The Application of PID Control to Robotic Head

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***Abstract* — The objective of this project is to improve efficacy of the movement of the robot's head with proficient and humanoid movement. In order to do it, we proposed a system using PID control to control robot's head movement. The system consists of six main parts; 1) part of to detect robot's head movement using HMC5883L and MPU6050, 2) Signal processing part using Arduino Uno R3 and Complementary filter, 3) Wireless transmitter and receiver using Nrf2401L module, 4) Video signal transmission, 5) part to control a servo motor by PID control system and 6) Design and Construction part for robotic component using Catia Program and 3D printer. Our experimental results show the effectiveness of our method to control the robot's head movement.**

***Keywords*— PID Controller, Complementary filter, Robotic Head**

I. Introduction

Nowadays, the robotic technology has been used extensively. The robot is more useful in our life such as replacement of human labor, cost reduction time saving and risk reduction to perform a job to be required. Many papers ([1] ~[5]) have been proposed on design and construction of system to control the movement of the robot's arms research . The paper [1] proposes a design of robot working the movement following user's arms movement. The paper [2] presents a design method to control system of the robot's arms using leap motion controller.

A method [3] to develop an angle measurement using the Kalman filter was proposed to adapt the balance of the wheelchair usage. Then a method [4] to improve the Kalman Filter measurement is proposed. Furthermore, a method [5] was proposed to improve efficiency of regular system of measurement. In [5], the comparison of the efficiency between complementary filter and Kalman filter was shown with the measurement simulation only. The results of the efficiency in the both filters are not so different.

We propose a realization of a hardware using the complementary filter and PID control system to control a robot's head movement and perform experiments using the system. It was shown from our experiments that the proposed system gives proficient and humanoid movement of the robot's head.

II. Hard ware Design

We propose structural design for putting servo motor and design space for placing sensors. We have two servo motors for angle control in pitch and yaw shown in Fig. 1

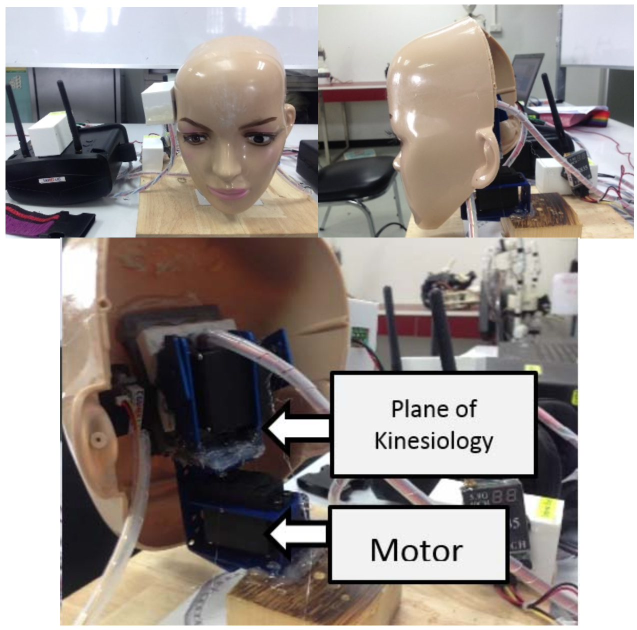

Fig. 1, Robotic Head

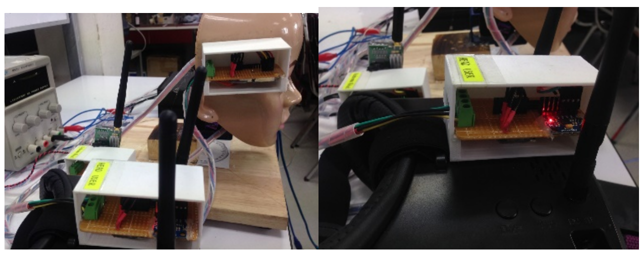

Fig. 2, Space for placing sensors

III. Inertial Measurement Units

We design Gyroscope and Accelerometer to approximate angle output and use the sensor MPU6050 which consists of Gyroscope and Accelerometer. Power supply (DC.3.3 V) is used to control the rotations.

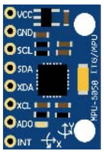

Fig. 3, Sensor MPU6050

In addition to roll rotation of the robot's head, we use digital compass module HMC5883l and Power supply (DC.3.3V).

