

Modular Multi-Channel GPS Environmental Logger

P. Kot^{*1}, J.D. Cullen¹, M. Al Jader¹, A. Shaw¹, A. Mason¹, A. Al-Shamma'a¹, T. Cockcroft², S. Jackson²
and M. Cleave³

¹Built Environment and Sustainable Technologies (BEST) Research Group, Liverpool John Moores University,
15-21 Webster Street, Liverpool, L3 2ET

²Stagecoach Merseyside & South Lancashire, Gillmoss Garage, East Lancashire Road, Liverpool, L11 0BB

³Merseytravel, PO Box 1976, Liverpool, L69 3HN

*Patrykkot.90@googlemail.co.uk

Abstract— In this paper, an experimental methodology for the modular multi-channel GPS environmental logger is presented, and the preliminary real route test is demonstrated. The paper concentrates on methods used for transmitting real time data from electrochemical analyser and GPS unit into Graphical User Interface. Test was made in environmental conditions and route of the vehicle was plotted on the map with the data from emission analyser. All results are presented and concluded.

Keywords: GPS; Arduino; Logger; Environment; Combustions; Quintox; WGS84; OSGB36

I. INTRODUCTION

Recently there has been undertaken a huge amount of research about better performing engines which could increase the speed, power and economy of the vehicles. Unfortunately, that research gave the rise of pollution evaluated into environment [1]. Gas emissions is unhealthy for people, animals and environment. Diesel engine exhaust emissions are a mixture of different gases, vapours, liquid aerosols and substances made up of particles. They contain the products of combustion such as carbon, nitrogen, water, carbon monoxide, aldehydes, oxides of nitrogen, oxides of sulphur and polycyclic aromatic hydrocarbons. The carbon particle or soot content varies from 60% to 80% depending on the fuel used and the type of the engine [2]. Most of the contaminants are absorbed onto the soot. Petrol engines produce more carbon monoxide but much less soot than diesel engines. There are some factors that may affect the composition of diesel fumes. The quantity and composition of diesel fumes may depend on the quality of diesel fuel used, the type of engine (standard, turbo), state of engine tuning, the fuel pump setting, the engine temperature and whether the engine has been regularly maintained. Breathing in diesel fumes can affect health and cause irritation of eyes or respiratory track. There is some evidence that exposure to fumes could lead to coughing, chestiness and breathlessness [2]. According to BBC News the exhaust fumes from a car or lorry's engine contain a large number of chemicals. Once exhaust emissions are released into the air, emissions are breathed in and transported to all the body's major organs. BBC wrote "It's estimated that air pollution - of which vehicle emissions are the major contributor - is responsible for 24,000 premature deaths in the UK every year.

Many of these deaths are due to asthma, bronchitis and other respiratory diseases - all of which are known to be aggravated by exposure to car fumes." [3]. Nowadays it is important to reduce the amount of emissions from all types of vehicles. In addition, it is impossible to monitor the combustions gases from moving vehicles. The present technology used to measure the level of gas emissions from vehicles requires using gas analyser and vehicle has to be conducted in garage to get required readings. Data provided by this technology is not accurate because it is not possible to imitate the exact conditions on the different types of surfaces. In addition, it is time consuming as the technique requires testing each vehicle individually by special stations. To solve this problem a new technology is required which allow remotely monitoring of combustions gas from a vehicle and overlaying this into geographic information system. System will be able to draw the route of the vehicle on the map and show the combustion gasses level at specific locations. This will enable observing the places where vehicle emits the highest amount of emissions.

II. LITERATURE REVIEW

A. Types of gas emissions from combustions

Exhaust emissions are major contributors to environmental pollution. Classic emissions contain gases such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). Also emissions contain all criteria pollutants such as carbon monoxide (CO), total nitrogen oxides (NO_x), sulphur dioxide (SO₂), non-methane volatile organic compounds (NMVOC) and particulate matter (PM) are the other major components. Toxic compounds include benzene, butadiene, aldehydes and lately- ethers, methanol.

