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Navigation control of Drone using Hand Gesture based on Complementary Filter Algorithm

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Navigation control of Drone using Hand Gesture based on Complementary Filter Algorithm

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Abstract. One of the most important things to use UAV is navigation control. Navigation control is a way to adjust the direction of the quadcopter movements according to the command of the pilot. Natural User Interface (NUI) is a new way to interact with a system as navigation control. In this study, a wearable device was made that can detect hand gestures and gives instructions to the Dji Tello drone. The MPU6050 sensor is used to provide response in two dimensional axes. The complementary filter implements low pass filter on the accelerometer and integrates the value of the gyroscope with the previous angle output. After that, the value will be fed to the high pass filter. The results of the two filters will obtain stable angle, by adjusting the filter coefficient and the sampling time. The aim of complementary filter method is to reduce noise in angular transformation when the pilot makes hand gestures. Based on the experiments, the results show that hand gestures could give command for Dji Tello drone movements successfully. Therefore, it has been proven that the hand gesture can be used for the navigation control system on the Dji Tello drone.

1. Introduction
Unmanned Aerial Vehicle (UAV) is an unmanned robot that can move in the air. UAV does not require a pilot to control; thus, it must be controlled remotely using a remote control from outside the vehicle that is called Remotely Piloted Vehicle (RPV). Also, UAV can move automatically based on programs that have been embedded in the computer system. In the military field, UAV has a role as an airborne Intelligent Surveillance Reconnaissance (ISR), making it easier for the Air Force to carry out the main task of air observation in Indonesia's border areas.

Quadcopter is one of Unmanned Aerial Vehicle (UAV) that is widely used in various fields of activity [12]. Drone Quadcopter uses four rotors as its driving force [3]. Navigation control is a way to adjust the direction of the movement of quadcopter. Generally, remote control is used to navigate the UAV. On the other hand, quadcopter control can use the Natural User Interface (NUI) method. NUI is a user interface method that uses the natural ability of humans to interact with the system [4]. This natural ability is then used as input to the system. By implementing NUI, it can reduce the learning process for novice users in interacting with the system.

Gesture is one type of interaction that can be applied as NUI input. The gesture is a form of non-verbal communication that uses body actions to communicate certain messages. Gesture recognition can be done using devices such as Kinect and leap motion [5-9]. The use of these sensors has a weakness where the hardware costs have a quite expensive price. The other devices, that can be used to recognize gesture, is Inertial Measurement Unit (IMU) sensor [10]. The IMU consists of gyroscope and accelerometer sensor. In this research, a complementary filter algorithm is implemented to improve the accuracy of the gyroscope sensor angles in the IMU that use to move the Dji Tello. The movements are pitch and yaw [11].

The writing organization of this paper starts with introduction and research background. Section 2 explains the concept of the complementary filter algorithm that is applied in drone control. Section 3 focuses on the experimental setup and results analysis. The final section is a conclusion and discussion as well as suggestions for further research.

2. Experimental

Conceptual framework of this research uses Dji Tello drone as the platform with wireless communication between the drone and the Raspberry Pi 3. The MPU6050 gyroscope connects to Raspberry Pi 3 as input sensor. The sensor will be read and filtered to obtain an accurate angle. The results of the angle use as commands to move the Dji Tello drone. The conceptual framework is shown in figure 1.

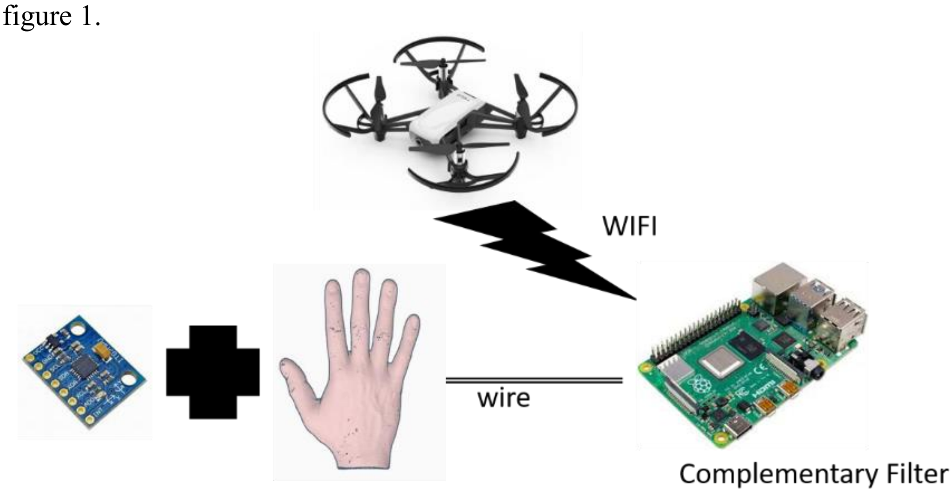

Figure 1. Conceptual Framework.

