MTRN4010

Noise in Gyroscope's measurements

Gyroscopes' measurements are polluted by randomly fluctuating noise and by certain offset (bias).
The bias is an unknown value, which is slowly time variant, and that for short period of time can even be considered constant.

When the value of that bias is known, it can be used to compensate it by simply "removing" it from the measurements.

$$\omega_{improved}(t) = \omega_{measured}(t) - B$$

For instance, for estimating the heading of a platform that operates in a perfect 2D context, and in which the sensor is installed,

$$\theta(t) = \theta(t_0) + \int_{\tau=t_0}^{t} \omega_{real}(\tau)\cdot d\tau \approx \theta(t_0) + \int_{\tau=t_0}^{t} \omega_{improved}(\tau)\cdot d\tau = \theta(t_0) + \int_{\tau=t_0}^{t} \left(\omega_{measured}(\tau) - B\right)\cdot d\tau$$

Note: we are integrating only the gyro Z, assuming $\frac{d\varphi_z(t)}{dt} = \omega_z(t)$, because we know that the platform operated on an almost flat surface and that the IMU is installed aligned to the platform.

As we are not able to sample at infinite rate but at a "fast enough" rate, i.e. 200Hz, we need to implement the integration in a numerical way.
Given certain rate $\alpha(t) = {dA(t)}/{dt}$, then its associated integral relation is $A(t) = A(t_0) + \int_{\tau=t_0}^{t} \alpha(\tau)\cdot d\tau$. The continuous process can be approximated by the following discrete-time process:

$$A(t_n) = A(t_0) + \sum_{i=1}^{n} \alpha(t_{i-1})\cdot(t_i - t_{i-1}).$$

This approximation is valid in cases in which $(t_i - t_{i-1})$ are small enough. The integration process can also be expressed in a recursive fashion, as follows,

$$A(t_k) = A(t_{k-1}) + \alpha(t_{k-1})\cdot(t_k - t_{k-1}).$$

This recursive process can be easily implemented in a computer program, and it can be exploited for integrating the heading rate in our problem. The kinematic model of the platform, which we use in the project, applies that procedure for the prediction of the heading.

The noise which pollutes the gyroscope's measurements is also composed by a fluctuating perturbation, which behaves as Gaussian white noise (GWN). For verifying it, the lecturer took measurements during a period of time, in which the IMU was completely static. The readings were statistically analyzed, after the bias had been removed. A tool for verifying "whiteness" is the cross-correlation, which indicated there was almost no statistical correlation for shifts in time ~=0 (as it can be seen in Figure 1).
In addition, through applying a histogram, it was verified that the shape was almost Gaussian (as shown in Figure 2). Based on this, we can later use the measurements assuming that the noise present in those is GWN (Gaussian White noise)

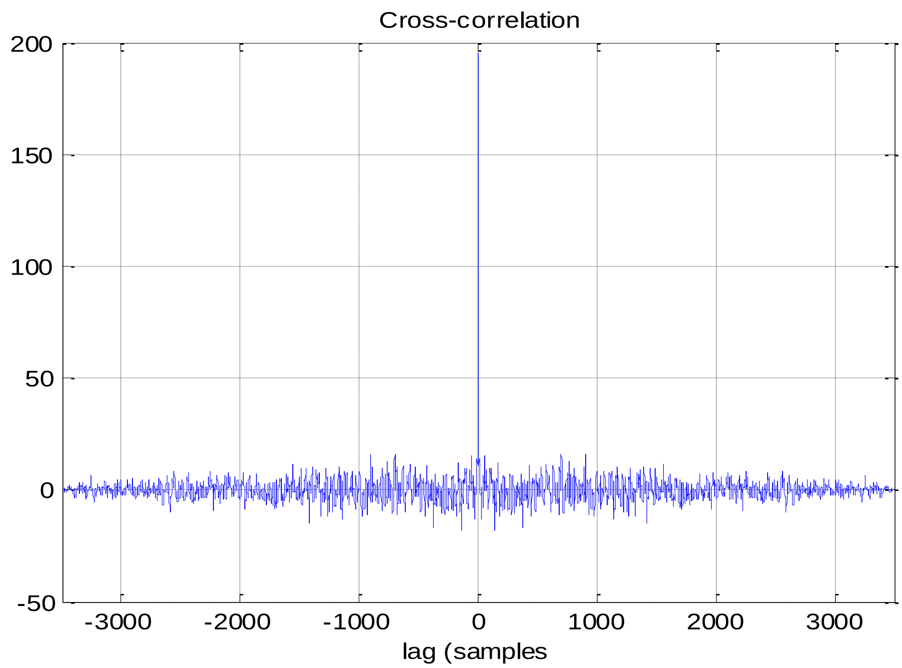

Figure 1: Cross-correlation of the first 3500 samples

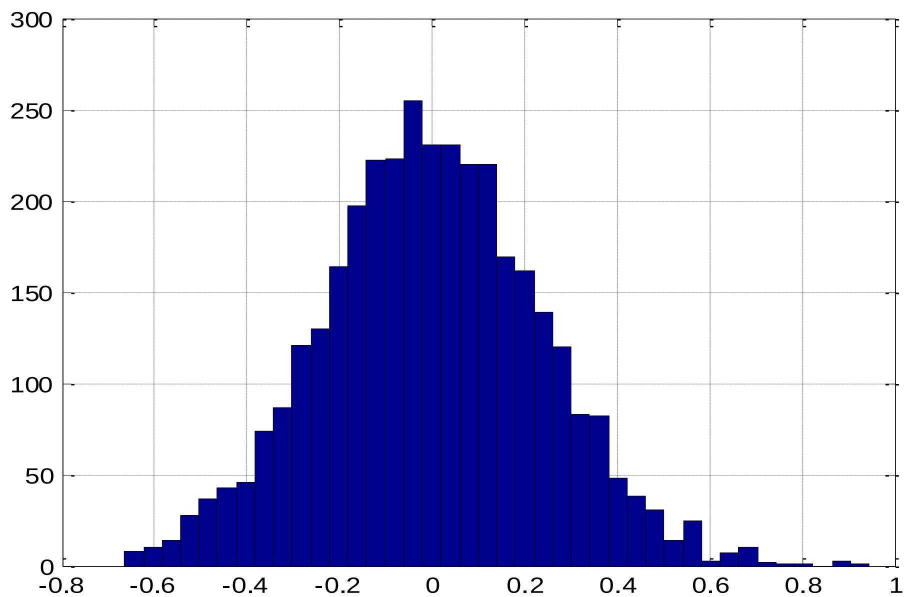

Figure 2: Histogram of the first 3500 samples. It can be seen it has a strong unimodal shape, gaussian-like. Having a standard deviation ~0.25 (expressed in degrees/second)

If you have questions, ask the lecturer via Moodle's Forum, or by email (Email: j.guivant@unsw.edu.au)