Design of Accurate Navigation System by Integrating INS and GPS modules

M. RAJA*[,1,a], Gaurav ASTHANA[1,b], Ajay SINGH[1,c], Ashna SINGHAL[1,d], Pallavi LAKRA[1,e]

*Corresponding author
[1]Aerospace Department, University of Petroleum and Energy Studies Bidholi, Dehradun - 248007, Uttarakhand, India,
mraja@ddn.upes.ac.in*, gaurav.asthana0@gmail.com, ajsinghrajput7@gmail.com, Singhal-ashnasinghal16@outlook.com, lavi0398@gmail.com

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Abstract: *Navigation has a huge application in aviation and aircraft automatic approach. Two widely used navigation systems are Global position System (GPS) and Inertial Navigation System (INS). Triangulation method used to determine the aircrafts location by GPS, speed whereas an INS, with the aid of gyroscope and accelerometer, estimates the location, velocity and alignment of an aircraft. Aircraft navigation is a complex task and using only one of the above navigation systems results in inaccurate and insufficient data. GPS stops working when satellite signal is not received, susceptible to interfere occasionally has high noise content, and has a low bandwidth, INS system requires external information for initialization has long-term drift errors. Certain errors like ionosphere interference, clock error, orbital error, position error, etc. might arise and disrupt the navigation process. In order to outrun the limitations of the above two systems and counter the errors, both INS and GPS can be integrated and used to attain more smooth, accurate and faster aircraft attitude estimates, as they have complementary strengths and limitations. GPS is stable for a long period and can act as an independent navigation system whereas INS is not susceptible to interference and signal losses has high radio bandwidth and works well for short intervals of time. In order to get accurate and precise attitude estimation, calculation of the parameters at different altitude using both systems is done; furthermore the comparison and contrast between the results is performed, measured quantities are transformed between various frames like longitudinal to rolling, calculation and elimination of errors is done producing the final solution. Because of integrated GPS and INS, the navigation system exhibits robustness, higher bandwidth, better noise characteristics, and long-term stability.*

Key Words: *GPS, INS, GLONASS, NMEA, APM*

1. INTRODUCTION

Navigation is the means by which we can monitor and control the position of an aircraft or a vehicle moving from one place to another. It consists of four parts: land navigation, marine

[a] Assistant Professor-SS
[b] Student
[c] Student
[d] Student
[e] Student

navigation, aeronautical navigation and space navigation [1]. Navigation is use to find the location of object, knowledge of speed and angular motion with respect to the reference frame. Navigation techniques involves knowing a reference location and thus calculating the position of navigator. Navigation is thus the sum of the technique used to determine the position and direction. In this sense, navigation includes coordinating and pedestrian navigation.

GPS (Global Positioning System)

The global Positioning system (Illustrated in Fig 1) was earlier known as Navistar GPS which is owned the by the government of United States and is operated by US air force. It is a radio based satellite navigation system. It is a global system, which use line of sight navigation mode of propagation to determine the position and time of object on the earth surface, which is in direct line of four or more satellites. Mountain and buildings block the signals that are already weak by the time they reach earth. The GPS uses the concept of the known time and position of the GPS satellites in the outer space. There is atomic clocks on the satellites, which are synchronize with each other and with the ground clocks. These clocks are monitored daily and any drift is corrected on the daily basis. Such high precision is taken into account to determine the location of satellites. The clocks on the receiving station are accurate but not as accurate as the atomic clocks. Each satellite continuously transmits a radio signal, which contains the current position and time of that particular satellite. The speed of radio waves is constant and is not dependent on the speed of satellite and there is a time delay between the transmitting and receiving of the signal, which is directly proportional to the distance where the satellite is positioned. Multiple satellites are monitored by GPS receiver and solves equations to calculate the precise location and time. Minimum four satellites should be in the visual field of the receiver to calculate the precise location and time. With three satellites, there may be a variation from the actual position, [3].

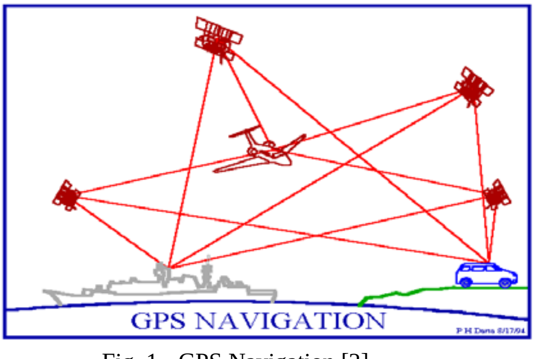


Fig. 1 - GPS Navigation [2]

Structure

There are mainly three parts of GPS, namely the space segment, user segment and control segment.

Space Segment

The space segment comprises 24 satellites in the medium earth orbit and it has the payload booster. This part roughly weighs about 19000lbs.

User Segment

The ground module that communicates with satellites is the user segment. The modules have a computer that is programmed to do all the calculations to find the accurate location from the data provided by the satellites.

Control Segment

There are stations on ground that control the proper functioning of the satellites. There are five of them spread worldwide.

They track the exact location of satellites in space and ensure their proper functioning by keeping a close look on any malfunction. They continuously track the position, location and time of the satellite.

INS (Inertial Navigation System)

It works in accordance with Newton's first law that states that a body in motion will stay in motion until an external force acts on it. INS is a dead reckoning system (see Fig. 2) which requires initial velocity and position to initialize the model. It consists of three gyros that are mounted in three orthogonal axes to do the calculations for the position and time and three accelerometers. This is done because the three-axis acceleration value has to be solved in accordance with a reference frame and it has to calibrate to remove the constant gravity values from the outputs. An INS consists of a module containing accelerometers, gyroscopes or other motion sensing devices and a microcontroller to calculate data.

The INS is initialized by giving it the speed and position from an external source (a GPS satellite receiver, a computer, etc.) and the initial alignment; thereafter it calculates its position from the previous values and thus the velocity by combining the information from the sensors.

It has the major advantage of being a standalone system and does not require any other source for its functioning. INS efficiently detects even a minor change in the system's geographic positon like a shift towards East, West, North or South. It also detects a change in its velocity and orientation about a particular reference axis.

