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Implementation of control system and tracking objects in a Quadcopter system

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Abstract. In this paper we implement a quadcopter assembly with control and navigation module. The project also includes design of control panel for operator, which consists of a set of the microcontroller and the glove equipped with sensors and buttons. The selected module has a touch screen that displays current parameters such as vehicle status, information of orientation and geographical coordinates. The concept of quadcopter control is based on the movement of the operator hand. In addition we included the object detection for detecting the objects from quadcopter view. To detect an object, we need to have some idea of where the object may be and how the image is divided into segments. It creates a kind of chicken and eggs problem, where we need to recognize the shape (and class) of the object know its location and recognize the location of the object, we must know its shape. Some visually different features, such as clothes and the human face, they can be parts of the same subject, but it is difficult know this without recognizing the object first.

Keywords: Drone, Quadcopter, Kalman Filter, GPS, IMU.

1 Introduction

The wide use of drones in present times and the desire to use the knowledge gained during studies inspired the authors to assemble their own flying vehicle and program its control system. In the beginning, the concept of drone was defined and the division was made on the basis of constructions. Next, the principle of action and quadcopter maneuvers were presented. At the very end, the exemplary realizations available on the market are described and the goals and scope of work were set.

The most essential matter in control is the estimation of quadcopter and glove orientation, which have to determine the angles of inclination, lean and rotation called the roll, pitch and yaw. Estimation of pitch and roll angles is founded on the work of two independent Kalman filters, and the yaw angle is determined by the operation of the integration of data from a gyroscope. Based on the current and set angle, an error is calculated, which next is enter on proportional integral-derivative regulator [1]. The controller generates the control signal as a PWM which is sent to the motor controllers.

The computer simulation showing the readings from the gyroscope and accelerometer, and then simulates the operation of the complementary filter. Due to the fact that the results obtained with the complementary filter were not satisfactory, we decided to implement the Kalman filter. Kalman filter gave satisfactory results and was implemented in the project. At the end the tests was carried out to stabilize and control the flying vehicle on the platform, allowing rotation in 3 axes.

1.1 System Description

The operation of the created system is based on communication between the quad-copter control modules. The operator's device is a module with both diagnostic and control functions. The module consists of an electronic system equipped with a tactile display on which parameters such as: current quad-copter kits and geographic coordinates will be displayed. The set of operators will also be equipped with a button. The buttons will be responsible for activating the engines, changing the speed of the engines and enabling the control mode. The device will be powered by a lithium-polymer battery. The principle of system operation is presented in Figure 1.

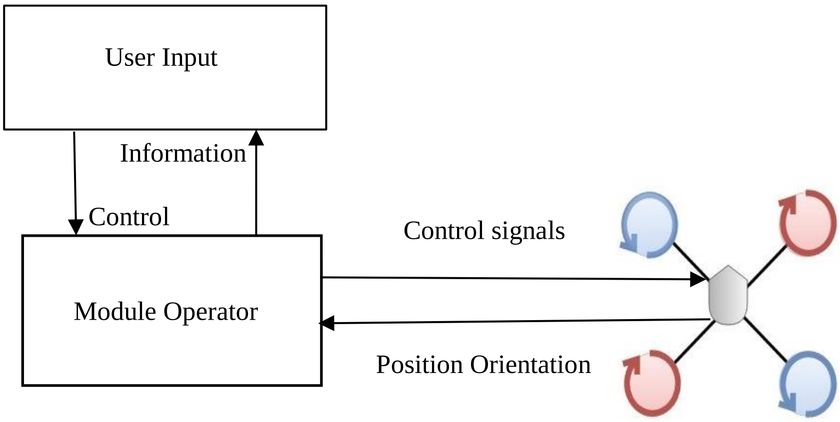

Fig. 1. Basic Quadcopter architecture

A part of the quadcopter and the operator's device has been used on the market. The project uses: roaming, lithium-polymer batteries, RC apparatus, 4x motors, 4x ESC regulators, propellers, voltage converters, IMU sensors, microcontrollers, radio systems and a GPS pick box. Using all the above-mentioned parts, a quadcopter was assembled as well as the operator's device. The assembly process of the vehicle was divided into 2 parts. In the first part, the subset of the frame. Next, ESC regulators were attached to arms by means of clamps and the motors were attached with screws. In the lower part of the central lobe using a Velcro, a battery was attached, while the upper part included a microcontroller, a GPS receiver, a radio system, a RC apparatus receiver and an IMU system.

