Accurate Positioning Using Integration of Inertial Navigation System based on GPS and Inertial Measurement Unit

Dr. M. S. Zaghloul Arab Academy for Science, Technology, and Maritime Transport, Electronic and Communication Department, P.O.1029, Alex, Egypt,(E-mail: dr_mszaghloul@yahoo.com)

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This paper is a practical implementation of Inertial Navigation System (INS) based on GPS and Inertial Measurement Unit (IMU) sensors. The data are extracted from sensor and processed by using kalman filter software to obtain an optimal estimate of the state variables. Transmission data wireless based on Wireless Module Serial UART (200M Range-433 Mhz) to a computer station which enable continuous tracking for the all vehicles' situation from any place without restrictions .The simulated system built by using Lab View version (13) the

Keywords: IMU, Microcontroller, sensors, GPS, Lab View

I. INTRODUCTION

Normally to calculate the position, orientation, and velocity (direction and speed of movement) of a moving object without need of external references via dead reckoning Inertial Navigation System (INS) is the aid that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes). It is used in multi applications such as ships, aircraft, guided missiles and spacecraft [1]. Many researchers realized different methods to develop a INS integrated system by using GPS/MEMS technology, which is able to provide a navigation solution with accuracy levels appropriate for land vehicle navigation. A accuracy of the parameter estimation is enhanced via applying the use of two Kalman filters in parallel and this enable simulation and performance analysis of an GPS/INS system is investigated [2]. By using a Pentium class microprocessor running a real-time operating system a navigation system depend on Odometer/GPS/INS fusion by means of an Extended Kalman Filter was implemented [3]. These previous systems have been developed in this paper and integrate in one electronic circuit to be used in small applications. The powerful data acquisition program Lab View and microcontroller circuit's that have a positive impact on the operations is applied. The system enables the user to connect multiple sensors with lower cost than using other individual hardware system in addition to send the data wireless via Wireless Module Serial UART for continuous tracking. The output of all signals is displayed on the electronic screen to enable continuing monitoring of wireless position variations. The organization of the paper is as follow: section 2 present Experimental work; section 3 presents Lab View software; section 4 present Results, and finally section 5 present Conclusions.

II. INS CONSTRUCTION AND KALMAN FILTER

Inertial navigation is devices that can be used to determine the accurate position and can be work depend on GPS or individual. It can be used for Vehicles or marine ships and many other applications through the implementation of inertial sensors. Inertial Navigation system relay on concept that an object will stay in uniform motion unless disturbed by an external force. This force in turn produces acceleration on the object. If this acceleration can be calculated and then apply mathematical integration, then we will be able to determine change in velocity and position of the object with respect to an initial condition [4]. Acceleration in INS system is measured by inertial sensors, that is used to measure the angular velocity and attitude and by applying mathematical integration and provides changing of the angle in relation to an initially known angle with assist of

Both sensors (accelerometers and gyroscope) position of the vehicle can be possible to determine. For inertial navigation system contains three accelerometers that mounted with their sensitive axes perpendicular to one another. Its theory of working is based on the Newton's laws.

To navigate in relation to the inertial reference frame, it required to maintain track of the direction in which the accelerometers are pointing. Gyroscopic sensors is used to sense rotational motion of the body relation to the inertial reference and used to determine the orientation of the accelerometers at all times. By using this information before the integration process takes place on each time step it is possible to transform the accelerations into the computation frame. Kalman filter is considered the heart of the integration of GPS and INS , that can offer a combined system with higher performance in comparison to other systems operate in stand-alone mode as shown in fig 1[6-7-8].

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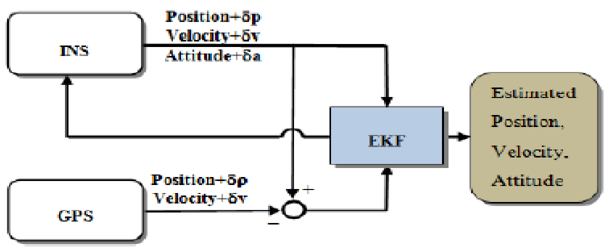

Fig.1. INS Block Diagram

Optimal estimate of the state variables can be done using Kalman filter which is a linear estimator that uses information of the current system's dynamics.

