## Attachment 1 Kalman Filter Implementation with Mbinet Sensor

**Sensor Initial State Measurement**

**Initialization of gyroscope bias and initial state**

The sensor used is Mbient Lab, the maximum frequency of gyroscope data collection is 125 Hz, for this test, 100 Hz was used, and measured after 5 seconds to get continuous 1000 samples.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Trial 7 | Trial 8 | Trial 9 | Trial 10 |
| Bias X | 0.17111 | 0.16696 | 0.17544 | 0.18538 | 0.18514 | 0.18239 | 0.188 | 0.18276 | 0.18788 | 0.1827 |
| Bias Y | 0.89414 | 0.82606 | 0.65477 | 0.62684 | 0.61311 | 0.60878 | 0.59341 | 0.58139 | 0.58176 | 0.5662 |
| Bias Z | -1.0414 | -0.98777 | -0.91896 | -0.89829 | -0.89121 | -0.88316 | -0.87474 | -0.87462 | -0.87254 | -0.86443 |

**Noise Measurement Matrix (Measurement covariance)-Rk (constant)**

The noise measurement matrix is used to characterize the covariance of the accelerometer as it is used for measurement update, and such covariance matrix is used in the Kalman gain calculation for measurement update. As the measurement update is based on the Euler angles directly measured, the noise measurement matrix contains the variance of the roll, pitch, and yaw in the diagonal. As we assume the three Euler angles are mutual independent, the other elements in the matrix are zero.

Here we used the accelerometer covariance calculated from the trials. The trials setup is like this:

1. The magnetometer is fixed at 10 Hz, the accelerometer is set as 25 Hz to correspond to the mag.
2. With the sensor output, the time point is round to 2 decimals for mag and access (as it would be easier to find the same time point without considering the third decimal)
3. The tests last for 124 seconds, we choose 21-120 seconds as sample data (1000 sample).
4. The Euler Angle is calculated by the following formula
5. For the yaw, the tilt compensation is considered for now
6. As here we only need variation of measurement, the actual meaning of output will be discussed later

**Error Covariance Matrix Q0 (aka state covariance matrix)**

There are two parts in the Error covariance matrix, the first part is quaternion part, and the second part is the variance of the gyro in each axes. The gyro and accelerometer variances are calculated by putting the sensor flat on a table without rotation for 120 seconds at 50 Hz (as total frequencies of sensors could not exceed 125 Hz), and choosing the consecutive 100 seconds after first 20 seconds to calculate the variance.

|  |  |  |  |
| --- | --- | --- | --- |
| Standard Deviation | X-Axis | Y-Axis | Z-Axis |
| Accelerometer | 0.001105 | 0.000936 | 0.00130 |
| Gyroscope | 0.03729 | 0.03460 | 0.03512 |

Therefore, the initial Error covariance matrix will be

Question: how to initiate the quaternion part, possible initiation:

Q=[1 0 0 0]T

Q=[1 0.0011052 0.0009362 0.001302]T

For the quaternion part, based on the small angle approximation, the following equation will be used to initialize the attitude quaternion covariance matrix at initial time([Kuipers, 1999](#_ENREF_36)).

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Therefore the initial state covariance matrix is

**Noise Model Covariance Matrix (Process Noise Covariance)-Pk (constant)**

There seems no consistent approach of finding the constant process noise covariance, some just use an arbitrary way to set up the parameters, which could be based on the bias of programming software (like C++ used in([Leccadito, Bakker, Niu, & Klenke, 2015](#_ENREF_39))). As here we try to use Matlab as a tentative approach, the model covariance matrix may be different, and we try to use a measurement based approach to get a relatively accurate measurement of the model covariance matrix. Here use the precision of float variable in programming with Matlab, which is 10-7. [[1]](#footnote-1)

Initial given values

LOOP Calculation begin

()-1

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Loop: K=K+1

1. https://www.mathworks.com/help/fixedpoint/ug/floating-point-numbers.html [↑](#footnote-ref-1)