)!}[(M-1)^{2M+5} - 2M^{2M+5} + (M+1)^{2M+5}]\right\}$$
$$-\sin^2 a\left\{\sum_{p=1}^{M}\{\frac{(-1)^M\lambda^{2M+3}}{(2M+3)!}[(p-1)^{2M+3} - 2p^{2M+3} + (p+1)^{2M+3}]\}x_p\right\}$$

Coning algorithm precision in this paper is analyzed by comparing with the 4-order Runge-Kutta algorithm. The coning compensation algorithm with filtered angular rate input in this paper has better precision than 4-order Runge-Kutta algorithm.

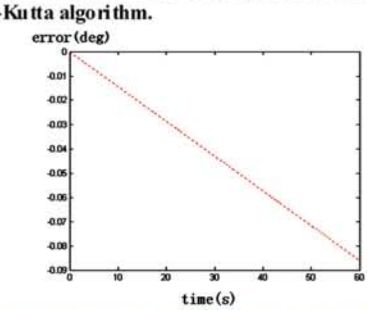

Fig 2. pitch angle error of 4 order Runge-Kutta algorithm

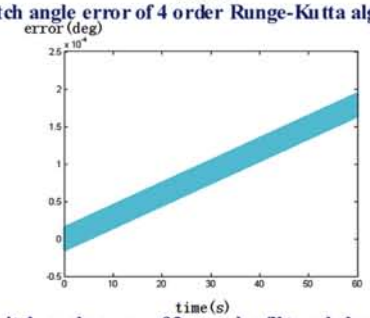

Fig 3. pitch angle error of 2 samples filtered algorithm

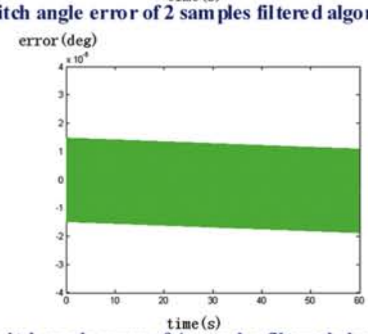

Fig 4. pitch angle error of 4 samples filtered algorithm

The coning compensation algorithm with filtered angular rate input has better performance than other kinds of attitude algorithms, and it is good for improving the accuracy of engineering SINS.