II. GPS/INS INTEGRATION

An electronic circuit is designed to integrate GPS/INS to build a simple INS model with low cost to integrate with different systems.

The system consists of two parts:

Part I: The physical parts, which consist of transmitter and receiver system .Transmitter system is a circuit board that consist of microcontroller board which connected to two sensors
A. Transmitter Circuit

1-GPS/IMU SENSORS

a-GY-80 10 DOF that contain inside it a gyroscope (L3G4200D), an accelerometer (ADXL345), a Magnetometer (HMC5883L) and a Barometer and Temperature sensor (BMP085) as shown in fig. 2.

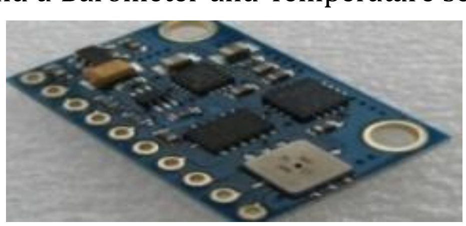

Fig.2. GY-80 IMU sensors

b- GPS (SKM 53) module with embedded GPS antenna enables high performance navigation in the most stringent applications and solid fix even in harsh GPS visibility environments. The module support GPS, GALILEO, SBAS (WAAS, EGNOS, MSAS, and GAGAN) as shown in fig3.

Fig.3. GPS (SKM

2- RF transmitter which is based on Texas instrument CC1101 chip, which can work as one to many and also can work directly with Micro-controller via Serial UART. The reading of each sensor is sent wirelessly through UART protocol using serial communication, 200 m distance range and 433 Mhz frequency as shown in figure 4.

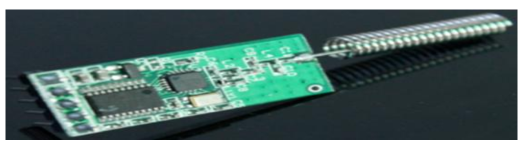

Fig.4. Serial transmitter Wireless Module UART (200M Range-433 Mhz)

3- Microcontrollers (PIC 16F628A and P16F886) to each four sensor individually, and one for main RF transmitter as shown in figure 4.
4- SD card module that enable the user to save data in select two formats (.txt or .log) and analysis the output data by any data represent like excel as shown in fig 5.

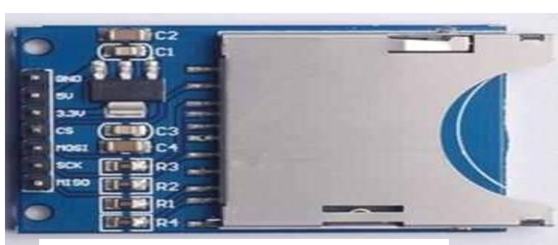

Fig.5. SD Card Module

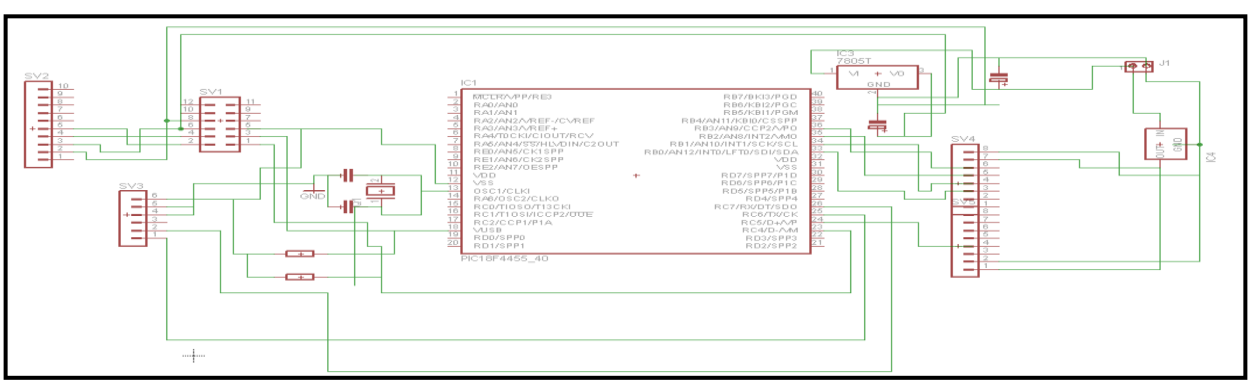

Fig.6. Transmitter circuit

4- Power supply input terminal to feed the circuit with power is designed as shown in figure8