Figure 1 shows that the complementary filter algorithm is applied to Raspberry Pi 3. The design of the hand gesture basically utilizes the angular and acceleration transformation of the MPU6050 sensor when the hand is moved to specific area. The complementary filter value is implemented on the motion of the drone on both the pitch and roll axes. The complementary filter algorithm applied can be illustrated in the following flowchart as in figure 2.

In figure 2, it can be seen that the processing uses the complementary filter method continuously. which is adapted into the program code to run a program that runs on the MPU6050 sensor connected to the raspberry pi. The initial step of the programming is to determine the variables α (constants) and δ, which are differentials in the time domain. After obtained the angle data from the gyroscope and accelerometer, complementary filter is employed based on Equation (1).

$$angleC = \alpha * (angleC + ang\_gyro * \delta t) + (1 - \alpha) * (ang\_accl) \quad (1)$$

where variable *angleC* is the result of a complementary value, $\alpha = \tau / (\tau + \delta t)$ where τ is the desired time constant (reading speed in response), ang_gyro is output of gyroscope, δt is the delta time with the value $\delta t = 1 / fs$ where *fs* is the sampling time constant frequency, *ang_accl* is the accelerometer output, and *t* is the length of time the signal output updates from the complementary filter.

Complementary filter is a combination of two types of filters, i.e. high pass filter and low pass filter. Low pass filter works to filter the output of the accelerometer and high pass filter is used to filter the gyroscope output. The raw data from gyroscope have a continuous shifting thus high pass filter is applied to eliminate the shifting. The filter passes a signal with a short duration and eliminates the shift of the gyroscope measurement.

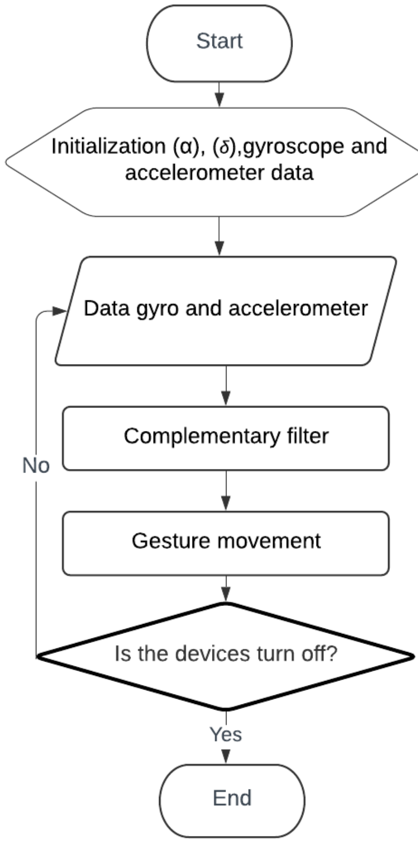

Figure 2. Flowchart of Complementary filter Algorithm.

The combination of the two filters can overcome both problems in the accelerometer output and the gyroscope. Low pass filter implements in the accelerometer, which has function to pass through data alteration in the long term and filter fluctuations data in the short term. High pass filter is a type of filter that the characteristic is opposite to the low pass filter.

The MPU6050 attaches in the wearable device in order to obtain convenient movement for the user. The following figure 3 below shows the wearable device that was made.

Figure 3. Wearable device.

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Figure 2 shows that the device is consist of glove, Raspberry with LCD panel and sensor MPU6050. The sensor is attached on the glove. By using wiring connection, communication is built from the sensor to the Rapsberry Pi.

In Table 1, it can be seen that the definition of hand gestures and their relationship to the system output, namely the movement of the drone. The part of the hand that is detected is the part of the hand to the wrist as in figure 1. The selection of the hand in the study aims to facilitate the use of the system, because only the gestures on the right hand are applied.

Table 1. Design and definition of hand gestures with drone devices.

