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Enhance GPS Accuracy via Integration of Artificial Intelligence

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Abstract

GPS has improved navigation and location-based services, its precision is still affected by things like weather and building materials. The purpose of this research was to investigate the feasibility of using AI methods to enhance GPS precision. This research proves that GPS accuracy has increased significantly, making it suitable for use in increasingly important fields including driverless vehicles, precision agriculture, geospatial mapping, and more. These results highlight the revolutionary potential of incorporating AI to improve the accuracy and reliability of GPS technology, ushering in a new era of navigation and location-based applications. In this study, authors introduce an Artificial Intelligence technique, to increase the precision of GPS receivers. Interoperability of Sensors Mostly made out of a Three-Axis Accelerometer Once GPS signal is lost with any cause, this change in delta latitude and delta longitude will be computed by our trained artificial neural network, and then, based on this interpolation, artificial neural network calculates latitude and longitude. The 3-axis gyroscope is part of an inertial measurement unit (IMU) that is used in conjunction with AI to predict navigation parameters when GPS loses communication with a satellite.

Keywords: *GPS accuracy, GPS accuracy Improvement, Ground Plane Antenna*

1. Introduction

GPS receivers are becoming increasingly popular for use in measuring vehicle speeds as a result of their decreasing size, decreasing cost, and increasing dependability. Calculating velocities, which represent rates of movement, requires correct measurements of both distance and time. There are two main ways to compute GNSS (Global Navigation Satellite System) velocity data: track points or Doppler shift. By periodically collecting and analyzing calculated locations, or "track points," a GNSS receiver may "trace" a course across space. However, the estimated speed is less dependable and exact as a result of the inherent imperfections associated with each track point. This causes the line joining the track points to look choppy, regardless of how smooth or straight the actual path is. Moving in a zigzag pattern increases both the total distance travelled and the average speed as the length of a zigzag line is always higher than that of a smooth or direct path.

Doppler shift measurements of available GNSS satellite carrier frequencies may also be used by the GNSS receiver to calculate its speed relative to the satellites. Doppler shifts, which are related to the speed of transit towards the satellite, will cause a difference between the carrier frequency and the reception frequency. The receiver must constantly track four satellites in order to get its 3D velocity vector. When compared to traditional GNSS position determination methods, which rely on measuring things like satellite distances and phase delays, Doppler-based speed measurement offers the advantage of being more accurate. It is not perfect, however, because its precision depends on the quantity and placement of accessible satellites.

There has been a lot of study into the precision of GNSS velocity measurements, with many of these studies use GNSS data in real time to evaluate performance in realistic environments. Ionic and tropospheric delays, GNSS satellite geometry, radio frequency interference (RFI), obstacles, and multipath effects are only some of the factors that might introduce error into these estimations without the user's knowledge or consent. The ideal approach to test GNSS receivers is to broadcast genuine GNSS signals, simulate different satellite configurations, and play around with different error parameters. With this technique, environmental factors like signal interference and obstruction are eliminated from the evaluation of GNSS receiver performance. Accurate location and navigation are made possible by the Global location System (GPS), which relies on the interplay between satellites and GPS receivers. Satellites of the Global Positioning System (GPS) constellation are placed in various orbits around the planet, with most of them being in medium Earth orbit (MEO). These orbits permit numerous satellites to send and receive messages reliably from any given location on Earth. Multiple satellites can be found in each of the six satellite orbital planes. This setup guarantees that a GPS receiver can usually connect to multiple satellites, allowing for precise positioning. Important data, including as the satellite's location and the time the signal was sent, are carried by the constant transmissions from each satellite. Light speed transport ensures that these signals reach their destinations and are picked up by GPS sensors on Earth. A GPS receiver, which can be built into mobile devices or standalone navigation systems, monitors the sky for transmissions from a constellation of satellites. Trilateration is the technique by which the GPS receiver determines its own location by analyzing the signals it receives from at least four satellites at once.

Trilateration requires timing the passage of a signal from a satellite to a receiver on the ground. The time difference between the satellite and the receiver may be used in conjunction with the known speed of light to calculate their relative locations. During this process, it is helpful to keep in mind the idea of fundamental direction. The GPS receiver must take into consideration the distances to the satellites as well as the locations of the satellites themselves in order to provide an accurate position fix. To accomplish this, you must be familiar with the satellites' latitude, longitude, and altitude coordinates in addition to the direction of their orbits in three-dimensional space. A GPS receiver's and the satellites' initial relative positions are crucial to the device's operation. Signals from satellites strategically placed in orbit around the Earth carry precise location data and timestamps. To achieve precise location determination and navigation, GPS receivers on Earth's surface use signals from numerous satellites to calculate their own positions via trilateration, factoring in the satellites' coordinates and orbital information.

