Design and validation of a mobile embedded data acquisition system for monitoring automotive parameters in real time via Internet

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***Abstract*—This paper describes the development of a mobile embedded data acquisition system for monitoring parameters like speed, geographic position, slope of the road and exhaust emissions concentrations. These parameters will be acquired and monitored through a web interface using a low cost microcontroller, a GPS receiver and the GSM technology; so we could obtain conclusions of the vehicle´s behavior in different traffic circumstances, with this, we will propose a new methodology for developing driving cycles in Mexico, in order to reduce the large amount of environmental emissions induced by the actual traffic conditions in our country.**

***Index Terms*—Microcontroller, GSM/GPRS, Web Server, HTML, GPS, vehicle, driving cycles.**

I. Introduction

Previously we reported the design and development of a portable data logging system in order to build driving cycles for the metropolitan zone of the Mexico´s Valley [1]. Although this data logging system allowed us to obtain great conclusions about the traffic conditions, we consider necessary to improve the test procedure by monitoring the speed profile and the vehicle´s trajectory in real time, so we can determine the traffic density, then make a statistical analysis of the data through software numeric simulations and finally we can develop a mathematical model that represent the involved variables to estimate the amount of emissions and the final driving cycle model.

A driving cycle is a velocity profile plotted on a velocity-time graph; it represents a typical way of driving at the different streets and highways of a city, for this, it is necessary to consider factors like the vehicle technology, the traffic on the city ways, geographical and weather conditions. To create driving cycles, the first phase resides on the development of a representative cycle, regardless the length of the desired cycle into account, where representative refers to that all relevant influences that have to be included, similar to real-life [2]. Thereby, based on this last definition, the need to perform these real life influences, our new proposed methodology seems to be good criteria for determine driving cycles and exhaust emissions in cars, trucks and motorcycles that drive along the representative ways in Mexico´s Valley, such as small streets, primary avenues, roadways and highways. If we can know the driving profile of some trajectory under study, at real life and time conditions, then it´s possible to give out all useful information in order to characterize the trajectory, for example, at specific hours in which the amount of traffic is big, we can estimate parameters like: speed average, time of the trip, acceleration and exhausted emissions.

II. System Overview

A. Hardware Design

The hardware of the system has been built around the ATMega2560 8-bit microcontroller as the central process unit. All the devices and sensors are hooked up to it through several hardware interfaces and software protocols. Also, the microcontroller performs some mathematical operations in profit to give the useful parameters for the final study. The firmware of the microcontroller is written in C language including all the necessary functions to perform the communication with the external devices.

A Global Position System (GPS) receiver is used in order to obtain information about the ground speed of the vehicle, also the position is determined using latitude and longitude coordinates. It is important to mention that the receiver sends a raw character string that needs to be processed in order to obtain useful data, for example the position coordinates needs to be converted to [rad] format; for complete that purpose we developed a series of ANSI C string based functions in order to process the NMEA sentences given from the GPS satellites constellation. The use of a GPS receiver has some advantages for example the speed measurement turns on a non-invasive procedure because is not necessary the use of sensors or hardest instrumentation on the car, but in the other hand we can say that the use of the GPS receiver may present problems at the moment of a real time-acquisitions because of the GPS source errors that have a strong relationship with the weather or the line of sight in where the receiver is installed.

When a vehicle roads over a “strong” way like a big upslope, the engine´s load increase as well as the exhaust emissions, those kind of street ways are visible in most of the Mexico´s Valley and if we can identify them by using the real-time acquisition system, then it will be possible to determine more information about the ambient consequences. For determining the slope in the vehicle's trajectory we use a 3 axis digital accelerometer (Analog Devices™ ADXL345) based on the I2C protocol in order to establish communication with the microcontroller. By default, the output of the X axis is in g units, so, by computing the trigonometry equation given in Eq. 1, we finally have the slope information in [°].

$$\Theta = \sin^{-1}\left(\frac{A_{xout}[g]}{1[g]}\right) \tag{1}$$

Because the accelerometer readings fluctuate quite a bit and this throws a non-quantifiable uncertainty in the final compute, it´s necessary to remove these short-term fluctuations, it can be achieved by means of a Low-Pass Filter; this type of filter attenuates the higher frequencies of the signal, thus providing a smoother reading.