Name of Gesture	Description	Drone Movement
Take off	tilting hand upward (30^o-60^o)	Take off
Hovering	straightening the hands parallel to the forearm	Hovering
Forward	tilting hand upward (60^o-90^o)	Forward
Backward	tilting the hand down	Backwards
Right	tilting the hand to the right side	Turn right
Left	tilting the hand to the left side	Turn left
Landing	Hands straighten down	Landing

The gestures are divided into seven types of movement. The gestures movement are representation of the movement from the remote control or mobile device. Thus, the gesture can replace the role of remote control and easier for the user to control the drone.

3. Result and Discussion

3.1. MPU6050 Sensor Angle Testing. The test is carried out by describing the angle value of the MPU6050 to the angle of motion given. The value of X axis is roll motion, which positive value determines movement to the right and negative is value to the left movement. Y axis value is pitch motion, which positive values are down motion and negative values are up motion. The time is given for 10 seconds with a time interval of 0.5 seconds. This test consists of angular values measured based on predetermined variables that will result in motion in the Dji Tello drone in the form of forward, backward, turning right, turning left, take off, landing, and hovering motion.

3.2. Forward Gesture.

The forward gesture is used to control the drone to move forward, which is done by tilting hands upward. This gesture is defined by storing a reference value that is used as a comparison with the angle transformation value detected by the MPU6050 sensor based on the pitch angle. The reference value for this forward gesture is 30^o to 60^o at pitch angle. The angular values for forward motion of the Dji Tello drone can be seen in figure 4.

Figure 4 shows that if the sensor is directed upward at angle range between 30^o and 60^o then the pitch value on the MPU6050 sensor is positive. Therefore, command for moving forward will send to Drone. In order to distinguish between forward movement and take off movement, certain angle range will be determined.

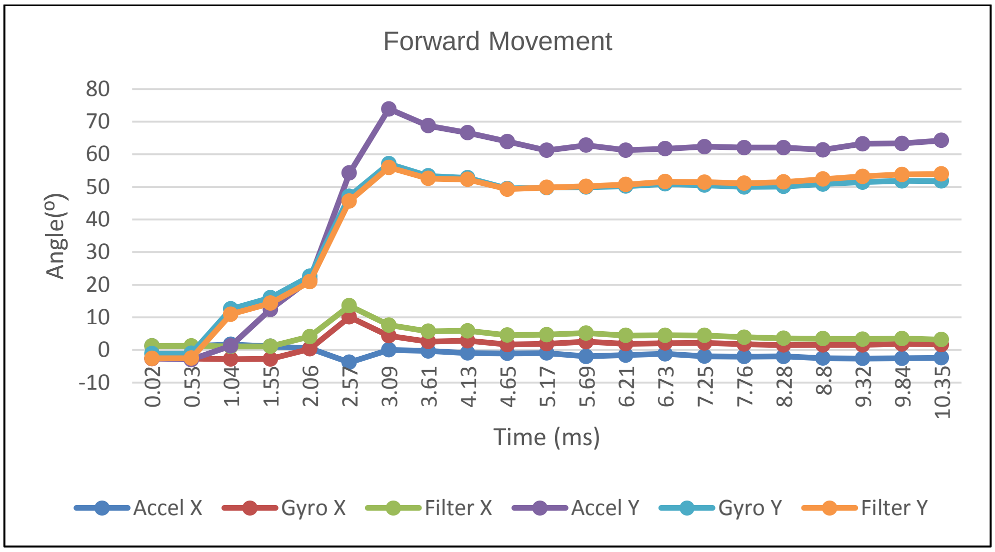

Figure 4. Forward Movement.

3.3. Backward Gesture.
The backward gesture is used to control the drone for reverse maneuvering. This gesture is done by tilting the hand down with the value of –30° to -60° at pitch angle. The following figure shows the graph of the angular values for backward motion of the Dji Tello drone.