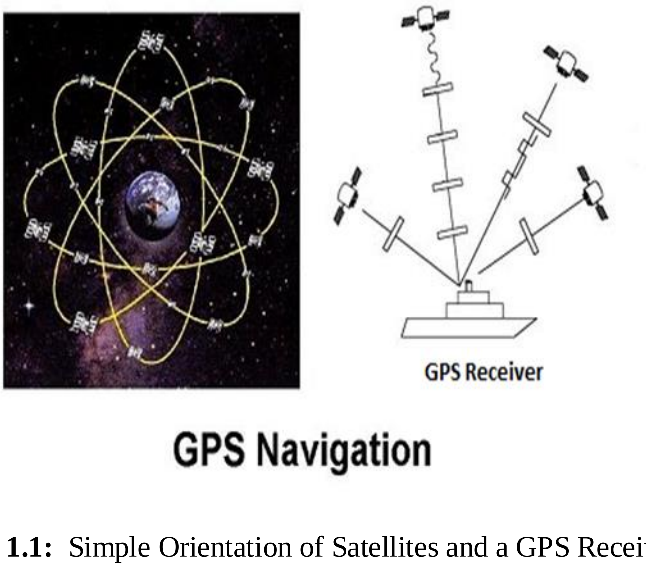

Figure 1.1: Simple Orientation of Satellites and a GPS Receiver [14]

1.1 Neo 6m GPS Module

Figure 1.2: Commercial Neo 6M GPS Module (Makers, 2018) [16]

In particular, the NEO-6M GPS module excels as an integrated GPS receiver. It has a small ceramic antenna (25 x 25 x 4 mm) that can identify and track a wide variety of satellites. The module's power and signal indicators may be checked to determine its readiness for use. The module has a data backup battery to prevent data loss in the event of an unexpected power outage.

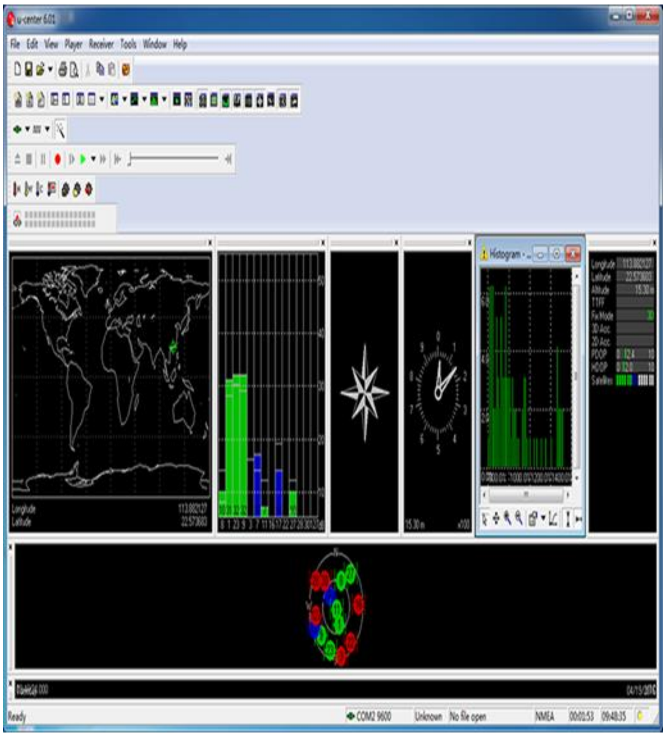

Figure 1.3: software with the data collected by a standard GPS device [15]

1.2 MPU-6050

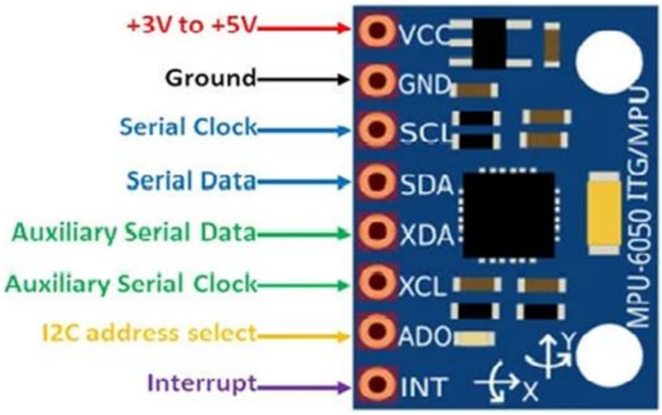

Figure 1.4: MPU-6050 [17]

The MPU-6050 is the first and only low-power, low-cost, high-performance 6-axis motion tracking device designed specifically for smart phones, tablets, and wearable sensors. The MEMS MPU6050 micro-electro-mechanical system has a 3-axis accelerometer and 3-axis gyroscope. Speed, direction, acceleration, and distance covered are just few of the motion properties that may be measured with its help. The MPU6050 operates on the basis of a 16-bit A/D converter. Because of this, it can capture three-dimensional motion simultaneously. This module is compatible with widely used microcontrollers like the Arduino due to its wide range of features that are easily accessible by programmers. The MPU6050 is an excellent choice for those in need of a motion sensor for their unmanned aerial vehicle (UAV), self-balancing robot (BSR), or radio-controlled vehicle (RCV). This board employs an I2C module to exchange data with Arduino. The inexpensive MPU6050's main advantage is that it is compatible with accelerometers and gyroscopes.

