ESE 650, SPRING 2021

HOMEWORK 2

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Solution 1 (Time spent: 3 hour)**.**

(1) sampling x

```
eps = np.random.normal(loc = 0.0, scale = math.sqrt(1.0), size=None)
x_k = a * X[-1] + eps
```

(2) sampling y

```
y_k = math.sqrt(x_k**2)+np.random.normal(loc = 0,scale=math.sqrt(0.5))
```

(3) State vector:

$$X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} x_k \\ a_k \end{bmatrix} = \begin{bmatrix} x_{k-1}a_{k-1} + \epsilon_k \\ a_{k-1} + \zeta_k \end{bmatrix} = f(X) \tag{1}$$

$$\bar{X} = \begin{bmatrix} x_{\bar{k}-1}a_{\bar{k}-1} \\ a_{\bar{k}-1} \end{bmatrix} \tag{2}$$

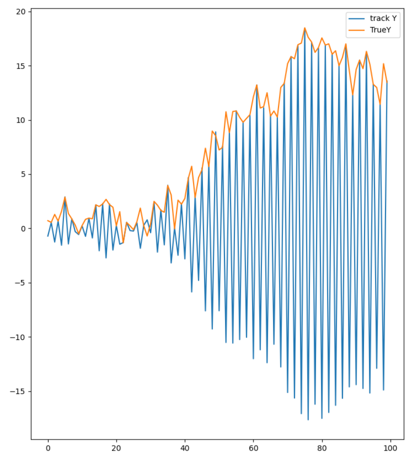
$$\frac{\partial f}{\partial X} = \begin{bmatrix} a_{k-1}, x_{k-1} \\ 0, 1 \end{bmatrix} \tag{3}$$

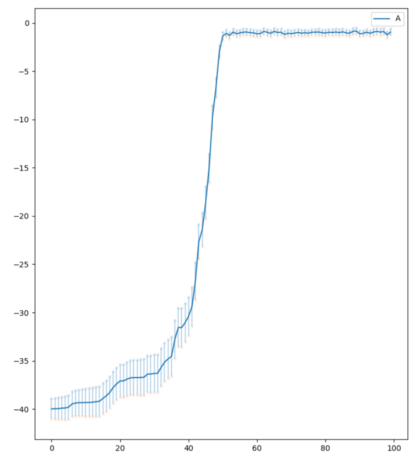
$$y_k = \sqrt{x_k^2 + 1} + \nu_k \tag{4}$$

$$\frac{\partial g}{\partial X} = \left[\frac{x_k}{\sqrt{x_k^2+1}}, 0\right] = C \tag{5}$$

$$\tag{6}$$

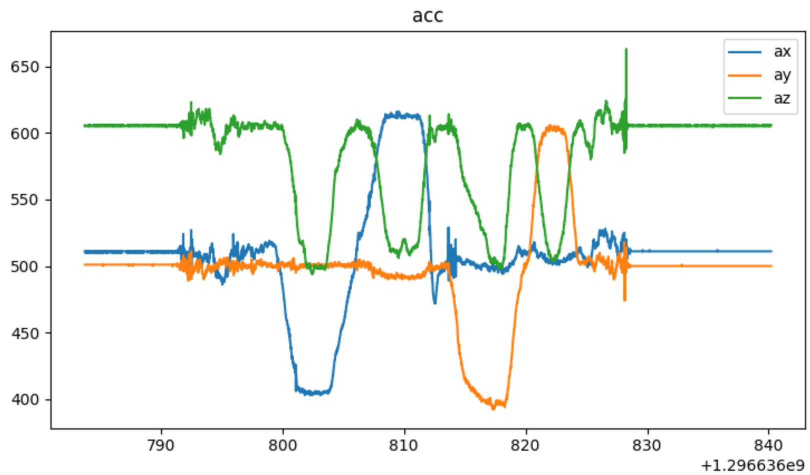
(4) the error reduced as iteration goes up, and a goes to -1


track Y
TrueY
20
15
10
5
0
−5
−10
−15
0
20
40
60
80
100


A
0
−5
−10
−15
−20
−25
−30
−35
−40
0
20
40
60
80
100

Solution 2 (Time spent: 15 hour)**.** Your solution goes here.