- Carbon Monoxide

Carbon monoxide is highly toxic gas, which binds strongly to the iron atoms in hemoglobin, the principal oxygen-carrying compound in blood. CO cannot be released from hemoglobin easily so, the body's hemoglobin becomes saturated with carbon monoxide and is rendered incapable of carrying oxygen to the body. This reduces amount of oxygen taken up to brain, which could result in brain damage or even a death from anoxia [4].

- Nitrogen Oxides

Nitrogen oxides are a group of highly reactive gasses, which their primary source of exist are in vehicle's emissions. NO_x can contribute to formation of photochemical zone known as "Smog" and have health consequences. Therefore, nitrogen oxides can lead to acid rain and contribute to global warming [4].

- Sulphur Dioxide

Another pollutant is sulphur dioxide (SO₂), colourless gas that is irritating to the lungs and is described as smelling of burning sulphur. It could cause breathing difficulties and also may cause nausea and vomiting. It is toxic to plants and could cause acid rain when it reacts with moisture in the air. This gas is one of the main chemicals that cause acid rain. In UK the main source of sulphur dioxide are power stations and refineries. Sulphur dioxide is a common air pollutant. It is produced naturally by active volcanoes and forest fires [5].

B. Different gas analysis techniques

- Infrared gas analyser

Rapid IR filter spectrometer can be used to measure the concentration of various exhaust gas components simultaneously with a time resolution of five milliseconds. An infrared gas analyser measures trace gases by determining the absorption of an emitted infrared light source through certain air samples. Infrared gas analysers usually have two chambers. One is a reference chamber while the other chamber is a measurement chamber. Infrared light is emitted from some type of source on one end of the chamber, passes through a series of chambers that contains given quantities of the various gases in query [6].

- Flue gas analyser

Another method to measure the gas emissions from the vehicle exhaust is flue gas analyser. This type of gas analyser draws gases directly from the flue. Readings from flue gas analyser are accurate for Petrol and Diesel but unfortunately, this type of analyser will not provide accurate readings for an LPG. Some of the modern devices have built in Bluetooth device but they require constant assistance of an operator to run the device [7].

- Electrochemical analyser

The last method of gas analysis technique is electrochemical sensor for sensing a gas dissolved in a liquid. The sensor includes a probe that has a cylindrical body and a rounded face. A working electrode, a reference electrode and an auxiliary electrode are buried in the probe body and have distal ends reaching conformingly to the face. A pulsed polarizing voltage is impressed between the auxiliary electrode and the working electrode for polarizing the probe, and a capacitor is provided for storing the charge, which flows to the working electrode during periods of polarization. The concentration of the dissolved gas is determined by measuring the voltage across the capacitor. The most common technique of measuring and analysing the gasses is by using IR gas analyser but this equipment is expensive. In this project, the best way to analyses emission gases is electrochemical gas

analyser, which can provide accurate readings. In addition, electrochemical gas analyser has better ability to connect the Arduino board rather than other types of gas analysers. Arduino device will be used to hold and transmit data to the Graphical user interface. The device that will be used to analyse an emission gases is Quintox Kane KM9106. To take sample of flue gas it is essential to wait once the automatic calibration procedure has been completed and the specific fuel has been selected, the probe can be inserted into the desired sampling point. To achieve most accurate results it is essential to make sure that the sampling point is located at least two flue diameters downstream of any bend and that the probe tip is in the center of the flue (this is normally the point of the hottest temperature). With balanced flues and other domestic units the probe should be positioned far enough into the flue so that no air can 'back flush' into the probe. The probe depth stop cone provided with the instrument allows the probe to be used in holes whose diameters range from 8 mm to 21 mm [8], [9].

C. Global Positioning System

- Sure Electronic GP-GS010_ver2.0

The device used for tracking vehicle was Sure Electronic GP-GS010_ver2.0. This device use Global Positioning System to determine the precise location of the vehicle. This model has sensitive MG613S module and supports NMEA 0183 V 3.01 protocol. There is a possibility to send different information from the GPS. This project used data called "Recommended Minimum specific GNSS Data" (GPRMC). The example of incoming data is presented below and explained in Table1 [10].
\$GPRMC,161229.487,A,3723.2475,N,12158.3416,W,0.13,30 9.62,120598,,*10 where:

TABLE I. GPRMC DATA FORMAT.