1.3 Arduino Development Board

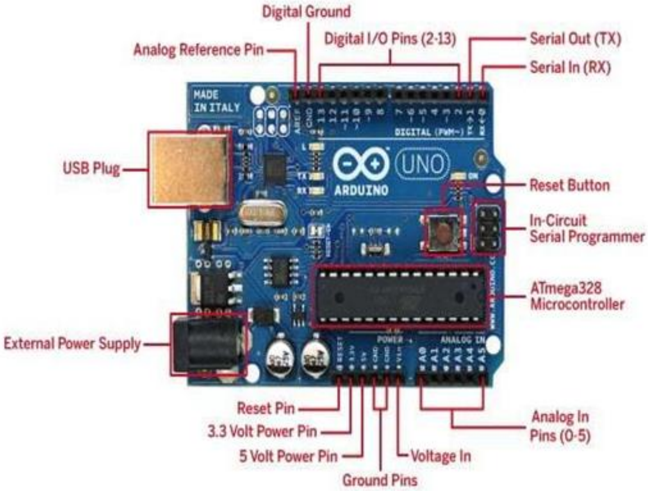

Figure 1.5: Arduino Uno Development Board [18]

Arduino UNO is a low-cost, highly flexible, and easy-to-use programmable open-source microcontroller board that may be used in a broad variety of electrical applications. This board offers outputs for connecting to other Arduino boards, Arduino shields, and Raspberry Pi boards, and inputs for relays, LEDs, servos, and motors. This controller board was utilized in our project to aggregate information from the many sensors.

2. Literature Review

Aly M. El-naggar et. All (2011) GPS has proven to be a useful tool for applications that demand pinpoint navigation or location services. Common-mode errors between reference and rover GPS stations due to ionospheric and tropospheric refraction and delays, satellite and receiver clock biases, and orbital imperfections may be eliminated entirely using differential GPS techniques. Error in GPS-based positioning and navigation is mostly attributable to the ionospheric delay in the transmission of GPS signals. By linearly combining the L1 and L2 data, a dual-frequency GPS receiver may effectively erase the ionospheric delay (to the first order). The consequences of ionospheric delay are most noticeable when dealing with information sent at a single frequency. In this research, nearby regional GPS stations were used to transform single-frequency data from the target station. A mathematical model for TEC, which is dependent on latitude (U) and longitude (k), was developed using the TEC readings from each GPS station.

Samir A. Elsagheer Mohamed et. All (2012) In this study, authors address the issue of location in VANET programmes. The suggested system depends on the differential global positioning system (DGPS) and the received signal strength (RSS) from several RSUs. Real-world scenarios are tested in the field to improve the RSS. The first one is doomed because of the inevitable interference caused by all the WAPs using the same wireless channel. Those working on the same issue utilize this set up. Therefore, the findings they got were flawed. The elimination of near-far and channel interference makes this a masculine solution. As the RSUs used distinct channels to function, the interference was greatly reduced, allowing for much better results in the second round of studies. Based on our findings, authors advocate for training neural networks (NN) to solve the placement problem using the data we've collected.

Nelson Acosta et. All (2012) In order to measure distances with the highest possible precision, this adjustment is employed by another receiver to refine its own location. Positions used to estimate distances are derived from the various experimental data sets, with an inaccuracy of up to 1 meter for 95% of the measurements and as low as 0.2 meters in exceptional circumstances. The idea is grounded in filters and other mathematical and geometric functions. Other receivers can benefit from the methods outlined in this article, which can be used to provide a smoothing error and a value that is constant over time. Getting the location error down to 0.1 meters is the ultimate objective of this continuous work.

Md. Rashedul Islam et. All (2014) In this study, authors introduced a novel, efficient technique for enhancing GPS location precision for inexpensive conventional GPS navigation. The suggested technique reduces the effects of rounding errors by translating coordinates and checking for erroneous data, and it predicts positioning accuracy based on direction angle, velocity, and distance. To evaluate how the suggested technique stacks up against the competition, authors used a GARMIN GPS 19xHVS receiver. Based on experimental results, the suggested method reduces the considerable data volatility of actual data from low-cost GPS devices, resulting in a positioning accuracy improvement of 4-10 meters.

Khomsin et. All (2019) The acronym GNSS refers to all of the satellite navigation systems in use or planned for use around the globe. There are several distortions and biases introduced into GNSS measurements made in the wild. Some theoretical flaws and biases may be removed or subtracted using satellite geometric power. Increasing the number of satellites picked up by the receiver is one way to improve the quality of the satellite geometric. As a rule, the quality of the geometric satellites received by a given set of receivers improves with the number of satellites received. Thanks to advancements in receiver technology, it is now possible to simultaneously receive signals from GPS, GLONASS, and BeiDou.