In order to determine the exhaust emissions concentrations, we use a miniature automotive exhaust gas analyzer (ANDROS 6600) that uses single-beam, Non-Dispersive InfraRed (NDIR) measurement technology, to characterize HC, CO and CO2 gas concentrations, whereas NOx and O2 gases are measured using electrochemical sensors [3]. The main advantage of this device is based on the portability of it, so, it is possible to install it on board the vehicle. This analyzer is interfaced with the microcontroller trough the RS-232 standard; a simple and comprehensive command set, provides the host with operator free control of the analyzer. One important function of the gas analyzers is to proof that the combustion in the vehicle´s motor has been normal, however, for development driving cycles, it is necessary to know the gases concentrations that the motor emits in different circumstances like: acceleration, cool start, hot start, stops and constant speed.

The the Global System for Mobile Communications (GSM) / General Packet Radio Service (GPRS) modem, allows us to monitor all the read parameter through internet using the cell network and its 3G band. The modem is interfaced with the central processing unit via the Universal Asynchronous Receiver Transmitter (UART) module; once the modem was hardware hooked-up, we programmed the necessary AT commands for establish HTTP (Hyper Text Transfer Protocol) communications and all the settings necessary for establishing communication with the remote server.

In fact, the use of the GPRS cell network will allow us to monitor the acquired data, sometimes during the vehicle´s trip this network may be not available, so we decided to use a microSD card that perform a backup module for the data, this card is connected to the microcontroller with the Serial Peripheral Interface (SPI) protocol. The data file stored in the microSD is compatible with FAT16/FAT32 formats, so, it can be loaded on a Personal Computer or Laptop.

With the large amount of data that would be acquired by the system, is important to perform another operation, a synchronization stage. This process gives to the system the necessary sample rate in order to take data at specific time, so the final information can be useful in further analysis; the selected device for this task is a digital Real Time Clock (RTC) governed by the microcontroller. One more function that RTC performs is to attach time and date to the acquired values, this way; a primary data organization is completed in the acquisition process.

A Graphic Liquid Crystal Display (GLCD) with touchscreen performance was installed in the system, this device has two important tasks, in one side it provides the user capability to select from a menu the several functions of the system: initialization, configuration or visualization, in the other side it is possible to verify the status of each one device, so, in case of fault the user can know it in order to correct it.

For the hardware fabrication we use Surface Mounted Device (SMD) technology, with this technique we can improve the size of the system, about 10[cm] x 12 [cm] thus giving portability and non-invasive test procedures. Other benefit of the SMD lies in the fact to reduce electromagnetic noise (EMN) which can affect the measurement process because of the interference vulnerable devices, i.e. GPS receiver and GSM/GPRS modem. In Fig. 1 we present the designed Printed Circuit Board (PCB) layout.

Finally, in table 1 we resume all the parameters and devices that compose the proposed mobile embedded system.

B. Web Interface Development

As we said previously, the data will be acquired via Internet. For this stage, we developed a client-server architecture system. Once the microcontroller, used as the client, processes the sensor data, verifies that the modem is connected to the cellular network by an Access Point Name (APN) provided by a mobile technology company in Mexico. Using Hyper Text Transfer Protocol (HTTP) and its basic methods for data package interchange between devices: POST (in the side of

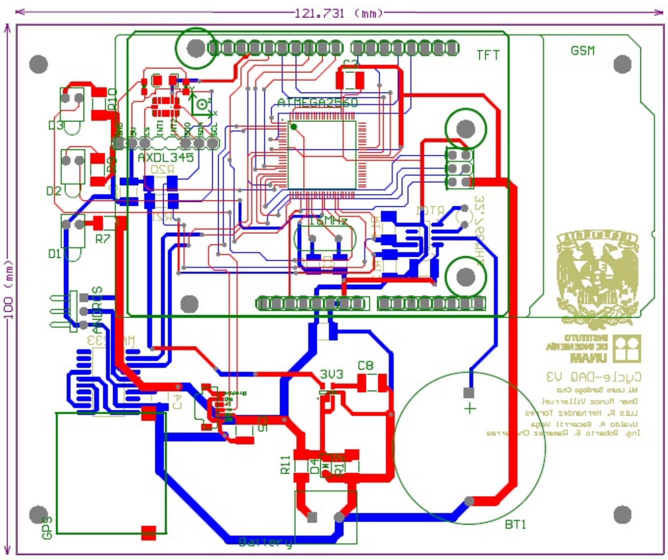


Fig. 1. PCB layout.