Fig. 4, Sensor HMC5883LUnits

IV. DESIGN Algorithm Of Filter

A. Complementary filter

Complementary filters are defined mathematically. We design two input systems are an output system as follows.

$$y_k = Av_{k-1} + Bu_{k-1} + w_{k-1} \quad (1)$$

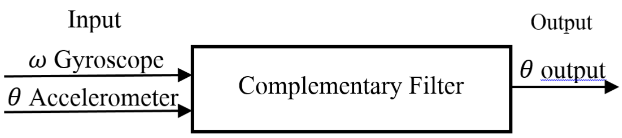

Fig. 5, Complementary filter in MPU6050

In Fig. 5, the parameters to be used in the Complementary filter are given as follows.

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

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

$$u_k = input\ of\ accelerome\ tor\,;$$

$$y_k = output\ of\ system\,;$$

Fig. 6, Complementary filter in HMC5883L and MPU6050

In Fig.6, the parameter to be used in the Complementary filter are given as follows:

$$A = 0.7\,;\, B = 0.3\,;\, w_k = 0\,;\, dt = 0.0015\,;$$

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

$$u_k = input\ of\ Compass\,;$$

$$y_k = output\ of\ system\,;$$

Complementary filter is mathematical technique estimating the output of the system of interest. We use Complementary filter with HMC5883L (magnetometer) and MPU6050 (gyroscope) to detect the roll of the rotation of the robot's head. In addition, we use Complementary filter with MPU6050 (gyroscope and accelerometer) to detect the pitch rotation.

V. DESIGN Algorithm of CONTROL SYSTEM

A. PID Controller (Proportional Integral Derivative)

PID is the value shown in the Fig.7.There is the set point compared with output to create value. The value of error in controller is used to adjust the new output. PID consists of Proportional term, Integral term and Derivative term given by

$$u(k) = K_p e(k) + K_i \sum_{0}^{k} e(k) + K_d \frac{e(k) - e(k-1)}{\Delta t} \quad (2)$$

In (2), the parameters to be used in the Equation has the form by the following below:

$$K_p = 0.3\,;\, K_i = 0\,;\, K_d = 0.02\,;\, \Delta t = 0.0015\,;$$

$$e(k) = Setpoint - Output\ of\ Complementary\ filter;$$

$$u_k = Output\ of\ Controler\,;$$

In PID controller, we use the step response obtained from Ziegler-Nichols tuning methods to tune the variables Kp Ki Kd and manual tuning techniques.

The algorithm for the system is designed by the Setpoint. Subsequently, two PID controllers are designed to control the roll of rotations and the pitch rotations to control robot’s head.

The roll angle of rotations is measured by gyroscope and magnetometer and pitch rotations are measured by gyroscope and accelerometer to give the feed back of the measurement of signal to the controller.

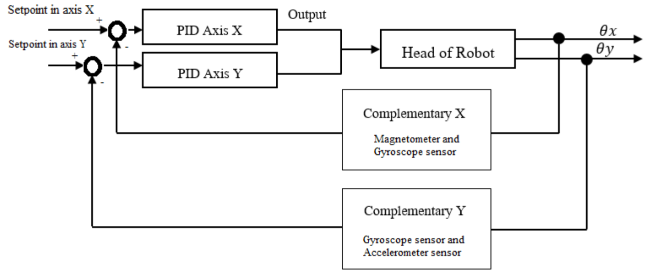

Fig. 7, Control systems

VI. RESULTS

In our experiments, the tests were conducted for using Complementary filter with Gyroscope sensor and Accelerometer sensor (MPU6050) to detect the motion of the head to pitch rotation. We used Complementary filter with the Digital Compass Module (HMC5883L) and Gyroscope sensor (MPU6050) to detect the motion to control the roll of rotations. The following four experiments were performed:

1) The experiment without Complementary filter and PID controller.

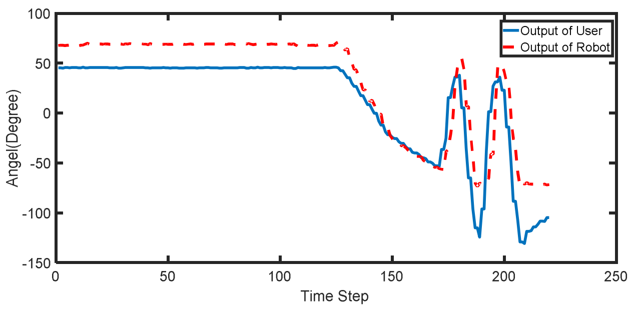

Fig. 8, The output of the Robot's head without Complementary filter and PID controller in roll rotations

In Fig. 8, the results between the output of user and the output of the Robot's head are shown. Angles of the output of user for each 50 degrees and the output of the Robot's head for each 70 degrees are shown. It can be seen form Fig. 8 that the difference between them is neatly 20 degrees.

