GPS Receivers to Measure Moving Devices

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ABSTRACT: *Using the 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer, barometer and GPS receiver, we have introduced the 11 DoF system to measure the dynamic moving devices. This process will solve the navigation tasks with the IMU and GPS systems. To send the inertial data with the help of GPRS connection to the remote servers the GSM modem is developed. The inertial and navigation data is used for the transfer of experimental data to represent the system possibilities. In this work, we have developed the efficiency of automated classifiers in the systems for measuring the quality.*

Keywords: Inertial navigation, IMU system

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1. Introduction

The dynamics analysis and localization of the moving objects define the necessity of the information and communication system with maximum number of degrees of freedom. MEMS technology allows production of small, cheap and low power consumption devices which may measure the linear and angular accelerations and may be used in different commercial applications [1]. Unfortunately the low-cost MEMS devices need of algorithms for compensation of their disadvantages, such as GPS-IMU system integration [2] to reduce the numerical integration errors, barometer – accelerometer combination [3] to reduce the dependency of the accelerometer data over the inclination or combined algorithms for calculation of the heading angle in the compass system [4].

The current paper proposed 11 DoF system based on 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer, barometer and GPS receiver to calculate the dynamic response of the moving device and to solve the navigation tasks by combination of the IMU and GPS systems. The existing IMU measurement systems are combined only with a GPS receiver [5] and some of them also have build-in GSM modem, but the sampling frequency is much lower [6]. The sampling frequency in these systems varies from 20Hz [5] to 84Hz [7] while the proposed system read the inertial and navigation data with sampling frequency of 100Hz to minimize the integration errors. It is shown that the proposed system is capable to send the inertial and navigation data to database server in real-time situations and the navigation error may be reduced to increase the inertial navigation accuracy.

2. System Description

The system block diagram is shown at Figure 1. It consists of the following main blocks used in the experiments:

• IMU system – 9DoF system, consists of 3D linear accelerometer, 3D gyroscope and 3D magnetometer, which are integrated in the single IMU unit, produced by Atmel. One of the supported IMU systems is 9DoF Atmel Inertial One ATAVRSBIN1 board, which contains:

• InvenSense three-axis MEMS gyroscope (ITG-3200)

• Bosch Sensortec three-axis MEMS accelerometer (BMA150)

• AKM three-axis electronic compass (AK8975)

• Temperature sensing through ITG-3200 or BMA150.

The second supported IMU system is Atmel Inertial Two ATAVRSBIN2 board which contains:

• InvenSense three-axis MEMS gyroscope (IMU- 3000™)

• Kionix® three-axis MEMS accelerometer (KXTF9)

• Honeywell three-axis electronic compass (HMC5883)

• Temperature sensing through IMU-3000.

The microcontroller read the data from the IMU system via CH0 channel of I^2C multiplexer.

• MEMS barometer based on the Atmel ATAVRSBPR1 board, which contains the high precision Bosch Sensortec digital pressure sensor (BMP085) with a temperature control and correction of the barometric data. The microcontroller read the data from the barometric board via CH1 channel of I2C multiplexer.

• I2C multiplexer based on PCA9540, which is 1-of-2 bidirectional translating multiplexer, controlled via the I^2C bus. The SCL/SDA upstream pair fans out to two SCx/SDx downstream pairs or channels. The I2C multiplexer allows connecting two identical boards to the system expansion slots to increase the reliability for some critical applications such as unmanned devices.

• Micro SD card – The additional flash memory up to 2GB is used to record the inertial, navigation, magnetic, temperature and barometric data. The microcontroller read/write the data from/to the micro SD card via SPI interface (MSSP1 module).

• GPS receiver – The navigation data are obtained by the GPS/GNSS module (LEA 6S) produces by Swiss-based ublox. This module has been designed for low power consumption, low costs and UART, USB and DDC (I2C compliant) interfaces. The GPS receiver is capable to update the navigation data up to 10Hz.

• GSM/GPRS modem is used to send the navigation and inertial data to the database server at a real-time. It is based on the quadband GSM (LEON G100) produced by the same company due to the simple integration of u-blox GPS and A-GPS and quad-band GSM/GPRS, class 10.

