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The Effect of Average Filter for Complementary Filter and Kalman Filter Based on Measurement Angle

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***Abstract*— The objective of this research project is to construct an Inertial Measurement Units (IMU), which will design filter for users use equation on average filter complementary filter and kalman filter and use algorithm on MCU. The sensor design, we use low-cost sensor on gyroscope and accelerometer, to measurement angle of system. The filter structures of the system, based on complementary filter and kalman filter and use series average filter for measurement. This project will get data form experimental results to develop on simulation to illustrate the effectiveness of each filter scheme. Simulation study of average filter on different parameter to using on complementary filter and kalman filter.**

Keywords— Average filter; Complementary Filter; Kalman Filter;

I. Introduction

Filters are an important tool. That allows estimation of the answer. And work for a perfect system, It has many more filters to use, Such as moving-average Filter Complementary filter and Kalman filter.

In research, the iBOT is an electric powered wheelchair that was developed by Dean Kamen[1]. In the similar research, wheel chair[2] will design to use Fuzzy logic control to to self-balancing and adaptive kalman filter using equations 1D for Approximations output of angle.

For Quadrotor helicopter [3] has controlled PID to keeping the plane flying by process of estimating the angle will use average Filter and Kalman filter for Approximations output of angle in systems.

In addition, the research, the movement of the robotic arm [4] is designed to control robots related with the angle when it moved.

The important of the above factors, it has employed in Inertial Measurement Unit [5] (IMU) with using Moving-average Filter, Complementary filter and Kalman filter for Arduino microcontroller. We design for use packing module to other research.

And the research, we will discuss the Moving-average Filter Complementary filter and kalman filter in 1D to study response of the estimation system simulation results and conclusion.

II. Hardware Design

The research from Design and Construction of System to Control the Movement of the Robot Arm.

There has been improved on the parts of range control the robot's head in a motion to send the image to users, follow form Fig. 1

Fig. 1, Robot's head and system neck of android

System control section head has a structure in the tilt angle (angle of uprising/angle of depression), which consists of a structure of 3 part, 1. Plane of kinesiology, 2. Gear, 3. Motor. Tilt angle of depression can change degree in -30 to +40 degree in angle of uprising and angle of depression

III. Inertial Measurement Units

Inertial Measurement Units (IMU). We design gyroscope and accelerometer to work together approximations output of angle in low-cost sensor and using gyroscope by LPR503AL LPR510AL LPR550AL, Angular Measurement Rate $\pm 30, \pm 90, \pm 100, \pm 400, 500, 2000°/sec$, and Null

Accuracy $\pm 1, \pm 2.5^{\circ}/\sec$. Power supply at 3 .3 V. By the estimation of the angular velocity, follow form Eq. (1).

$$\omega_{gyro} = \frac{LSB_{read} - LSB_{Zero\ rotation\ value}}{Nominal\ sensitivity} \tag{1}$$

In accelerometer, we used in MMA7361L, Measurement Range $\pm 1.5, \pm 6g$, Sensitivity $\pm 800, \pm 206\ {}^{mV}\!/_{g}$. Power supply at 3.3V. By the estimation of the angular, follow form Eq. (2).

$$\theta_{Accele} = \arcsin\left(\frac{LSB_{read} - LSB_{Zero\ rotation\ value}}{Nominal\ sensitivity}\right) \tag{2}$$

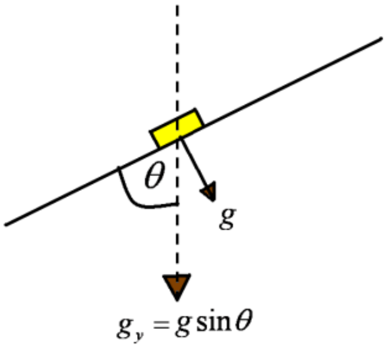

Fig. 2, Output of angular

IV. DESIGN ALGORITHM OF FILTER

A. Average Filter

In statistics, a moving average is a calculation to analyze data points by creating series of averages of different subsets of the full data set, follow form Eq. (3).

$$y_k = \frac{1}{N}\sum_{i=k-N}^{k} x_k \tag{3}$$

Fig. 3, Average filter

$y_k = Output\ of\ system$

$N = Number\ of\ full\ get\ data$

$x_k = input\ of\ accelerometer$

B. Complementary Filter

Complementary filters are defined in mathematical terms and in the context of Weiner. We design two-input system, one input will provide information with high frequency noise, and is thus low-pass filtered. By y_k is output of system, follow form Eq. (5).

$$y_k = Av_{k-1} + Bu_{k-1} + w_{k-1} \tag{5}$$

Design block diagram has designed 2 part, Figure 1 is a Complementary filter normal and Figure 2 the design the output of accelerometer. The through average filter before remove the output through then average filter used with complementary filter, follow form Fig. 4

