

Modelling and Controlling the Orientation of an Arduino Based 3 Axis Camera Gimbal in Matlab Simulink

Sourav Basu ,Himali , Saikat Banerjee , Sudhir Kumar Chaturvedi

Abstract: The gimbal mechanism was used for mounting compasses during 1500 century and it was described by Italian mathematician and physicist Gerolamo Cardano however it is also said that gimbal mechanism was first described by Greek inventor Philo of Byzantium. Despite all of this fact, the gimbal has huge application in the field of rocket engines, film and video making, marine chronometers, inertial navigation and so on. In the field of photogrammetric feature, identification and image matching are two important tasks. In this context, merits saying that numerous techniques distributed with codes and algorithms to fulfill the ordinary needs of capturing photos and videos. So here design, simulation and controlling of a three axes gimbal for holding and controlling the orientation of the camera in unmanned vehicles have been analysed. The control system has been developed and simulated for the stability of the camera position by MATLAB Simulink. This would be helpful for applications like aerial photography, target tracking, autonomous navigation, and surveillance etc. The camera gimbal process is the substitute of many typical tracking systems like radars which are heavy and huge to be attached with UAVs, that's why the stability of the gimbal process is very important for to eliminate distortions. The three-axis orientation of the camera is maintained by a motion sensor and three brushless dc motors. A lot of camera gimbal stability techniques have been acknowledged. The challenge is to have the capability to the execution of photos and videos capturing utilizing the target criteria. Recently there has been significant progress in the use of camera gimbal towards the detection of different types of subjects.

Index Terms: Brushless DC motor, IMU sensor, camera gimbal, gimbal stabilization, Kalman filter, MATLAB Simulink.

I. INTRODUCTION

There are basically three types of gimbal such as single axis, dual or two axis and three axis gimbals. Here the experiment is about designing a three-axis camera gimbal. The aim of

designing an Arduino UNO based 3-axis camera gimbal using MATLAB Simulink is to provide a better control strategy for the smooth performance of the gimbal mechanism, which can be used for various applications like mapping, safeguard instrument, aerial photography, target tracking, autonomous navigation and surveillance etc [1]. This orientation of the camera can be controlled by this gimbal technique which would be mounted on UAVs or MAVs. Because of the moving airborne vehicles, the gimbal has to face different types of disturbances like spring torque, motor friction etc which can affect the camera stability, and tracking of moving targets is tough to capture properly, that is why the control system of the gimbal has to be efficient [2]. And another advantage of designing a camera gimbal using MATLAB Simulink is that there is no need for complicated coding and algorithms, which is time consuming [3].

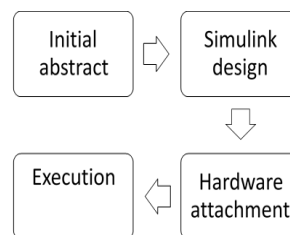


Fig.1: Block diagram of the basic concept of the project

Now discussing the hardware portion, generally, there are different types of gimbal constrained by various types of dc motor however in this project a three axes gimbal is structured with three brushless DC motors [4]. The principle reason to utilize the brushless DC motor is that the back emf of a brushless DC motor is extremely low and that is how the gimbal can deliver an efficient output [5].

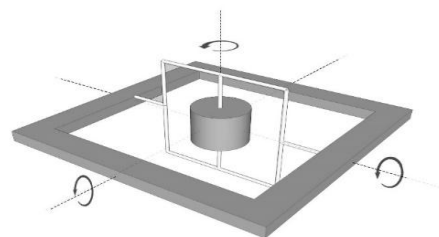


Fig.2: The orientation of the gimbal

Camera gimbals are usually connected with UAVs, MAVs, UGVs.

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* Correspondence Author

Sourav Basu*, M.Tech, Power Electronics student, Department of Electrical Engineering, Jalpaiguri Govt Engg. college, Jalpaiguri- 735102, West Bengal, India.

Himali, Student, Aerospace(Avionics)Engineering, Department of Aerospace Engineering, UPES Dehradun-248007, Uttarakhand, India.