• Microcontroller – The 8-bit high performance RISC PIC18 microcontroller is used to read the navigation and inertial data and to control the external devices according to their position. The PIC18 microcontrollers are optimized for C programming and have advanced peripherals (SPI/I²C™, UARTs, PWMs, 10-bit ADC, etc.).

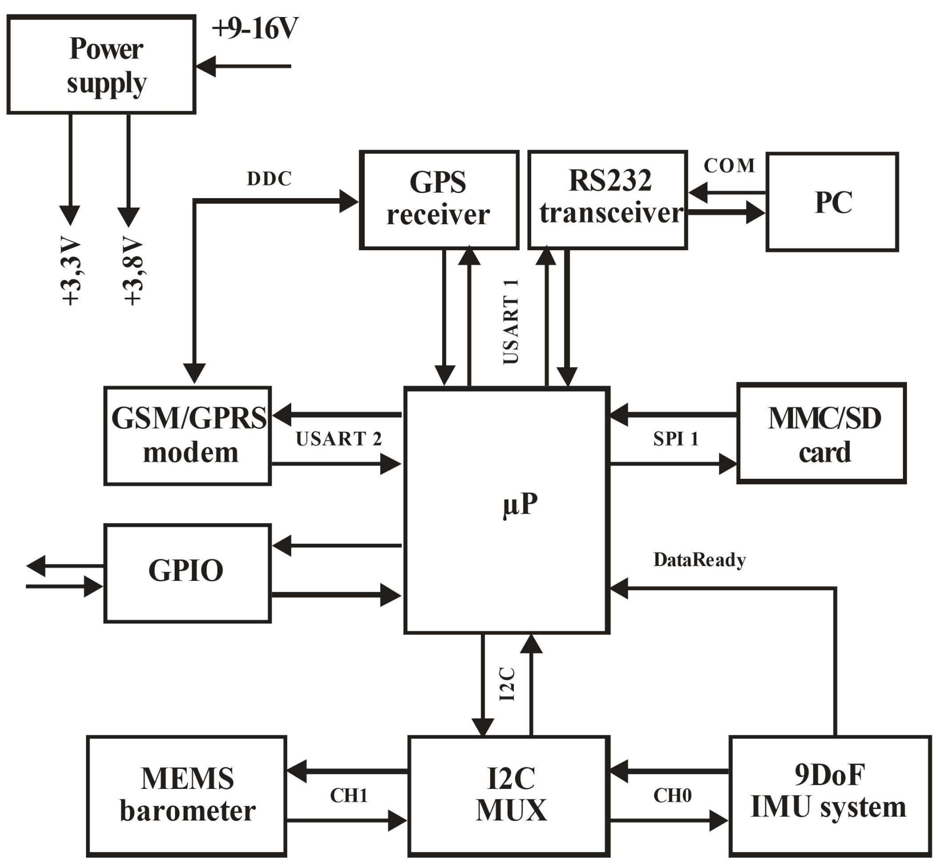


Figure 1. System block diagram

One of the system specific features is fastened with the I2C multiplexer, so the reading algorithm had to be capable to switch between the both I^2C channels.

The data acquisition algorithm is shown at Figure 2. It consists of 10 frames with time duration of 10ms, so the 10 frames form 100ms duration data block. This data block contains of:

• NMEA 0183 RMC message (maximum 80 bytes);

• NMEA 0183 GGA message (maximum 80 bytes);

• 10 measurements of the 3-axis linear accelerometer (60 bytes);

• 10 measurements of the 3-axis gyroscope (60 bytes);

• 5 measurements of the 3-axis magnetometer (30 bytes) multiplexed with 5 temperature measurements from accelerometer and gyroscope (30 bytes);

• 1 barometer measurement and 1 temperature measurement of the barometer temperature for temperature corrections of the pressure.