Device	Measured parameter(s)
GPS Receiver	Lat./Long, Speed, Distance
3 axis accelerometer	Slope sensor
Gas Analyzer Bench	CO, CO_2, HC, NO_x and CO_2
MicroSD Card	Data backup system
Graphic Touch Display	Data display and user menu
GSM/GPRS Modem	HTTP Web Service
Real Time Clock	Synchronization

TABLE I
SYSTEM DEVICES FEATURES

the microcontroller firmware) and REQUEST (in the side of the server), the client sends the acquired to the server via a comma separated string, through GSM/GPRS.

The server based on Apache server contains a Hyper Text Markup Language (HTML) web page, in where we programmed a socket using PHP language to receive the string. Once it is successfully received, the PHP script performs once the operation to split the string using the "explode" method, and then a cast procedure is used to convert the string data to an integer or double type for each variable.

For storing the data, the use of a database is needed, when the string is processed it´s necessary to perform a connection between the web page and the data base by using JavaScript and MySQL language. By INSERT and QUERY operations on the data base, the web page at that time, is refreshed and shows a real time plot of speed-time. In order to give that graphic representation of the speed we use the High Charts™ API, which is a charting library written in pure JavaScript, offering an easy way of adding interactive charts to the web site [4]. In the other hand the site also presents the trajectory of the vehicle, i.e. latitude-longitude graph, which is refreshed at real-time, thus achieving have a view of the vehicles behavior and ubication. In this last operation, we used the Google Maps API, so we can insert the geographic coordinates to it using the PHP and MySQL operations. Figure 2 shows the complete block diagram of the proposed system.

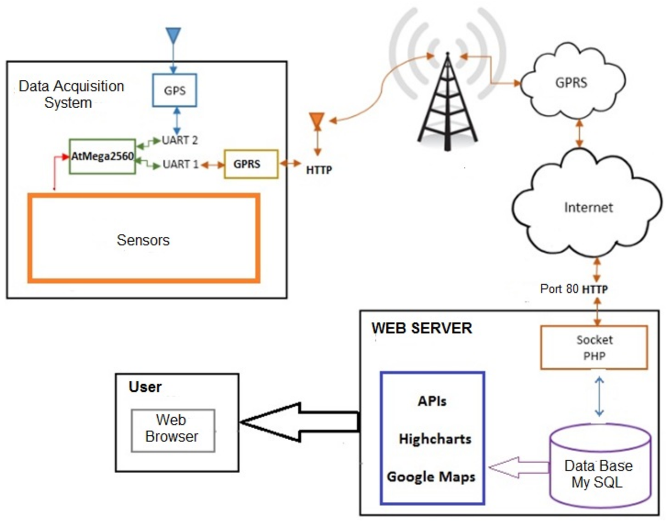


Fig. 2. System block diagram.

One more feature of the designed web site resides on the capability to download a spreadsheet file that contains all the acquired data just clicking a button. Whit this function is possible to have an historical set of files as representative useful information for the different ways of Mexico´s Valley.

III. DATA ANALYSIS

When data are stored in the data base, it is necessary to perform a statistical analysis of them [5]. The first step consists into identify the useful micro-trips, i.e. the most representative trips that a vehicle follows, this micro-trips are divided in: semi-urban, urban and highway and are included at different times of day: morning, evening and night, so them establish several kinematic sequences, this stage is shown in Fig. 3.

Once the micro-trips are taken-off as shown in Fig. 2, the data presents several fluctuations, in order to obtain smooth data we perform a Moving Average Filter (MAF) which attenuates data fluctuations, thus gives the possibility to show more clearly the trend in the speed profile. The MAF uses a specific number of data points (previous), averages them, and use the value as a point on the line trend as shown in Fig. 4.

