Inertial Measuring System

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Abstract: **Inertial measuring Unit (IMU) is an integrated chip that has an on-board accelerometer and gyroscope. The application using this chip is infinite and vivid, this paper dives into the automation paradigm of the IMU and we intend to develop a system that enables an automobile to drive through a bumpy road with ease and smoothness. The values provided by the IMU gives a steady reference with respect to the ground for the microprocessor to process the information and adjust the position of wheels.**

Keywords: IMU, Accelerometer, Gyroscope, DoF, Yaw, Pitch, Roll, Axis.

I. Introduction

This project will serve as a prototype which can be further implemented in large scale with help of this unit we are able to track position an object to which this unit is attached in real-time

This project can be related to hand gesture project, but this project has a capability to track as well as log position parameters as well

Power management has been one of the most discussed topic in the past decade because of the decrease in the energy reserves. Power shutdown is a major problem now-a-days and it occurs because a lot of power is wasted in industries.

1.1 Importance of the project and its background:

- Real time tracking
- Accurate results
- Data recording
- Energy Saving

II. Methodology

Real time motion tracking technology is the upcoming high end technology. Wireless transmission of the coordinates after processing various parameters like linear acceleration, angular momentum, magnetic flux after its integration into a processor, which provides the position of the object to which the IMU is attached.

We have designed this project with minimum external modules and peripherals making it cost effective

A. Types of IMU

IMU available in market now are in various types and shape. So, user can select what type, size and shape. The IMU can be selected from its degrees of freedom (DOF) that being developed by manufacturer. User can select from three DOF, five DOF and six DOF. For three DOF, the sensors configurations are two accelerometers and a gyroscope that measures yaw. For five DOF, the sensors configurations are three accelerometers and two gyroscopes that measure pitch and roll. For six DOF, all axes for accelerometer and gyroscope for measurement are available.

A. About MPU-6050 Six-Axis (Gyro + Accelerometer)

The MPU-6050 devices combine a 3-axis gyroscope and a 3-axis accelerometer on the same silicon die, together with an on board Digital Motion Processor™ (DMP™), which processes complex 6-axis Motion Fusion algorithms. The device can access external magnetometers or other sensors through an auxiliary master I²C bus, allowing the devices to gather a full set of sensor data without intervention from the system processor. The devices are offered in a 4 mm x 4 mm x 0.9 mm QFN package.

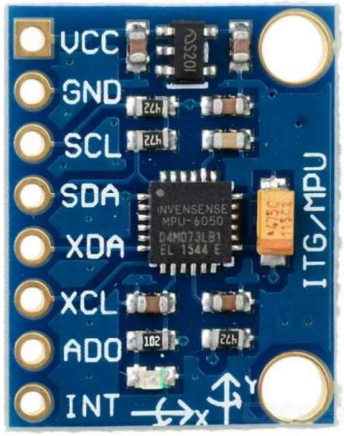

Fig. 1 MPU 6050

B. MPU 6050 features:

- I2C Interface.
- Supply voltage: 3 to 5 V.
- I/O voltage: 2.3 to 3.4 V.
- Triple axis gyro (angular rate sensor) with selectable scale (from ±250 to ±2000 dps)
- Triple axis accelerometer with selectable scale (from ±2g to ±16g)
- Temperature sensor with digital output.
- Digital Motion Processing™
- Size: 20 mm x 15 mm.

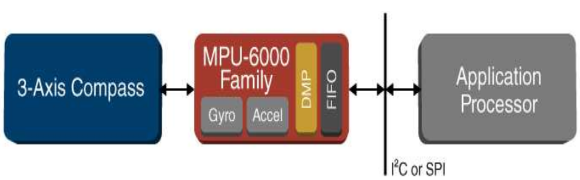

Fig 1-2. Block Diagram of MPU 6050

For precision tracking of both fast and slow motions, the parts feature a user-programmable gyro full-scale range of ±250, ±500, ±1000, and ±2000 °/sec (dps), and a user-programmable accelerometer full-scale range of ±2g, ±4g, ±8g, and ±16g. Additional features include an embedded temperature sensor and an on-chip oscillator with ±1% variation over the operating temperature range.