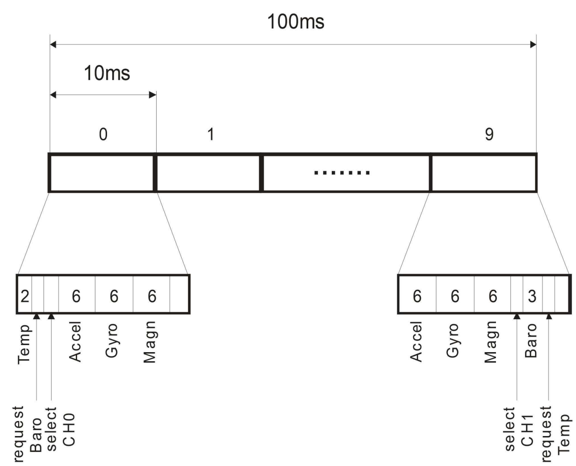


Figure 2. Data acquisition algorithm

The data acquisition algorithm is agreed with the time conversion requirements of the barometer. The temperature measurement requires 4.5ms delay while the ultra high resolution pressure measurement – at least 25,5ms. The establishment of the corrected temperature and pressure data are accomplished on the basis of the barometer calibration EEPROM values and Bosch BMP085 Barometer Floating Point Pressure Calculations.

3. Experimental Data and Analysis

An experimental test of the system is accomplished to test the ability of read, store and send the inertial and navigation data to

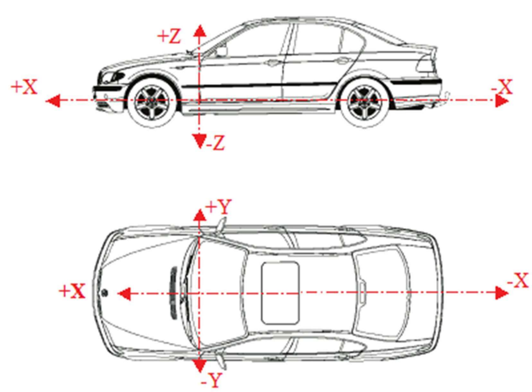


Figure 3. IMU axes orientation

the remote server. The data are recorded to the local system FLASH memory (micro SD card with capacity of 2GB) and after that the data are processed using MATLAB routine. The orientation of the IMU axes in relation to the vehicle axes is shown at Figure 3.

The results are shown at the following figures:

