GPS/INS Automotive Tracking System

Rossen Miletiev[1] and Rumen Arnaudov[2]

Abstract: **The proposed GPS/INS automotive tracking system includes base station with map software and mobile stations. The combination of the GPS receivers, GPRS service communication, MMC/SD card, micromechanical sensors and map software allows offline and real – time tracking, motion analysis and possible construction of an automotive black box to visualize the mobile station on the map or to reproduce the road situation by a virtual reality at the road accidents. The proposed system is capable to update the navigation data (1Hz) and inertial data (up to 2560Hz) to design an Extended Kalman Filter with very high accuracy due to the high inertial data update rate.**

Keywords: **GPS, micromechanical sensors, MMC/SD card**

I. Introduction

The realization of the GPS/INS automotive tracking system evolves from the necessity to solve complex transportation tasks for the overloaded transportation traffic in the big cities. The system purpose is connected with the location of the moving objects by using GPS receivers and radio transmission connection like GSM or radio-link network. The combination of the GPS positioning system with the map software enables to find the optimum solutions and allows the quick and adequate decisions of the transportation tasks [1]-[2]. In the same time the inertial system (INS) allows monitoring the automotive drive style, dangerous places and route conditions.

The MEMS accelerometers and gyroscopes are both sensors which can perfectly address active safety systems in the automotive domain. Control of car roll-over, vehicle stability for skidding and antilock braking, parking brake energy, activation of wheel pressure monitoring, suspension adaptation to car and road condition, and other ones are all features are extending more and more any active safety system will be embedded soon in the cars.

Moreover MEMS sensors allows instantaneous detection of any information used by those functions, with an high level of precision and accuracy, with a very low impact in term of space, together with high level of integration with other systems.

Because the Global Positioning System (GPS) and an Inertial Navigation System (INS) complement each other, it is common practice to integrate the two systems in applications calling for continuous high accuracy and reliability [3]-[4].

[1]Rossen Miletiev is with the Technical University of Sofia, 8 Kl. Ohridski Blvd, 1000 Sofia, Bulgaria
E-mail: miletiev@tu-sofia.bg
[2]Rumen Arnaudov is with the Technical University of Sofia, 8 Kl. Ohridski Blvd, 1000 Sofia, Bulgaria
E-mail: RA@tu-sofia.bg

Kalman filtering is the basis for correcting the INS with GPS measurements of satellite range and range-rate. At the same time, the INS provides smooth and accurate short-term measurements of acceleration and velocity that can be used to aid GPS receiver code and carrier tracking [5]. Together the two systems permit improved navigation accuracy especially when GPS is degraded or interrupted because of jamming or interference [6].

The proposed system is capable of measuring acceleration over a bandwidth of 640 Hz for all axes [7] (update rate up to 2560Hz), while the bandwidth of the analogue accelerometer sensors is limited to 100Hz. The higher update rate may significantly decrease the integration errors due to the approximation error reduction. The proposed system also allows full tracking report and analysis and improves the route safety and security.

II. System architecture

The block diagram of the GPS/INS tracking system is shown at Figure 1. It consists from the following main modules:

- *Power supply block*. The module transforms the input DC voltage to 3,3V (accelerometer power supply and Vdd_IO lines) and 5,0V (microcontroller and gyroscope power supply). The designed power supply is based on the LDO regulators to produce a low ripple output voltage.
- *GPS receiver*. The module sends the appropriate NMEA 0183 messages to the master board microcontroller;
- *Inertial system*. The module scans the 3 - dimensional linear accelerometer and angular rate sensor (gyroscope) to establish the current object accelerations. The inertial system is upgrade to the basic GPS system and may be installed in the same system case;
- *MMC/SD card*. It stored the GPS RMC messages and inertial sensor data as an archive information (backup function), which allows offline tracking analysis. This module is optional and supports MMC/SD cards up to 2GB (FAT16 file system format);
- *GSM modem*. The module sends the navigation and inertial sensor data via GSM network by GPRS service using the embedded TCP/IP stack to perform a real time tracking function;
- *Serial interface*. The system supports some serial interfaces to enable the communication with external devices, especially with computer based platforms. The supported serial protocols include RS232, RS422 and synchronous serial transfer.