Formula:

$$\text{Required\_value} = \frac{\text{raw\_value}}{\text{proper\_sensitivity}} \qquad (1)$$

C. Scope of the project.

This project has a very wide scope in visual reality where ever minute motion is tracked and analysed to produce an amazing life-like experience. The air bags in vehicles needs to be deployed on a specific degree of Impact, it should not malfunction and deploy on minor jerk or on applying brakes. If it happens so then the safety system might itself result into a mishap. Hence in order to sense the impact IMU can be used which can be calibrated to trigger on a specific intensity of impact. As the technology is advancing the is much more research activity in domain of Real time motion tracking.

D. Current scenario

Currently in order to track any object in 3- dimension we need complex wiring and grid of sensors for its real time tracking or we can track it using GPS but there are some limitations to it, like the position is not accurate and may vary due to environmental conditions and other physical parameters.

E. The proposed system

The system which we have proposed is very compact is size and hence it can be attached to any moving object like vehicles or on humans. The proposed change makes our system wearable as well as the components used in it makes the complete device cost effective and rugged. The inertial measurement unit works by detecting linear acceleration using one or more accelerometers and rotational rate using one or more gyroscopes. A magnetometer is utilized, which is commonly used as a heading reference. Typical configurations contain one accelerometer, gyro, and magnetometer per axis for each of the three vehicle axes: pitch, roll and yaw. Due to the presence of on board accelerometer, gyroscope and magnetometer on a single chip and with a central processor too the values are obtained in a systematic manner and these sensors provide our project with the ability to have nine degrees of freedom for motion tracking.

F. 3D orientation of MPU 6050

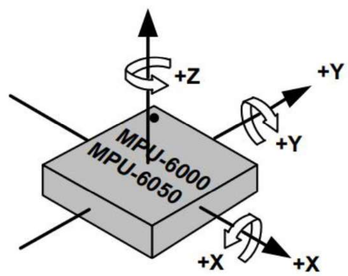

Fig 1-3. Orientation of Axes of Sensitivity and polarity of rotation

G. Block diagram

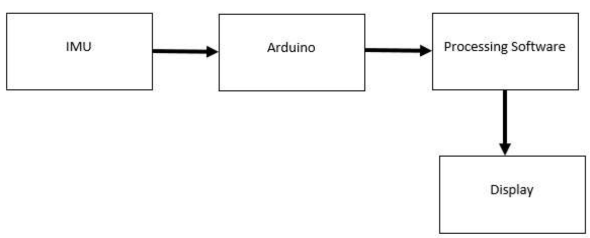

Fig 1-4. Block Diagram

1 2.9 Design Phase: Circuit Diagram

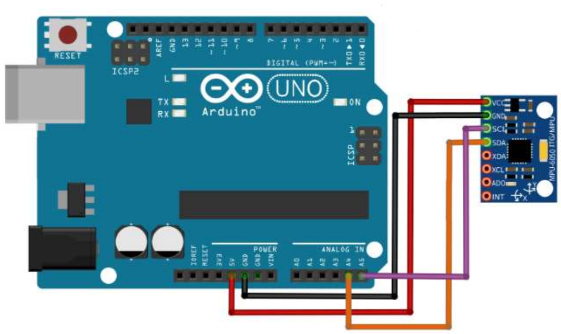

Fig 1-1. Interfacing IMU with Arduino

2.10 Interfacing the Arduino MPU 6050

The MPU 6050 communicates with the Arduino through the I2C protocol. The MPU 6050 is connected to Arduino as shown in the following diagram. If your MPU 6050 module has a 5V pin, then you can connect it to your Arduino's 5V pin. If not, you will have to connect it to the 3.3V pin. Next, the GND of the Arduino is connected to the GND of the MPU 6050.