CALIBRATION



The raw data of accelerometer is plotted above. Assume the quadrotor stands still at first several seconds. The bias can be guessed reasonably as:

$$bias_x = 373.7 \tag{7}$$
$$bias_y = 375.7 \tag{8}$$
$$bias_z = 370.1 \tag{9}$$
$$\tag{10}$$

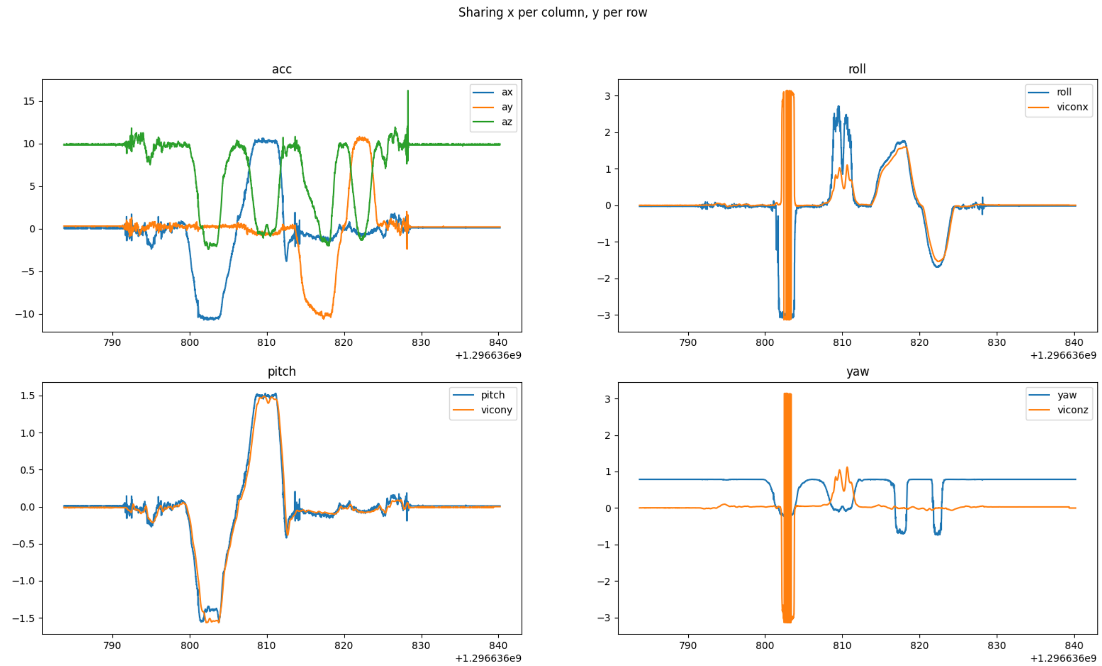
And after removed bias from the raw data, they are centered at zeros. And it's a bold guess that the maximum and minimum of the reading are positive gravity and negative gravity direction. Then the sensitivity could be gotten from the formula:

$$sen_x = 32.5 \tag{11}$$
$$sen_y = 32.5 \tag{12}$$
$$sen_z = 29.5 \tag{13}$$
$$\tag{14}$$

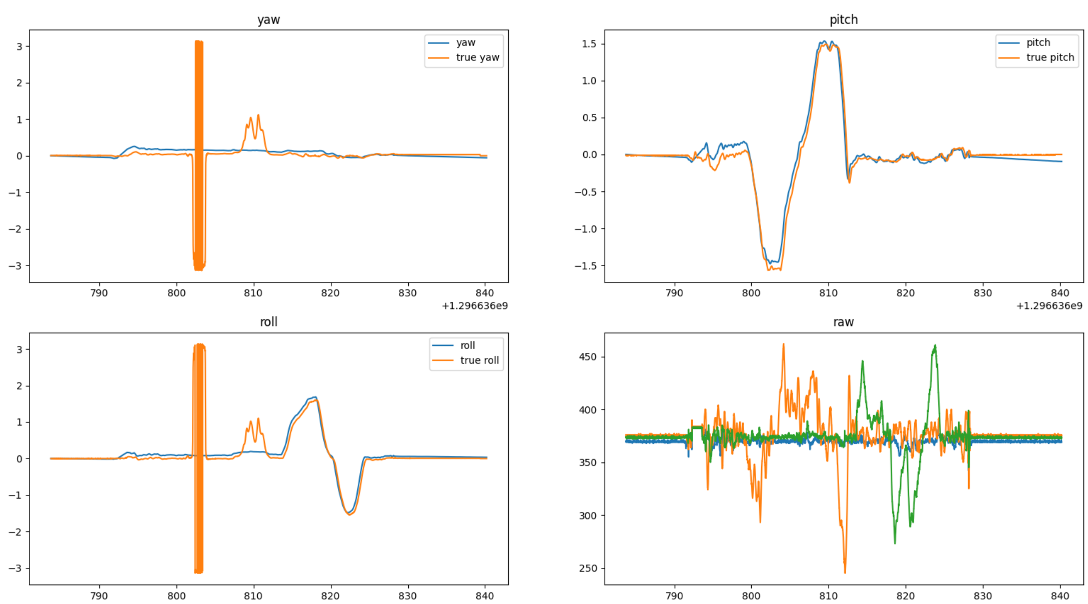
scaled for the right orientation data:

$$roll = arctan(\frac{acc_y}{acc_z}) \tag{15}$$
$$pitch = arctan(\frac{-acc_x}{norm(acc_y, acc_z)_2}) \tag{16}$$
$$\tag{17}$$