2) The experiment for the control of the rotations of the system using Complementary filter and PID controller.

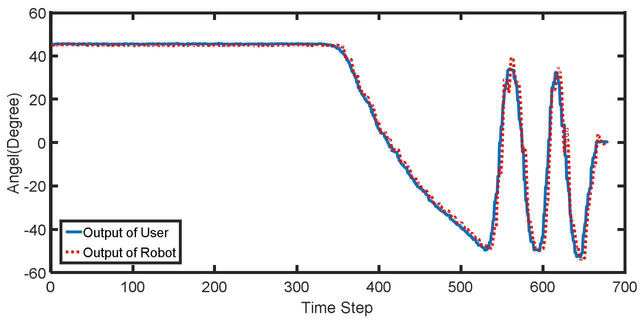

Fig. 9, The output of the Robot's head using Complementary filter and PID controller in roll rotations

Fig. 9 shows the comparison results between the output of user and the output of the Robot's head. In the figure, the output of user for each 45 degrees of angle and the output of the Robot's head for each 45 degrees are shown. It can be found from the figure that the both results are not so different.

3) The experiment of pitch rotations of the Robot's head in the system without Complementary filter and PID controller.

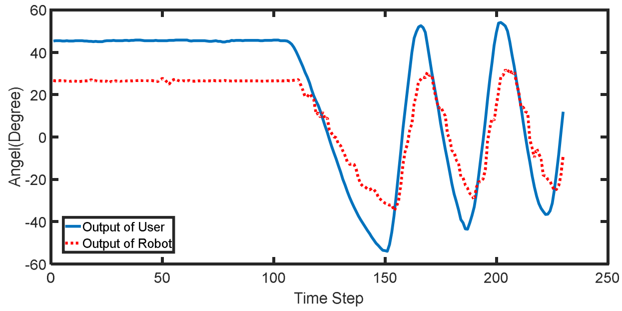

Fig. 10, The output of the Robot's head without Complementary filter and PID controller in pitch rotations

In Fig. 10, the output of user and the output of the Robot's head are shown. In the figure, the output of user for each 45 degrees of angle and the output of the Robot's head for each 25 degrees are shown. It can be seen form Fig.10 that the difference between them is neatly 20 degrees.

4) The experiment on pitch rotations of the Robot's head in the system using Complementary filter and PID controller.

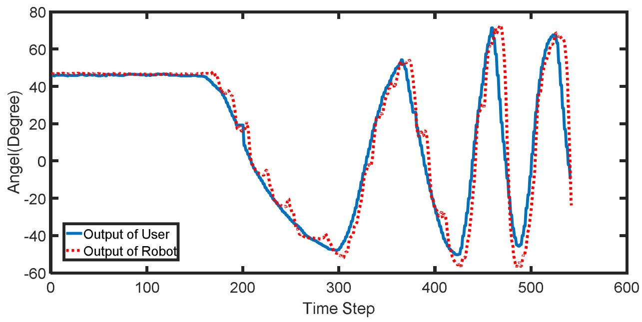

Fig. 11, The output of the Robot's head using Complementary filter and PID controller in pitch rotations

In Fig. 11, the output of user and the output of Robot's head are shown. In the figure, the output of user for each 45 degrees of angle and the output of Robot's head for each 46 degrees are shown. It can be seen form Fig.11 that the difference between them is neatly 2 degrees.

VII. CONCLUSION

We proposed a system consisting of six main parts using PID control to control robot's head movement. The results of the project to control the Robot's head in PID controlling system and Complementary filter is more accurate than the old system without a controller and the Robot's head has more superior control stability.

The Complementary filter improves the measurement accuracy of the sensor. This filter also reduces the noise of the system in the measurement. The parameters A and B in the equation (1) are selected by cut and try method, because it is sometimes difficult to determine manually to tune and test the system before use.

PID controller develop the system to have better than open loop control which the system has a lower value error and the faster system response into steady stage.

The system error may occur if the measurement of the sensor is poor and not good enough.

The gain values (K_p, K_i, K_d) of the system should be determined adaptively. The resulting parameter are better than fixed parameters.

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