Name	Example	Description
Message ID	\$GPRMC	RMC protocol header
UTC Position	161229.487	hhmmss.sss
Status	A	A= data valid or V= data not valid
Latitude	3723.2475	ddmm.mmmmm
N/S Indicator	N	N= north or S= south
Longitude	12158.3416	dddmm.mmmmm
E/W Indicator	W	E= east or W= west
Speed Over Ground	0.13 knots	

The data from the GPS unit is presented in WGS84 format, but UK mapping data from the Ordnance Survey is in OSGB36 format.

These are explained briefly below:

- World Geodetic System 1984 (WGS84)

The datum used for GPS positioning is called WGS84 datum is a set of conventions, adopted constants and formulae.

It consists of a three-dimensional Cartesian coordinate system and an associated ellipsoid so that WGS84 positions can be described as XYZ Cartesian coordinates or latitude, longitude and ellipsoid height coordinates. The ellipsoid is designed to best fit the Geoid of the Earth as a whole. This means it generally doesn't fit the Geoid in a particular country as well as the non-geocentric ellipsoid used for mapping that country [11].

- Ordnance Survey Great Britain 1936

OSGB36 is the national Grid of Great Britain (England, Wales and Scotland). It is a horizontal coordinate system, which consists of a traditional geodetic datum using the Airy ellipsoid. The coordinate system in OSGB36 is important because it is defined as a flat surface and hence is able to describe positions and features on British maps [11].

The difference between WGS84 and OSGB36 can be seen in Figure 1 [11]. WGS84 is a spherical model, shown in flattened form using the solid curving lines, the dotted lines are the true (defined as flat) representation of OSGB36.

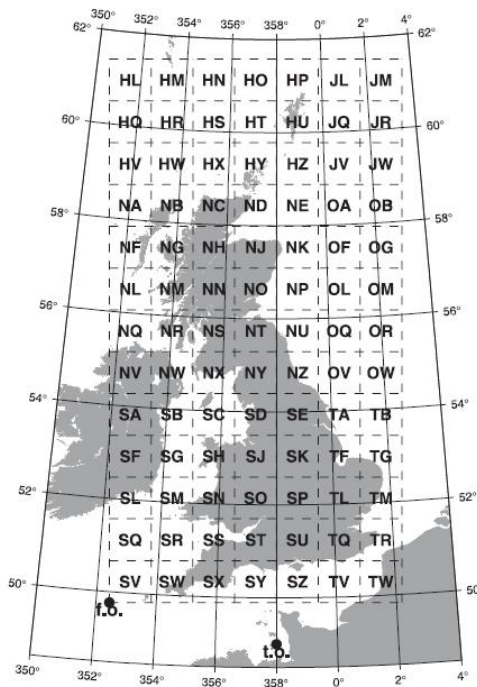


Figure 1. Comparison of WGS84 (global) and OSGB36 (regional) ellipsoids.

III. METHODOLOGY

The main board which was responsible for collecting data from all devices and transferring data to the interface device was selected. Board which has been used was Arduino Mega 2560. This board is power supplied by 5V. Serial ports have been used to communicate with other devices. This board has an opportunity to get data from three different devices at the same time. Microcontroller on this board is Atmega 2560 with Arduino bootloader which allows programing chip via open source Arduino Software. The power to the device could be supplied from car cigarette lighter socket or additional power

supply bank. This project has been done in parts. Firstly, connection between Arduino Mega and Quintox has been setup. To connect those two devices it was essential to use MAX RS232 TTL converter to be able to connect RS232 cable from Quintox unit to Arduino Mega. To create serial communication it was essential to write the code. Serial Monitor in Arduino Software allows observing incoming data on the screen. Secondly, connection between Arduino and Bluetooth has been set up. This connection require additional voltage regulator because Bluetooth device operates on 3.3V. To be able to communicate between Arduino Mega and Bluetooth it was essential to modify the actual code. At this point of project Arduino Mega was able to transmit data from Quintox unit and transmit it via Bluetooth to Interface. The last device which has been connected to Arduino Mega is GPS module. The chosen model is Sure Electronics GP-GS010 ver2.0 Model. This model is responsible for tracking vehicle during test. GPS model has to be connected to Arduino Mega which transmits data from GPS to the graphical user interface. This GPS transmits different lines of data. The most significant data for this project is GPRMC. This line of data gives important information about latitude, longitude, if there is data valid or if there is no data and also the speed of the vehicle in knots. Complete set up of device is presented on Figure 2.