The program we will be running here, also takes advantage of the Arduino's interrupt pin. Connect your Arduino's digital pin 2 (interrupt pin 0) to the pin labelled as INT on the MPU 6050. Next, we need to set up the I2C lines. To do this, connect the pin labelled SDA on the MPU 6050 to the Arduino's analog pin 4 (SDA) and the pin labelled as SCL on the MPU 6050 to the Arduino's analog pin 5 (SCL). That's it, you have finished wiring up the Arduino MPU 6050!

III. LITERATURE SURVEY

A. How does accelerometer works:

Basic working of Accelerometer Operation:

According to newtons second law of motion that the acceleration (m/s^2) of body is directly proportional to the net force acting on that body, and inversely to its mass

Acceleration=Force(Newton)(m/s^2) *Mass (gram)

A micro Gimbal like mechanism which is used to detect the force in a particular direction. It basically measures acceleration through the force applied to one of the accelerometers axes.

An accelerometer is an electromechanical device, including holes, cavities, springs, and channel, that is fabricated using microfabrication technology. Accelerometers are fabricated using a multi – layer wafer process,

i. Piezoelectric Effect

A accelerometer works on piezoelectric effect. Let us imagine a cuboidal box with a small ball inside it, like shown in the diagram below. The walls of this box are made with piezoelectric crystals, if the box tilt on any of its side, the makes the box inclined and the gravity forces it to collide with the wall on that particular side, this results into production of piezoelectric current. Six walls in pair of three corresponds to 3 axis in 3D space. X, Y and Z Axes. Depending on the current produced from piezoelectric walls, we can determine the direction of inclination and its magnitude.

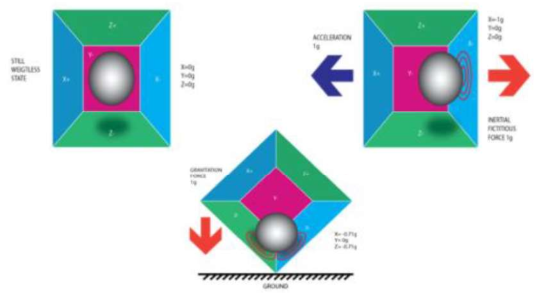

Fig 1-2. Piezoelectric Accelerometer

ii. Capacitive Effect

In case of accelerometer that works on capacitive sensing, outputs a voltage dependent on the distance between two planar capacitive surfaces. Both these plates are charged with an electrical current. As the gap between the plates changes the electrical capacity of the system, which can be measured as voltage output. This method of sensing results in high accuracy and stability. As capacitors are less affected by noise and other electromagnetic interference, the same goes with this type of accelerometer hence they are less prone to noise and variation with temperature and the typically dissipate less power, and can have large bandwidths, due to internal frequency circuits.

