Construction and design of a camera stabilizer based on a gyroscope and accelerometer sensor

Article *in* Journal of Advanced Research in Dynamical and Control Systems · July 2020

1 author:

Roshan Umate
Datta Meghe Institute of Medical Sciences (Deemed University)

Construction and Design of a Camera Stabilizer Based on a Gyroscope and Accelerometer Sensor

Kaustubh Dapurkar, Department of Electronics and Telecommunication, Yeshwantrao Chavan College of Engineering (Autonomous)

Swati Borkar, Department of Electronics and Telecommunication, Yeshwantrao Chavan College of Engineering (Autonomous)

Kartik Raut, Department of Electronics and Telecommunication, Yeshwantrao Chavan College of Engineering (Autonomous)

Rupam Muley, Department of Electronics and Telecommunication, Yeshwantrao Chavan College of Engineering (Autonomous)

Sahil Bagde & Sandip DesaiDepartment of Electronics and Telecommunication, Yeshwantrao Chavan College of Engineering (Autonomous)

Roshan Umate,Research Scientist, Jawaharlal Nehru Medical College, Datta Meghe Institute of Medical sciences, Wardha

Abstract - Nowadays to record the moment everyone wants it to be perfect. Beyond resolution, we need to get steady shots whatever the surrounding conditions may be. The camera stabilization system ensures a stable image by blocking unwanted, noisy and fluctuating disturbances avoiding the transfer to the camera lens axes. Thanks to the Three Axis camera stabilizer, perfect images can be achieved by minimizing these unwanted disturbances. In short, a three-axis camera stabilizer can be assembled and developed everywhere where a fixed image or stabilized video output is needed. It is a single-handed device which can be operated by anyone because of its light weight and ease of use. The users just have to hold the device in their hands and turn the power on and it will start working seamlessly. No configuration or pre arrangements needed.
The aim of this study is to show an experimental model of the Three Axis camera stabilizer mechanism. Three separate servo motors are installed on each axis for nullifying any vibrations or unwanted disturbances or abrupt movements. The control system for this stabilizer is developed using various control methods and algorithms to provide better and efficient performance with flexibility, accuracy and feasibility. The stabilizer also has an inertial measurement unit which has a gyroscope and accelerometer close to the camera mount point. This IMU is transmitting all the inertial data to an Ardiuno microcontroller which is processing this data and controlling the servo motors based on the inputs. After we have built the stabilizer, we will be able to record vibration less videos and take sharp and clear photos with a camera mounted on it. The purpose of this study is to emphasize on the ease of fabrication and also the cost of manufacturing if done on an industrial scale. Also, there can be some improvements in the reaction time of the process i.e., the time between sensing the motion and performing a corrective movement could be even lowered by using specifically built controllers and sensors which can also be cheap to manufacture.

Keywords- Inertial Measurement Unit, 3 Servo Motor, 6 Axis Inertial Measurement System, Arduino Nano, Camera, Blur.

Introduction

Cameras these days have gotten very good at capturing breathtaking photos and videos with all the fancy features one can imagine. Still the biggest hurdle these cameras face in terms of capturing sharp photos/videos is the absence of complete stabilization. Most cameras these days come with a built in stabilization system based on either EIS (Electronic Image Stabilization) or OIS (Optical Image Stabilization) but these inbuilt systems still cannot provide a completely blur free image/video because of their stabilization units being capable of handling only small or minute vibrations. The standalone stabilization system being discussed in this paper can help solve this issue.
In this system a motion sensing unit or an inertial measurement unit is being used to sense the movement of the camera. The work of processing this data is being done by a small Arduino based microcontroller. The last and arguably the most important aspect of the stabilizer's operation, the motion of the stabilizing arms is being executed using servo motors which are also the only moving parts in the build.

**Corresponding Author: Kaustubh Dapurkar,*
Article History: Received: September 04, 2019, Accepted: Dec 12, 2019

Inertial Measuring Unit (IMU) Sensor gives the data required for reverse motion which is placed near the camera mount. The IMU Sensor finds out all the information of camera movements and reports it to a microcontroller. The sensor first calibrates its position with respect to the ground, records the readings and starts to adjust the position of the camera mount accordingly. It also finds out the relative position of the camera according to the ground. As the sensor detects motion it instantaneously sends the data to the microcontroller. This microcontroller then processes this data and sends commands to the Servo Motors which facilitate the motion of the arms of the stabilizer. Thus, a smooth image/video can be obtained with the help ofservo motors that produces opposite movement of the Camera.