2 System Implementation

One of the main problems in the implementation of the project is to determine the current orientation of the vehicle and the human hand. The estimation of the arrangement consists in determining the values of the angle of inclination, deflection and rotation of the device (roll, pitch, and yaw). A gyroscope and accelerometer were used for this purpose. To eliminate the disadvantages associated with the sensors, filters based on the fusion of measurements were implemented.

This section presents the estimation results of only the value of the deviation angle, while the design uses orientation estimations for all axes.

2.1 Gyroscope

A 3-axis gyroscope was used for the measurements, which measures the bending rate in three axes X, Y, Z. During data readings, the sensor was placed on a quadcopter, which was stationary on a flat surface. The graph of the measurement of angular rate measured with the use of the gyroscope in the Y axis has been presented in Figure 2.

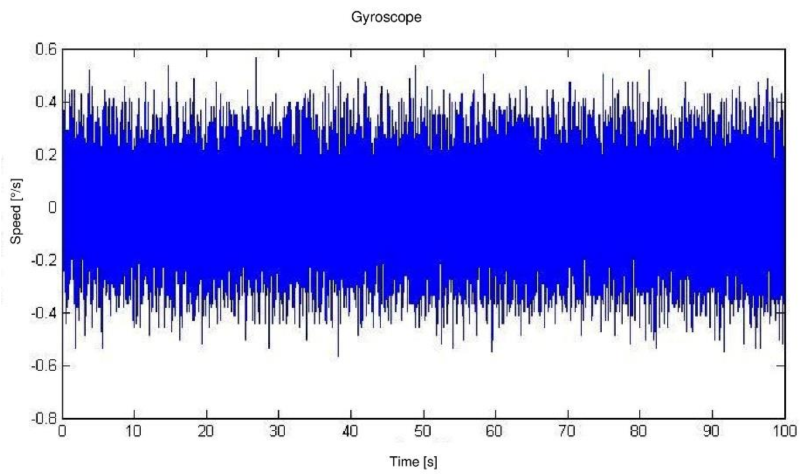

Fig. 2. A graph showing the angular velocity in the Y axis read using the gyroscope.

In Figure 2 it is evident that the bit rate measured with a gyroscope is noisy. Noise accepts the value of -0.5°/s to 0.5°/s. Having data on the gyroscopic angle of the gyroscope, it is possible to obtain information about the Roll, Pitch and Yaw (φ, θ, ψ) angles by applying integration operations. The overall angular velocity shown in Figure 2 was given a value of θ (Pitch). The result of integration is shown in Figure 3.

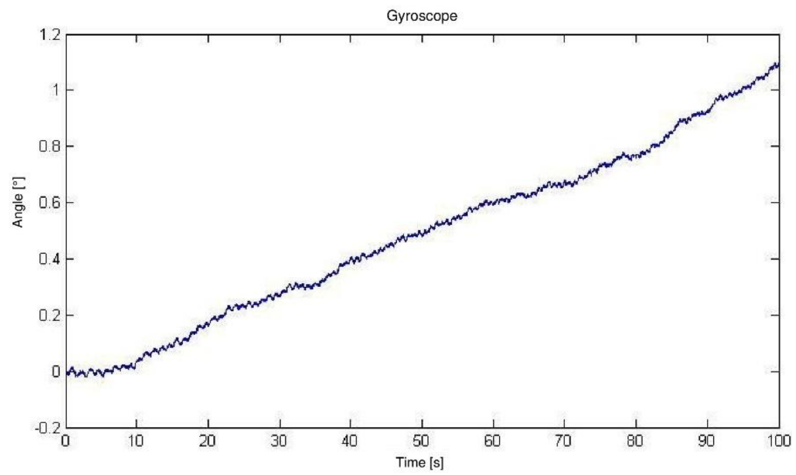

Fig. 3. A graph showing the angle θ after the angular rate integration.