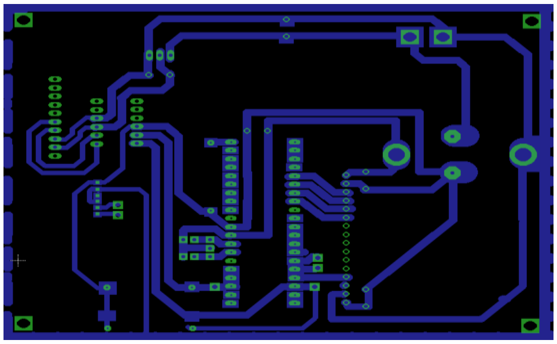

Fig.7. Practical Circuit

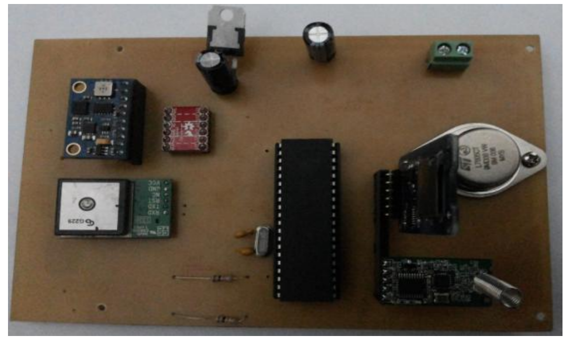

Fig.8. Layout of Circuit

By enabling the microcontroller (micro_ gyroscope) via (m1) and activate IMU sensor which is connected to the microcontroller via I2C communication. The micro controller is programmed to extract the output of each gyro and accelerometer in (X, Y, Z), and by using equations to obtain Roll and Pitch values, sending them via serial communication to the master micro controller U1 [10].

$$\tan \phi_{xyz} = \left(\frac{G_{py}}{G_{pz}}\right) \quad (1)$$

$$\tan \theta_{xyz} = \left(\frac{-G_{px}}{G_{py}\sin\phi + G_{pz}\cos\phi}\right) = \frac{-G_{px}}{\sqrt{G_{py}^{2} + G_{pz}^{2}}} \quad (2)$$

By enabling the microcontroller (micro_ GPS) via (m1) and activate Gps receiver module which attach to microcontroller via serial communication via Rx pin with baud rate (9600). From the NMEA data and by program the microcontroller.

B- Receiver system

The Receiver System consists of:

1- RF Receiver which can connect to a serial computer or via serial-to-USB which can able to receive data wireless from transmitter circuit board and connect to a computer station as shown in figure 9.

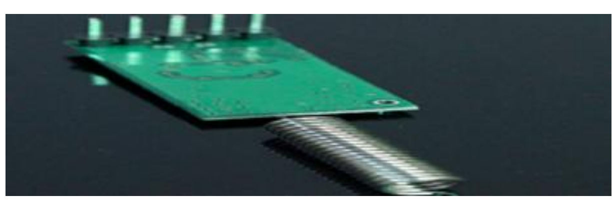

Fig.9. RF Receiver

III. LAB VIEW SYSTEM

Lab View is a system-design platform and development environment for a visual programming language from National Instruments and it is a dataflow programming language. [10-11], Execution is determined by the structure of a graphical block diagram (the LV-source code) on which the programmer connects different function-nodes by drawing wires as shown in figure 10.