- *USB interface*. The Serial-to-USB module includes FTDI single chip IC, which accomplished the asynchronous serial data transfer to PC according to USB 1.1 and 2.0 protocol specification. The module has UHCI/OHCI/EHCI host controller compatibility.
- *I/O ports*. The optional I/O digital and analog ports allow connecting the additional external sensors such as temperature sensors, fuel level sensors, passenger detectors, etc. The analog inputs include the 10-bit analog microcontroller channels and the both 12-bit analog gyroscope inputs AN0 and AN1. The both microcontrollers support I/O ports to ensure the low and high priority of the external sensors.

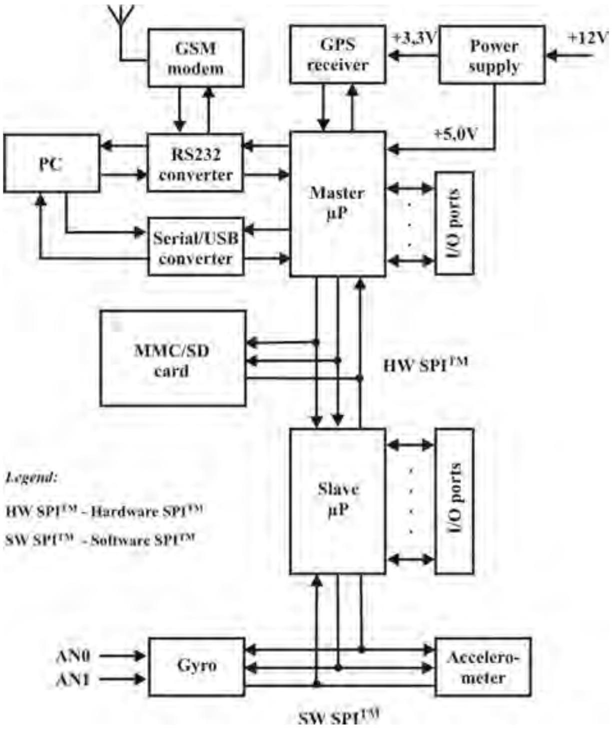

Fig.1. System architecture

The final assembly of the GPS/INS system is shown at Figure 2.

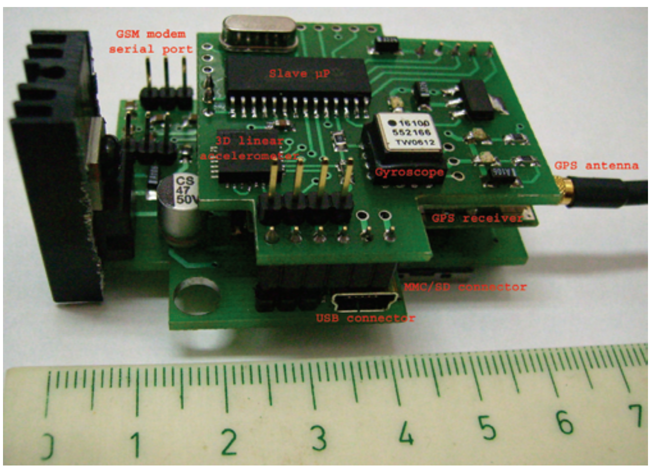

Fig.2. GPS/INS tracking system assembly

III. ACCELEROMETER DESIGN

The accelerometer sensor is based on LIS3LV02DQ – a three axes digital output linear accelerometer, produced by *ST*. This sensor includes a sensingelement and an IC interface able to take the information from the sensing element and to provide the measured acceleration signals to the external world through an I^2C/SPI serial interface. The LIS3LV02DQ has a user selectable full scale of ±2g, ±6g and it is capable of measuring acceleration over a bandwidth of 640 Hz for all axes [7].