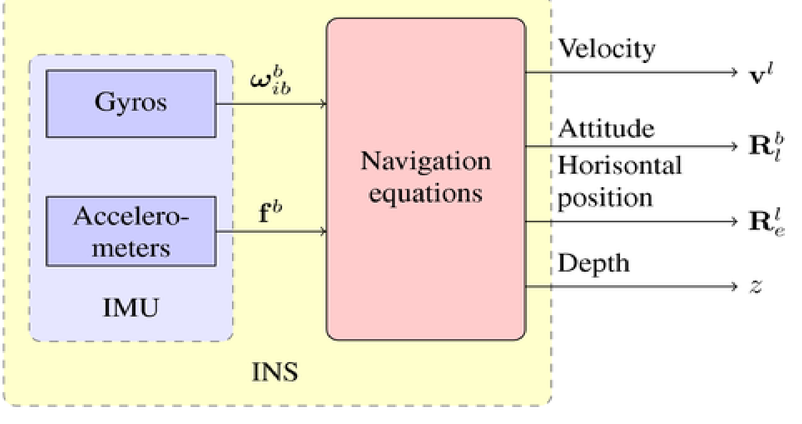


Fig. 2 - INS Navigation block diagram [4]

The analysis includes a series of measurements of the system's angular velocity and linear acceleration. INS do not require an external reference once it is initializing and hence it can overcome deception and jamming effectively.

The angular velocity of the sensor frame is measured with respect to the inertial frame with the aid of a gyroscope.

The real-time orientation of a system is considering the initial condition as the original orientation of the system in the inertial frame and integrating the angular velocity, consecutively.

Accelerometer aids in the measurement of the linear acceleration of the vehicle in motion in the body frame. Since the accelerometers are fixed, mounted on a system they are bound to move with the system, unaware of their own orientation and hence the direction measured is only relative to the system in motion [5].

For the determination of linear acceleration of a system in inertial frame, it is necessary to measure the current angular velocity of system and current linear acceleration of the system.

Consequently, application of integration and accurate kinematic equations, to the inertial accelerations keeping the original velocity as initial condition the inertial velocity of the system can be determined and further integration of the extracted value gives the inertial position.

2. EXPERIMENTAL SET UP AND ANALYSIS

The following apparatus are used for the experiment:

MPU - 6050

The MPU-6050 is a movement processing innovation. By joining a MEMS 3-axis accessible Digital Motion Processor™ (DMP™) fit for taking care of complex 9 dimensional Motion counts, the MPU-6050 disposes of the cross dimensional arrangement problems of the gyroscope and a 3-point accelerometer on comparative silicon die together with a local that can crawl up on separate parts [6].

Its features are:

• I2C Digital-yield of six or nine-D Motion Integration information in rotation matrix, quaternion, Euler Angle, or crude information design

• Potential Difference: 2.3 - 3.4V

• Clock, FSYNC are available

• Tri-Axis accelerometer with a programmable full-scale scope of ±2g, ±4g, ±8g, and ±16g

• Digital Motion Processing™ (DMP™) motor offloads complex Motion Fusion, sensor timing synchronization, and motion location

• Embedded calculations for run-time predisposition and compass alignment. No client intercession required

• Digital-output temperature sensor

Arduino Uno

Atmega 328P is the board on which Arduino Uno is developed. It has 14 advanced input/output pins6 simple data sources, a 16MHz quartz crystal, a USB association, a power jack, an ICSP header, and a reset catch. It contains everything expected to help the microcontroller; essentially associate it to a PC with a USB link or power it with an AC-to-DC connector or battery to begin.

Arducopter

APM 2.8 Multicopter Flight Controller (Shows in Fig 3) is an updated rendition of 2.5 2.6 with Built-in Compass for FPV RC Drone Aircraft is the new APM 2.8 flight controller. The sensors are actually equivalent to the APM 2.6 flight controller; this has the choice to utilize the inherent compass, or an outer compass through a jumper. This makes the APM 2.8 perfect for use with multi-copters.

The APM 2.8 Multicopter Flight Controller is a finished open-source autopilot framework and the top of the line innovation that won the renowned Outback Challenge UAV rivalry. It enables the client to turn any fixed, revolving wing or multirotor vehicle (even autos and pontoons) into a completely independent vehicle; equipped for performing modified GPS missions with waypoints.

This correction of the board has a discretionary locally available compass, which as intended for vehicles (particularly multi-copters and wanderers) where the compass ought to be set as a long way from power and engine sources as conceivable to stay away from the attractive impedance.

(On fixed wing, airship it's regularly simpler to mount APM far enough away from the engines and ESCs to maintain a strategic distance from attractive impedance, so this is not as basic however, APM 2.8 gives greater adaptability and is a decent decision as well).

This is intended to be utilized with the 3DR uBlox GPS with Compass so the GPS/Compass unit is mount further from commotion sources than APM itself [6].