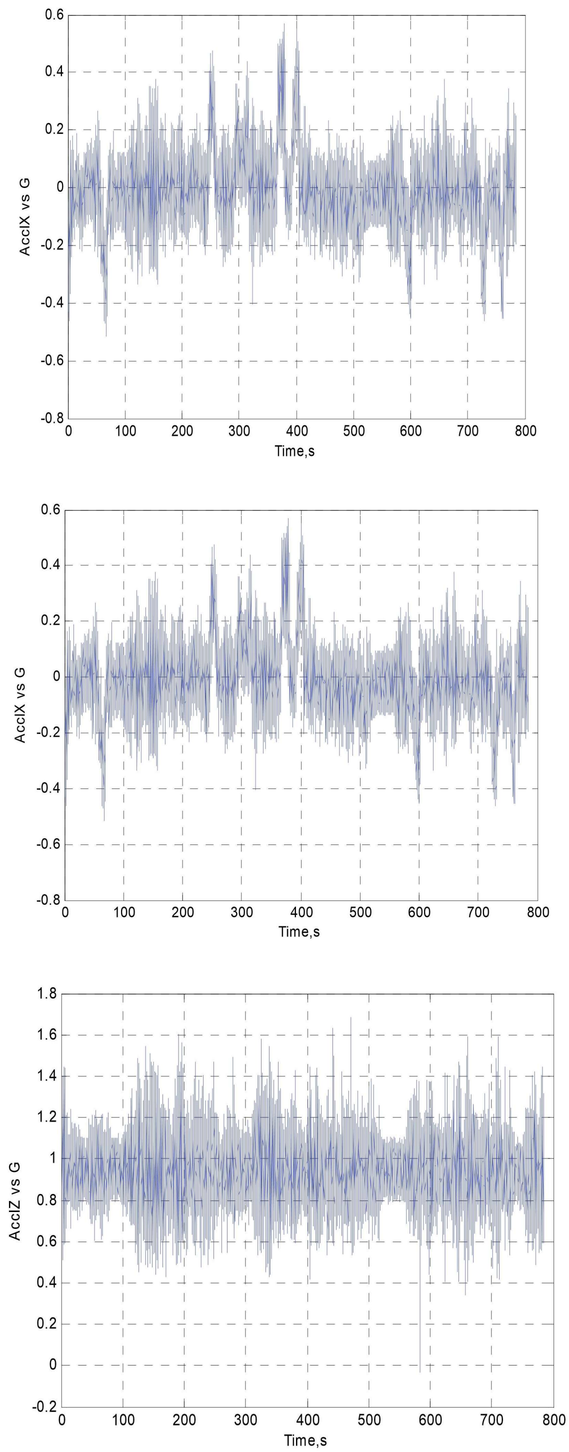


Figure 4. X,Y,Z Accelerometer data

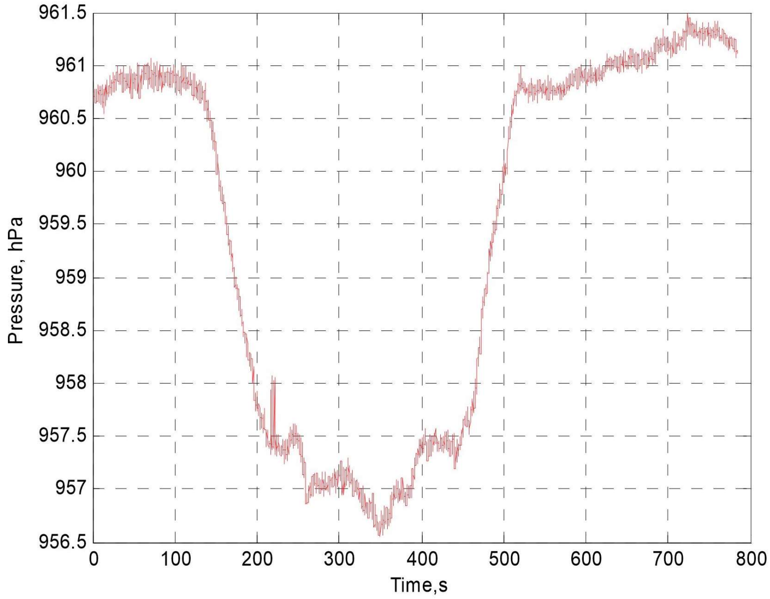
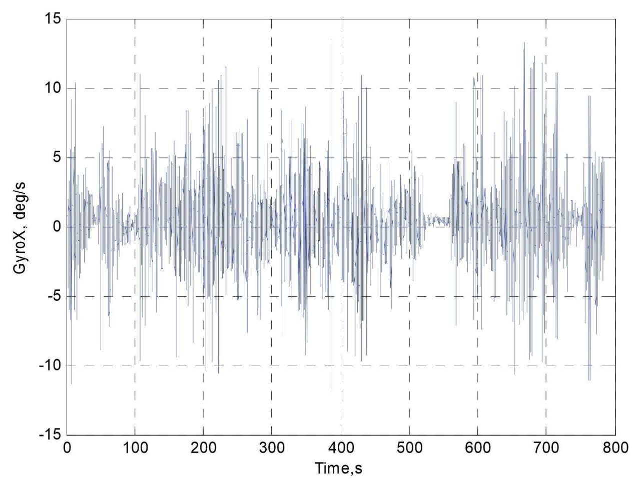
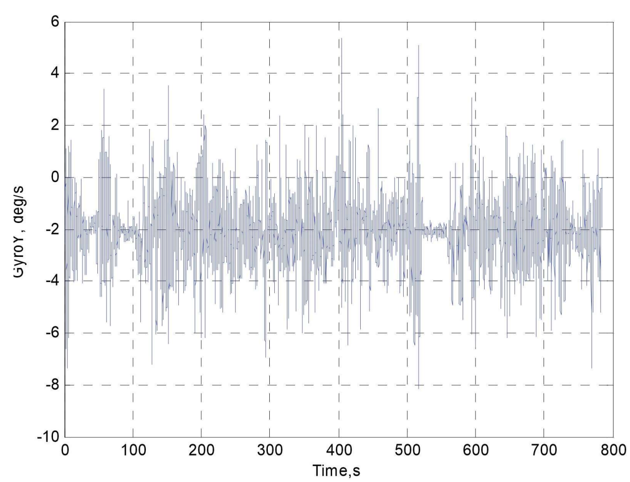