The complete measurement chain is composed by a low-noise capacitive amplifier which converts into an analog voltage the capacitive unbalancing of the MEMS sensor and by three ΣΔ analog-to-digital converters, one for each axis, that translate the produced signal into a digital bitstream (Figure 3) [7].

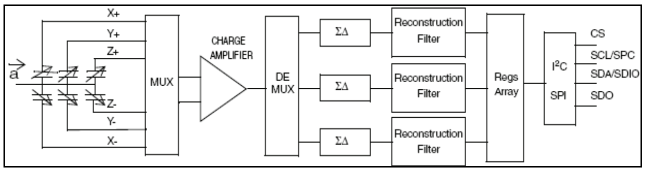

Fig.3. Block diagram of the three axes digital output linear accelerometer [7]

The gyroscope sensor is based on ADIS16100 - a complete angular rate sensor that uses Analog Devices' surface-micromachining process to make a functionally complete angular rate sensor with an integrated serial peripheral interface (SPI). The digital data available at the SPI port is proportional to the angular rate about the axis normal to the top surface of the package. This sensor is able to measure angular rates up to 300°/s while the sensitivity is equal to 0,244°/s/LSB, noise density – 0,10°/s/√Hz rms and bandwidth – up to 40Hz. Also an access to an internal temperature sensor measurement is provided for compensation techniques. Two pins are available to the user to input analog signals for digitization. An additional output pin provides a precision voltage reference [8].

IV. OPERATION ALGORITHM DESCRIPTION

The operation algorithm of the GPS/INS tracking system should be capable to:

- Receive all NMEA 0183 messages;
- Read and save the linear accelerometer data according to the selected update rate;
- Read and save the angular rate data, temperature value and scan the both gyroscope 12 – bit analog channels;
- Read and save the I/O port states of the master and slave microcontroller;
- Write all data to MMC/SD card.

Due to the very complex system tasks the operations are shared to the both microcontrollers. The master one reads the GPS navigation data, scans its I/O ports and writes the data to the MMC/SD card while the slave microcontroller controls the inertial block and sends the data on request.

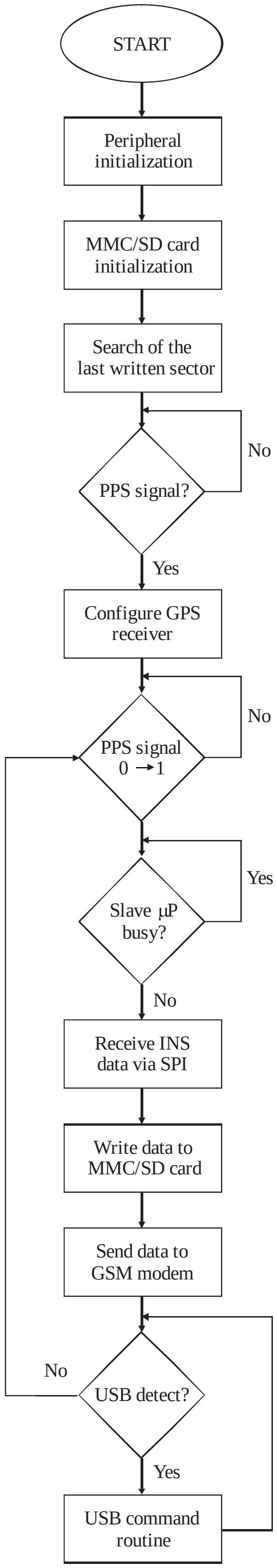

Fig.3. Master µP operation algorithm

The operation algorithm is closely connected with the total number of the navigation and inertial data, analog voltage values and temperature data. The stored data are divided at the following sections:

- Navigation data – up to 80 bytes. The RMC NMEA messages are allocated here;
- Inertial data (320 bytes). This space stores the inertial data (240 bytes) and gyroscope data (80 bytes). The update rate for the inertial block is equal to 40Hz;
- Analog data (100 bytes). The selected space stores the data from the build in 10 – bit ADC. The slave microcontroller may convert up to 5 analog channels while the master one – up to 6. The sampling rate may be independently chosen for each channel;
- Gyroscope peripheral data (6 bytes). The temperature and the analog channel values are updated ones per second.
- Reserved data (6 bytes).