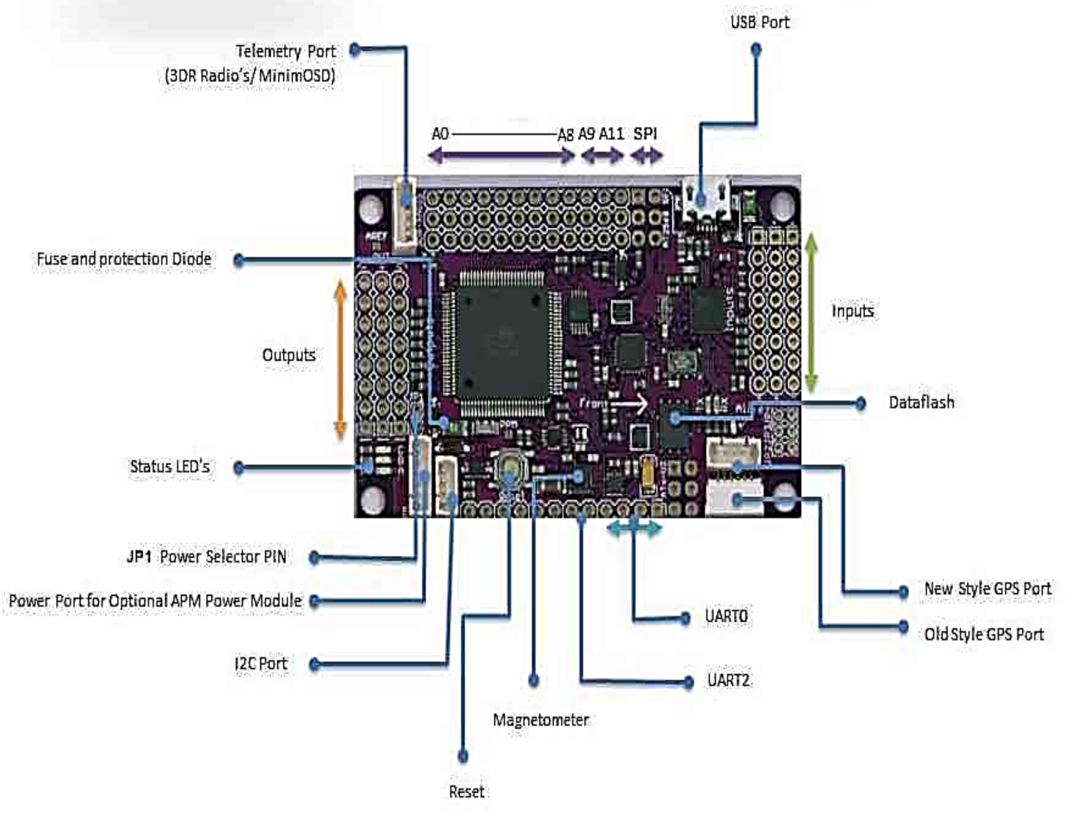


Fig. 3 - Arducopter PIN Design

SD Card Logger module

This is a small-scale SD CARD interface module. It has interfaced as a fringe to your module. All SD cards work on the 3V interface. The interface board gave is to microcontrollers running at 3V. From Fig 4.

Aspects: - Shown in Table 1

- This SD card module can make your SD application simple and adaptable.
- It is used to effectively interface the module.
- All SD SPI pins yield, MOSI, SCK, MISO, and CS.
- Support 3.3V input.
- High-quality PCB FR4 Grade with FPT Certified.

DESIGN SPECIFICATIONS

Table 1 - SD card logger Specifications

PIN	NAME
1	Voltage (3.3V)
2	Gnd
3	5v
4	MISO
5	MOSI
6	SCK
7	CS
8	CD

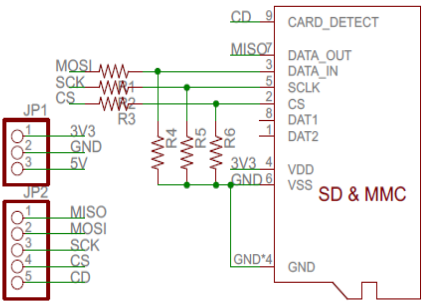


Fig. 4 - SD Card Logger

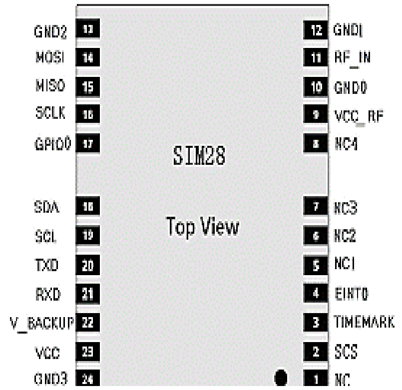


Fig. 5 - GPS Sim 28 pin design

GPS Module Sim28

SIMCom presents an ultra-compact and dependable GPS module-SIM28 [7]. This is an independent L1 recurrence GPS module; it is designed with the MediaTek MT3339 high affectability route motor, allowing to accomplish the business' most elevated amounts of affordability, precision and Time-to-First-Fix (TTFF) with the least control; utilization is as shown in Figure 5.

Highlight

- 6-channels GPS web search tool
- Ultra low power plan (38mA, run of the mill)
- Compact size
- Built-in low clamor, high increase dynamic receiving wire
- Super-strong attractive for the establishment
- High affectability/efficiency? (Up to - 152dBm sort)
- Compatible to have gadgets with USB or RS232

Technical Aspects

- Supply voltage: 9V-12V DC.
- Compatible with TTL and sequential.
- Antenna Frequency – 1575.42 MHz

COMMUNICATION: TELEMETRY

This is 433 MHz 100mW Radio Telemetry Kit that depends on the 3DR Telemetry pack and is 100% perfect as it runs a similar firmware locally available. This firmware utilized by 3D Robotics is totally open-source, which is, obviously, the reason which empowers its utilization for the wanted variant at Unmanned Tech. The Telemetry Kit works perfectly with Ardupilot or Pixhawk-based frameworks and permits a simple expansion of two-way communication between the ground station and the receivers on-board [7]. This is the as good as ever V2 of the Unmanned Telemetry pack.

The full highlights and determinations have recorded beneath yet the fundamental highlights are that both air and ground module is presently compatible, and each is with a USB connector and a DF13 connector.

I2C Protocol

The Inter-incorporated Circuit (I2C) Protocol is a master slave protocol, which allows the user to connect multiple chips and control it with one board only. In contrast to the Serial Peripheral Interface (SPI), which has expected for short-separation correspondences inside a solitary gadget, I2C as utilized for interchanges between sensors for information trade. The IMU sensor speaks with the Arduino through the I2C convention.

The I2C transport primary consists of two dynamic wires and a ground association. The dynamic wires are bi-directional, known as SDA (Serial data line) and SCL (Serial clock line). Each gadget snared to the transport has its very own one of a kind location, even though the gadget is a MCU, LCD driver, memory, or ASIC.

Every one of these chips can go about as a beneficiary as well as transmitter, contingent upon the usefulness.

Evidently, an LCD driver acts only as a beneficiary, while a memory or I/O chip can work as a transmitter as well as a collector. The I2C transport is a multi-ace transport. This implies more than one IC fit for starting an information move can be associated with it. The I2C convention particular expresses that the IC that starts an information move on the transport as viewed as the Bus Master.