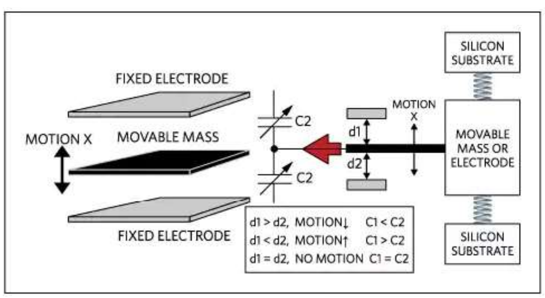

Fig 1-3 Acceleration associated with a single moving mass

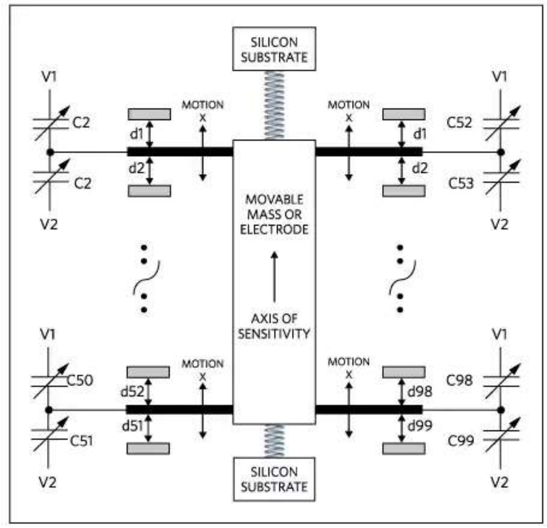

Fig 1-4. Acceleration associated with multiple masses

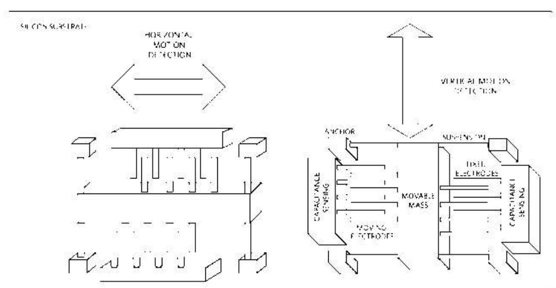

Fig 1-5. Mechanical model of 2-axis accelerometer

Basic working of Gyroscope

Gyroscopes work on the principle of Coriolis acceleration. Imagine that there is a fork-like structure that is in a constant back and forth motion. It is held in place using piezoelectric crystals. Whenever you try to tilt this arrangement, the crystals experience a force in the direction of inclination. This is caused as a result of the inertia of the moving fork. The crystals thus produce a current in consensus with the piezoelectric effect, and this current is amplified. The values are then refined by the host microcontroller.

Tuning Fork Gyroscope:

This type of Gyroscope contains a pair of masses that are driven to oscillate with equal amplitude but in opposite directions. While rotating the Coriolis force creates an orthogonal vibration which can be sensed by many types of mechanism. The figure below (Figure:9) uses comb type structure to drive the tuning force into resonance

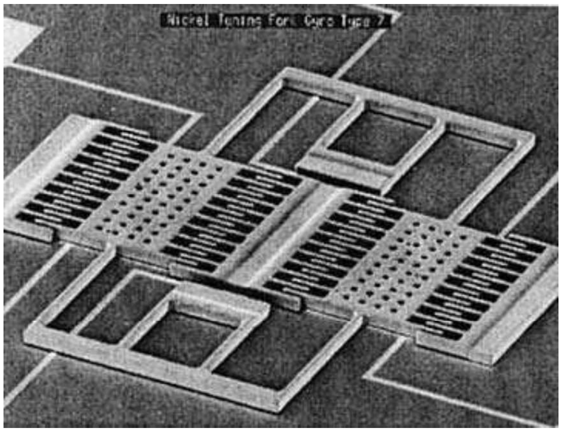

Fig 1-6. Comb type Tuning Fork Gyroscope Structure

The rotation caused the mass to vibrate which in turn vibrate out of the plane, this type of motion is sensed by the structure

IV. Result and Discussion

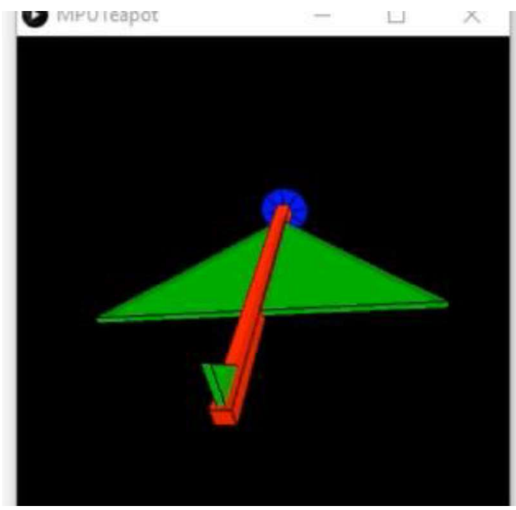

Fig 1-7. Result of 3D simulation

1. Raw data of accelerometer

Table 1. X-axis Readings

Ax	Range	Sensitivity	X-Axis
-15608	2g	16384	0.95g
-945	4g	8192	0.11g
256	8g	4096	0.06g
2655	16g	2048	0.8g

Table 2. Y-axis Readings

Ay	Range	Sensitivity	Y-axis
5065	2g	16384	0.31
-4856	4g	8192	0.59g
-255	8g	4096	0.06g
-589	16g	2048	0.28g

