Ecological predictive maintenance in urban fleets

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Abstract: - Motor vehicles are one of the largest sources of air pollutants worldwide. Several studies had concluded that particulate matter (PM) are responsible for some respiratory, cardiovascular, lung diseases, increasing in death from heart and may cause lung cancer. Others studies refer that PM are one of the most important pollutants of the Diesel vehicles. Another important pollutant from the vehicles emission gases are the nitrogen oxides (NO_x) that are produced from the burning of engine fuel. In developed countries, road transports are responsible for about 50% of all NO_x emissions that also have an important contribution for the formation of acid rain. At same time, these pollutants combined with hydrocarbons contribute to form low level ozone pollution. Other pollutant is the carbon monoxide (CO) that is generated from the incomplete burning of engine fuel. The road traffic produces about 90% of all CO emissions in developed countries. When it is inhaled it reduces the oxygen carrying capacity of the blood and can cause headaches, fatigue, stress, respiratory problems and, at high levels, may cause death. At last, it arises the hydrocarbons (HC) that are compounds of hydrogen and carbon and are present in petrol and diesel. In developed countries, road traffic is responsible for about 35% of all HC emissions, which react with nitrogen oxides to produce a number of pollutants, including ozone, which can affect human health and also causes plant damage. Benzene itself can cause some forms of cancer.
On-road remote sensing can address the problem of inter-vehicle differences by quickly and cheaply measure the emissions of large numbers of vehicles. These measurements can be used to define the contribution of total vehicle emissions to the air pollution in a specific area and to identify groups of vehicles, even specific vehicles and operating conditions that result in very high emissions. These data provide important information for the design of mitigation strategies.
These are the subjects that are treated in the paper and specifically the related to urban transports. It also is analysed the effect of Vehicle Specific Power (VSP) on emissions detected, that represents the effect of engine load on emissions. Another subject that is treated, with value-added in innovation, is the use of Hidden Markov Models (HMM) to determine the vehicle state, where the models incorporate a double stochastic process, with a non visible stochastic process, because it is not seen but can be observed through another stochastic process that produces the sequence of observations that, in this case, are pollutant emissions. The time series of collected data corresponds to inputs to an HMM for dysfunction classification.

Key-Words: - Ecological; environmental; maintenance; predictive; degradation; exploitation; HMM; pollutant emissions; particulate emissions.

1. Introduction

On-road remote sensing is an efficient method for determining the tailpipe emissions from passing vehicles [1]. While routine inspection and maintenance programmes, commonly referred to as ‘gases and smog tests’, measure emissions from single vehicles every year for limited operational conditions, remote sensing offers the opportunity to individually sample thousands of vehicles in a time lapse of days with new technologies [2]. Furthermore, the measurements can be repeated at a specific location at different times, separated by days to years, to assess temporal changes in the vehicle emissions for a specific area. The European Commission had launched a program of inspection of in-use cars in order to attain minimum emissions of pollutants and optimum energy efficiency [3]. In all these cases, a snapshot of the exhaust emission rates of the on-road vehicle fleet at the time of measurement is obtained. These measurements can be used to define the contribution of total vehicle emissions to the air pollution in a specific area and to identify groups of vehicles, which result in very high emissions. These data provide important information for the design of mitigation strategies.

Until nowadays vehicle exhaust remote sensing systems have only measured exhaust gases. Commercial systems are available for nitrogen oxide (NO), hydrocarbons (HC), carbon monoxide (CO) and carbon dioxide (CO_2).

The maximum power output of an engine is achieved when the mixture is richer than stoichiometric, whereas best fuel economy and minimum CO emissions are achieved when the mixture is slightly lean. Higher levels of CO and HC emissions are associated with rich mixtures, whereas NO_x (mainly NO and a smaller proportion of NO_2) emissions peak happen when the mixture is slightly lean.