Thusly, around then, the various ICs as respected to be Bus Slaves. As transport experts are for the most part microcontrollers, here for example, the transport ace is Arduino Uno. In like manner, the MPU sensor is the Bus Slave.

Mission Planner

Mission planner is an open platform application for the ground station of ardupilot and developed by ardupilot venture [8].

Mission Planner is used as a ground station for APM boards that is mounted on RC planes, multi-copters and rovers.

It is compatible with Microsoft Windows. It can be used to give controls to the self-sufficient RC aircraft in case of emergencies. Here are the things that one can do with the mission planner.

- There is pre-programmed firmware, which can installed to the APM board
- There are many rechecks available for safe flights
- Mission planning is available for fully autonomous missions.
- Datasheets can download for analysis.
- Compatible with pilot test program to make a full equipment insider UAV test system.
- Proper telemetry equipment [8]:
    - Real time check of the vehicle while activity.
    - Record telemetry logs, which contain significantly more data the locally available autopilot logs.
    - View and break down the telemetry logs.
    - Operate your vehicle in FPV (first-individual view).

3. METHODOLOGY

The method followed was as follows:

Yaw, Pitch and Roll from MPU 6050

At each time dependent step, the INS produces an approximation of the body location and attitude explained in Fig. 6. These approximations with the location of the landmarks were used to compute estimated location and attitude; this has done using camera-based navigation and velocity approximations at high rate.

The variation between the approximated and measured location of the picture was used to approximate the INS errors.

Arduino code has a setup part and a loop, which runs continuously containing the calculations. IIC is used with “6 DOF” IMU sensors to get values of angles changed from initial position along the entire three axis and angular velocities of the same. These values are used to input values and Arduino.

IMU consists of an accelerometer, gyroscope, Pressure and magnetometer. The values read from these components were calibrated to get the desired sensor values.

For IMU configuration with Arduino, firstly initialize the IMU libraries and I2C bus for data transmission.

The data (pitch, yaw, roll) used to set the Free Six IMU object of six DOF. Record any errors that may occur and set it to zero. Now, begin UART, I2C, and set baud Rate to 115200. Then initialize Acc and Gyro by sixDOF.init(); An infinite loop is generated and values of Yaw, pitch and roll are collected, Data Transmission to ground station is done by I2C communication and wire.h that works on UART protocol.

Digital pin 2 used as interrupt. Then ports are set to begin with 115200 baud rates, an infinite loop is generated in which data received from serial port is sent to my serial and vice versa. In this way, communication is done both by ground station to object And Object to Ground Station. (See Figure 6)