Ashwani Kumar Aggarwal (2020) GPS location estimate has several uses, including but not limited to autonomous cars, mobile robotics, the gaming industry, and augmented reality. Sensor noise, weather, moving objects, a canyon of buildings, and other factors all contribute to inaccurate GPS location data, making its usage a problem. This study delves into the use of computer vision and deep learning-based techniques to improve GPS location accuracy. It is not necessary to collect a massive amount of data over a lengthy period of time in order to enhance GPS location accuracy using computer vision and deep learning algorithms.

Raj Bridgelall et. All (2020) Rapid deterioration of potholes, frost heaves, swelling, and cracking can occur on roads subjected to fluctuating vehicle loads and climatic conditions. Therefore, transportation authorities must routinely monitor the system for irregularities and fix them before they compromise safety or cause damage to vehicles. Scanning for abnormalities using current technologies is too costly to be used often or over a large network. As a result, a plethora of research cropped up to find ways to utilize common automobiles to collect data on ride quality. A viable approach, however, requires that conventional automobiles already have the necessary gadgets installed.

Narges Rahemi et. All (2021) Increases in GPS functionality are needed to keep up with the technology's rapidly growing user base. The receiver's location accuracy degrades as its speed rises. Both the LS and KF algorithms are used extensively in GPS location. There have been several attempts to enhance these techniques, but they still have poor accuracy when dealing with fast or dynamic motion. To improve the accuracy of high-speed single-frequency GPS receiver location by more than 70% without increasing the computing complexity, a thorough solution is provided here.

Farzaneh Zangenehnejad et. All (2021) Android devices running Nougat or later have the capability to pull Global Navigation Satellite System (GNSS) data. Since then, researchers have focused extensively on improving GNSS Smartphone location. The increasing volume of work in this area is indicative of the field's growing importance in recent years. Since GNSS smart phones are so inexpensive, they may be used for everything from cadastral surveys and mapping surveying to vehicle and foot navigation. High-precision smart phone location is currently unavailable due to a number of barriers. Noisy GNSS observations from smart phones, interference from the surrounding environment and different ways of holding the device, and the need for algorithmic refinement are all factors.

Wenjiu Zhu et. All (2021) In this research, authors provide an approach for mitigating GPS-related inaccuracies. Kalman filtering, instead of more conventional physical procedures, is used to improve GPS accuracy. Authors trials and simulations provide evidence that our algorithm and system work as intended. Despite the fact that our outside trial data are constrained by the worry about the danger scenarios the ADAS may bring, they are nevertheless fairly satisfactory and realistic. Nonetheless, there are a few problems that will have to be fixed in the near future. First, there is still a lot of room for improvement in the realm of GPS location accuracy, since filtering may not be the best solution. Also, improving the way experimental data is processed is important and valuable for accurately determining the algorithm's capabilities. Finally, authors believe the system has real-world potential for use in ADAS, which would greatly improve vehicular traffic flow.

Chenyu Xue et. All (2023) Bridge monitoring is a vital activity for assessing and maintaining the integrity of bridge structures. The primary benefit of using GNSS technology to measure bridge displacement is that it may be done in a completely independent global coordinate system. The primary reason for GNSS's limited use in bridge monitoring is the expensive price of the GNSS stations, which comprise of dual-frequency receivers and geodetic GNSS antennas. As a proxy for monitoring dynamic motion, such as bridge reaction, we evaluated the effectiveness of inexpensive multi-GNSS receivers. Controlled trials with horizontal and vertical motion were used to evaluate the effectiveness of the inexpensive GNSS receivers. For the horizontal motion, the cheap GNSS receivers were compared to the dual-frequency geodetic receivers through controlled trials of circular motion of varied predefined radius between 5 and 50 cm.

R. Anil Kumar et. All (2023) The IRNSS is commonly referred to by its operational moniker, "Navigation with Indian Constellation" (NavIC). Positional precision of 10 meters for military usage and 0.1 meters for civilian use is offered. IRNSS systems' positional accuracy is impacted by a wide variety of factors, including as ionosphere and troposphere delays, multipath errors, and receiver faults. RTK-GPS, D-GPS, and A-GPS are only a few of the several types of GPS error correction techniques available. Weak signals are disregarded in this paper's location accuracy calculations since SNR and the Doppler Effect of the receiving signal are considered. This technique is used to determine the precision of the Global Positioning System (GPS) in published works. In this research, authors use a suggested approach to calculate the positional accuracy.