A potential application of remote sensing is a "surveillance" component on inspection and maintenance programs, either to detect high emitters or direct them to an Inspection and Maintenance (I/M) programs, or to detect clean vehicles to exempt them from I/M testing.

Having identified an on-road gross emitter, we need to motivate and verify proper repair. Motorists could go to an unscheduled I/M test that would simulate real-life driving conditions (loaded mode as opposed to idle mode).

Our goal is to monitor the emissions to evaluate the overall effectiveness of inspection and maintenance programs and identify the high emitting vehicles for inspection or enforcement purposes.

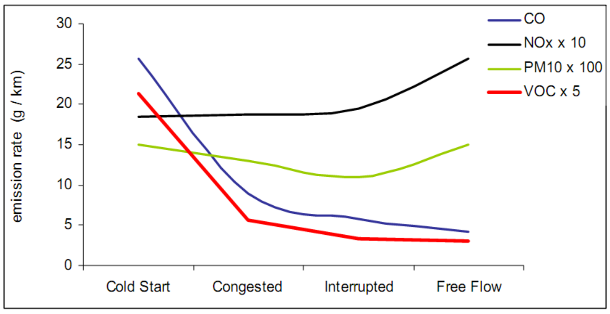

Fig.1 - *The relative differences in emissions under different driving conditions*

One problem is the quantification of real-time particulate emissions during transient operation and its association with maintenance needs (Fig. 1). In this paper it is described a continuous measurement remote sensing methodology with a fast response.

2. Remote sensing and health

Emissions for all four gaseous pollutants are dominated by a small number of gross emitting vehicles. The "most polluting" 10% of vehicles are responsible for about 60% of CO emissions, 60% of Smoke and HC emissions, and about 50% of NO emissions. With respect to the adverse human health effects of NO_x, NO_2 is the species of primary concern. On the other hand, the cleanest 60% of the fleet contribute less than 10% of the total emissions for each pollutant [4].

PM is known to contribute to regional haze, global climate change, air toxics and can also be important for acid rain. Atmospheric particles have been long recognised with adverse effects upon health and environmental impact. The health consequences of these particulates depend on their ability to penetrate and deposit in the respiratory system. Generally speaking, the smaller the particle, the deeper it can travel through the respiratory system to the lungs, and most likely to be responsible for adverse health effects. Particles greater than 5 to 10 µm are screened out quite easy at the upper inhalation system. Particles between 1 and 2 µm size range penetrate the alveoli and bypass the upper respiratory tract. Those particles undergo deposition at places where they can do the most damage. Particles with diameter less than 1 µm are considered to be the most dangerous.

Even low concentrations of PM_{10} have been related with increased mortality numbers, as well as high numbers of hospital admissions for aggravate asthma or other respiratory illnesses and cardiovascular disease.

Emission control seems to be a double-edged sword; however, reductions in PM result in increased total NO_x emissions. Their relationship can be visualized as being relatively hyperbolic as shown in Figure 2.

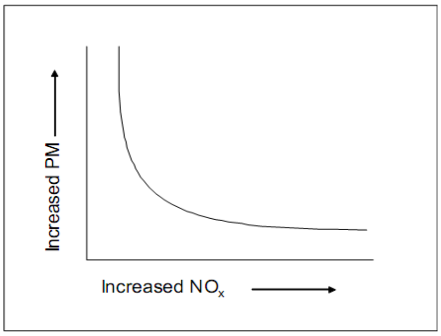

Fig. 2 - *Relative relationship between NO_x and PM emissions*

The third group of pollutants is the noise that is increasingly recognized as a serious health hazard as well as a nuisance. The World Health Organization (WHO) recognizes community noise, including traffic noise, as a serious public health problem. The effects must be considered in the European context where half of citizens live in noisy surroundings, and a third experience levels of night time noise that disturb sleep. There is a general consensus about the noise levels which cause health impacts. However, it is accepted that:

- Environmental noise above 40-50dBA Leq is likely to lead to significant annoyance.
- Noise levels between 65-70 dBA Leq may be risk factors for school performance and ischemic heart disease.
- Outdoor noise levels of 40-60 dBA Leq may disturb sleep.
- Traffic noise of 70dB(A) may cause hearing impairment.