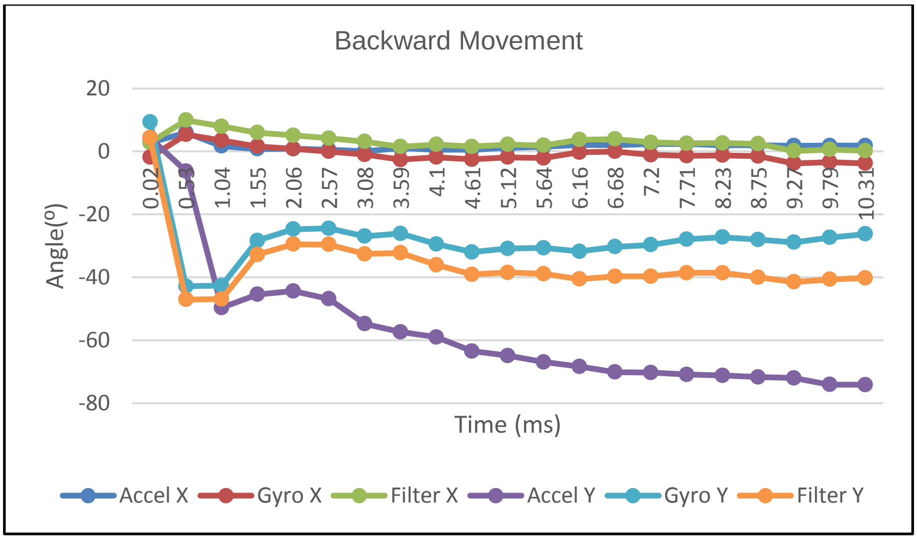

Figure 5. Backward Movement.

Figure 5 shows that if the sensor is down at an angle limit of -30º to -60º then the pitch value on the MPU6050 sensor is negative.

3.4. Right Gesture.
This gesture movement is by tilting the hand to the right side from the angle transformation value detected by the MPU6050 sensor based on the roll angle. The reference value for this right-hand gesture manoeuvre is 30° to 90° as in figure 6.

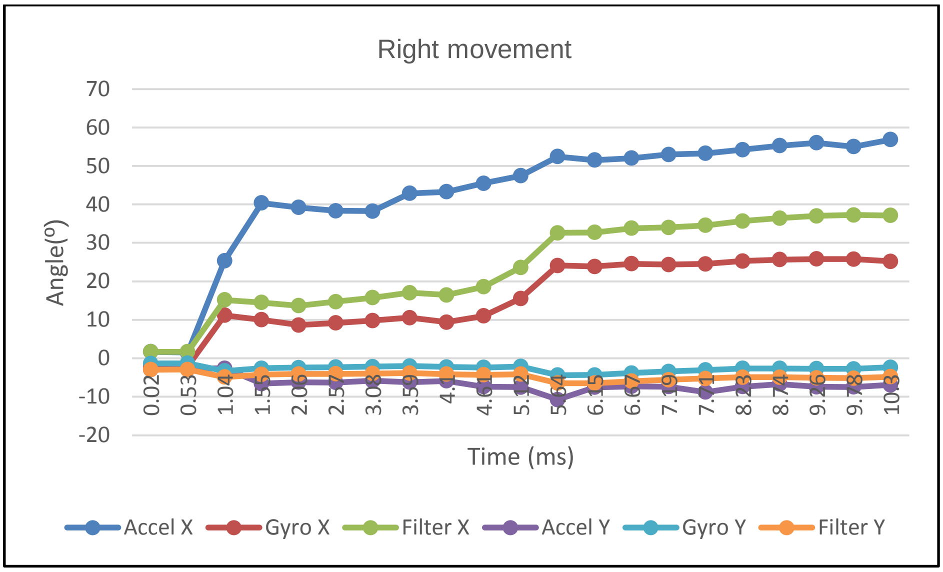

Figure 6. Right Movement.

Figure 6 illustrates that if the sensor measurement more than 30º then the roll value on the MPU6050 sensor is positive.

3.5. Left Gesture.
Left hand manoeuvre is used to control the drone to move left. The gesture is tilting the hand to the left side. The reference value for this left sliding gesture is -30º to -90º at the roll angle. Figure 7 shows that if the sensor is directed to the left at angle of more than -30º then the roll value on the MPU6050 sensor is negative.

