Self-Stabilizing Platform Using Mpu 6050 - a Boon for The Society To Reduce Accidental Death

Vinayak Tripathi, Richa Gupta

Abstract*: Due to increasing population and accidents on roads, sometimes doctors are bound to perform minor medical procedures/operations in the moving vehicle like ambulances, helicopters or ships. But due to the continuous movement of vehicles, it is very challenging to keep the patients and medical equipment stable. This paper discusses an application of MPU 6050 as the self-stabilizing platform to demonstrate how it can be used in moving vehicles like ambulances and on ships for keeping patients and medical equipment stable.This paper is the extension of our published paper entitled "Development of Self Stabilizing Platform using MPU 6050 as IMU", presented in International Conference on Signal Processing and Communication (ICSC) 2018 held at JIIT, Noida, India, in which implementation of the platform, which was capable of stabilizing itself in the horizontal plane despite any movement in the horizontal or vertical axes, was demonstrated and received a lot of appreciation.

***Index Terms*: Accelerometer, Accidental Death, Gyroscope, IMU, Medical Facility, MPU 6050, Stabilization**

I. INTRODUCTION

Human life is indeed a precious gift, and the protection of every human life is our duty. But sometimes, we find ourselves helpless in being able to save someone's life despite having the right tools, but just not the right operating conditions. One such pitiable situation comes up in a medical professional's life when the patient's life can be saved by a simple medical procedure, but the physical conditions don't allow the procedure to be feasible. Any medical procedure needs a certain minimum required demands – stable platform is one of them. That's why, even a minor medical procedure or operations is extremely difficult to perform on moving vehicles – ambulance, helicopter and so is the case with the ship. This is because for performing operation, stability of the patient is one of the main required conditions which cannot be satisfied under normal conditions on ships and in ambulances. This is due to the fact that ships travel on the seas and oceans, i.e. on water and the water waves perform horizontal and vertical motions, due to which anything moving on its surface will be vibrating up and down. Due to this keeping patient stable during medical treatment on ships is a big issue. Ambulance, on the other hand, travels on roads which are man-made and are usually flat and smooth. But in some developing countries, like India, conditions of roads are pathetic. The roads in India are filled with glitches and small pits, making the driving uncomfortable. For this problem, we present a practical solution, a self-stabilizing platform, which remains stable even if there is any to and fro motion made by the surroundings. The technology used in the making of the platform is Inertial Measurement Units (IMU's), which are used to measure the position and angular motion of the body.

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II. LITERATURE SURVEY

After any mishappening on the road or on ships, the initial few hours are the most crucial. But many a times, those crucial hours are spent transporting the patient to the hospitals, where the required procedure can be performed in ideal & stable conditions. This leads to the loss of several lives every year, where the patient is declared dead on arrival at the hospital. These lives can be easily saved by performing the required, or at least supportive procedures during the transportation itself. The major modes of transportation include ground (Ambulance), air (Helicopter Ambulance), and water (ships). Performing even minor medical procedures requires a calm and stable environment. But none of the above modes of transportation can possibly provide a suitable environment. Ships travel on ever agile water bodies, with waves always rocking the ship vigorously. The helicopter ambulances prove to be more stable than the ships, but still the air currents don't allow stability. As the Ambulance moves on the road, which are considerably more stable than the other two mediums. However, the roads also fail to provide stability due to number of pits, speed breakers and other such factors, which cause sudden jerks. Because of this keeping patient stable during medical procedures is a big issue, which in turn deprives the patient of the treatment in the crucial hours. To solve this problem, we present a practical solution, a self-stabilizing platform, which remains stable despite any disturbing motion caused due to the surroundings. It uses a combination of accelerometer and a gyroscope to stabilize the platform in a 6 axis system [1] [2]. This feature allows the platform to be able to stabilize in any direction despite of any tilt in the structure and in any direction.

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It can be feasibly implemented into the patient beds. If implemented, it will provide the required stability to the bed. This would resolve the limitation of instability and enable themedical professionals to provide patients with the much needed treatment during the initial crucial hours, all while in transit to the hospital. This implementation can save several lives and allow for the development of the human society.

III. TECHNOLOGY USED

For keeping the patients and medical equipmentsstable, we first need to know the orientation of their body, i.e. the angles which they make with the horizontal plane, which has the x and the y axis. For measuring this we take help of the Inertial Measurement Units (IMU's). IMU's are used to measure the effect of gravity on the body, its angular velocities, and sometimes the magnetic field surrounding the body. The measure of magnetic field doesn't give any relevant information, but the effect of gravity and the angular velocities are used to find the orientation of a body. For measuring the effect of gravity on an object, accelerometers are used, whereas for measuring it's angular velocity, we use gyroscopes. So IMU's are combinations of accelerometers and gyroscopes embedded in a single chip, so that they are easy to use. IMU's are basically used for the purpose of stabilization of objects, they may be unmanned vehicles, planes, quadcopters, etc. For our purpose, we will be stabilizing the platform on which the patients are to be placed for treatment.