The synthesis of impacts is shown in figure 3.

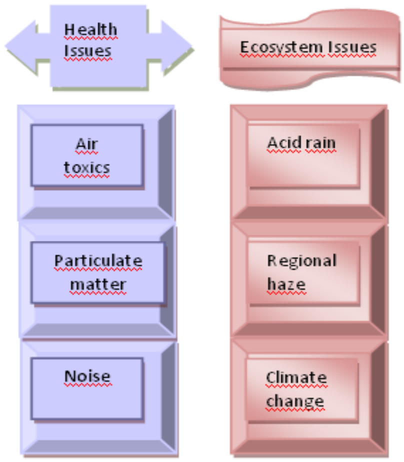

Fig. 3 - *Transports health and environmental impacts*

The averaging time for each pollutant concentration varies according to the assessment criteria defined by the usual ambient air quality standards and guidelines, i.e. PM_{10} is assessed on a 24-hour basis, NO_2 is assessed on a 1-hour basis, and CO is assessed on an 8-hour basis.

The health effects examined in several studies are premature mortality and various types of morbidity including bronchitis and other types of chronic obstructive pulmonary disease, hospital admissions due to cardiac and respiratory ailments and restricted activities days. Once the concentrations are determined, the health effects can be assessed.

3. Remote sensing technologies

Traffic-related emissions represent a major component of airborne pollution [10]. In recent years, significant scientific effort has been focused on the measurement and analysis of real-world vehicle emissions and health monitoring methods, where were identified its advantages and disadvantages.

Many authors had trying a new approach to reducing emissions [11]. Potential applications of different perspectives can be evaluated and optimized, according to the role of ecological predictive maintenance [14].

3.1 Gas measurement

According to Beer´s Law, translated by respective mathematical expression, for a given frequency, each molecule can be thought of having an apparent cross-sectional area (“absorption cross section”, σ(ν)) for photon absorption by the molecule. The change in intensity, dI, of a parallel light beam of a single frequency (ν), as is traverses an infinitesimally small distance, dx, is given by:

$$dI = \sigma(\nu)\, N\, I\, dx$$

where N is the density number of the absorbing molecule, in molecules/cm^3. A schematic parallel beam transmission through gas Non-Dispersive InfraRed analyzers, NDIR, operating upon the principle of selective absorption, can be seen in Figure 4.

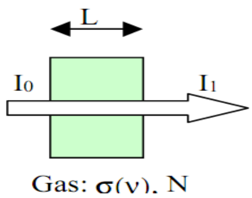

Figure 4 - Transmission of a parallel beam through a gas

The NDIR determines gas concentration by the amount of transmitted (or absorbed) energy in the selected wavelength band. The transmission (or absorption) is directly proportional to the concentration of the component gas that is being measured. Detection of the amount of transmission (or absorption) is accomplished by one of two methods. The first simply involves the direct measurement of the emerging light from a single cell.

The vibrating molecule may absorb electromagnetic radiation if it produces an oscillating electrical dipole moment that can interact with the electric field of the radiation. The molecules that do not produce dipoles moment, when they vibrate, such as O_2 and N_2, do not interact with radiation by this mechanism. Molecules such as CO, NO, and CO_2, whose dipole moments varies while they vibrate, can absorb photons of energies that correspond to their quantized vibrational energy levels.

The Beer-Lambert law defines the relationship between absorbance and concentration of an absorbing species shown in equation (1). At low concentrations (up to many tens of ppm) the Beer–Lambert law approximates to a linear relationship:

$$\frac{I}{I_0} = e^{(-\varepsilon c l)} \qquad (1)$$

where *I* is the transmitted intensity, I_0 is the incident intensity, *l*(cm) is the optical path length, *c*

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($cm^{-3}mol$) is the concentration of the species and ε ($cm^2\ mol^{-1}$) is the molar absorbtivity of the species.