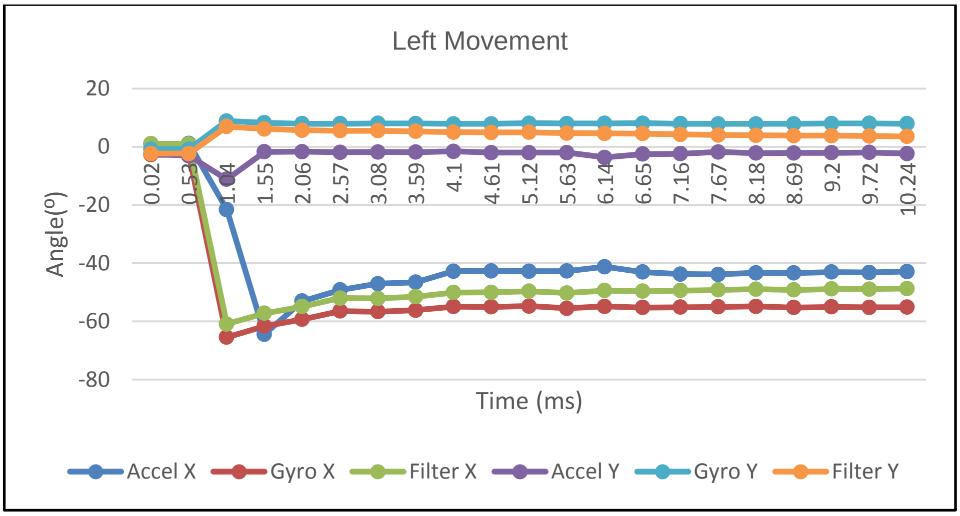

Figure 7. Left Movement.

3.6. Hovering Gesture.
The hovering gesture is used to control while the Dji Tello is hovering, which means a condition for maintaining its altitude position. During hovering movement, the drone does not make roll and pitch movements. The gesture is done by straightening the hands parallel to the forearm. The reference value is based on the roll angle, pitch and acceleration on the z axis when the hand is moved. The

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reference values for gesture hovers are -30° to 30° at roll angle, and -30° to 30° at pitch angle. In figure 8, it shows that if the sensor measurement angle is less than 30° then the drone will be stationary.

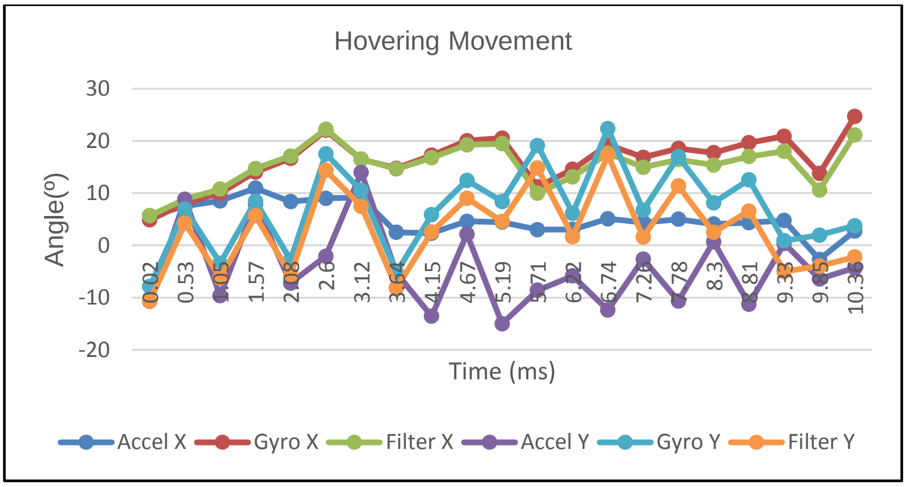

Figure 8. Hovering Movement.

3.7. Take Off Gesture.

Gesture take off is used to control the drone to move up by tilting your hand upward. The gesture is defined by value detected by the MPU6050 sensor based on the pitch angle. The reference value for this take-off and rise gesture is 60° to 90° at the pitch angle. Figure 9 explains that if the sensor is directed upwards at an angle range of 60° to 90° then the pitch value on the MPU6050 sensor is positive, which impacts the drone to take off.

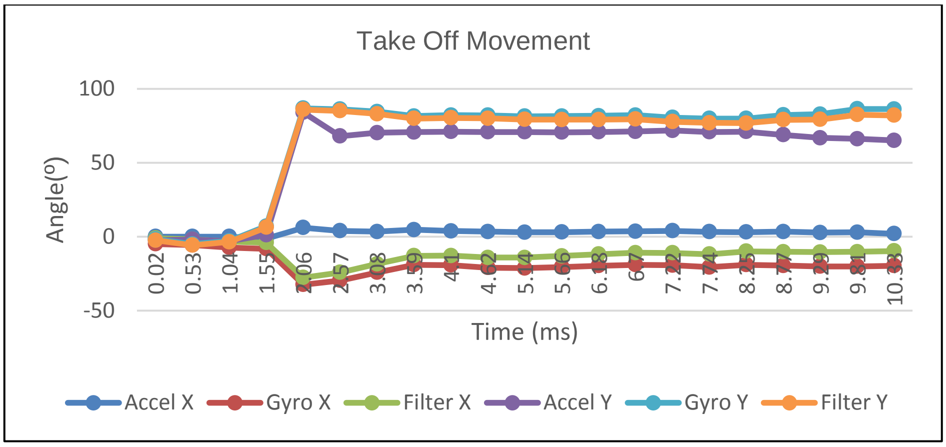

Figure 9. Take Off Movement.