Saikat Banerjee, Director, Department of UAV and Remote Sensing, Wingbotics, Kolkata-700092, West Bengal, India.

Sudhir Kumar Chaturvedi, Faculty, Department of Aerospace Engineering, UPES, Dehradun-248007, Uttarakhand, India.

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In this experiment the effective relocation of the camera and the three-axis alignment would be maintained by a motion sensor, IMU MPU6050, with a programmable full-scale range of $\pm 2g$, $\pm 4g$, $\pm 8g$ and $\pm 16g$ and angular rate sensor (gyro) with a sensitivity up to 131 LSBs/dps and a full-scale range of ± 250 , ± 500 , ± 1000 , and ± 2000 dps [6]. The basic idea of the experiment has been shown in Fig.1, while the angle orientation diagram of the gimbal is shown in Fig.2.

II. HARDWARE ATTACHMENTS

The active stabilization of camera in gimbal is developing for a long time for capturing stabilized photos or video footages for different purposes. Nowadays it becomes very flexible to control the camera stability remotely [7]. The aim of this experiment or project is to create a new control system to stabilize the 3-axis gimbal camera position in MATLAB Simulink. To obtain this control technique, the advanced control theory for 3-axis movements is required with a microcontroller which is an Arduino UNO for this experiment, and to design a motor driving control logic for 3 axis movement [8]. And the filtering of unwanted signals will be executed in the Arduino.

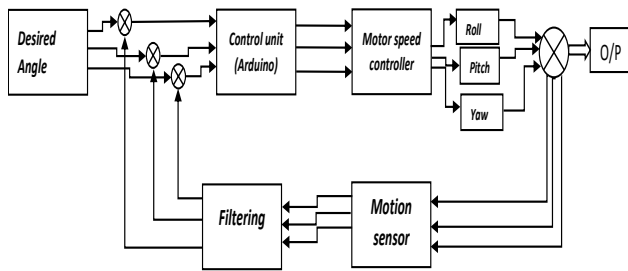


Fig.3: Schematic diagram of the 3-axis gimbal circuit for the experiment

From Figure.4, the schematic diagram of the control system, a general idea can be obtained from the experiment. And the full circuit diagram of the experiment is shown in Figure.3. From the Figure it can be understand that pin3(D), pin5(D), and pin6(D) are used for the input signal for the three motors of the gimbal, because the motors of the circuit is meant to be getting fluctuating i/p signals at every second during the running mode of gimbal circuit, and digital pin 3, 5, 6 of Arduino able to generate pulse width modulated (PWM) signals [9]. An inertial measurement unit (motion sensor) (IMU) sensor block is drawn to circuit only with gravitational force function of it only to sense the inappropriate alignment of the hardware circuit and give the error feedback to the Arduino so the servo system can maintain the axes as per requirement [10].

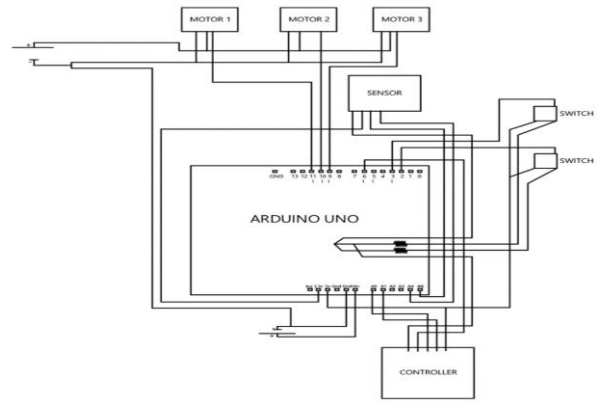


Fig.4: Circuit diagram of the experiment

Brushless DC motors can produce higher torque and reliability [11]. Brushless DC motor has the ability to be synchronized with input signals promptly that's why the delay is less over other dc motors [12]. To obtain optimum efficiency brushless DC motors are used in this gimbal circuit. By gaining the idea of running and controlling a brushless DC motor form the studies of previous research papers [13], the fundamental mechanisms are implemented in the simulation model.