The results obtained after the integration operation are characterized by low noise. Based on the Figure 3, it can be noticed that despite the fact that the vehicle was stationary during the measurements, the value is changing by approximately 1.1° in 100 seconds. This phenomenon is referred to as drift. This is the main disadvantage of the gyroscope, forcing its compensation by other sensors.

2.2 Accelerometer

The sensor, which is an accelerometer, returns the acceleration values along the 3 axes (a_x, a_y, a_z). Based on these data and the appropriate trigonometric operations [2], it is possible to determine roll and pitch angles defining the quadcopter rotation along the X and Y axes. The obtained rates of acceleration (a_y, a_z) are shown in Figure 4.

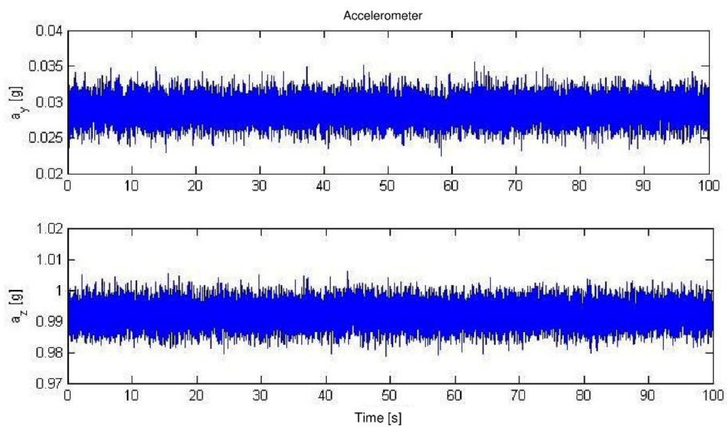

Fig. 4. A graph showing the values of accelerations (a_y, a_z) read from the accelerometer.

$$\varphi = arctg\left(\frac{a_x}{a_z}\right) \tag{1}$$

$$\theta = arctg\left(\frac{a_y}{a_z}\right) \tag{2}$$

In order to determine the value of θ (pitch), measurements of the acceleration value from the 3-axis accelerometer were carried out. During the quadcopter measurements, similarly as in the case of an unscrewing of the flat acceleration of the plane.

Since accelerations did not have any accelerations except for Earth, the total sum of a_x, a_y, a_z the moment is 1 g. On the basis of (Figure 3) the Pitch angle was determined. The results are presented in Figure 5.

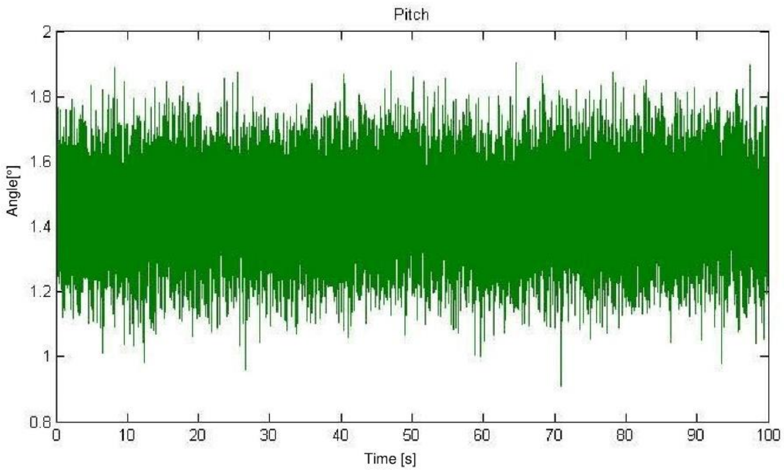

Fig. 5. The value of θ is calculated by means of trigonometric transitions.