There are many IMU's developed with advanced and accurate accelerometers and gyroscopes. The IMU we have considered to use to fulfil our needs is MPU 6050. It is a Motion Tracking device which consists of an accelerometer and gyroscope capable of measuring the motion in three axes along with a Digital Motion Processor (DMP) [3] [4] integrated on a single chip. The chip is designed using MEMS (Micro-Electro-Mechanical Systems) technology. If needed, we can interface a magnetometer with this through a dedicated bus present in the sensor. The sensor communicates with the processor/controller through I^2C protocol [4], so it requires very less hardware for interfacing, and also the speed of communication is pretty fast (400 kHz).

For digitizing the outputs of accelerometer and gyroscope, 16-bit ADC's are inbuilt in the DMP. For tracking the fast and slow motions precisely, the accelerometer is full-scale programmable with full-scale range of $\pm 2g$, $\pm 4g$, $\pm 8g$, and $\pm 16g$, and so is the gyroscope with full-scale range of ±250, ±500, ±1000, and ±2000°/sec (degrees per second) [2]. The orientation of axes of the sensor can be seen in Fig 1.

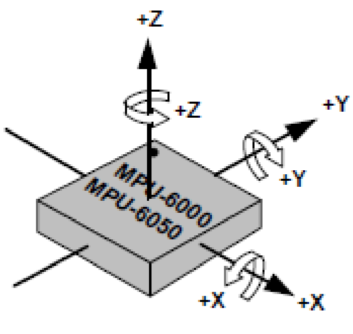

Fig. 1. Orientation of the sensor's axes [3]

After measuring the orientation of the body, we have to move the platform, so that the body is aligned in the horizontal axis. For this, we can use high torque DC motors or Servo Motors. For demo purpose, we have used servo motors which can handle a weight of 13 kg.

Now for processing the data coming from the sensor and actuating the servos, we have to use a processor or a controller. We have many options available for this. We can use an 8-bit AVR controller or a 32-bit ARM controller. The choice of the controller will depend on the speed of computation we require, along with the memory present in the controller. For demonstrating the working, we have used AVR series of controllers.

IV. BLOCK DIAGRAM AND FLOWCHART

The block diagram which we will use for construction of self-stabilizing platform for stabilizing patients is as shown in Fig 2. In this, the controller/processor will receive data of accelerometer and gyroscope from MPU 6050. The data will be processed by the processor to compute the orientation angles of the object (in our case, patients), then accordingly the PWM waves are generated to drive the servo motors, which would move the platform such that the object on it becomes horizontally stable.

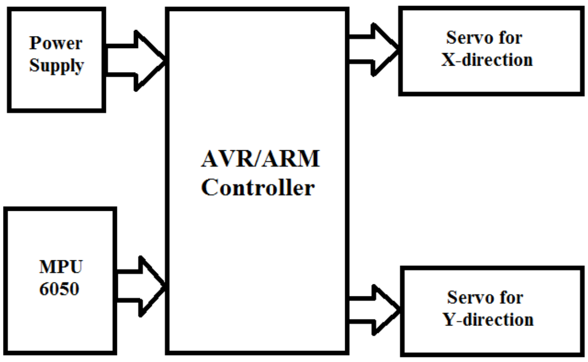

Fig. 2. Block Diagram of the system

The flow of the working is depicted pictorially as shown in Fig 3. The flow first starts with the initialization of all the variables used for storing of data in the code and the I/O pins of the controller. Then the data from accelerometer and gyroscope of MPU 6050 are fetched by the controller. The data is them processed for calculation of orientation angles. Now, accelerometer gives the effect of gravity in terms of g (1g = 9.8m/s) and gyroscope gives the angular velocity of the body. So firstly, we integrate the readings of gyroscope to get the angles. But these values drift in long-terms. So the readings of gyroscope are not reliable for long-term. Also the readings of accelerometer are not dependable for short-term use. So we need a blend of both of the readings. For this, we use complementary filter, which is a weighted-average filter, and will be discussed in the coming topics. So, after getting the correct angles of orientation of the body, we have to control the motion of the servos accordingly so that the body is stable.

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For controlling servos, we generate PWM (Pulse Width Modulation) waves from the controller. The frequency of the wave is 50 Hz, whereas pulse width varies from 1ms to 2ms (1ms for 0° rotation, 2ms for 180° rotation). So the duty cycle varies according to the orientation of the body. These waves are then fed to the servos controlling the motion along x and y axis so that the platform remains horizontal.