BRUSHLESS DC- A2212/10T, 1400KV

Brand- Matlogix

Weight-59gm

Model number-6499468896760

Arduino UNO

MPU-6050

And for sensing the axes alignment IMU sensor MPU6050 module has been used. For the simulation only, the gravity function has been used [14]. The main frame of the gimbal circuit has been dismantled from a DJI spreading wings S-1000 UAV. The length of the frame is 14 cm and the width is 8.4 cm. And for the power source, an 11.1volt battery has been used. And all the elements are finally attached with an Arduino UNO.

III. THE BASIC IDEA AND SIMULINK MODEL

The concept behind the project is to give the degree of freedom (DOF) for three axes (x, y, and z) to the gimbal system. And to get that kind of flexibility to the axes the circuit needs to get attached with moving elements i.e. brushless DC motor to give the 360 degrees of freedom (DOF) for three axes (x, y, and z) to the gimbal system. Thus three 3 dc motor would be implemented to get a gimbal system [15,16].

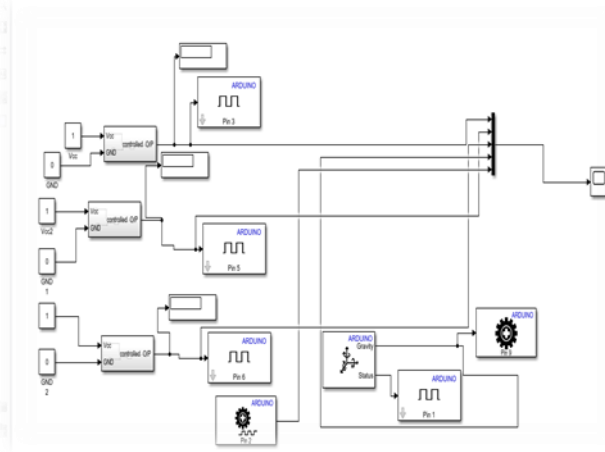


Fig.5: Simulink model of three axis gimbal circuit

From the Figure.5 it can be understanding that pin3(D), pin5(D), and pin6(D) are used for the input signal for the three motors of the gimbal, because the motors of the circuit is meant to be getting fluctuating i/p signals at every second during the running mode of gimbal circuit, and digital pin 3, 5, 6 of Arduino able to generate pulse width modulated (PWM) signals. An inertial measurement unit (IMU) sensor block is drawn to circuit only with gravitational force function of it only to sense the inappropriate alignment of the hardware circuit and give the error feedback to the Arduino so the servo system can maintain the axes as per requirement [17,18]. And that is how the 3-axis gimbal circuit will be in working condition. The noisy signals or the distortions will be eliminated through Kalman filtering in the control unit which is pre-programmed with this feature of noise elimination [19]. And when the design of the control system for the camera gimbal is done, it will be initiated in the hardware portion to check whether its working or not. If all the hardware components and control technique is appropriate for each other then it will show the output in the screen for every motor for each axis [20]. And from the output characteristics of the motors, it will be easy to understand the efficiency, delay and position of motors. And it can be controlled as per the requirement of the application.

III. ANALYSIS

The most important part of the project is to create the control system for the camera gimbal. Because the whole gyroscopic movement will be controlled by the control strategy which will help to maintain the stability of the camera gimbal. The higher the efficiency of the control technique will be, the delay would be less for the system. One other thing should be in mind that if the mechanical and other external loses can be reduced or mitigated, the efficiency of the camera gimbal would be better. And that is how the captured photos or the videos would be better in quality. The control strategy has been elaborated below with a block diagram.