By performing trigonometric transformations, the value of Pitch was obtained. Maybe in favor considering that the calculated angle is not affected by the drift that occurred in the case of the gyroscope, but it is characterized by a greater noise. The non-zero obtained value of the angle results from the non-ideal alignment of the sensor during measurements.

2.3 Kalman Filter

The Kalman filter is a linear estimate of the state model [2] and is modeled by means of state:

$$X_{k+1} = Ax_k + Bu_k + W_k \tag{3}$$

$$Y_k = Hx_k + Z_k \tag{4}$$

where A, B, H denote the state, input and output matrices respectively, X is the state vector, **u** is the input, Y is the measured value, W is the process noise and Z is the measurement noise. The Kalman filter assumes that the measurement and process noise are not correlated with each other and their average values are zero.

The Kalman filter algorithm is divided into two stages. The first stage is called the time update. The second stage of the Kalman algorithm is the update of measurements [2]. Figure 6 is a graph showing the operation of the Kalman filter for a stationary angle.

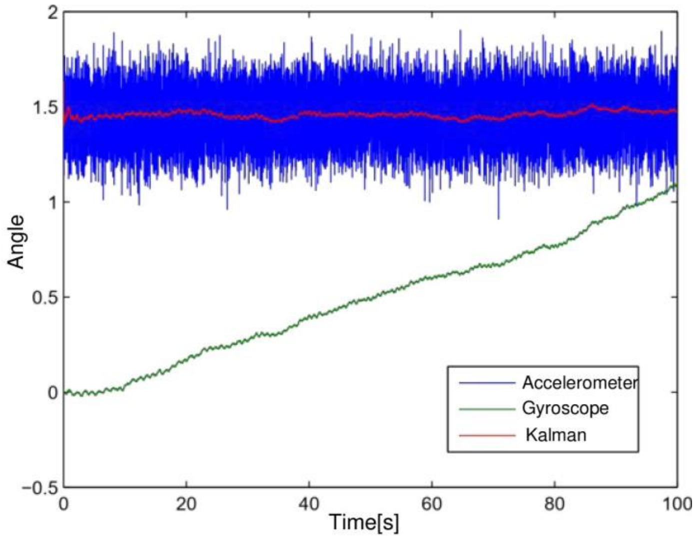

Fig. 6. The result of the operation of the Kalman filter for a stationary rod.

The Kalman filter eliminates the initial error of the gyroscope and suppresses noise from the accelerometer. The operation of the Kalman filter for a stationary rod gives similar results to the complementary filter. The result of the Kalman filter for the rapidly changing angle value is presented in Figure 7.

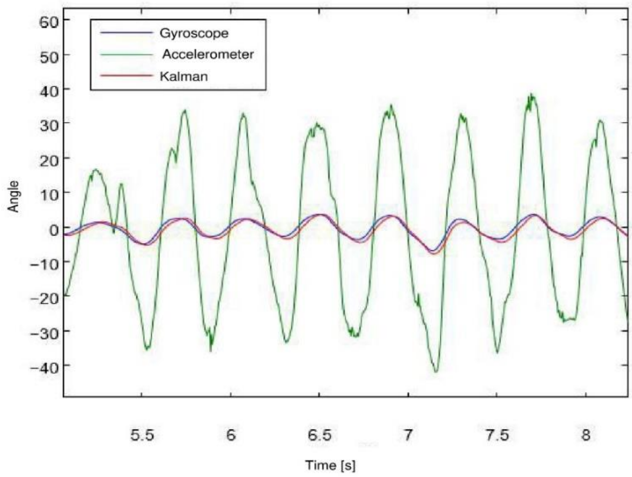

Fig. 7. The result of the Kalman filter operation for rapid angle changes.