Fig. 4, Complementary filter

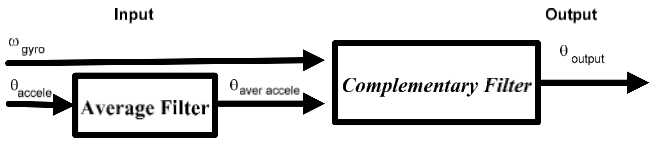

Fig. 5, Average filter using on complementary filter

For the parameter to using in complementary filter by follow form

$A = 0.98\ ; B = 0.02\ ; w_k = 0\ ; dt = 0.0015\ ;$

$v_k = (y_{k-1} + (dt * input\ of\ gyroscop))\ ;$

$u_k = input\ of\ accelerometer\ ;$

$y_k = output\ of\ system\ ;$

C. Kalman Filter

The kalman filtering is an algorithm that uses a series of measurements observed over time. We can design discrete-time of kalman filter on table I and table II

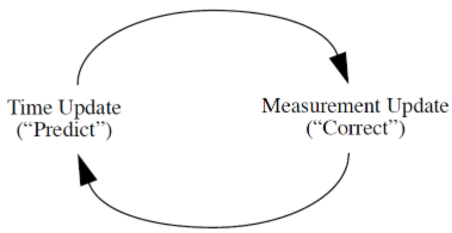

Fig. 6, Loop of kalman filter equations

TABLE I. DISCRETE KALMAN FILTER TIME UPDATE EQUATIONS

Predicted (a priori) state estimate	$\hat{x}_k^- = A\hat{x}_{k-1} + Bu_{k-1}$
Predicted (a priori) estimate covariance	$P_k^- = AP_{k-1}A^T + BQB^T$

TABLE II. DISCRETE KALMAN FILTER MEASUREMENTS UPDATE EQUATIONS

Optimal Kalman gain	$K_k = P_k^- H^T (HP_k^- H^T + R)^{-1}$
Updated (a posteriori) state estimate	$\hat{x}_k = \hat{x}_k^- + K_k(z_k - H\hat{x}_k^-)$
Updated (a posteriori) estimate covariance	$P_k = (I - K_k H)P_k^-$

To design block diagram has designed 2 part, Fig. 7, is normal kalman filter and Fig. 8, on design the output of accelerometer using on average filter before set data of output of average filter to input of kalman filter.

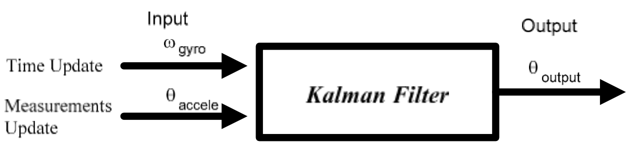

Fig 7. Kalman Filter

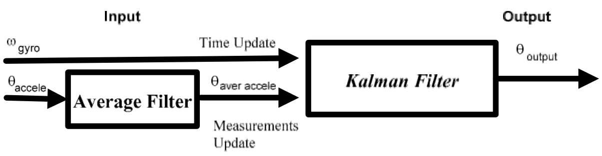

Fig. 8, Average filter using on Kalman Filter

For the parameter to using in kalman filter by follow form

$$A = 1; B = 0.0015; Q = 0.999; R = 0.001;$$
$$H = 1; I = 1; u_k = \textit{input of gyroscop};$$
$$z_k = \textit{input of accelerometor};$$
$$\hat{x}_k = \textit{Output of system}$$

V. SIMULATION RESULTS

The results of the simulation system the tests were conducted for using average filter on accelerometer, normal complementary and complementary will use average filter, nomal kalman filter, Kalman filter wish using average filter. The results are shown below.

In parts of average filter at using results of accelerometer. The filtration found system has valuated the past filter reduce the frequency a cause of measurement of accelerometer have be follow form Fig. 9

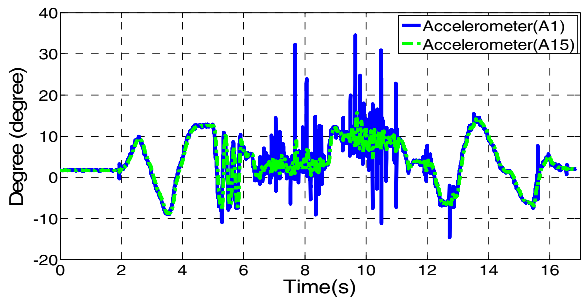

Fig. 9, Average filter VS average filter(A15)

From Fig. 9, compares the results of the first to use and average filter using 15 parameters.

In the time at 6-12 second, system will have less noise than normal average filter.

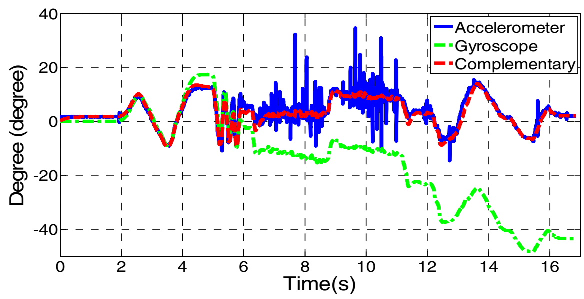

Fig. 10, Output of complementary filter

From Fig. 10, The results of the complementary filter, signal form accelerometer and gyroscope found that line of accelerometer reliability, but when the system is vibration in the time at 6-12 second.