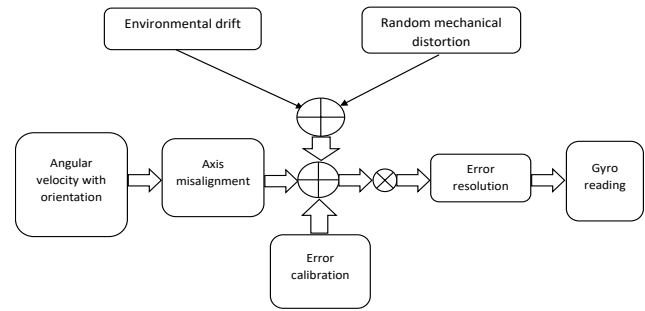


Fig.6: Control Strategy of the gimbal circuit

The full control strategy to make the gimbal circuit stable (shown in Figure.6), the data provided by the IMU unit is first converted into an angular displacement parameter, and after that, the converted data is compared with axes misalignment of the gimbal and the error calibration feedback is gained. To get the desired and efficient output from the IMU sensor and Arduino UNO Kalman filtering is needed. In this paper 0.0001 to 0.001 s noise, covariant parameters' characteristics will be discussed [21] The application on the microcontroller Arduino UNO is based on. For a linear system, the state space equation can be written as,

$$X_{k+1} = AX_k + BU_k \dots (1)$$

In Kalman filter, Refer to “(1)” will be converted into;

$$\begin{bmatrix} A \\ B \end{bmatrix}_{k+1} = \begin{bmatrix} 1 & dt \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A \\ B \end{bmatrix}_k + \begin{bmatrix} dt \\ 0 \end{bmatrix} u_k \dots (2)$$

Here u is the reading from gyroscope and A, B are taken arbitrarily for the first-time execution. The most crucial issue of this project is the estimated error for the covariance noise [22]. This value will let us know how much unsteadiness is getting by the sensor module. As the Arduino UNO has the general purpose ATmega microcontroller so the matrix operation has to convert into the simple mathematical equation for the reduction of the complexity of calculation. And that’s how the above equations would be converted into simplified form given below.

$$A_{k+1} = A_k - Bdt + u_k \cdot dt \dots (3)$$

$$B_{k+1} = B_k \dots (4)$$

And equation (3) can be written as,

$$A_{k+1} = A_k - (u_k - B_k)dt \dots (5)$$

On introduction, tests were taken as a counterbalance the standard for every sensor while the system was still and level to account static mistake in all likelihood because of temperature affectability, misalignment or different other aspects for the accelerometer yield representing predisposition.

$$\phi_1 = \phi_{prev} + \frac{\phi_{new} - \phi_{bias}}{s} * \Delta t \dots (6)$$

Here a is the standard acceleration, a(bias) is the offset acceleration during initialization, and s is the sensitivity of the sensor. The IMU control the rotational direction of motors by the sensing range it has been manufactured with.

$$\phi = a. \tan 2(a_x, a_z) \dots\dots\dots (7)$$

Here Refer to “(7)” is the establishment of the linear relationship at the output side of the sensor. Φ is the roll rate of gyroscope, and Δt is the sampling rate. This is the algorithm to get the compulsory data for every axes of the gimbal system. And the sensor had taken the most important part to initiate these types of experiments. After all it is the sensor for which the whole gyroscopic movements have been possible to execute in collaboration with the above-mentioned conditions because without the help of sensors the camera gimbal stability is impossible to obtain. The camera gimbal orientation can be controlled in two different ways i.e. the controller (wi-fi module or Bluetooth) of the circuit can manoeuvre the direction of the camera as per requirement or the gimbal can automatically maintain its camera position which will be given pre-programmed in the MATLAB simulation. At the result portion of the simulation, only x(roll) axis’ characteristic graph has been shown in the output.

IV. RESULT AND OUTPUT

At first the simulation results for the estimated angle from the Kalman filter with 0.0001(Fig.7) and 0.001(Fig.8) as of measurement covariance noise. And then the output of one gimbal motor has been taken out to show the output curve (Fig.9) of the system and how it acts as per the inclination of the hardware system and how the curve varies with angular displacement. The output curve can be obtained with more accuracy if the IMU sensor is used with multiple functions for the feedback to the system.