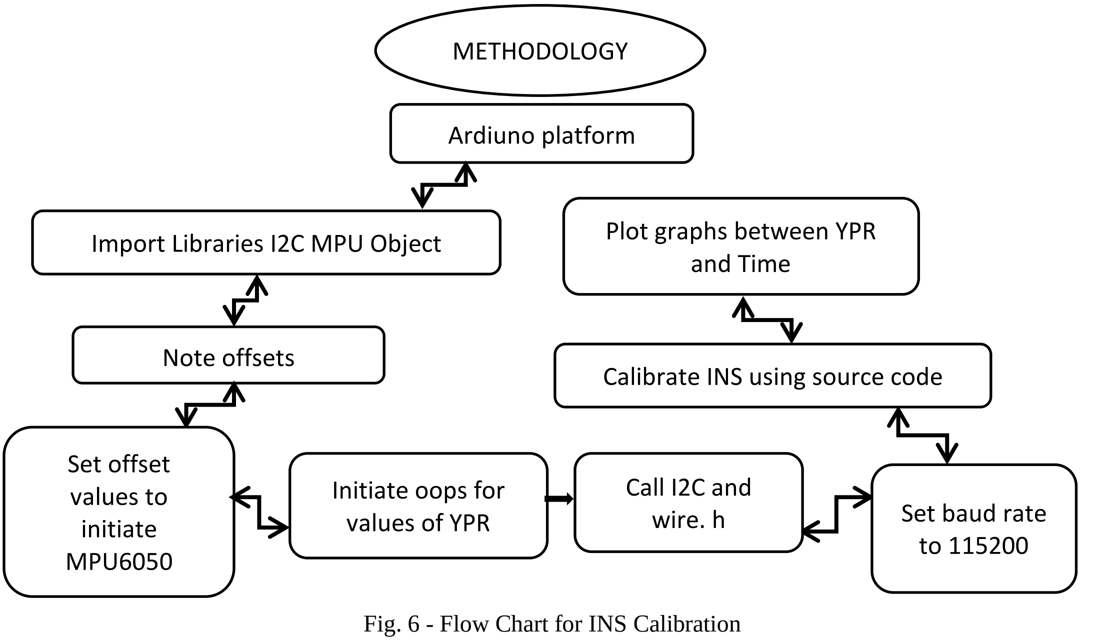


Fig. 6 - Flow Chart for INS Calibration

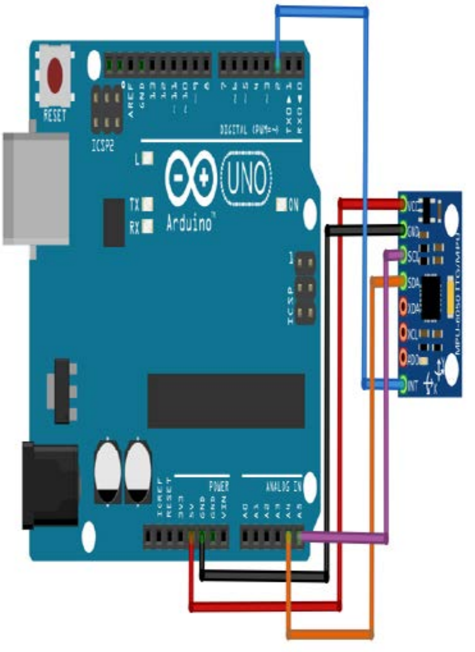


Fig. 7 - Connections of MPU6050

Design Steps

1. Include the i2c bus header file (inter integrated circuit protocol allows slave circuit to communicate with the master circuit.
2. Include wire. h header file (allows to communicate with the i2c devices).
3. Create MPU object to develop an interface between the master slave and serial monitor (See Figure 7).
4. Choose an output measurable function.
5. Interrupt pin definition so that processing of different source codes can be implemented (internal).
6. Define a digital interrupt for a readable form and define Boolean values for these readable forms via led.
7. Use unsigned integer values to define different status and counting values and define the default value of the FIFO storage buffer.
8. Obtain values for quaternion and vector quantities for different frames of references and Euler angles, yaw, pitch, and roll conversion sets.
9. Detect interrupt state via the digital interrupt on the board itself to verify interrupt control connections.
10. Use communication function is wire. begin.
11. Set up a baud rate since accuracy is the foremost priority thus setting up a high baud rate for maximum bit rate per second is essential.
12. Call in the MPU protocols to ensure proper connection.
13. Use the function pin mode to set the interrupt as the primary input.
14. The connection is successful.
15. Use the MPU library to test connection and display, it to the user refer Fig. 8.
16. Add a default value to the empty buffer to initialize the whole data set.
17. Add offsets to understand the calibration needed to supply accurate measurements.

18. Receive different status either sets on or off to understand activity and properly work on the chip and connect external and internal interrupts.
19. Use a flag variable.

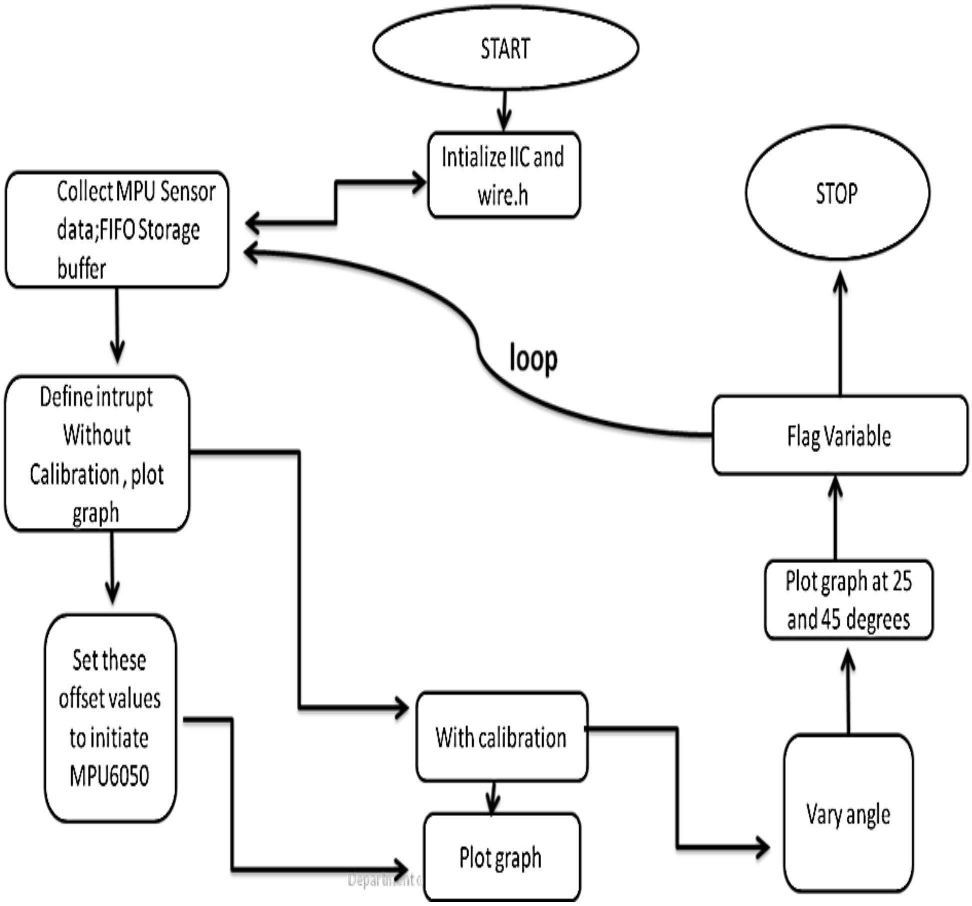


Fig. 8 - Flow chart of MPU Sensor

Kalman Filter

A Kalman filter (KF) is the most favorable approximation design used to approximate the states of a system from deviant and unpredictable calculations [9]. This tool is best to incorporate two data, the cacophony and the expected state to produce the best impartial approximation and hence it is a strong tool to combine data in unpredictable situations, KF is the best way to approach a system whose nature is unpredictable. It is best suited for real-time problems and embedded systems, as it does not keep any history other than the previous input.

Regardless of its high accuracy it runs to get results in terms variable of interest by putting the available data as the input, which are the graphical description, cacophony errors and unpredictability in the system.

Kalman Filter Implementation using MPU 6050

Kalman Filter has a wide range of applications, one of which is accurately estimating the aircraft attitude [9]. (See Fig. 8)

The initialization is calibrating by generating Kalman Filter parameters, say X and Y. Then the computation of Yaw, Pitch, Roll and acceleration is calculated by using the

Gyroscope and the accelerometer, respectively. Then the I2C protocol RUN to obtain communication of the slave to the master. The result from the MPU, which contains error, initially begins to perturb with time and hence producing more error.

Kalman Filter then gets an estimate close to accurate data by repeating the process and getting rid of all the errors illustrated in Fig. 9.