Zihan Peng et. All (2023) Most modern smart phones have the ability to collect data from several sources, and part of this data may be represented as inequalities thanks to the inclusion of multiple sensors and the use of cutting-edge communication methods. The precision and reliability of smart phone location services might be enhanced by incorporating additional disparities. In this work, authors provide a new estimator for inequality constraints, as well as three applications that use inequality constraints for GNSS location on smart phones. It has been demonstrated that vertical velocity limitations enhance velocity and location estimation performance in the up component. Because of the method's indirect effect, the position series in particular became smoother.

3. Materials And Methods

3.1 Proposed System Schematic Diagram

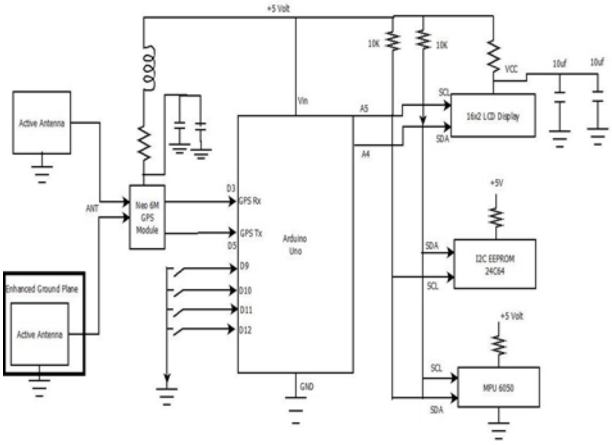

Figure 3.1: Proposed System Schematic Diagram

The above diagram is the our "Elevating GPS Accuracy via Active Antenna Ground Plane Enhancement, Sensor Fusion involving 3-axis Gyro Accelerometer, and Integration of Artificial Intelligence" proposed system diagram. Authors made a 5volt SMPS power supply for powering our whole proposed system. To achieve optimal performance, authors recommend a system that uses both a standard active antenna and an enhanced ground plane active antenna, as seen in the image. Here, authors are using a Neo-6M GPS module to gather location data, which is then sent to an Arduino through a serial connection for further processing. The NEO-6M GPS module's inbuilt 25x25x4mm ceramic antenna and potent satellite search capacity makes it a superior all-in-one GPS receiver. The module's power and signal indicators allow you to do just that. The data backup battery ensures that information is safe even if the main power is unexpectedly turned off. The aeroplane can maintain a steady altitude, return to Home, and fly automated waypoints thanks to the 3mm attachment holes. authors utilized an external EEPROM (external) for storage, a "16X2 LCD display for outputting data, and a push button for mode selection. In this instance, an MPU 6050 was used". A gyroscope and three 3-axis accelerometers are packed into a compact package. Additionally, it has a temperature sensor built right into the chip. It can talk to microcontrollers thanks to the I2C bus interface. You may hook up a variety of other sensors to the Auxiliary I2C bus, such "a 3-axis magnetometer, pressure sensor, and so on". It's used to make the system we're building more efficient.

3.2 Proposed Hardware

Figure 3.2: Our Proposed Hardware

The picture of our hardware shown above includes a LCD (16x2) screen for displaying parameters and data, as well as four buttons for switching between operational modes. For this project, authors used a BMS (battery management system) and a li-ion battery as a secondary power source, In order to charge a battery without killing it.

Button and its operations

Table 3.1 : Hardware Buttons and its Mode of Operations

Button Name (Mode)	Use
"Raw GPS Mode"	"Raw NMEA String Testing"
"Raw IMU Mode"	"IMU Parameter, Temperature of IMU, Acceleration in 3 axis, Gyroscope data in 3- axis, acceleration Angle 3- axis, angle x,y,z"
"GPS+ IMU Mode (Navigation Mode)"	"Testing of Latitude and longitude , Acceleration in X,Y,Z , Gyroscope data in X,Y,Z and Time printing on LCD"
"GPS on/off"	"This button is used for GPS on/off Simulation"