Though the stabilizer is simple and easy to use, it can also be used in industries like entry level photography and film-making. It can prove to be very useful for people who are looking for cheap, simple and easy to operate stabilizers to fulfill their needs which can range from casual hobbies or professional needs.

The construction and working of such a camera stabilizer which uses this process to achieve the specified goal is discussed in this study. The components of the moving platform system are detailed in the second chapter whereas in the third chapter focuses on the algorithm which is applied on the input data from the sensor . Finally, proposals and conclusions are submitted in the fourth chapter.

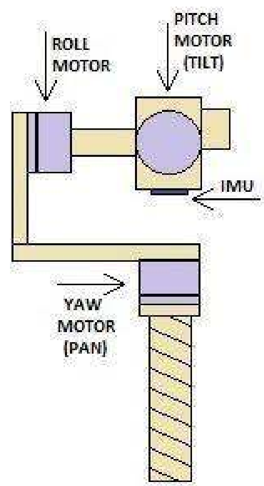

Figure 1: Stabilizer Structure Block Diagram.

Literature Review

We have undoubtedly seen many videos shot on camera tripods. It can create eye-catching videos, images which can make a great addition to YouTube channels or film advertisements. Technically, Camera stabilizer is a type of support which gives an access to an object to rotate on a single axis, but here we are accessing it in 3-axis where it can rotate in x, y and z direction by which it can keep the motion of the camera stable and compensate unwanted movements[3]. The use of IMU (Inertial Measuring Unit) that is placed near the camera mount is to provide reverse motion and senses the motion, report it to the microcontroller. The result is buttery-smooth video, no matter how jerky the camera operator's movements may be. In the past, this was only done with mechanical camera stabilizers like Steadicams (1975).

Mechanical Structure

The frame carrying the system should be able to handle all the stressing and straining forces and light enough to provide ease of use. For this purpose, we have used 3D printed fibre plastic structure. This structure is designed in such a way that it facilitates the movements of the arms and also takes into consideration the capabilities of the servo motors. The motors provide a limited amount of torque as we have used small servo motors which provide a torque of up to 10 N at 1 cm distance from the axis of rotation.

A six-axis IMU sensor (MPU 6050) which has both a three-axis gyroscope and a three-axis accelerometer. It is often used in such projects which require precise acceleration and gyroscope data. Using this sensor, we can obtain the information about orientation, speed, and position of the camera mount from a single unit. The chip also has an inbuilt DMP (Digital Motion Processor) which helps us to eliminate any error that gets into the output during operation over time.

The three axes mentioned in this study are shown in Figure 2. which are called pitch, yaw, and roll. Three separate servo motors are mounted corresponding to the axes of the camera lens to absorb unwanted movements. The servo motor mounted on the pitch axis cancels out all the unwanted up-down movement of the camera lens, undesired right-left motion is cancelled out by the motor mounted on the yaw axis, and undesired rolling motion from one edge to the other is absorbed by the motor mounted on the roll axis.

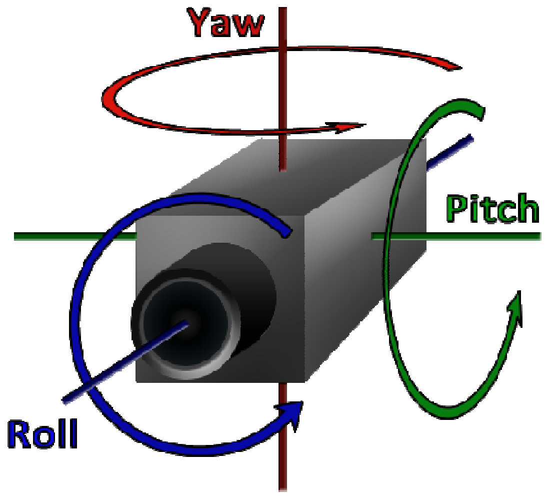

Figure 2: Camera Lens Axes.

Motors mounted in the line with the camera lens receive feedback from the sensor and are used to provide a rotational motion in the opposite direction of the movement to keep the camera lens steady. In this study, servo motors are preferred because of their ability to micro adjust quickly and smoothly.