Table 3. Z-axis Readings

Az	Range	Sensitivity	Z-axis
450	2g	16384	0.027g
8159	4g	8192	0.99g
-3698	8g	4096	0.9g
898	16g	2048	0.43g

2. Raw data of gyroscope:

Table 4. X-axis Readings

Gx	Range	Sensitivity	X-Axis
-349	250	131	-2.66
65497	500	65.5	499.977
894	1000	32.8	27.25
2655	2000	16.4	161

Table 5. Y-axis Readings

Gy	Range	Sensitivity	Y-axis
-204	250	131	-1.355
31	500	65.5	0.756
6512	1000	32.8	198.53
-589	2000	16.4	-35.91

Table 6. Z-axis Readings

Gz	Range	Sensitivity	Z-axis
-247	250	131	-1.88
41	500	65.5	0.311
23645	1000	32.8	720.88
898	2000	16.4	54.75

V. Conclusion

By the realization of the above proposed system we can not only track real-time position of an object in 3-Dimension but also use the data for many other applications after processing it using various algorithms.

Acknowledgement

We thank our mentor's guide Prof. Archana Belge and Mr. Ganesh Gore for their valuable inputs and suggestions which were very instrumental in making this project a reality.

REFERENCE

[1] Webpage for interfacing IMU with Arduino: http://hotresistor.blogspot.in/2015/09/interfacing-arduino-with-gy-87.html. Accessed: October, 2017
[2] Video for interfacing IMU with Arduino: https://www.youtube.com/watch?v=x2vVsO5Hr2I. Accessed: October, 2017
[3] Webpage for interfacing MPU 6050 with Arduino: https://diyhacking.com/arduino-mpu-6050-imu-sensor-tutorial/. Accessed: February, 2017
[4] https://github.com/guywithaview/Arduino-Test/blob/master/GY87/GY87.ino. Accessed: October, 2017
[5] http://www.circuitstoday.com/interfacing-gyroscope-arduino Accessed: February, 2017
[6] Webpage for study of MPU 6050 Accelerometer and Gyroscope: https://www.invensense.com/products/motion-tracking/6-axis/mpu-6050/. Accessed: January, 2018
[7] De Nardi, R., & Holland, O. (2006). Swarmav: A swarm of miniature aerial vehicles. In Proceedings of the 21st Bristol International UAV Systems Conference, April 2006
[8] Bills, C., Yosinski, J.: MAV stabilization using machine learning and onboard sensors. Technical Report CS6780, Cornell University (2010)
[9] Saska, M., Vonásek, V., Přeučil, L.: Roads sweeping by unmanned multi-vehicle formations. In: IEEE Int. Conf. on Robotics and Automation (2011)
[10] Zhang J. Tao T. Mei X. Jiang G. and Zhang D. "Non-linear robust control of a voltage-controlledmagnetic levitation system with a feedback linearizationapproach" Proc. Institution of Mechanical Engineers Part I: Jour. of Systems and Control Eng. Vol.225 2011
[11] Muscroft R.J.M. Sims-Williams D.B. and Cardwell D.A. "The Development of a Passive Magnetic Levitation System for Wind Tunnel Models" SAE Transactions: journal of passenger cars: mechanical systems 115 (6) pp. 415-419 2006
[12] Gysen B. Paulides J. Janssen J. Lomonova E. "Active Electromagnetic Suspension System for Improved Vehicle Dynamics" IEEE Transactions on Vehicular Technology Vol. 59 Issue 3 pp. 1-6 2008
[13] Babak, E, Hamidreza, B, Mir, BK, Golnaraghi, F (2011) A hybrid electromagnetic shock absorber for active vehicle suspension systems. Vehicle System Dynamics 49: 311–332
[14] Kawamoto, Y, Suda, Y, Inoue, H, Kondo, T (2007) Modeling of electromagnetic damper for automobile suspension. Journal of System Design and Dynamics 1: 524–535.
[15] Montazeri-Gh, M, Soleymani, M, Hashemi, S (2013) Impact of traffic conditions on the active suspension energy regeneration in hybrid electric vehicles. IEEE Transactions on Industrial Electronics 60: 4546–4553.