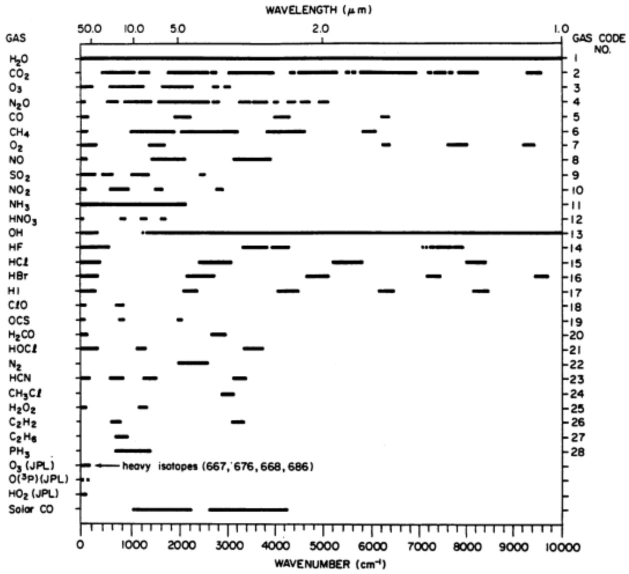

Fig. 5 - Spectral map showing the location of the absorption bands of the molecular species included in the 2000 HITRAN database

An application of the Beer–Lambert Law can be used through LabVIEW program to calculate the present gases concentration according to the following expressions:

$$\varepsilon = \sigma \times N_A \quad (2)$$

$$c = \frac{\text{ppm}}{w \times d \times 10^6} \quad (3)$$

where σ (cm^2/molecule) is the absorption line intensity, w is the molecular weight of the species, d ($kg.m^{-3}$) is the density of the species, N_A is Avogadro's constant and ppm is the gas concentration in parts per million. Factoring equations (2) and (3) into equation (1) gives:

$$\text{ppm} = \frac{-[\ln \frac{I}{I_0}]\left[w \times d \times 10^6\right]}{\sigma \times N_A \times l}. \quad (4)$$

The present gases concentration can be calculated using equation (4) with all other factors shown in the equation known.

When a motor vehicle passes through the beam of a calibrated instrument on the road, the computer notices the blocked intensity of the reference beam. It is an efficient method for determining the tailpipe emissions from passing vehicles [5].

An Infra Red (IR) light source that contains at least two different frequency regions is shined across the road to a detector. When a vehicle goes by, its exhaust gases traverse the optical path of the laser light causing some absorption which is detected and recorded [6]. The analysis of the relative absorption permits the quantification of a ratio of two gases, such as NO/CO_2, which is the primary result of the technique (Fig. 6).

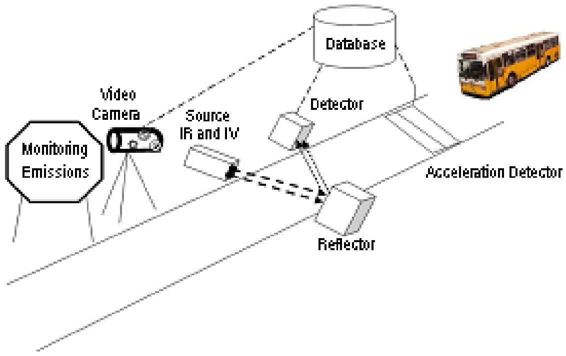

Fig 6 - Layout example

To better relate the emissions with operating conditions, a new parameter termed "Vehicle Specific Power" (VSP) is inserted. The dependence of PM, CO, HC, and NO_x emissions on VSP is better than on several other commonly used parameters, such as speed, acceleration, power, or fuel rate [4].