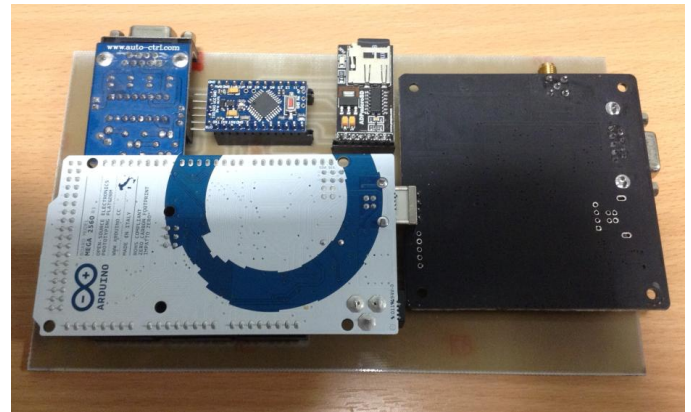


Figure 2. Device final configuration

Graphical User Interface has been created in LabVIEW software. This program displays parameters from GPS data, displays them on the map and also presents the data from the Quintox unit in the table. Speed of the vehicle is provided in mph and km/h. Print screen of the GUI is shown on Figure 3.

The vehicle test has been made in the environmental condition and the route of the test has been presented on Figure 4 [12]. The average speed of the vehicle was 30 mph not including motorway where the speed increase to over 40mph.

Test on this route has been done multiple times to assure repeatability of the measurements. The route was 28km and takes approximately 1 hour. There are different methods to determinate the coordinates of the vehicle location. WGS84 and OSGB36 has been compared at Figure 5.

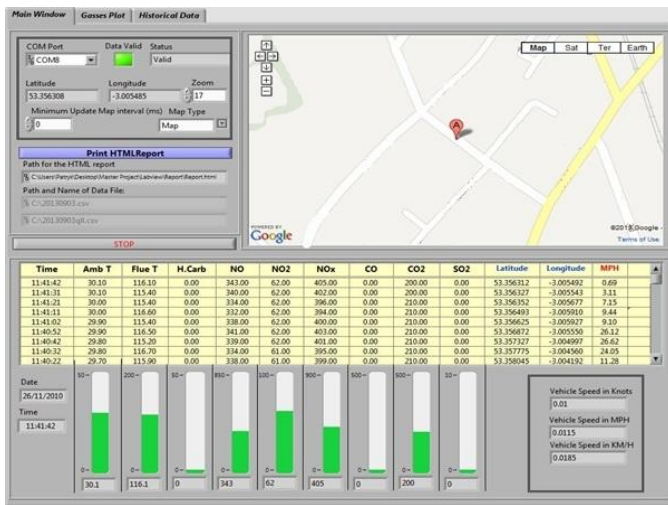


Figure 3 Graphical User Interface



Figure 4 Vehicle test trace

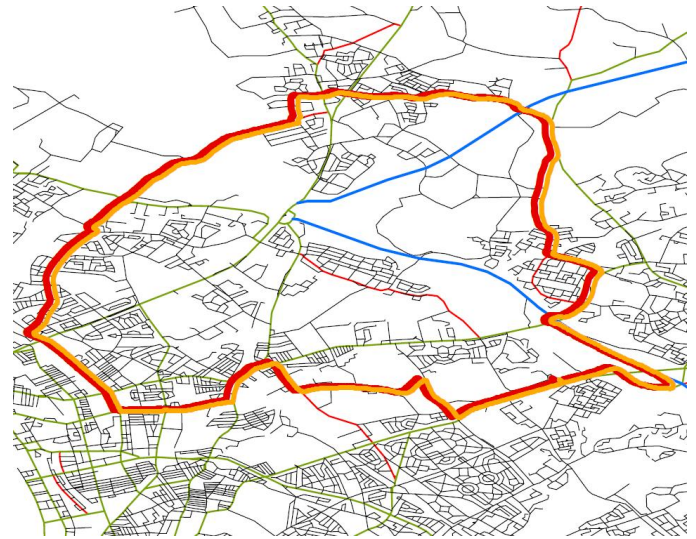


Figure 5 Comparison of WGS84 and OSGB36 on vehicle route

Orange line presents OSGB36 coordinates system and WGS84 is represented by red line. It is noticeable that there are changes between those methods. This is cause by different ellipsoid types used in both methods. The aim of this project is to be able to monitor the combustion gasses at real time. GPS module transmit signal every second and Quintox system transmit data every ten seconds results has been presented on Figure 6.