Software Design Requirements

MPU Data Fusing

The most important aspect of the algorithm is to manage the data regarding motion of the camera which comes from MPU 6050. It is a sensor based on MEMS technology i.e. Micro Electro Mechanical System. It is a combination of both accelerometer and gyroscope embedded in a single chip which uses I2C (Inter Integrated Circuit) protocol.

The gyroscope present in the chip detects rotation about 3 axes i.e. X, Y, Z. Coriolis effect causes vibration when gyros are rotated about its axes. Coriolis effect is the effect which describes a pattern of deflection taken by an object not firmly connected to the ground as they travel a long distance along the earth. These vibrations are picked by capacitors present inside the sensor circuit. The signal produced is then amplified, demodulated and filtered to produce voltage that is proportional to angular rate. ADC is used to digitize this voltage

When used in an application, I2C lines of MPU6050 are pulled up and the interrupt pin is pulled down by using a 4.7k resistor. When data is available in the output buffer of the sensor, the interrupt pin goes high. Now a microcontroller can read the data using an I2C communication bus. The data sent by the sensor contains Yaw, Pitch, Roll data values which are then acquired and processed by the microcontroller which in turn can be used to operate the servo motors accordingly. The microcontroller activates the motors even if the motion concerned is miniscule.

The raw data being received from the inertial sensor cannot be sent directly to the motors. The motors accept data in degrees in the range of 0 to 180 since these motors are 180° motors. Following are some mathematical operations being applied to the incoming data so that it can be sent to the motors to create appropriate movement.

The value of 1g acceleration in the IMU FIFO is set to 8792 i.e., +1g = +8192. Hence to calculate the gravitational acceleration being experienced by the sensor is given by,

$$x*8192, y*8192 \ \& \ z*8192$$

Where x, y & z are the motion vectors in x, y & directions as captured by the sensor.

*Corresponding Author: Kaustubh Dapurkar,
Article History: Received: September 04, 2019, Accepted: Dec 12, 2019

The Yaw, Pitch & Roll values received from the sensor are stored in an array variable name 'ypr' and these values are in radian units. Hence, these values first need to be converted into degree unit so they are manipulated as follows,

```
ypr[0] = ypr[0] * 180 / M_PI;
ypr[1] = ypr[1] * 180 / M_PI;
ypr[2] = ypr[2] * 180 / M_PI;
        M_PI  =>  pi = 3.142,
```

The before mentioned yaw, pitch & roll values are mapped from a range of -90° to 90° to a range of 0° to 180° using the map()function as follows,

```
ypr[i] = map(ypr[i],-90, 90,
    0,180);
where i => 0, 1 & 2
```

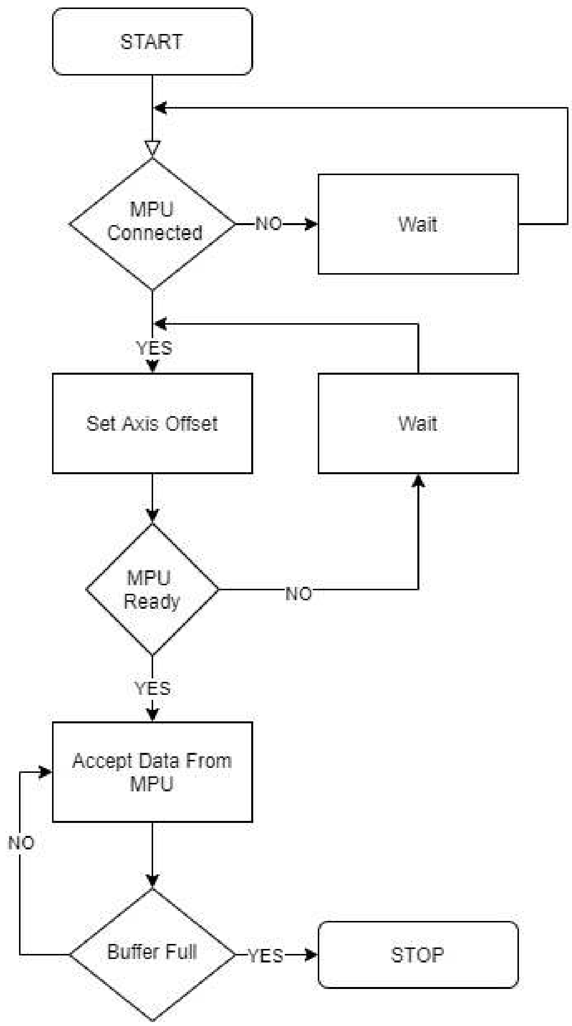

Figure 3: Flowchart.