3.3 ANN Flow Chart

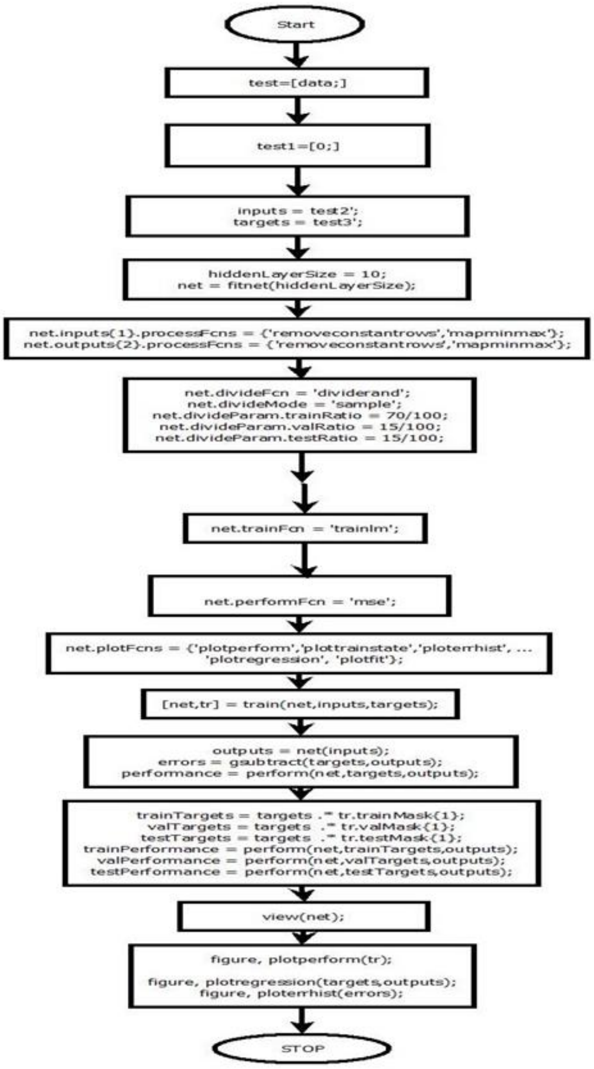

Figure 3.3: ANN Flow Chart

First, the ANN code is started, then the test and test1 values are called for, then the inputs and targets are specified, the hidden layer size is adjusted, the constant rows are eliminated, and finally the train, val, and test ratios are divided. First, the fcn is trained, then the function and training data (network, input, and output targets) are plotted, then the performance is calculated, and finally, after a few more plots (including plot regression and ploterrhist, or error histogram), the code exits.

4. Results and Discussion

In the authors complete proposed work authors have 3 kind of result that's are non-ground plane patch antenna results, ground plane antenna results, these are authors already explain in his previous published paper, in previous work authors explained, the seamless integration of sensors necessitated by the development of the electronic bridge is made possible by GPS, which makes navigation system selection and operation easier for ship operators. GPS Receiver Accuracy Using Antenna Optimization Techniques like Ground Plane Enhancement for SNR Improvement along with Sensor Fusion combined with Artificial Intelligence. Sensor Fusion Primarily comprises of 3Axis Accelerometer With 3-Axis Gyroscope forming an IMU, which along with AI, is used to predict. (URL:https://www.philstat.org/special_issue/index.php/MSEA/article/view/425/421), in this paper authors only explain trained artificial neural network results and serial results that is shown below.

4.1 ANN Results

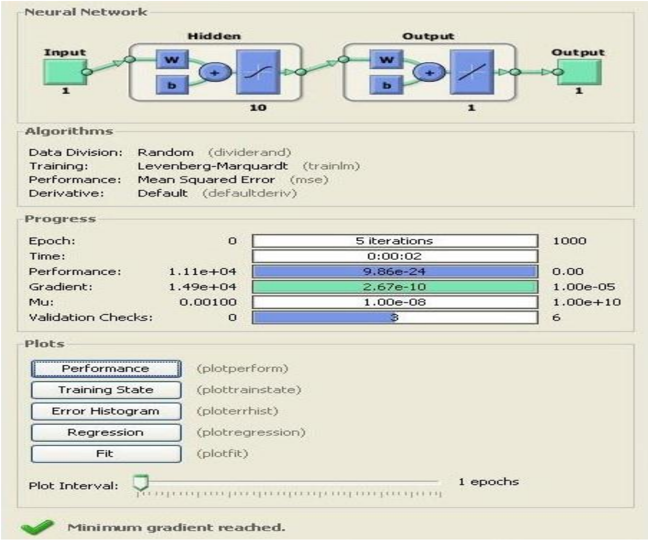

Figure 4.1: Neural Network

"This figure shows trained neural network with input and output here we used 10 neurons".

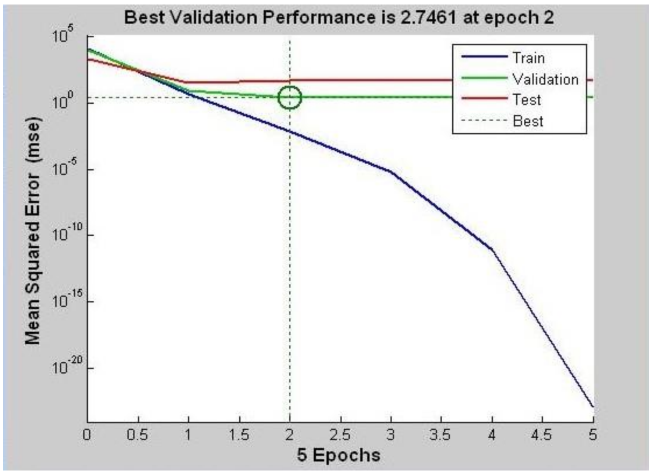

Figure 4.2: Best Validation Performance Plot

This is a representation of the best performing validation strategy: However, if the network starts to overfit the training data, the validation set error may start to rise as the number of training epochs grows. When the validation error keeps going up for six iterations in a row, the training is stopped and the best epoch is chosen automatically.