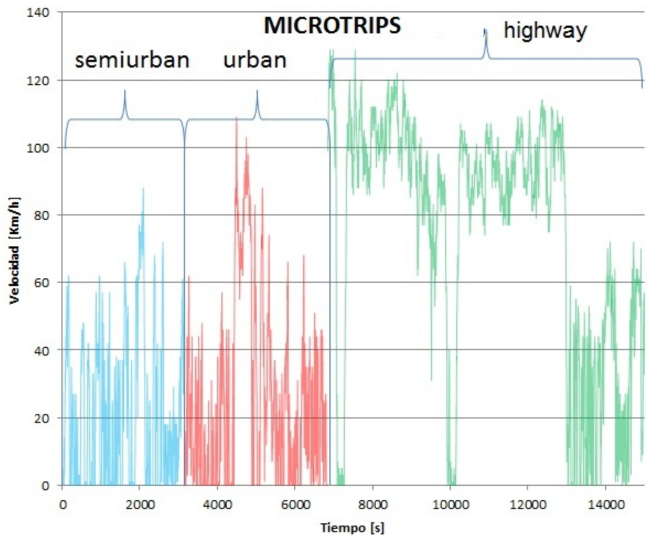


Fig. 3. Micro-trips obtained from statistical analysis.

Finally, we use a vehicle simulator in order to simulate the developed drive cycle, this simulator provides information of the most important parameter in a vehicle´s trajectory: engine torque, Power Absorption Unit (PAU), acceleration, fuel consumption, load percentage and exhaust emissions. In Fig. 5 is shown a plot that represents the percentile operating points of a vehicle versus the vehicle speed, these were obtained under the micro-trips conditions.

As a final result, we can compare the obtained data with the real time acquired data by the system in order complement our proposed methodology.

IV. TEST AND RESULTS

Finally, we present the test procedures of the system. The system was installed in two types of vehicles; one was a

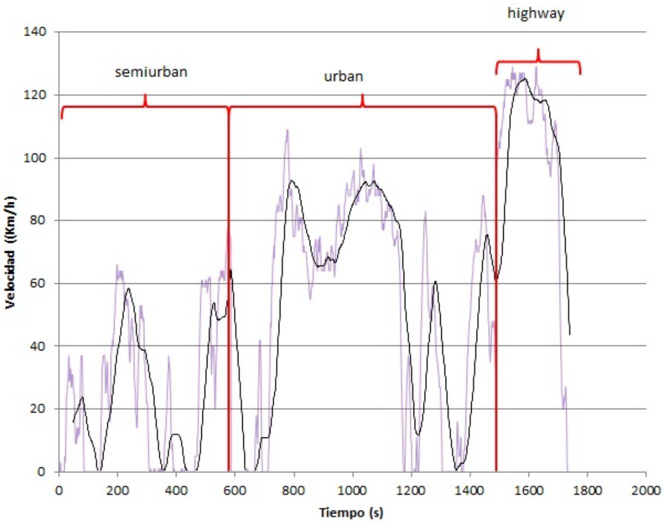


Fig. 4. Moving Average Filter Applied to the micro-trips.

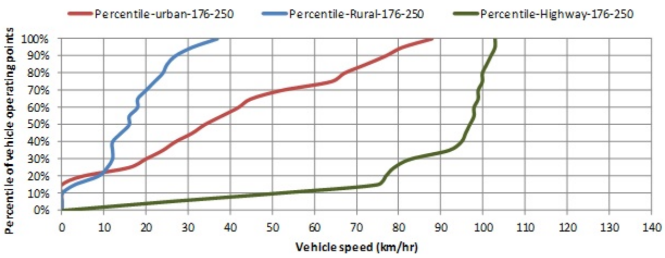


Fig. 5. Percentile of vehicle operating points versus speed.

compact internal combustion engine vehicle, second an electric vehicle as shown in Fig. 6. The use of an electric vehicle is based in the fact of determine the yield of the battery under real life traffic circumstances, with the acquisition procedure it was possible to say when the use of a electric vehicle in our city is recommended and when is not.

These tests allow us to verify and validate the well useful of the system. Figure 7 shows the web interface with collected speed plotted data and the vehicle´s trajectory at real time.

One more validation test was the download of the collected data organized on a spreadsheet; Fig. 8 shows the resulting file after the followed route by the vehicle.

V. Conclusions

The mobile embedded data acquisition system designed in collaboration by the Emissions Control Laboratory and the Engineering Institute from the National Autonomous University of Mexico, is a novel complete system in our country that to provide all the necessary data about automotive parameters. It combines all new instrumentation techniques using powerful tools that nowadays are present in the world, such as Internet. The benefit of the remote sensing and data acquisition gives to the research group strong bases to propose new driving cycles and quality air test procedures, in order to improve the actual related norms in our country.

