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ALGORITHMS FOR DETECTING DISORDERS OF THE BLDC MOTOR WITH DIRECT CONTROL

Marcin Chodnicki, Przemysław Kordowski
Mirosław Nowakowski, Grzegorz Kowaleczko

Air Force Institute of Technology
Księcia Bolesława Street 6, 01-494 Warsaw, Poland
e-mail: marcin.chodnicki@itwl.pl, przemyslaw.kordowski@itwl.pl
miroslaw.nowakowski@itwl.pl, grzegorz.kowaleczko@itwl.pl

Abstract

Unmanned aerial vehicles are used to observe objects from the air in both kind of users – military and civilian. During the flight, UAV constantly is changing its orientation. This is due to weather conditions and commands coming from the ground control station. It has directly influence to the quality of the video stream transmitted from the cameras to the GCS. That disturbed image is hard to effective analyse. In order to eliminate the interference, UAVs are equipped with stabilized gimbals. The most of gimbals designed in Air Force Institute of Technology are using BLDC motors. Some of these systems use encoders for determining the absolute angle of motor rotation. The smaller one, which is up to 200 g, is not provided with these sensors. This angle is calculated without any feedback from the system. It is calculated by the BLDC motor`s control signals. However, lack of feedback can provide unstable work of gimbal, if it will be pushed by any force from environment. During the flight, it is unacceptable to head optoelectronic stopped working steadily. Therefore, there is a need to develop algorithms for securing the proper operation of the system stability. These algorithms can be used in other systems using stepper or BLDC motors.

Keywords: *UAV (Unmanned aerial vehicle), video stream, BLDC motor, rotation matrix*

1. Introduction

The optoelectronic heads, which are using BLDC or stepper motors, can calculate the angle without feedback from the external sensor. The rotation angle of the motors is determined on the signals provided to the engine [1]. This method greatly simplifies the mechanics of the head and reducing the production costs. However, sometimes-calculated rotation is different from the real one. This error may occur by external force, which will influence directly to the motor. Therefore, there is a need to develop algorithms for the detection of loss of step and calculate the amendments to the control. The lack of such procedures will result in a loss of stability of the system [2].

2. Analysis of data from the inertial sensors

The observation heads discussed in this article are carried by unmanned and manned aircrafts. The dynamics of these objects is well known. Therefore, it is possible to determine the maximum changes of rates and accelerations of units. Fig. 1 shows the angles calculated from inertial sensors during normal operation of the head.

From the above chart, you can unequivocally state that the deviations do not exceed 1 degree. In connection with each change above this value may indicate that there has been an external force. The data from inertial sensors with external forcing and the lack of compensation algorithm is presented at Fig. 2.

External force took place in about 400th sample. Next, the system came into unstable state due to erroneous calculation of the angles of the engines.

Fig. 1. Pitch, Roll, Yaw angle during normal work of optoelectronic head

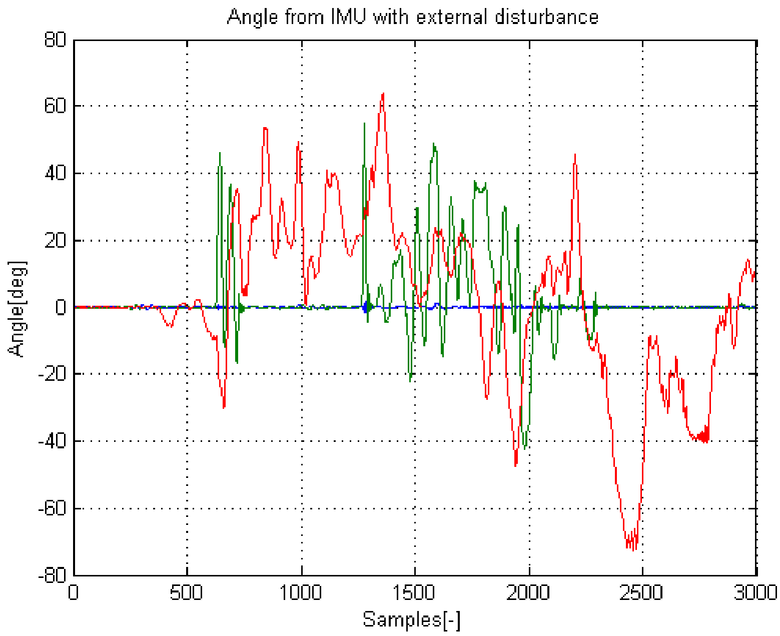

Fig. 2. Pitch, Roll, Yaw angle during disturbance work of optoelectronic head

3. Analysis calculated angles from motors

During performing standard flights, the maximum angles that gimbal must work is: ±90 degrees in pitch and roll angle and 360 degrees in the yaw. Fig. 3 shows the angles calculated from the engine without external interrupt.