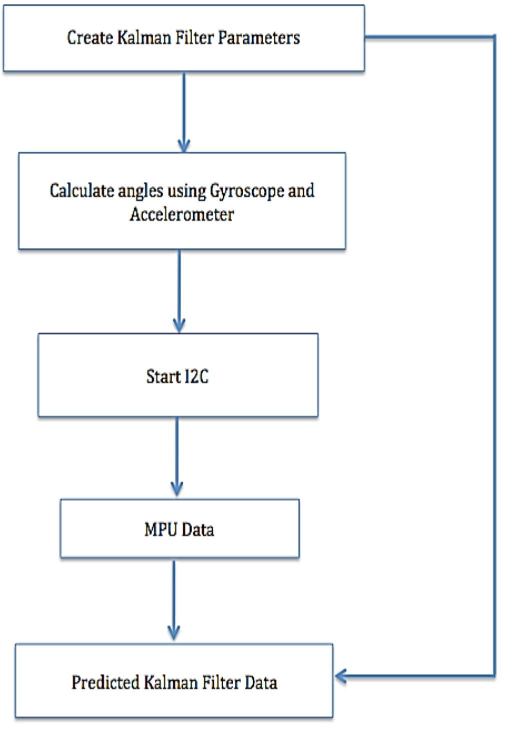


Fig. 9 - Kaman Filter algorithm

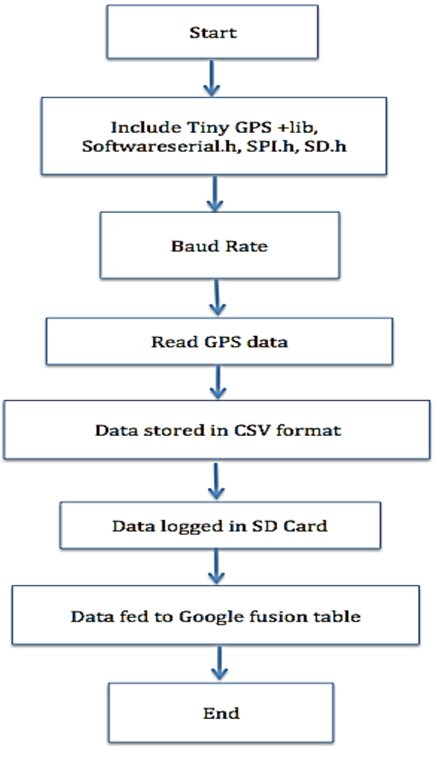


Fig. 10 - GPS data logging using Google fusion

Application of MPU6050

All present-day aerospace machine needs to have a proper understanding of dynamics and control to get better at the performance of the system.

A better system blueprint, dynamic characteristics will only be possible by having good knowledge of the fundamentals of dynamics.

One of the most pioneering discovery was the Aircraft attitude estimation, which was possible due to better calculation and processing of data by digital computers. The other factors that also contribute although not extremely are the progress in estimation, the blueprint of fly testing and basic aero modelling principle.

Kalman filter is an undeviating, most favourable approximate of state variables of time-dependent system being active in a Gaussian stochastic environment. Favourable approximates here is referred to a computational design that processes information (combined data of all available information) to reduce a minimum error factor of the state of a system.

Stabilization of aircraft using MPU6050

Under unfavourable aerodynamic conditions or wrong command fed by the aircraft pilot to the aileron motion controlling devices like servomotors, the aircraft may lose control.

Kalman filter spontaneously corrects the fed information by predicting the best possible result considering all the errors and removing them.

GPS DATA LOGGER

Every time GPS computes an estimate of the vehicle, position and attitude refer to Figure 10. GPS uses Trilateration method for getting the exact position.

An Arduino is initialized a GPS sim 28 module using UNO code. Initialization of serial data, libraries and variables as considered accordingly. The text file is created on SD card with header GPS data.

The use of Tiny GPS Basically makes the extraction of data like longitude and latitude from the slightly complex NMEA sentences that the GPS module spits out very easy and a direct process.

New soft Serial allows the transformation of any pin into “serial pin”, in this case, pins 2 and 3. Logging of all the GPS data onto a Comma Separated Value text file is prepared.

GPS logged data uploaded on to fusion table, which plots the logged raw data on the google map.

4. RESULTS

Inertial Navigation System. Figs 11 and 12 show the values of yaw, pitch and roll under the non-calibrated condition.

Figs 13 and 14 show the values of yaw pitch and roll under the calibrated conditions at 0˚, 25˚ and 45˚, respectively.

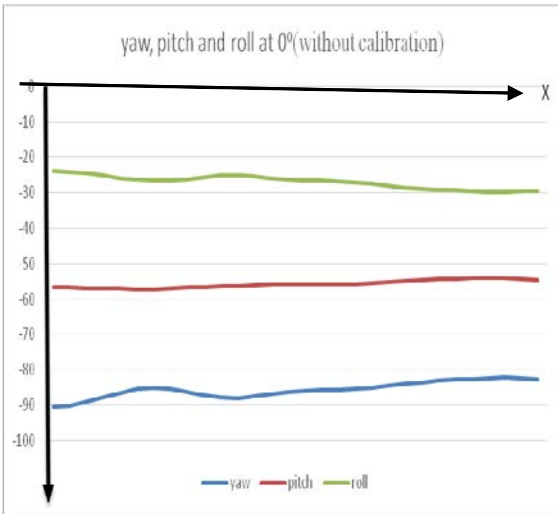


Fig. 11 - Attitudes at 0^0 vs time (without calibration)

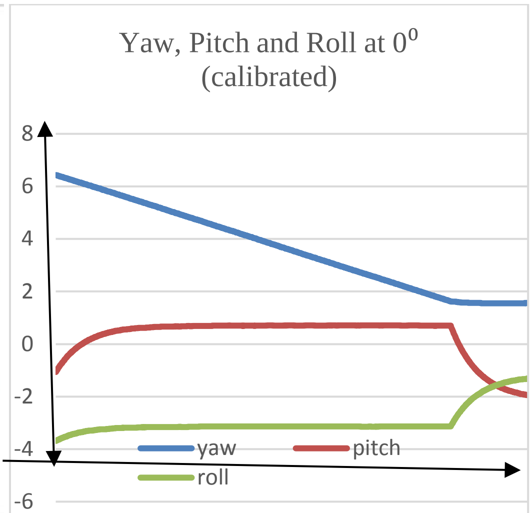
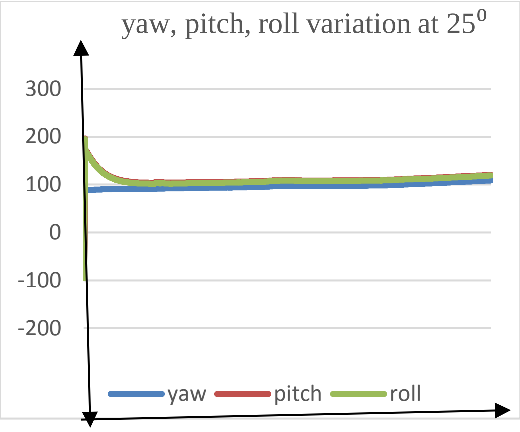


Fig. 12 - Attitudes at 0^0 vs time (calibrated)

The initial graph illustrates the numerous errors due to offsets, whereas the graph under calibrated conditions has overcome those errors.