Until recently, vehicle exhaust remote sensing systems have only measured exhaust gases. Commercial systems are available for nitrogen oxide (NO), hydrocarbons (HC), carbon monoxide (CO) and carbon dioxide (CO2). As an example, the derived emission factors for NO and NO_x for heavy-duty diesel vehicles can be seen on Table 1.

	NO	NO_x
Pollutant/CO_2 ratio	0.0125±0.0013	0.0136±0.0015
Emission Factor (grams/km)	34,3±3,4	37,3±4

Table 1 - Emission factors for NO and NO_x

Under the standard operating procedures the IR source is positioned on one side of a single lane of traffic and the detector on the opposite side. The IR beam, generated by the source unit, is directed horizontally towards the detector. The distance between the source and detector units is thus typically 6 to 15 meters with the IR beam nominally positioned at a height of between 20 and 30 centimetres above the road surface, corresponding to the height of the exhaust plume from most light duty vehicles. The introduction of vehicle exhaust into the IR beam results in a reduction in IR intensity, which may be detected as a voltage reduction. This voltage reduction, measured by the four individual detectors may be used to determine the concentration of CO, CO2 and HC at a point in the exhaust plume.

3.2 Particulate measurement

Here is described a PM measurement system utilizing a pulsed ultraviolet laser. There are also related systems for estimating soot mass loading in diesel particulate filters based on light scattering technique [7]. The system simultaneously operates in a backscatter LIght Detection And Ranging (LIDAR) mode and in a transmission mode. Light from a laser pulse is partially scattered back towards the system by particles in the exhaust plume. The backscattered light is used as a sensitive measure of PM mass concentration. This is complemented by a transmission measurement resulting in a UV opacity that quantifies PM mass concentration for dense plumes. Therefore, PM mass concentration can be measured over a broad range of sparse and dense vehicle exhaust plumes.

Simultaneous, with the PM measurement, the emitted gaseous components are measured by infrared absorption to quantify the emitted carbon content through the vehicle exhaust. The ratio of PM concentration measured and carbon concentration gives the desired fuel-based PM emission factor. Environment PM and gaseous backgrounds are measured by the system before the vehicle passes and are subtracted from the total PM and gaseous concentrations measured after the vehicle passes.

The ultraviolet laser beam transiting the exhaust plume is attenuated by absorption and scattering of the light by the constituent particles. For transmitted beams with intensity I_o and I_{2L} measured before and after vehicle passage, respectively, the two-way transmittance TR_2 influenced by the vehicle exhaust plume is defined as [13]:

$$\mathrm{TR}_2 = \frac{I_{2L}}{I_o} = \exp\left(-2L\int_0^{\infty} \sigma_{e,\mathrm{PM}}(D) N_{\mathrm{PM}} \bar{n}_N(D)\,\mathrm{d}D\right) \quad (5)$$

where L is the one-way distance between the laser source and a retro reflector on the far side of the roadway; the factor 2 account for the roundtrip path since the beam is reflected and sent back through the plume a second time before reaching the detector, which is collocated with the transmitting laser for this application. The quantity $N_{PM}\bar{n}_N(D)$ is the size distribution function and $N_{PM}\bar{n}_N(D)dD$ is the number concentration of particles with diameter between D and $D+dD$. N_{PM} is the path-average number concentration over the two-way distance 2L rather than the range-dependent number concentration of particles.