In this case, the angles are within the previously described ranges. It is another requirement for detection of external force. Fig. 4 shows the angles of the engine, when external force is applied in 400th sample. Regarding to the scale the significant values can be seen at 600th sample.

We can see that the angles are characterized by large amplitudes and significant changes of angle. This is because the gimbal heads algorithms are based on the PID, and the angle is calculated directly from the output of the controller. Factor D exacerbates the peaks and rapid changes that can be seen in the chart.

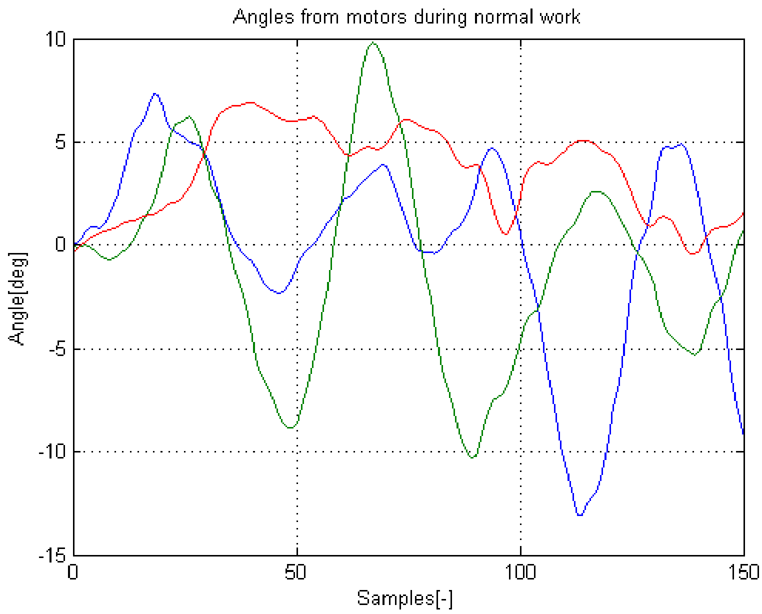

Fig. 3. Motor X, Y, Z axis angle during normal work of optoelectronic head

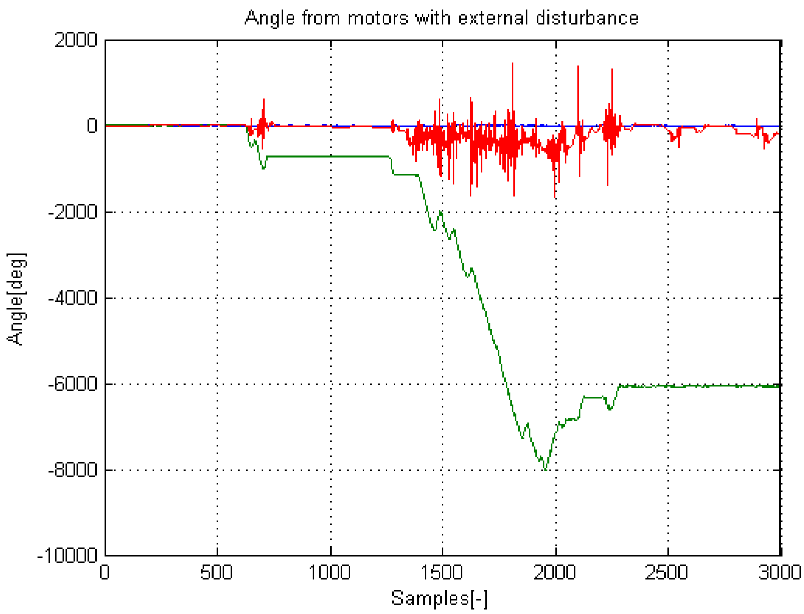

Fig. 4. Motor X, Y, Z axis angle during disturbance work of optoelectronic head

4. Conditions of detection motor's angle counting errors

The first step to developing an algorithm counting angle error compensation, is detect such an event. The figures from 1 to 4 allow to determine by the following boundary conditions:

1) exceeding the amplitude of the deviations,
2) exceeding the value of the angular velocity deviations,
3) very fast angle rates values from the meter engine,
4) the angle of the engine exceeding the limits,
5) pulsed voltage and current changes in the system.