The yaw, pitch and roll initially at zero degree, if increasing the angle to 25˚, a drift can be seen as time passes.

The drift at 45˚ increases with respect to its former value, thereby showing that the drift increases with the increase in angle.



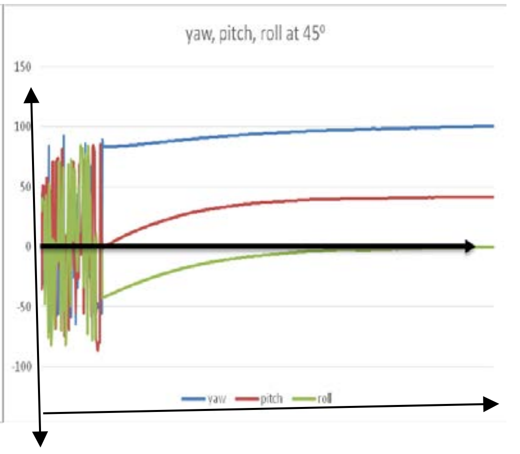


Fig. 13 - Attitudes at 25^0 vs time (without)

Fig. 14 - Attitudes at 45^0 vs time (with calibration)

Kalman Filter application

The results show that data logged using MPU consist of various errors and vary throughout the phase of time whereas with the integration of a Kaman filter errors are minimized and almost a constant variation can be seen in the graph for the two axes both for accelerometer and for gyroscope.

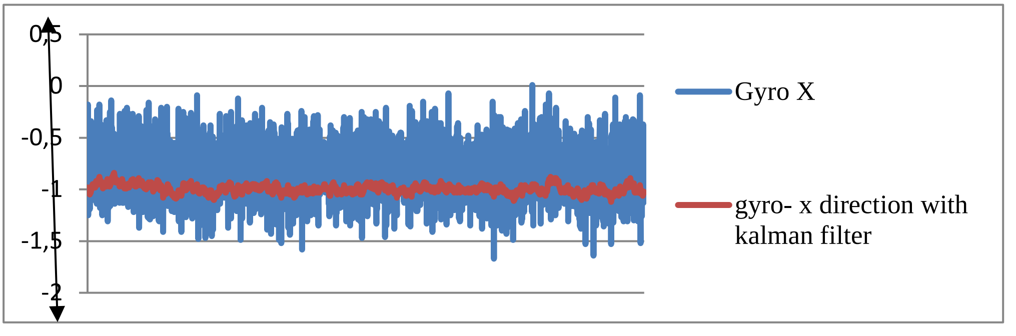
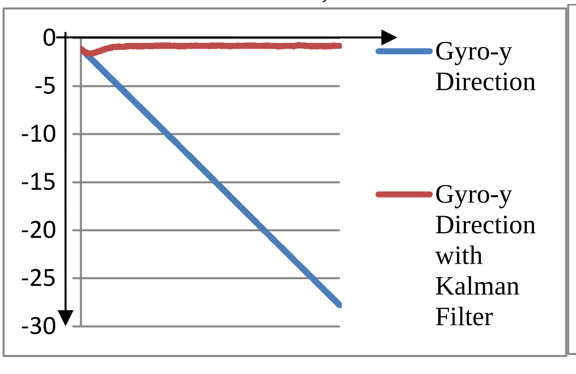


Fig. 15 - Gyro X Axis vs Time (with Noise)

In fig. 15, a curve between gyro x-axis and time is plotted with raw MPU6050 reading and implementation of Kalman filter.

It has almost stabilized the readings in spite of the deliberate noise produced. IT has predicted the best-set values, minimized the error from (-1.6,-0.2) to (-1.2,-1.0).



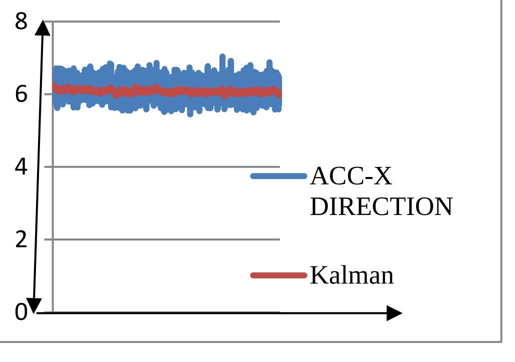


Fig. 16 - Gyro Y Axis vs Time

Fig. 17 - Accelerometer Y Axis vs Time

In Figure 16, a curve between gyro y-axis and time is plotted along with filtered kalman values. It can be seen that raw MPU6050 gyro readings were drifting apart with time because of the gyro drift, which is dominant in IMU. Integration of kalman filter with MPU6050 has eliminated the errors in the readings and given almost steady values of a stationary object. In Figure 17, the blue curve depicts that the there is a deaccelerating motion but the MPU6050 was stationary. The deceleration and negative acceleration error as minimized with kalman filtering. The result is a straight line, which means a constant value.

Hence the desired result. Implementation of Kalman filter to Inertial Navigation system, which has accounted for the errors in gyro and accelerometer drift has given far better results than normal values and has eliminated results like negative acceleration for a standing object. It has given best estimate of deliberate noise produced in case of Gyro and the best approximate values.