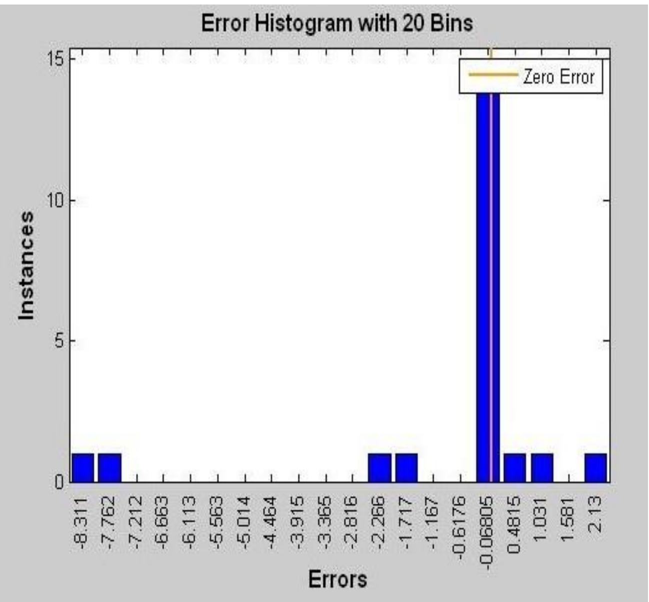

Figure 4.3: Error Histogram

Histograms, a special type of bar chart, divide "numerical data into discrete categories. After a Histogram object has been built", its look may be modified by changing its properties. Quickly altering the bins' settings or presentation is greatly aided by this.

4.2 Main Serial Results

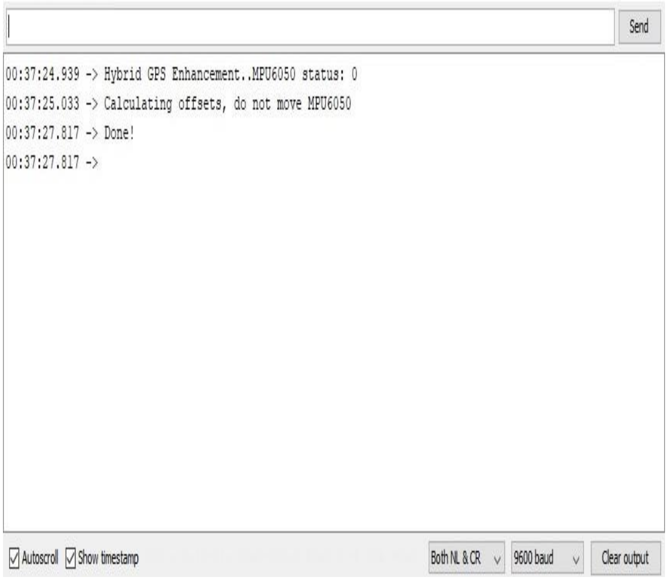

Figure 4.4: System Started

This figure shows data is print on serial for initialization, when the proposed system is started.

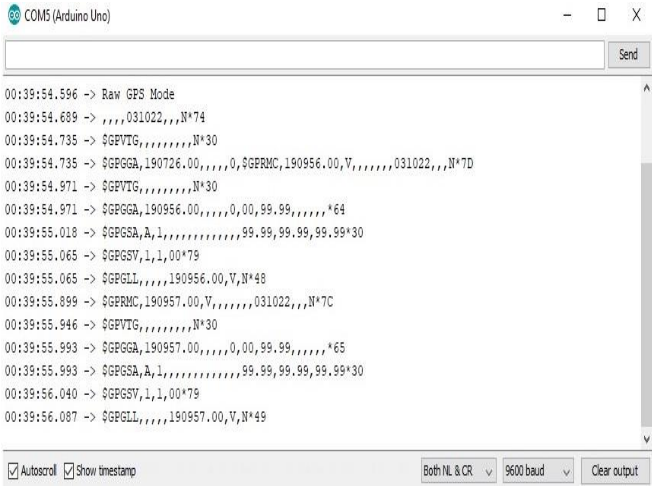

Figure 4.5: Raw GPS Mode Data Testing

The above figure shows readings send by authors system on serial monitor for raw GPS Mode.

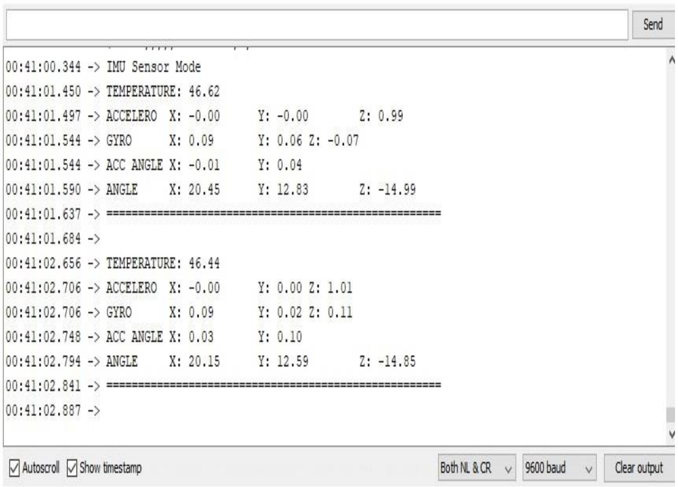

Figure 4.6: IMU Mode

This figure shows data of IMU Sensor Mode like Temperature of IMU Sensor, Acceleration in X, Y and Z Direction, Gyro in X, Y and Z direction and angle in X, Y and Z direction.