Fig. 6. System installed on an electric vehicle.

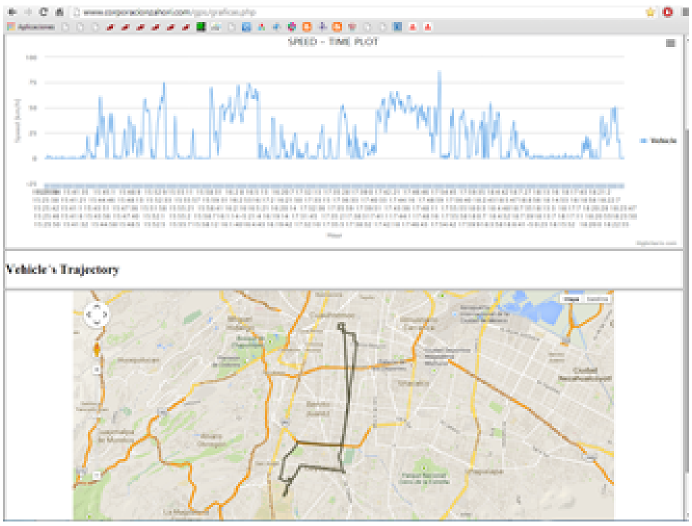
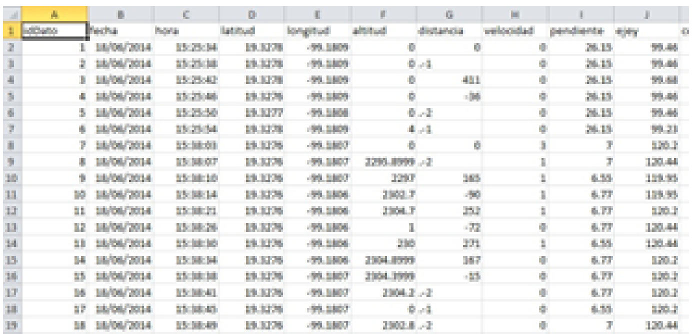


Fig. 7. Internet web site with real-time displayed data.



idDato	fecha	hora	latitud	longitud	altitud	distancia	velocidad	pendiente	ejey
1	18/06/2014	15:25:34	19.3278	-99.1809	0	0	0	26.15	99.46
2	18/06/2014	15:25:38	19.3278	-99.1809	0	-1	0	26.15	99.46
3	18/06/2014	15:25:42	19.3278	-99.1809	0	411	0	26.15	99.68
4	18/06/2014	15:25:46	19.3276	-99.1809	0	-36	0	26.15	99.46
5	18/06/2014	15:25:50	19.3277	-99.1808	0	-2	0	26.15	99.46
6	18/06/2014	15:25:54	19.3278	-99.1809	4	-1	0	26.15	99.23
7	18/06/2014	15:38:03	19.3276	-99.1807	0	0	1	7	120.2
8	18/06/2014	15:38:07	19.3276	-99.1807	2295.8999	-2	1	7	120.44
9	18/06/2014	15:38:10	19.3276	-99.1807	2297	165	1	6.55	119.95
10	18/06/2014	15:38:14	19.3276	-99.1806	2302.7	-90	1	6.77	119.95
11	18/06/2014	15:38:21	19.3276	-99.1806	2304.7	252	1	6.77	120.2
12	18/06/2014	15:38:26	19.3276	-99.1806	1	-72	0	6.77	120.44
13	18/06/2014	15:38:30	19.3276	-99.1806	230	271	1	6.55	120.44
14	18/06/2014	15:38:34	19.3276	-99.1806	2304.8999	167	0	6.77	120.2
15	18/06/2014	15:38:38	19.3276	-99.1807	2304.3999	-15	0	6.77	120.2
16	18/06/2014	15:38:41	19.3276	-99.1807	2304.2	-2	0	6.77	120.2
17	18/06/2014	15:38:45	19.3276	-99.1807	0	-1	0	6.55	120.2
18	18/06/2014	15:38:49	19.3276	-99.1807	2302.8	-2	0	7	120.44

Fig. 8. Spreadsheet file as the final result.

VI. Acknowledgment

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