Controller Design

Although, a variety of modern techniques are available for controlling camera stabilizer systems, because of their low cost, ease of implementation and high performance, microcontrollers are always preferred.

In our study, an Arduino Nano is used which has a THT IC called Atmega328p. This controller facilitates the control of the servo motors since the IC can produce PWM signals which are required to control a servo. Also, the output data about the rotation of the axes from the IMU sensor is received and operated upon by this controller. The controller helps the IMU to calibrate at start-up and provide power to it. After the calibration has been completed, the controller begins accepting data from the IMU.

Firstly, it offsets the input data so that the data matches with the actual application parameters and converts the angular data from radians to degree format. This degree formatted data is then fed to our algorithm which converts this data in such a way that we can control the motors using this data. Since the input for servo motors takes data only in terms of degrees between 0 and 180, we have to map the data from IMU to this scale and then proceed to send it to the motors for subsequent operation. Also, the data can be manipulated to nullify errors in servo motor alignment, if any.

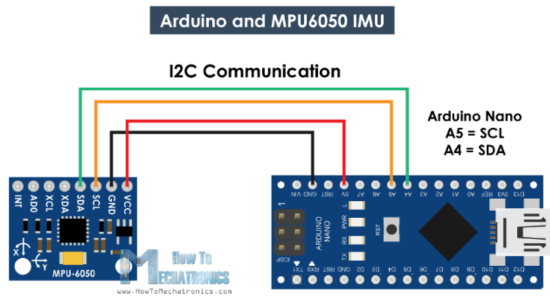

Figure 4: Connections Between Arduino Nano andthe IMU.

Conclusion And Recommendation

From this study, it can be concluded that the camera stabilizer being proposed can prove to be very helpful for usage in scenarios where cost and ease of use are of utmost importance. The output being achieved is optimal for certain cases which include hobbies, entry level photography and film-making, etc.

The cost effectiveness of the stabilizer comes from its simple to fabricate structure and widely available open source hardware. Also the components being used are cheap to make and replace. The body of the stabilizer being made of PLA plastic, it gives the whole structure reasonable strength and durability. If manufactured on a large scale the cost of individual units can be easily cut down. Also the future prospects of a different material being used to make the body is also very promising. The manufacturing unit can be easily configured to use a different fabricating material. The required properties of this new material can be fixed in a way that suits most for the application.

The second most appealing aspect of such stabilizer is its ease of use and high portability. Being a handheld device, it can be transported very easily. Also the body can be built in such a way that it can be disassembled and assembled again in under a minute or so. The pickup and go nature of operation of the stabilizer can attract a large audience that does not want to get into the nitty-gritty of using an industrial grade stabilizer(gimbal) but also wants to have a device that can fulfill their requirements with minimal hassle and a proper output.

References

[1] Ole C. Jakobsen and Eric N. Johnson, "Control Architecture for a UAV-Mounted Pan/Tilt/Roll Camera Gimbal", InfoTech @Aerospace, Arlington, Virginia, 26 - 29 September 2005.

[2] Jakob Johansson, thesis on "Modeling and control of an advanced camera gimbal", Department of Electrical Engineering, Linkoping's university, Linkoping, Sweden.

[3] R. J. RAJESH and Dr. Kavitha P "Camera Gimbal Stabilization Using Conventional PID Controller and Evolutionary Algorithms", School of Electrical Engineering VIT University, Vellore, Tamil Nadu, India.

[4] MD. Shusterand SD. Oh, Three-axis attitude determination from vector observations, J Guidance Control 1981.

[5] Y. S. Kwon, H. Y. Hwang, and Y. S. Choi, "Stabilization loop design on direct drive gimbaled platform with low stiffness and heavy inertia," in Proceedings of the International Conference on Control, Automation and Systems (ICCAS '07), pp. 320–325, IEEE, Seoul, South Korea, October 2007.

[6] J. M. Hilkert, "Inertially stabilized platform technology: concepts and principles," IEEE Control Systems Magazine, vol. 28, no. 1, pp. 26–46, 2008.

*Corresponding Author: Kaustubh Dapurkar,
Article History: Received: September 04, 2019, Accepted: Dec 12, 2019