The result is greater than the original. It was reliable was making not the cause, while gyroscope motion in the swing of the system. The movement of the gyroscope is the fault of the time. The measure is the sum of an actual system, but the time at 6-12 second. There were more vibration but no affect in measurements on the gyroscope, which measures both signals. Together through the complementary filter combines the advantages of both sensors together to found the movement of the line is similar to gyroscope line from around the median line of the accelerometer. On the time at 6-12 second, we insert vibration on the system. Output of complementary filter have more over shoot than gyroscope line.

In the simulation has been estimated by the average filter used in the estimation accelerometer by using 3 parameters the result was similar to the first trial but in the period of 6 to 12 seconds has dropped 1-2 degrees

If using average filter in 5 parameters, the result was similar to the first trial has dropped 3-4 degrees. On average filter in 10 parameters the result was similar to the first trial has dropped 4-5 degrees and average filter in 15 parameters the result was similar to the first has dropped 6-7 degrees, on the time have vibration, It can follow form Fig. 11, on the complementary filter VS complementary Filter (A15), The system that will vibration on system. output of complementary Filter (A15) have over shoot less.

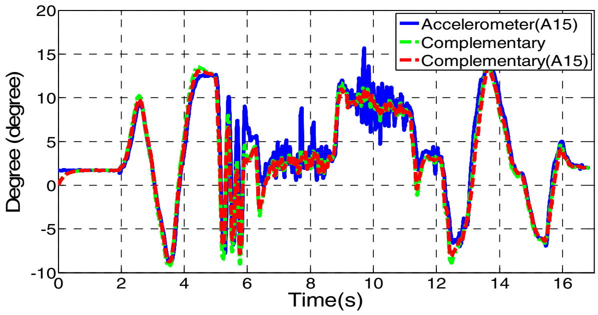

Fig. 11, Output of complementary filter VS complementary filter(A15)

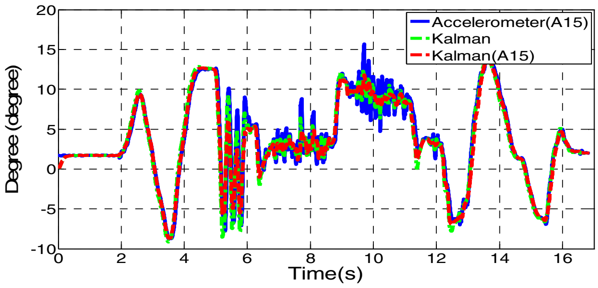

Fig. 12, Output of Kalman filter VS Kalman filter (A15)

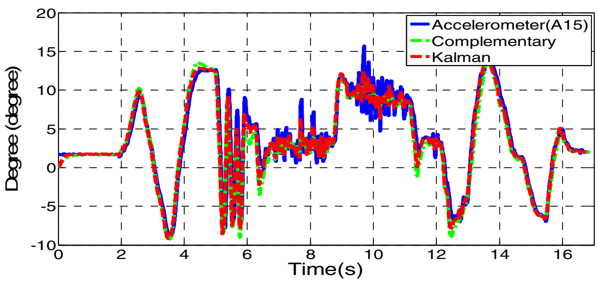

Fig. 13, Output of complementary Filter VS Kalman filter

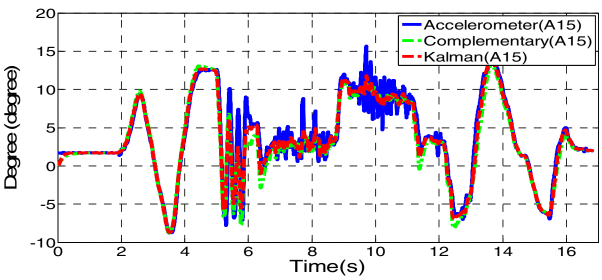

Fig. 14, Output of complementary filter(A15) VS Kalman filter(A15)

The Fig. 12, Kalman filter normally has an estimated value of reliability to a great extent. Line from approximately the middle of the line of accelerometer and has the appearance of lines, like a gyroscope line and the Kalman filter using average 15 parameters the output of system is looks like the trial of the first Kalman filter. It follows form the estimation comparison both systems show that the system of Kalman filter through a filter of the over shoot that has a range of high vibration, much less than Kalman filter(A15), it has small graph.

From Fig. 13, Complementary Filter VS Kalman filter. Complementary Filter is same the Kalman filter line and Fig. 14, is same too by output of filter on Kalman filter is better than complementary filter on vibration time.

VI. CONCLUSION

For example, to use applications filter, the output of the system has valuated better, the third line response was similar, on average filter complementary filter and Kalman filter. Found that the filter twain when the valuate angle normal input in the system, will have result output of the system as with typical use. But if the system has more variance, Kalman filter will a better performance than other filter, the Kalman filter has a good 2-4 degrees and the averages filter can help system if use series to complementary filter or Kalman filter, it can help to vibration reduction of estimation.

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