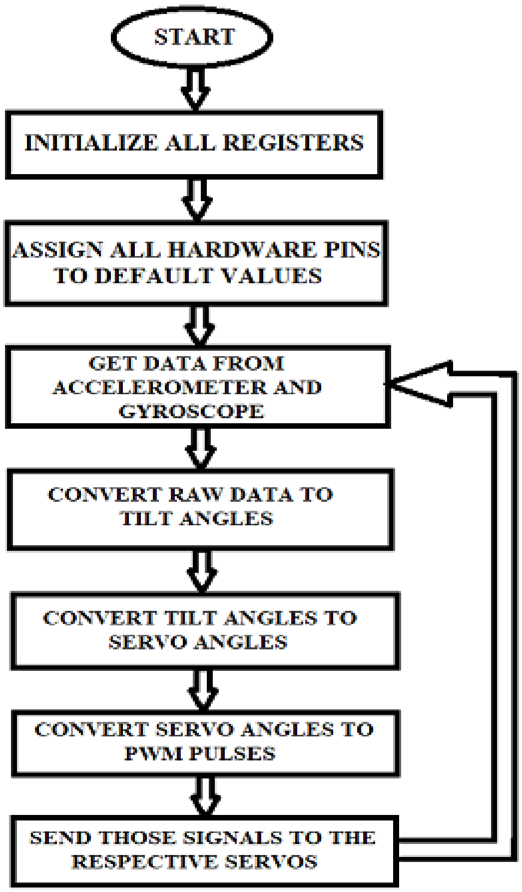

Fig. 3. Flow of working of the self-stabilizing platform

V. ABOUT COMPLEMENTARY FILTER

As discussed above, accelerometer or gyroscope individually are not able to predict the orientation correctly. So a blend of readings of both the sensors is a necessity. For this, we use complementary filter [5] [6]. The flow of working of the filter is shown in Fig 4. Complementary filter is nothing but an average-weighted filter which is an integration of a basic low pass and a high pass filter. The readings of accelerometer are passed through the low-pass filter and gyroscope readings are passed through the high-pass filter, and then the readings are integrated together. For this the accelerometer readings are first converted to angles through the following conversion –

$$\text{Roll} = \tan^{-1}(A_y/A_z)$$
$$\text{Pitch} = -\tan^{-1}\left(A_x/\sqrt{A_y^2 + A_z^2}\right)$$

Then the readings, along with the angles coming from the gyroscope are passed through the following equation –

$$\theta = (1-\alpha)*\theta_g' + \alpha*\theta_a'$$

Here θ_g' is the angle calculated by gyroscope readings, θ_a' is the angle calculated from the accelerometer readings, θ is the corrected orientation angle, and α is the filter coefficient [7].

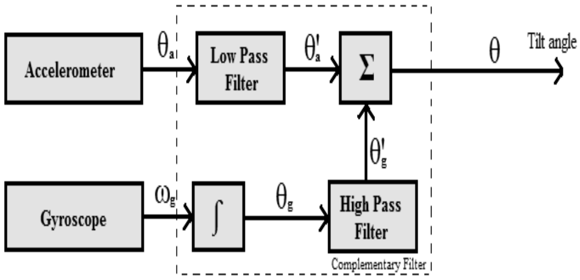

Fig. 4. Flow of Complementary Filter

The value of α can vary from 0 to 1. The values of α used by us for calculating orientation in x & y axis was 0.98 and 0.95 respectively.

VI. RESULTS

For the purpose of demonstrating the idea of self-stabilization, we implemented our proposed circuit on board and presented the working circuit successfully during the International Conference at JIIT [8]. Fig 5 represents a snapshot of working circuit with an object on it, where the object is a small bottle with green cap has been used here for demonstrating purpose.

Fig. 5. Working model of the proposed self-stabilizing platform

As it can be noticed from Fig 5 that despite of the tilting of the base of around 30 degrees and irrespective of the relative motion of the board, the platform managed successfully to keep on the object stable. This concept can be used in the medical area while dealing with minor medical procedures on moving vehicles for saving life of a billion people on-board. The Fig 5 shows a prototype of the proposed design. The servo motors which are used in the design can bear a maximum weight of 13 kilograms on its axle, so the design can bear a maximum weight of 26 kilograms on it.

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For handling the patient's weight, we can increase the pivot points on the platform, which would then distribute the weight across them, so these motors can be used. The controller, which we are using is also very cheap yet powerful enough to control the peripherals interfaced with it. The motors used are also not much costly, hence it will make the system more cost efficient. The cost for making the prototype was around 3,000 Indian Rupees.

VII. CONCLUSION

At this point of time, our prototype was able to stabilize the platform in horizontal direction despite of any movement made in the structure in any of the two-dimensional axes. The prototype made by us was cost-efficient, which means we can increase the accuracy of the system by using a more advance controller having advance architecture. The controller used by us is based on 8-bit AVR architecture. By using a 16-bit or 32-bit ARM architecture based processor, it's computation speed can be improved. The controller for this system was programmed using Atmel Studio 6 and Proteus was used for simulation purpose. The controller and the powersupply's circuit board were designed by us on Eagle 7.6.0 software. Also for the purpose of balancing a human body, we will be requiring motors which can handle a weight of around 60-100 kilograms.

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Vinayak Tripathi, completed his B. Tech. from JIIT, Noida, India, in the year 2018 and is currently working as an Associate Engineer at Spectral Design India Pvt. Ltd., a U.S. based VLSI company. His interest areas are Embedded technology, VLSI (mainly Verilog and MBIST).

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