The total amount of data is equal to 512 bytes. This allows reading and writing one MMC/SD card sector (512 bytes) every second, so the navigation data will be saved in the beginning of the sectors which allows a fast data processing.

The operation algorithms for master and slave microcontroller are shown at Figure 3 and Figure 4 respectively.

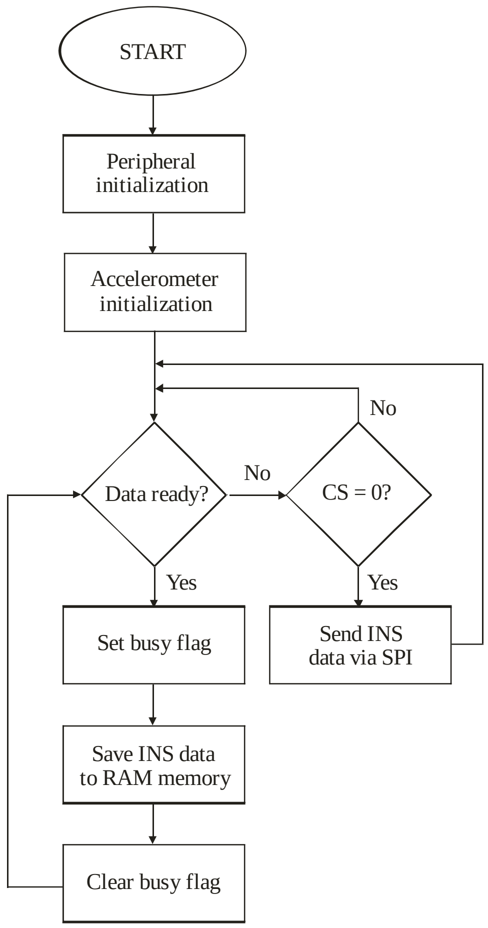

Fig.4. Slave µP operation algorithm

V. Conclusion

The used GPS receivers allow specifying the object location with very high precision – the location error is less than 10m, which is completely sufficient to solve the complex transportation tasks. In the presence of the optional inertial module the system solves the complex analysis of the moving object state – brake system status, vibrations, risky driving, etc. Therefore, the system may be used as a base for automatic obtaining of the actual information, formation of the statistic database, which described the transport traffic, optimal transportation routes calculation and optimal traffic management.

The additional information permit to reinforce the object control according to the following points:

- real – time object tracking;
- speed limitation control;
- driver style management;
- optimization of the transportation traffic.

The main system advantage consists in the integrated inertial sensors, which allows building motor vehicle event data recorder (MVEDR). MVEDRs collect, record, store and export data related to motor vehicle pre-defined events, so MVEDR is turned into the standard automotive system, which storage protocol is described at IEEE P1616.

VI. References

[1] Sivaram C. M. S. L., Kulkarni M. N., GPS-GIS integrated systems for transportation engineering, *IIT*, Mumbai

[2] Jurgen R. K., (1998) Navigation and Intelligent Transportation Systems, Pennsylvania: *Society of Automotive Engineers*, Inc.

[3] Grewal M.S., Weil L.R., Andrews A.P. Global Positioning Systems, Inertial navigation, and Integration, John Willey & Sons, Inc., 2001

[4] J. A. Farrell and M. Barth, The Global Positioning System & Inertial Navigation, McGraw-Hill, 1999

[5] Alonzo Kelly, Modern Inertial and Satellite Navigation Systems, 1994 Carnegie Mellon University, CMU-RI-TR-94-15

[6] Mohinder S. Grewal, Angus P. Andrews, Kalman Filtering: Theory and Practice Using MATLAB, 2nd Edition, Wiley 2001, ISBN: 0-471-39254-5

[7] www.st.com/stonline/products/literature/ds/10175/lis3l02dq.pdf - datasheet of LIS2LV02DQ linear accelerometer

[8] http://www.analog.com/en/prod/0,2877,ADIS16100,00.html – description of ADIS16100 angular rate sensor