5. Compensation errors algorithm during the flight of UAV

Compensation angle errors counting at the head used on objects less dynamic is relatively simple. However, when the optoelectronic head is used on the UAV, it is recommended to implement interface with the autopilot or operator. Fig. 5 is a flowchart of counting error compensation while the head is placed at the UAV.

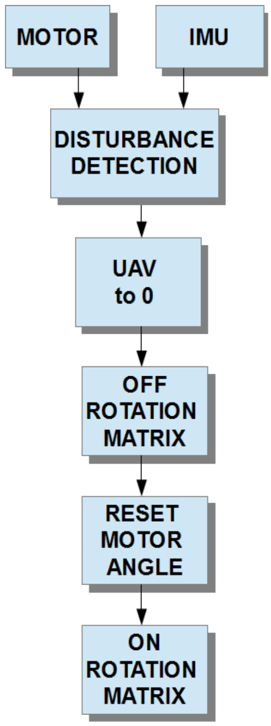

Fig. 5. Algorithm of motor counting error compensation

The stabilize algorithm of the gimbal head constantly watches over whether external force occurred. After discovering irregularities in the previously mentioned conditions, a command is sent to the UAV for entry to zero angles (angle of pitch and roll to 0). Then the rotation matrix is turn off so that the head is able to work steadily. After reaching deviations at a level shown in Fig. 1, the angles of the motors are set to zero. Over the next few samples if the conditions are false, the rotation matrix is turn on and the command is sent to the UAV for correct operation of the system. Fig. 6 and 7 illustrates the operation of the discussed algorithm.