3.8. Landing Gesture.

Landing Gesture is applied to control the drone for landing and descending movements. The gesture is employed by tilting hand down. This gesture is defined by storing a reference value between -60° and -90° at the pitch angle as seen in figure 10.

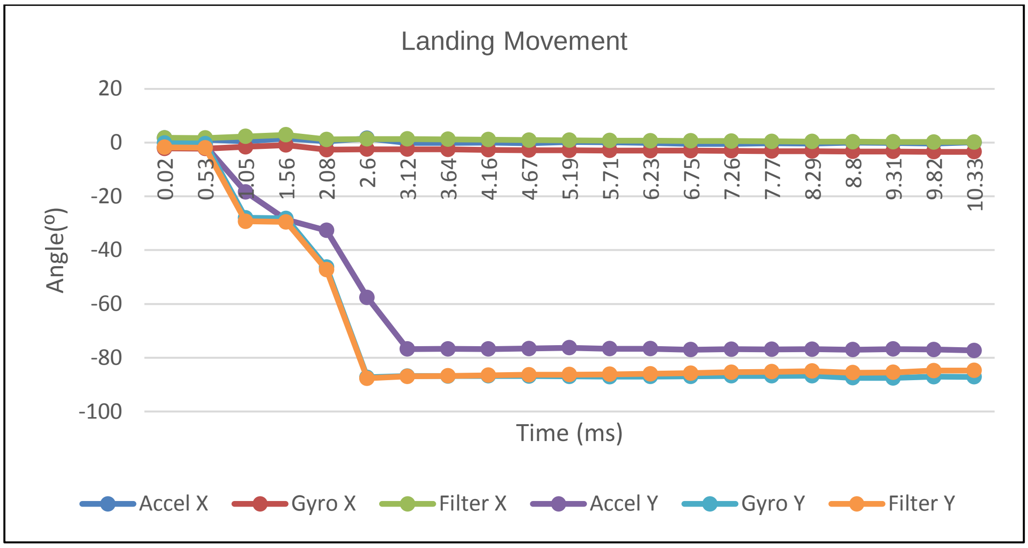

Figure 10. Landing Movement.

Figure 10 shows that if the sensor is directed down at the angle range of -60° to -90°, then the pitch value on the MPU6050 sensor is negative, which effects the drone to landing.

3.9. Drone Motion Testing.
The test of hand gesture is carried out 5 times on each motion and total test is 35 times. The output of the test is success or failed status when the system detects the user hand gestures. Success number of tests is compared with the number of total experiments of detecting hand gestures after applying the complementary filter method. Result of the test can be seen in Table 2.

Table 2. Test results detect hand gestures.

Gesture	Total Tests	Status
Take off Gesture	5	Success
Hovering Gesture	5	Success
Forward Gesture	5	Success
Backward Gesture	5	Success
Right Gesture	5	Success
Left Gesture	5	Success
Landing Gesture	5	Success

In Table 2, it can be seen that all the tests have been successfully and can be used to control the Dji Tello.

4. Conclusions

After the testing and analysis phase, the following conclusions can be described as follows. The MPU6050 sensor, which has embedded gyroscope and accelerometer sensors, can be used to detect the angle of the hand. The results of the sensor data will be processed by Raspberry pi, which is located on the back of the hand. Therefore, the resulting angle converts to the control of the Dji Tello drone.

Generally, the hand gesture program works well according to the MPU6050 sensor angle command because the complementary filter method was successfully implemented. The output value data is processed by Raspberry pi 3 B by having several variable parameters of the complementary filter method algorithm including alpha value, sampling time and angular tilt data. Sampling time is 0.96 in

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order to stabilize the output value of the MPU6050 sensor. Based on results, it can be concluded that wearable devices successfully controlling Dji Tello navigation.

Based on the results, several things can be used as guidelines for further research. Firstly, Dji Tello's movements are only limited to movements in the roll axis and pitch axis. Therefore, further research is expected to develop the yaw axis movement. Second, Dji Tello's movement has a delay between each command from the gesture. Thus, the delay is one problem that has to be solved in the future. The last, in order to enhance the satisfaction of user experience, the method of the gesture using IMU sensor can be integrated with the camera to take pictures and videos. The integration will affect more variation of user movement.

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