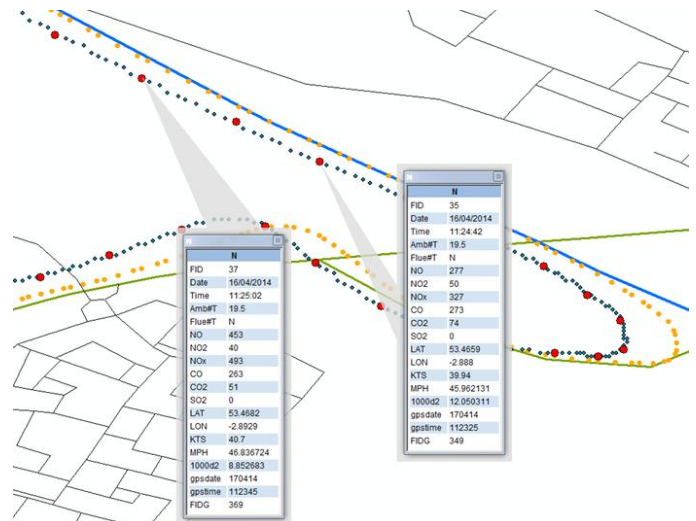


Figure 6 GPS (Blue dot) and Quintox data (Red dot) presented on the route

Figure 6 enable analysing vehicle emissions at certain location and time. Multiple test allow receiving more accurate results. By performing simple analysis of the latitude and longitude and comparing them to a known fixed point on the circular route, we can create a distance plot from this known point, see Figure 7.

$$\text{Degree Distance} = \sqrt{(\Delta \text{lat}^2 + \Delta \text{lon}^2)} \quad (1)$$

Degrees distance (1) are arbitrary units since longitudinal values correspond to decreasing distances as latitude increases.

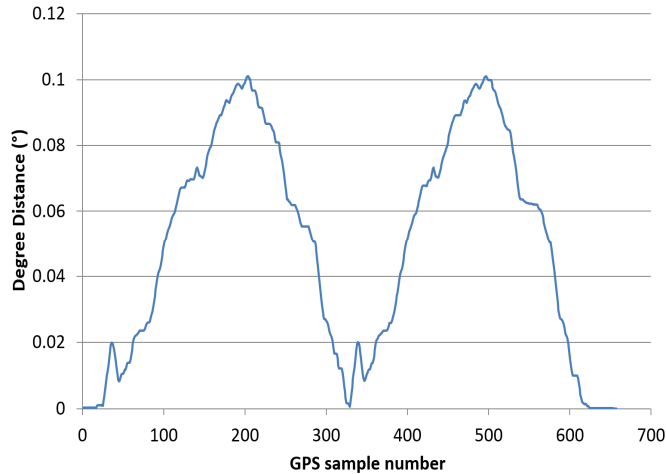


Figure 7 Multiple tests of vehicle emissions at the same route.

This plot shows the degree distance from the specified fixed point (the Start/stop point of each loop). When the distance is zero it means the loop has been completed, and the next loop starts from this point. This enables the analysis of the different loops to be automated, since at these zero points the data can be separated automatically into different files for analysis. The routes of tests have been the same but as it is possible to see there are slight differences. These also enable the identification of route characteristics since any major change to the route (roadworks, accidents and traffic load) will change the shape of this plot.

IV. CONCLUSION

System has been tested and the result are promising. Data is transferred from the electrochemical analyser and GPS into the Arduino board that enable to transmit the data to Graphical User Interface. Data is analysed and plotted on the map. All operations are done in real time environment which allow to collect accurate results of exhaust emissions of the certain vehicle.

V. ACKNOWLEDGEMENT

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