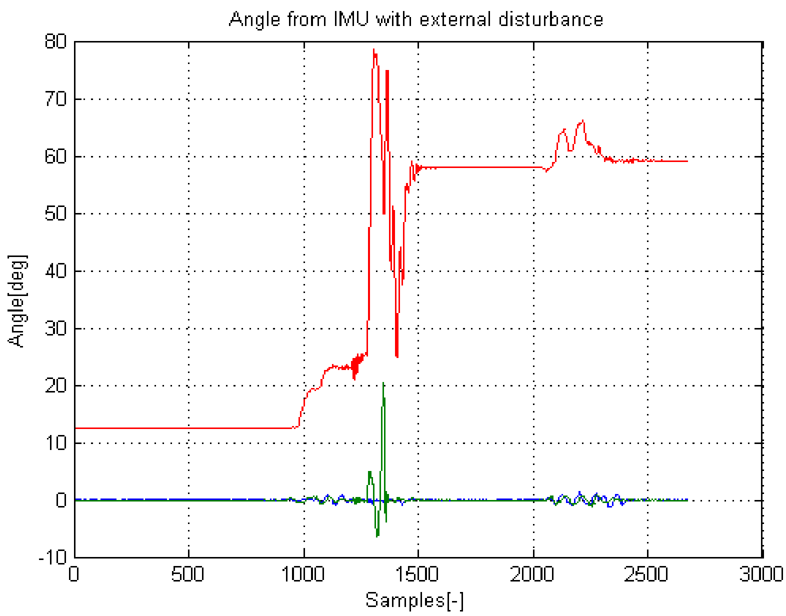

Fig. 6. Algorithm of motor counting error compensation

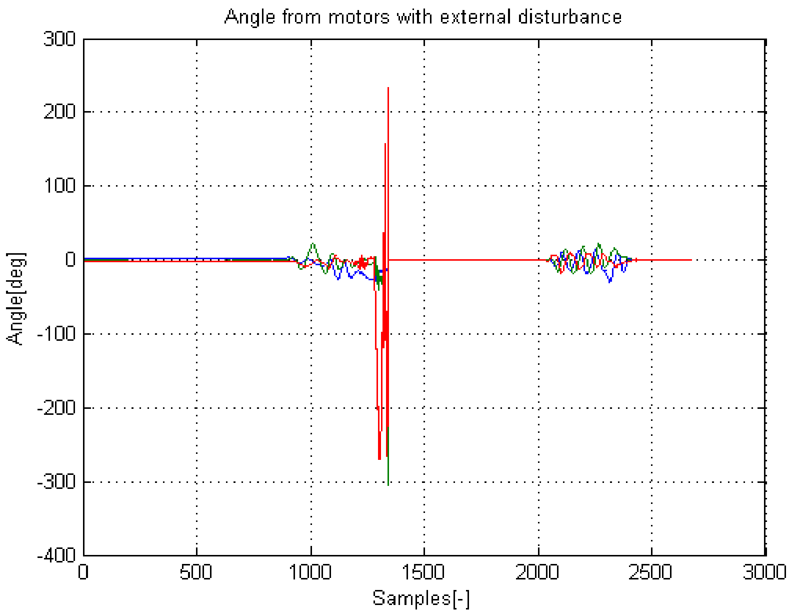

Fig. 7. Algorithm of motor counting error compensation

In the 1300th sample can be observed external force. Subsequently to 2000th sample showing the operation of a compensation algorithm (the motor angles are 0), and next the head is working stable.

6. Future algorithm

The next step is to develop algorithm by implementation of the analysis of the control signals at the motor windings. Fig. 8 shows the control signal at the normal operation of the engine. Average signal voltage is constant.

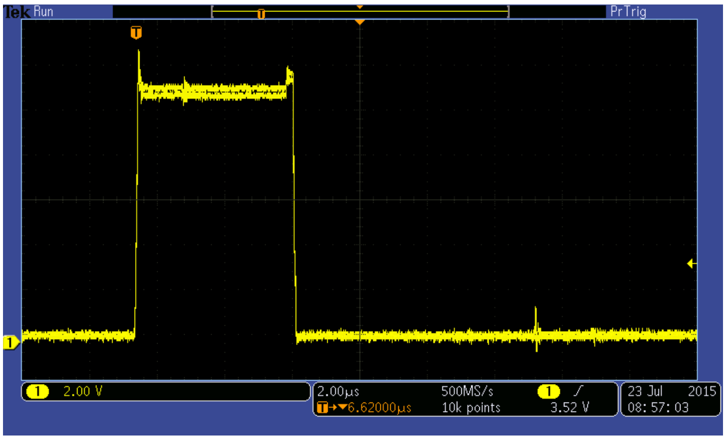

Fig. 8. Normal control signal at the motor winding

Figure 9 shows the same control signal while external force happened. This signal can be analysed by using ADC or digital input. The new algorithm does not require any additional sensors.

7. Conclusion

Problem miscounting angle of the engine (step loosing) is present in each device, which does not have feedback from the system. The article discussed and presented work of stabilized gimbal.

Particular attention was paid to the external disturbance, which provides the steps loosing. This algorithm has been tested in a simulation environment and implemented to the real system. The tests clearly showed the correct operation of the whole system while algorithm is implemented. Further research will rely on the analysis of the control signals described in the sixth chapter. Future algorithm can be implemented in the CNC, 3D printer and every device, which is using BLDC, or stepper motors.

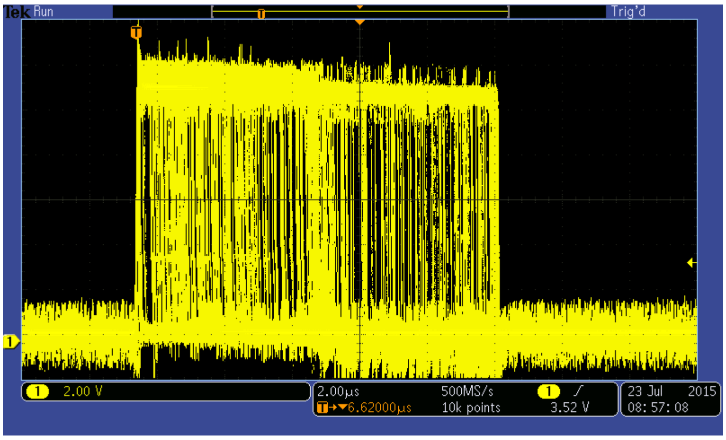

Fig. 9. Disturbed control signal at the motor winding

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[2] Chodnicki, M., Lorenc, W., Nowakowski, M., Kowaleczko, G., *The reference systems used in gimbals using BLDC motors*.