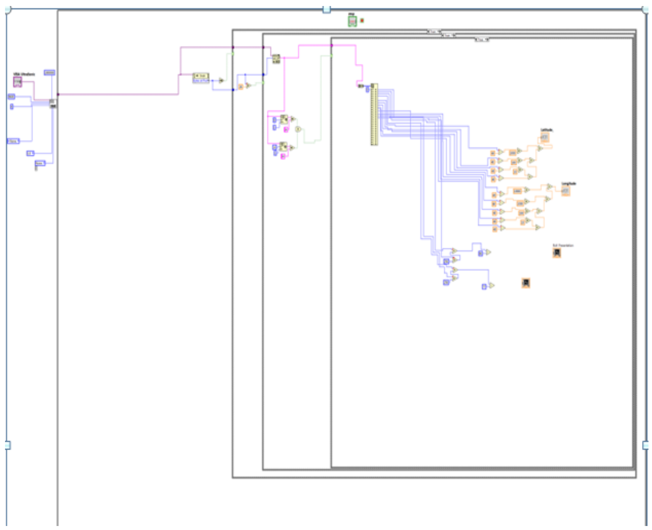

Fig.10. Lab view Block Diagram

The wired propagation variables and any node are executed as soon as all its input data are available. Lab View relates the creation of user interfaces (called Front panels) with the development cycle. Lab View programs/subroutines are called virtual instruments (VIs). Each VI has three components: a -block diagram, a front panel and a connector panel. By using Lab View software which programmed to accept data via VISA (Configure Serial Port) inside lab view and check the number of bytes sending and arranging them inside Index Array Function to separate them for final display and calculation.

IV. RESULTS AND ANALYSIS

- **The output of IMU sensor**

The output from IMU sensor for Roll and Pitch is displayed in analogue as shown in figure 11,

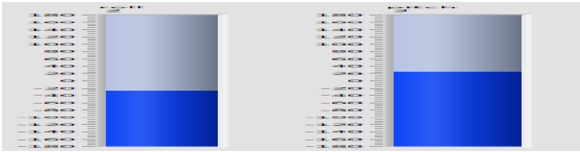

Fig.11. Real IMU sensor

- **The output of GPS/IMU sensor**

The output from both sensors has enhanced the system for accurate position after using the both sensors figure shown the latitude and longitude in both cases after and before integration. by using investigation area for tracking as shown in figure 12

Fig.12. Investigation Area

By using GPS Data by using portable SD card and analysis data as shown in figure 13.

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31.307998,30.062295
31.308104,30.061888
31.3082,30.061474
31.308296,30.061072
31.308402,30.06067
31.308503,30.060235
31.308617,30.059801
31.308736,30.059302
31.308814,30.058851
31.307563,30.058529
31.306238,30.058181
31.3049,30.057811
31.303351,30.057338
31.302077,30.057092
31.300793,30.056813
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Fig.13. Serial GPS Data

From above serial data it is easy to analysis this data and make a relationship curve between lat/long as shown in figure 14.

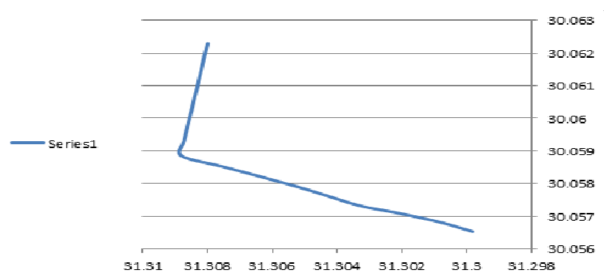

Fig.14. GPS data only.

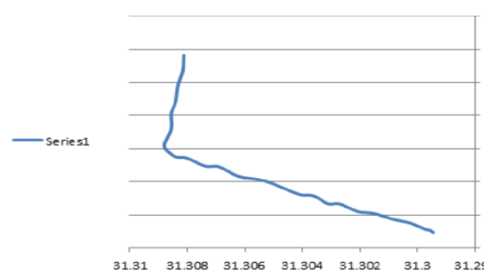

Fig.15. GPS with IMU data.

By add IMU data GPS and processing the two modules and analysis the output result as shown in figure 15

V. CONCLUSION

Navigation is the science and art that answers the questions of knowing where you are at the current moment and where you will be in the next moment.[12]Integration of GPS/IMU sensors has been built for accurate position estimation. The designed system based on microcontrollers (PIC 16F628A & P16F886),RF module transceiver , Lab View system and a group of sensors (GY-80 10) DOF, an accelerometer (ADXL345), (gyroscope (L3G4200D) ,a Magnetometer (HMC5883L) and a Barometer & Temperature sensor (BMP085)) GPS (SKM 53) module have been designed . All experimental data are performed in a fully automated computer display and analysis of each sensor has been done. The obtain data has been transmitted wireless using Wireless Module Serial UART (200M Range-433 MHz) to the base station computer destination. The system cost is relatively cheap by comparison with other systems of control navigation. Taylor-series method can be used to give a superior algorithm performance in coning environments and maneuver environments. [13, 14]

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