Removing the constant N_{PM} from the integral, (5) can be written as

$$\log_e \frac{1}{\mathrm{TR}_2} = 2L N_{\mathrm{PM}} \int_0^{\infty} \sigma_{e,\mathrm{PM}}(D) \bar{n}_N(D)\,\mathrm{d}D \quad (6)$$

The PM mass concentration is given by

$$\rho = N_{\mathrm{PM}}\langle m_{\mathrm{PM}}\rangle = \frac{1}{2L}\log_e \frac{1}{\mathrm{TR}_2} \frac{\int_0^{\infty} m_{\mathrm{PM}}(D)\bar{n}_N(D)\,\mathrm{d}D}{\int_0^{\infty} \sigma_{e,\mathrm{PM}}(D)\bar{n}_N(D)\,\mathrm{d}D} \quad (7)$$

where ρ is a path-average quantity as opposed to the range-dependent $\rho(r)$. This can be written as

$$\rho = \frac{1}{E_{\mathrm{ext}}2L}\log_e \frac{1}{\mathrm{TR}_2} \quad (8)$$

where E_{ext}, with units of $m^2.g^{-1}$, is the mass extinction efficiency,

$$E_{\mathrm{ext}} = \frac{\int_0^{\infty} \sigma_{e,\mathrm{PM}}(D)\bar{n}_N(D)\,\mathrm{d}D}{\int_0^{\infty} \eta V(D)\bar{n}_N(D)\,\mathrm{d}D} \quad (9)$$

and $\eta V(D)$ has been substituted for $m_{PM}(D)$.

The quantities that enable backscatter and transmission measurements to be converted to PM mass concentration are the efficiencies given by (9). Numerical evaluation requires that certain assumptions be made about particle morphology and composition as well as the size distributions of exhaust PM.

There exists ambiguity in defining other characteristics of exhaust particles, although some generalizations being possible. Spark-ignition exhaust particle volume consists largely of organic material, while diesel exhaust particles contain widely varying volume fractions of elemental and organic carbon. Particle bulk density is found to range from 1.0 to 1.5 $g.cm^{-3}$. In the absence of measure equipment it is possible to achieve results through the use of emissions models [8].

One result from the implementation of the measurement system is an information placard, as shown in figure 7, with the objective to awareness the drivers about yours car health.

Fig. 7 – Health car alert [4]

3.3 Noise measurement

The exposure to sound (E) and the level of exposure to sound (L_E) is the most appropriate scale to describe a short duration noise event, since the sound energy is integrated over time of occurrence of noise, as can be described by equations (10) and (11).

$$E = \int_0^{\tau} p^2 dt \quad (10)$$

$$L_E = 10\log\frac{E}{E_0} \text{ (dB)} \quad (11)$$

where E_0 corresponds to exposure to a reference sound, usually $(20\mu Pa)^2 s$.

The model estimation noise emissions recommended by the European Commission to predict the mapping strategy on road traffic is the

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French method, described in the "Noise Guide of Land Transports".

The overall sound generated by a road vehicle is the sum of energies associated with the sources of propulsion and rolling noise, calculated as follows:

$$L_{Tot} = 10\log(10^{L_{Prop}/10} + 10^{L_{Rol}/10}) \qquad (12)$$

(Keulemans, 2006) [12] states that the predominant noise propulsion at speeds below 50 km/h and rolling noise dominates at higher speeds (50-120 km/h). It can be concluded that when the sound pressure level of propulsion is measured during times of low vehicle speed or high engine speed, the overall level of noise can be considered to be equal to the propulsion level noise. She also states that the two main sources generating noise in a vehicle are located at 0.01 and 0.75 m above the ground for heavy vehicles, and that in light vehicles location is 0.01 and 0.30 m above the ground. Most of the noise of the engine considers it located under the body of the vehicle. The source of rolling noise can be found close to the ground but also issued on a higher position due to vibration produced by the sides of the tire in the wheel. He suggests a weighting for the two sources of noise associated with the propulsion and rolling. In [12] it is stated that 80% of the propulsion noise is attributed to the highest point and 20% to the lowest point. The rolling noise considers the weighted inverse, ie, 20% of the rolling noise is attributed to the highest point and 80% to the lowest point. He specifies that these weights showed the best correlation with measured values, especially at higher frequencies.

3.4 Vehicles identification

The last component of the remote sensing data acquisition system is the license plate imaging equipment. In order to obtain vehicle information such as model, year, and Vehicle Identification Number (VIN), and so on, it is necessary to obtain a readable image of each vehicle's license plate as it passed through the emissions measurement station.