I scaled and tuned up the the parameters with calculation of roll and pitch. Since there is not a solid way to get yawing from accelerometer data, it's a bit off.



The similar process is for the calibration of gyroscope data.



first eyeballing the bias:

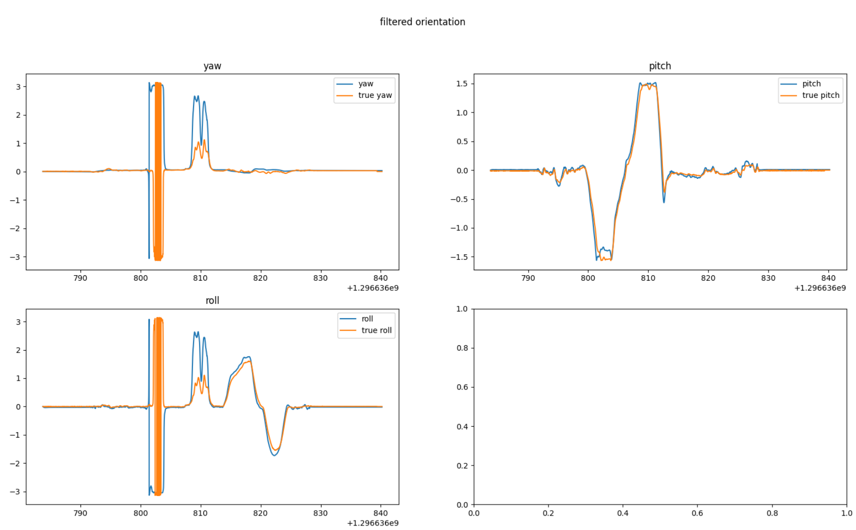
$$bias_x = 510.7 \tag{18}$$
$$bias_y = 498.7 \tag{19}$$
$$bias_z = 516.1 \tag{20}$$
$$\tag{21}$$

And after removed bias from the raw data, they are centered at zeros. And using integration the mapping to the orientation in vicon

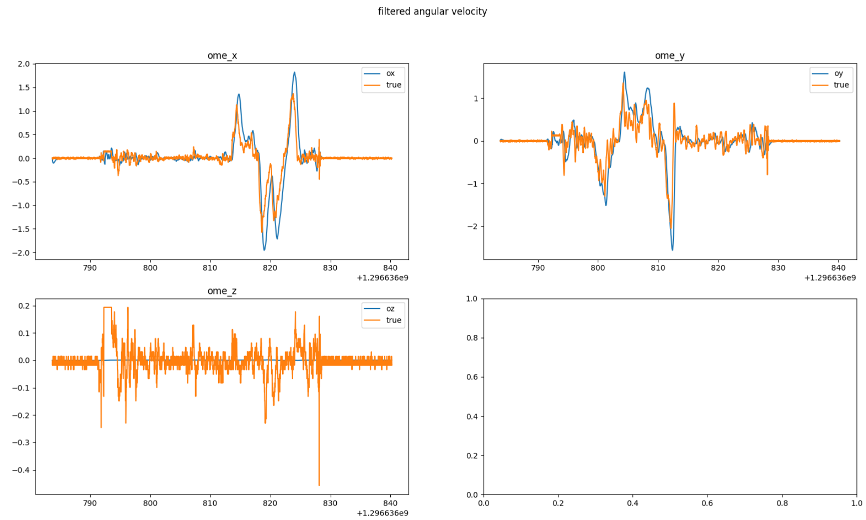
$$angle_t = angle_{t-1} + \delta t \omega_{t-1} \tag{22}$$
$$sen_x = 208 \tag{23}$$
$$sen_y = 208 \tag{24}$$
$$sen_z = 210 \tag{25}$$
$$\tag{26}$$