Figure 5. Atmospheric pressure graph





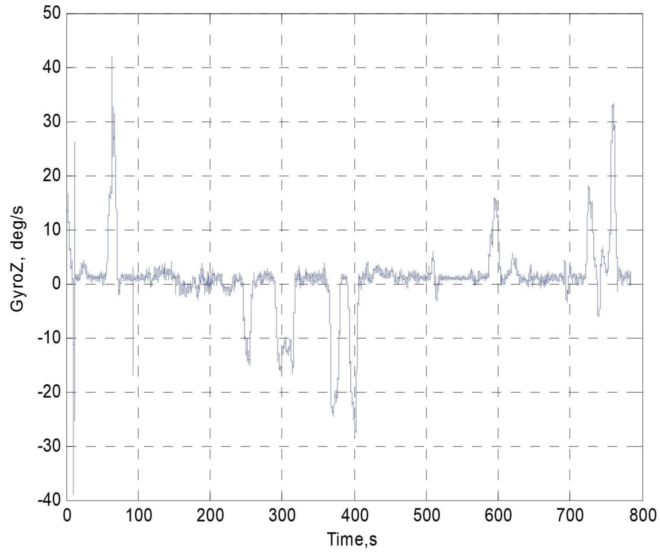


Figure 6. X,Y,Z gyroscope data respectively

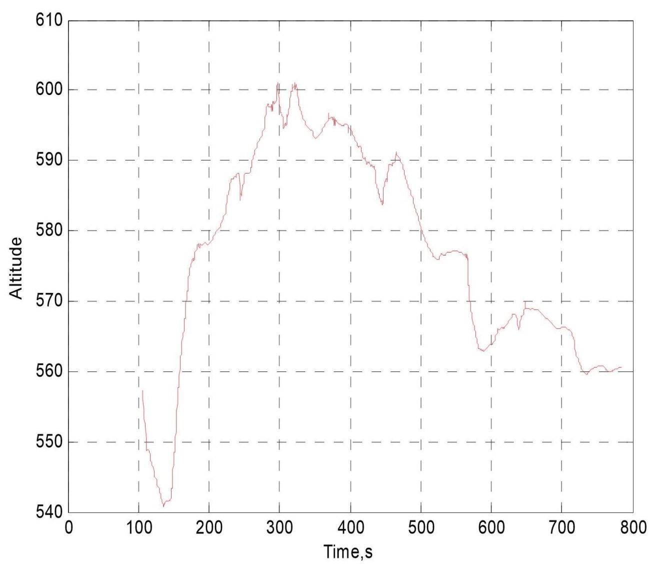


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Figure 7. Altitude graph (GPS data)

The shown graphic data proof the system ability to read all linear and angular accelerations, atmospheric pressure and GPS data and all chip temperature sensors (temperature graphs are not shown). The MEMS sensor information may be used for localization purposes when GPS signal is lost or is not available.

4. Conclusions

The current paper discusses the 11DoF IMU system which is capable to all inertial and navigation data to solve the navigation tasks by combination of the IMU and GPS systems.

The design of this system is inspired by the need of a high speed IMU system which is capable to store locally and send data to remote server. The existing systems are distinguished with the first or second feature while the proposed system combines the both ones. The system may be used for inertial navigation based on the EKF (Extended Kalman filter) due to the high