On the basis of Figure 7, it can be noticed that the one calculated using the Kalman filter has a much smaller delay in the phase and less influence of the noise from the accelerometer, than the one received using the accelerator. At the very end, a measurement was made to compare the operation of the complementary filter and the Kalman filter. For this purpose, the quadcopter was rotated by various angle values. A fragment of the measurement is shown in the graph in Figure 8.

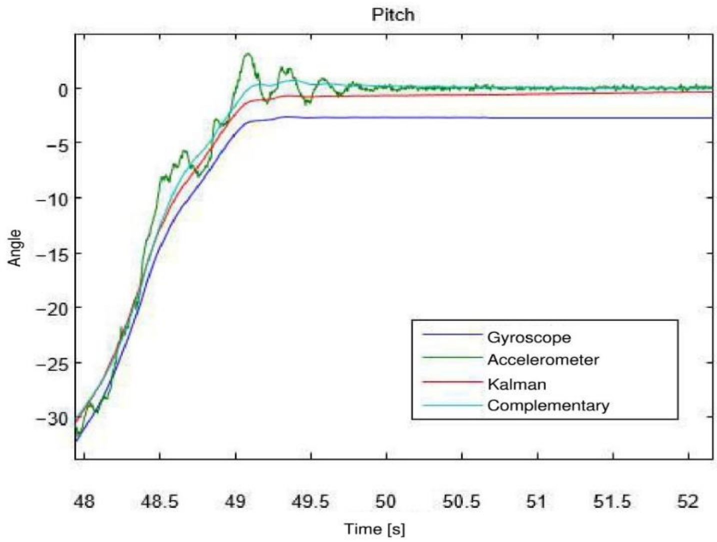

Fig. 8. A graph showing the operation of the Kalman filter.

Summarizing both filters, they are suitable for use in systems in which the angle change has low frequencies, whereas for systems characterized by rapid changes, the quadcopter is recommended to use the Kalman filter. In the project, two separate Kalman filters were used to determine the pitch and roll angles, while the measurements from the gyroscope were used to estimate the yaw angle. Orientation estimation has been implemented both in the quadcopter and in the operator's module.

2.4 Control Module

In the quadcopter, the steering module consists of a microcontroller to which external systems have been connected. The diagram of these connections is shown in Figure 9.

In the microcontroller's memory, control algorithms and functions realizing communication with such systems as: IMU sensor, GPS receiver, radio system, RC receiver, PC computer and engine controllers have been implemented. By transforming the information coming from the IMU sensor, the microcontroller determines the current quadcopter orientation. On the basis of the vehicle configuration value and the set values coming from the operator module, a control signal is determined, which is fed to the engine controllers in the form of PWM signals with appropriate filling [3]. Steering signals calculated only if a user triggers a signal to activate the motors by means of a brake. On the basis of data from the GPS receiver system, the control module determines GPS coordinates. Communication with a PC computer enables reading data to simulate the operation of algorithms on real sensor readings.