ANALYSIS

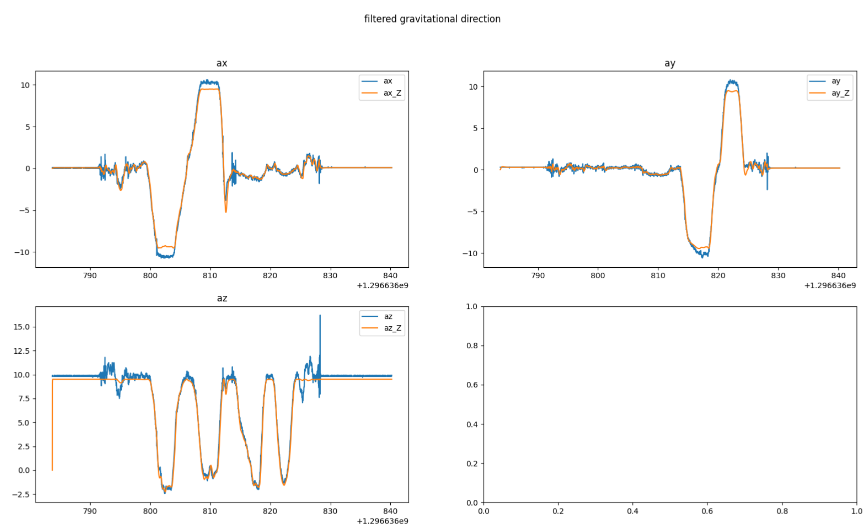
The filtered results roughly matches the vicon's results.

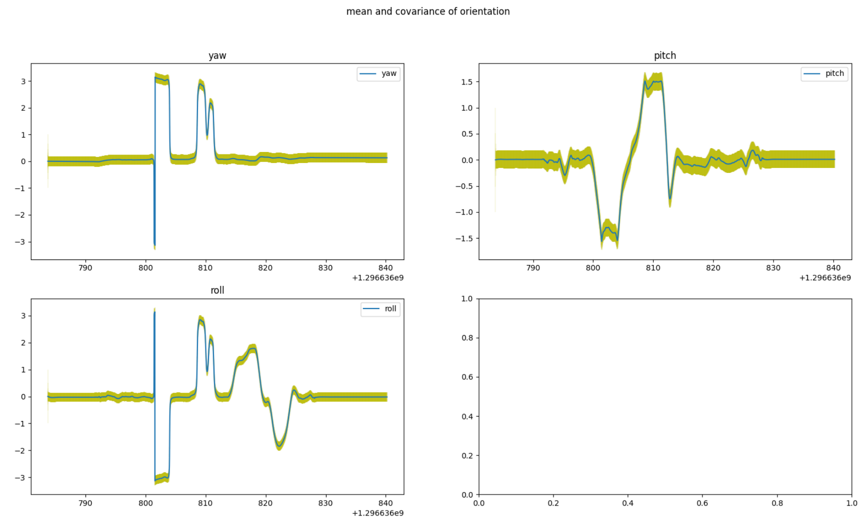


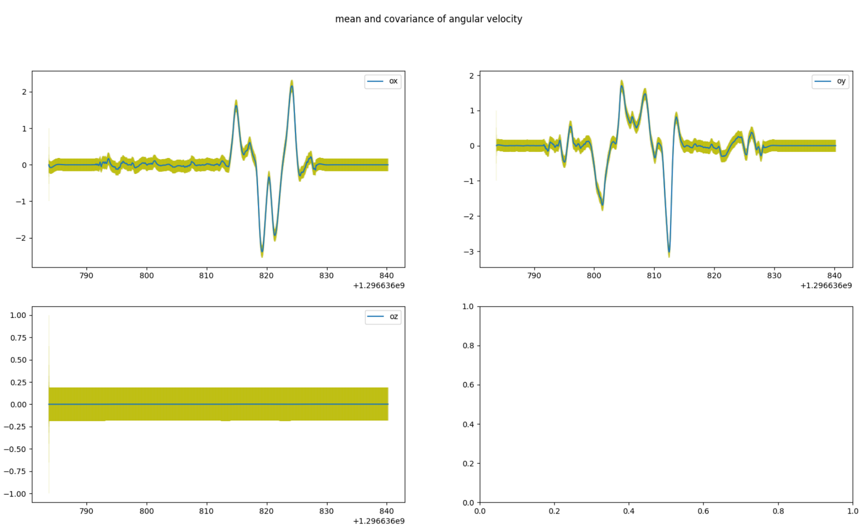
The results of estimate angular velocity is a bit noisy but still follow the trends



The results of measurement estimate of gravity match the accelerometer data means the orientation are close to ground truth







The covariance shrinks after first few iteration, that means the filter find the optimal estimator with minimal covariance.