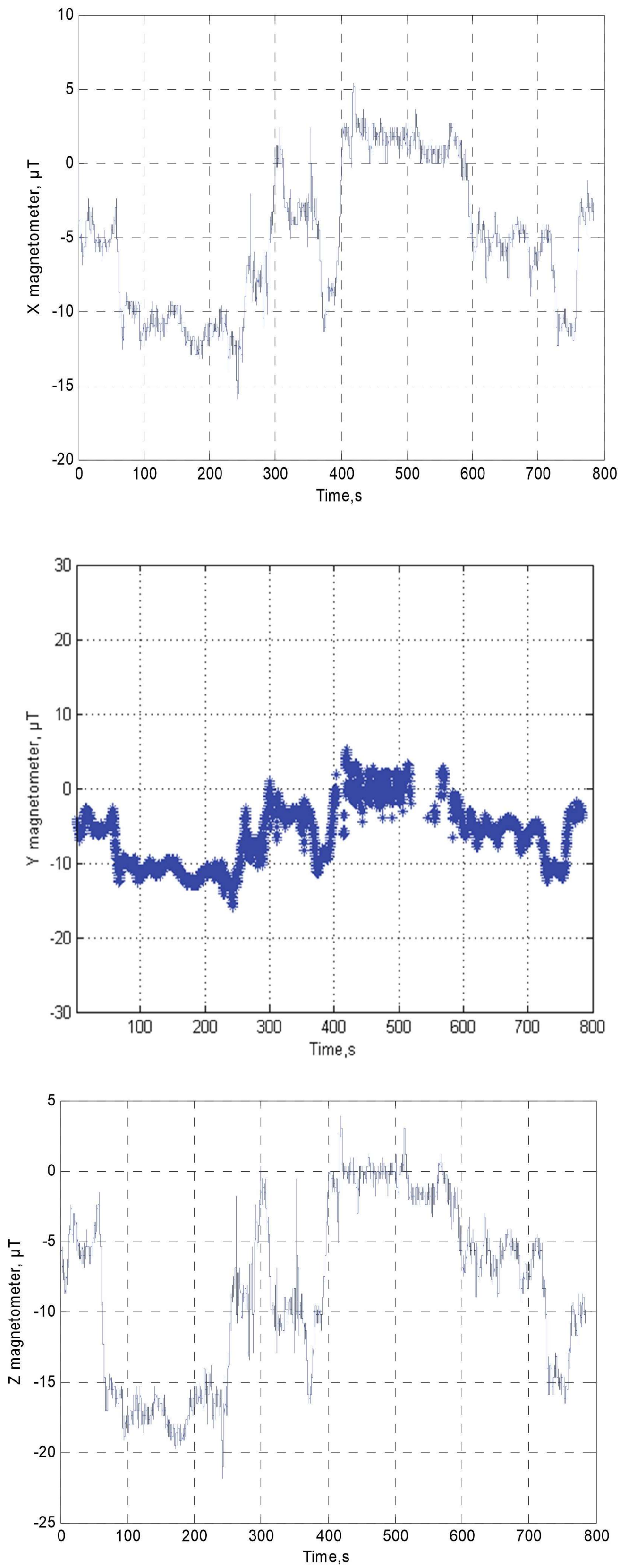

Figure 8. X,Y,Z magnetometer data respectively

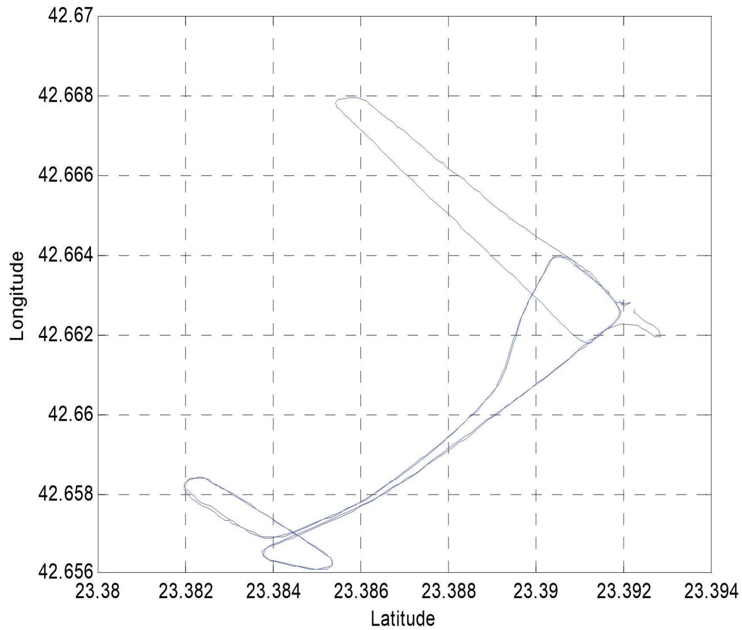

Figure 9. Driving track (latitude/longitude)

sampling frequency and small integration errors, gyro stabilized platforms, platform control due to the PWM interface, MVEDR (Motor Vehicle Event Data Recorder) systems or crash monitor for aircrafts, trains or cars.

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