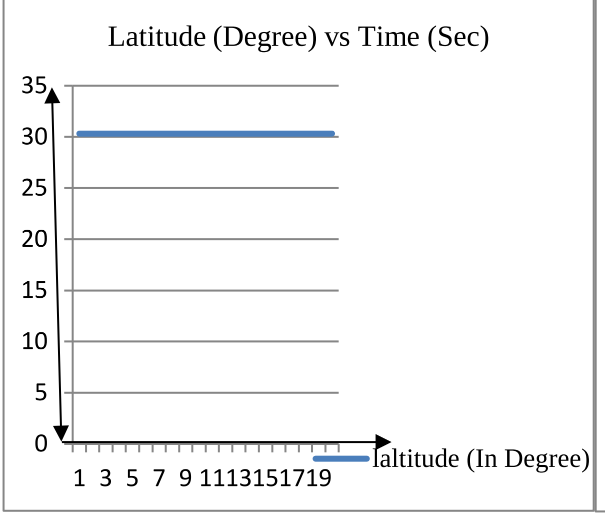


Fig. 18 - Latitude vs time

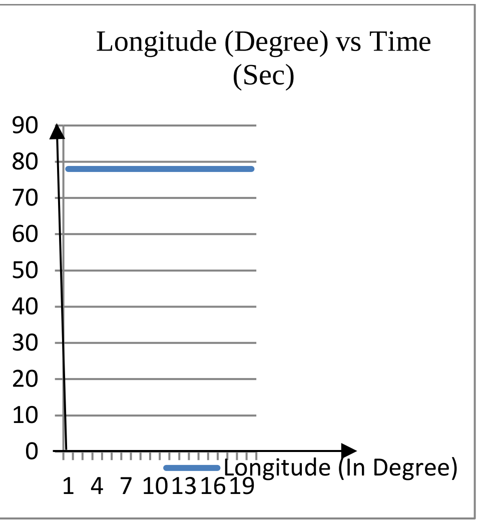


Fig. 19 - Longitude vs time

Global Positioning system results

GPS module Sim28 raw data longitude and latitudes are plotted against time. The GPS time to first fix indoors is about 120-150 seconds and outdoors is 30-40 seconds. The data are gathered for eight satellites locked in to the receiver. The receiving rate is every 0.1 seconds. The graphs are plotted for 750 values.

The values has been taken at ground level, when the apparatus has been mounted on the RC aircraft. There were some deviations with time at high altitudes because there were problems regarding the connection to only 4-5 satellites at times. The graphs for each longitude, latitude at ground level and airborne are plotted against time.

In Figure 18, the curve between latitude and time is plotted for a stationary object on the ground. The values are constant, there is slight to no variation in GPS latitude data, the initializing time to fix is more in some cases because of bad weather or being indoor.

In Figure 19, the curve between longitude and time is plotted for the same stationary object being used so far. Again, the longitude values are constant throughout because of good 3D fix of GPS module.

The GPS data for stationary object was found to be almost constant and no further filtering process is required to get data that are more accurate. The only problem was the delay in TTFT, which can be dealt with by integrating INS to GPS system, which will provide the GPS with initial values and thus the delay in the start was eliminated.

GPS Data for Airborne setup

The setup is mounted on an RC aircraft and the data are recorded at a particular height for five minutes. The variation in data can be seen from the plotting of points on maps. The results of stationary object have been found to be more stable than the airborne ones.

Integration of GPS and INS

For this purpose, arducopter 2.8 with an inbuilt MPU6050 and external GPS module Ublox NEO7M is used. MPU6050 stabilizes the quadcopter and gives initial values to the APM 2.8 these initial values are used to start the GPS module that in turn gives the attitude of flight. The GPS attains 3D fix it gives the yaw pitch and roll for the drone on the ground level as shown in Figure 20. The apparatus is made wireless with the help of telemetry kit which operates on frequency 433MHz. The ground module, which is attached to the computer and air module linked to APM on board. (See figure 2)

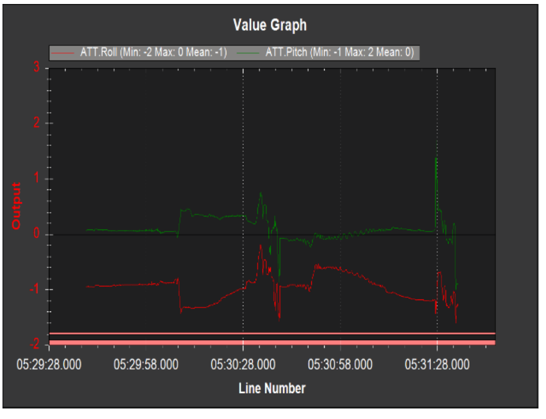


Fig. 20 - Integrated INS-GPS system

Fig. 21 - Integrated Navigation system

The flight path and instructions were provided through the mission planner software. The ground level attitude date and the coordinates at which the drone experiences a safe and steady flight, above ground level has fed to the mission planner. After the initialization, the waypoints of the desired location were transmitted to the mission planner. The real time heading and position can be seen on mission planner interface.

5. CONCLUSIONS

Numerous conclusions can be drawn from this project. Overall results depict the basic working of INS and GPS with different integration methods and estimation techniques. In this project, the raw data and calibrated data from IMU were compared. The results were displayed in various graphs. Thereafter, an application of Kalman filter to get the best possible result by filtering all inaccuracies and errors due to noise in the integrated raw data from INS and GPS, was depicted. The use of integrated INS and GPS can result in better accuracy and performance for the navigation system that operates in areas where the line of sight to the satellites is sometimes blocked for shorter periods. The Inertial Navigation System has a wide range of applications in the aircraft industry; such an application refers to the aircraft stabilization and has been successfully investigated in this work. With the use of MPU6050 and a remote control aircraft, it could be inferred that the roll motion, controlled by the ailerons present on the wing of aircraft, can be stabilized whenever the command fed is wrong or under some unfavorable aerodynamic conditions. Further, GPS modules are used in the RC Aircraft, to estimate the location coordinates i.e., the latitude and longitude of the aircraft at ground level and at a considerable height in the air. The results are plotted on the graph, and it is observed that, for ground level, eight satellites under flight condition.

The integration of INS and GPS was accomplished using the flight controller i.e., Arducopter which has inbuilt MPU6050 and with the help of external GPS module uBlox7M. The setup was mounted on a drone, and its real time position and heading were observed on the mission planner interface. The results for roll and pitch varying with times are plotted on the graphs and it is observed that the results were very consistent and stable. The design of an accurate navigation system is implemented using GPS, INS and Kalman filter were accomplished.

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