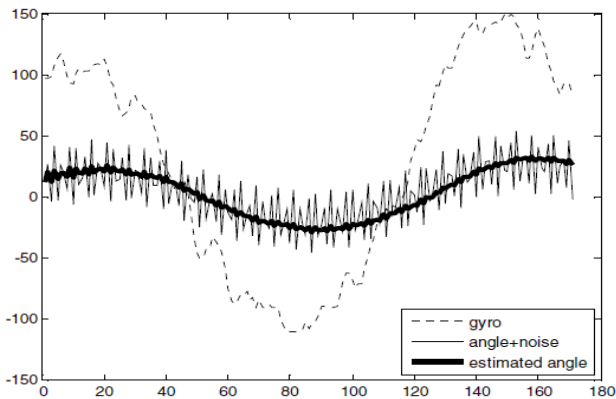


Fig.7: MATLAB simulation with 0.0001 as measurement covariant noise

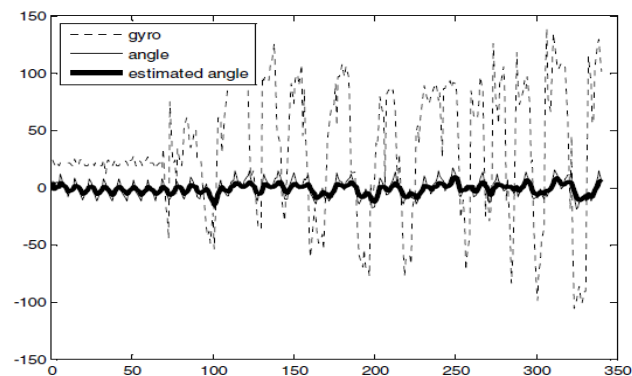


Fig.8: MATLAB simulation with 0.001 as measurement covariant noise

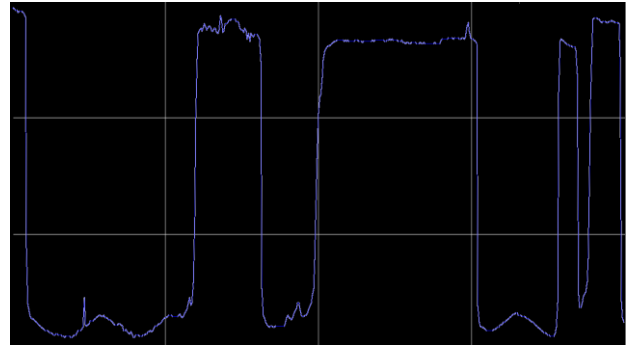


Fig.9: Output curve of a single brushless DC motor(roll) of the gimbal

From the study of previous research papers on the topic, it can be understood that the camera gimbal stability had been a primary topic to emphasize and develop for UAVs and MAVs for better surveillance or for any other purposes. That is why this project has been initiated for camera gimbal stability. And from the simulation results, it can be easily understood that this process is applicable and efficient for further study in this topic. Moreover, from the output curve or the movement of the motor can be read from the simulation result at it can be changed as per user’s requirement.

V. CONCLUSION

The project work undertaken addresses a few critical issues in the field of camera gimbal stabilization. A new approach to interior stability research using a gimbal is shown in this paper. The new method consists of a Simulink block and therefore gives us an approx. output. Evaluation of the system, after the studies of previous research papers on the gimbal which is based on the inertial measurement unit data, and only gives us an idea to the internal evaluation of the gimbal’s stability. The expected improvement of the internal simulation depends on the flight mode and gimbal quality. From the help of different previous researches on the gimbal circuit and its stability, the motive of stabilization in a real environment is to set up the reachable stabilization accuracy. With the mentioned test, the data range from 2.56° and 1.97°, and a standard deviation from 0.46° and 0.36° for pitch and roll parameters is obtained. The exterior orientation stability is enhanced 3 or 6 times in comparison to the flight tests, depending on the conditions of the flight. Considering the fact that a gimbal is minimum budget apparatus and that used technology is swiftly enhancing this objective will be reached soon. If this type of newly gimbal controlling idea is initiated in the practical field then we can get a multitasking system, that is by using MATLAB, the controlling of the gimbal, image processing and ground control system etc can be established with lesser complications. And this could be installed in various large and small projects from film or video capturing to airborne vehicles. The calibre of this experiment has been under the comparison with the hit and trial method which has been elaborated in the paper.

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