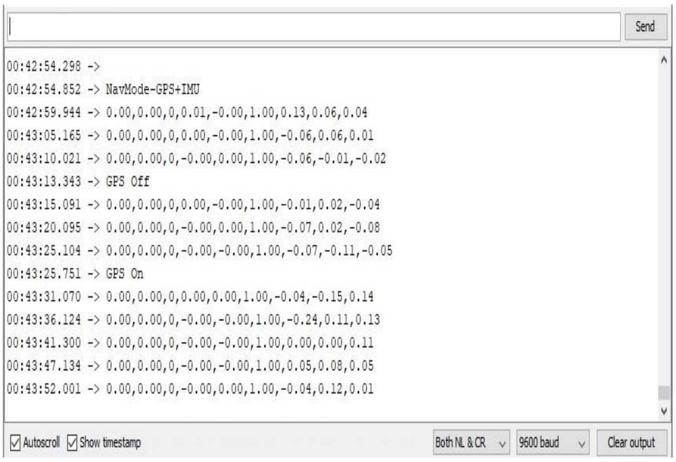

Figure 4.7: GPS + IMU Mode

This figure shows reading of GPS and IMU and by using button no. four, This is toggle button that is used for GPS on and GPS off Simulation, data in that condition will print on serial monitor.

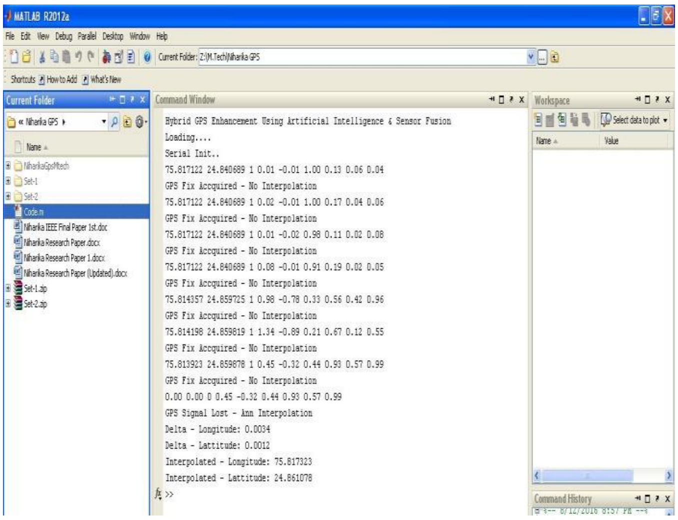

Figure 4.8: ANN Result when GPS Not Properly Connected to Satellite

If want to simulate what happens when the GPS signal drops for any reason, we may do so by pressing the button labelled "4" in the diagram above. After a loss of GPS signal, authors trained artificial neural network will interpolate the position of the user's position in latitude and longitude based on the known change in delta latitude and delta longitude.

5. Conclusion

Among the many new fields of research made possible by “GPS include geodesy, GIS, mapping, atmospheric science, hardware and software development.” Many universities and research labs throughout the world are actively studying GPS. The astounding improvements in GPS receiver hardware are creating new GPS observables, expanding the range of use cases for this cutting-edge method. There is much hope that artificial intelligence (AI) may be incorporated into GPS systems to improve accuracy and help them move beyond their current constraints. Simply put, the advent of more reliable and precise location-based services is heralded by the incorporation of AI into GPS technology, which is a major advancement in and of itself. It's useful for current applications, sure, but it also paves the way for brand new ones, ones that may shake up entire industries and make life better for people everywhere. The potential of AI integration, GPS accuracy has a brighter future than ever before. In this work, authors introduce a Artificial Intelligence technique, to increase the precision of GPS receivers. Interoperability of Sensors Mostly made out of a Three-Axis Accelerometer Once GPS signal is lost with any cause, this change in delta latitude and delta longitude will be computed by our trained artificial neural network, and then, based on this interpolation, artificial neural network calculates latitude and longitude.

6. Future Scope

A positioning inaccuracy of 0.1 metres or less is a future objective we aspire to achieve with continued improvements in accuracy. It's possible that an extra signal will have to be used to do this. Additional measurements will be used to analyse and derive from the acquired data. More types of vehicles, particularly quicker ones, will be able to benefit from the DGPS technology created here.

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