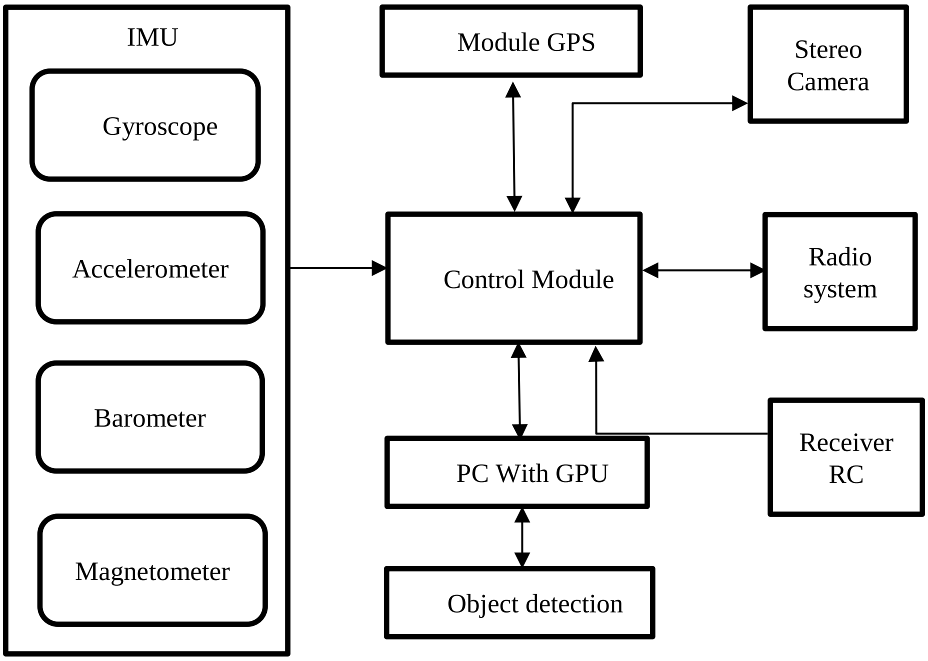

Fig. 9. Diagram of connections of the control module with external circuits.

3 Experimentation

3.1 Stability Testing

At the very beginning, it was checked how the quadcopter stabilizes in one axis. For this purpose, the value of the given angle was set at 0. The vehicle was prepared for testing by pulling the string through the center of the frame, and fastening one of the ends to the railing, while the other was held by one from the authors of the project. Initial tests were carried out using RC equipment. The completion of the station is shown in Figure 10.

The purpose of the test was to check the correctness of the implementation of the control algorithms and orientation estimation. After selecting the appropriate PID regulator settings, it was noted that the quadcopter is stabilizing. The test ended successfully. The next test was an attempt to stabilize the quadcopter in two axes and the choice of satisfying the PID regulations. In this case, it was possible to move the platform to a specific platform. Initially, the values of the integrating and unsetting elements were set to 0[4].

Fig. 10. Testing Stabilization with quad-copter

Only the proportional element was changed. In the case when the gain value was too small, the quadcopter slowly returned to the steady state, but it was not able to reach it. Gradually it increased - the settings were noticed that the quad the converter started stabilizing. In the case of excessive amplification, oscillations around the steady state occurred. After choosing the value of the proportional element, the values of differential and integrating values were changed. The differing elements influenced the speed of the quadcopter reaction, while the integral members reduced the value of the error.

3.2 Controllability Testing

The final phase of the tests consisted of controlling the quadcopter with the help of a glove. For this purpose, the vehicle is placed on the platform. During the tests, the operator checked if the quadcopter reacts to the control signals coming from the squeeze. At the beginning, the operation of 4 buttons was checked. According to the assumptions, the vehicle respectively: activated the engines, changed the speed of rotation of the engines and activated the manual control mode. Next, the operator, holding the pressed control button, turned the palm. Quadcopter at that time replicated the operator's movements.

3.3 Object Detecting

When it comes to precision, the results were promising. We showed how the system trained in general image data can be used to detect objects in a specific task (motion detection), thus showing the ability to adapt methods [6]. In many cases, it has detected more objects than annotators the original data has been marked. They were nevertheless marked as false positive clear possession of the appropriate class of objects through visual inspection.

Fig. 11. Detection from the view of quadcopter

4 Conclusion

To sum up, the project has built a quadcopter and implemented a navigation module and a steering module in it. The copter is able to perform basic maneuvers such as elevation, descent, forward tilt, lateral deviation and rotation about the central vertical axis. An important issue considered during the control was the estimation of the quad-copter and the squeeze orientation, which consisted in determining the pitch, yaw and rotation angles called roll, pitch and yaw. At the end, a series of tests were carried out to verify the accuracy of the implemented algorithms and methods.

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