Capturing the license plate images is accomplished by the use of a video camcorder (camera/recorder) equipped with a telephoto lens. The video camcorder was tripod mounted and placed approximately 9 meters upstream with respect to the direction of traffic flow from the location of the beam. The camera zoom and focus are adjusted so that the license plate image is in focus and large enough to be read clearly as the vehicle passes through the beam path. The camera shutter speed ought to be set at $1/500^{th}$ of a second to prevent blurring of the license plate image as the vehicle moved through the focal field. The camera was then set to run continuously, with a new tape being inserted every two hours. The video image is instantaneously transmitted to a monitor and additionally recorded on videotape. Superimposed onto this video image are the vehicle's associated emission concentrations (CO, HC and CO_2), and the time and date at which the measurement beam was broken. In addition, this concentration data and associated beam block time details are recorded numerically into computer media.

4. Remote sensing new trends

Many manufactures use industrial PLCs to control and acquire sensorial data. It is also normal to have a higher failure rate in these components due to instability in the power supply. These aspects give good arguments to use low cost hardware, also envisaging the possibility of supplying the hardware with photovoltaic panels or batteries avoiding the problems with instable voltage.

A solution proposed by (Inácio, 2009) [15] derived from wind power farms, uses PIC18F2685, ENC 28J60 for Ethernet connectivity, a dsPIC30F4012 for high speed acquisition a board using Microchip digital potentiometers to implement a Butterworth low pass filter of 4th order with cut-off frequency between 100 Hz and 50 kHz and two cascade amplifiers with gain range between 0.1 and 10. The frequency and gain are programmed by software and, finally, a board based on the microcontroller LM3S8962, an ARM-Cortex-M3 architecture with support for Ethernet packet time stamping in hardware, with two interfaces Ethernet at a 10/100 Mbps full/half duplex and a CAN 2.0B. All the programming tolls for this microcontroller as been constructed based on GNU GCC tool chain for ARM-Cortex-M3 version 4.3.3, Binutils 2.19.1 and newlib-1.17.0 under Gygwin. This is the most expensive component of the system; however, it is priced by 12 €/unit and, in addition, an operational board runs with a few elements. This board will be a gateway between the traffic from the CAN network and the Ethernet network.

This system was developed to read, store and transmit data from wind generators, but it is too versatile to be used where the distance and the necessity to measure remote data is imperative.

In the case under discussion, the low cost hardware and open source software have proven to be adequate and they are associated to an information system called SMIT (Terology Integrated Modular System) that is the basis to the management of all on-condition maintenance. This is because all this methodology implies to reach better maintenance through the prediction of new planned intervention before the effluents reach abnormal environmental values [14].

This kind of system, because its low cost and versatility, and because the boards to have an IP address, also permits to install it on-board vehicles and transmit data via commercial GSM networks.

5. HMM new trends

The final objective of this research is to diminish faults and respect the environment. The system has included a prediction algorithm for on-condition maintenance that uses a new forecast paradigm based on Hidden Markov Model (HMM) [9] [16] [17].

The use of artificial intelligence, as neural networks with the objective to maximize chances of success is a great challenge. The presented model begins with the measure of condition variables as source data that will permit to forecast the on-condition indicators and, next, through HMM models, predicts the new state.

For each model is created a transition state matrix and is associated only one state indicator *i*. As an example, if it will be considered 4 states and 6 different emission scenarios, the instructions in Matlab and outputs will be 2 matrix 4*4 e 4*6:

- seq1 = xlsread('inputsallbuses','ENGINE','b72:ao72');
- states1 = xlsread ('inputsallbusesenginesandparts','b18:ao18');
- [TRANS_EST,EMIS_EST] = hmmestimate(seq1,states1)

The transition matrix is the following (Table 2):

0,350	0,450	0,100	0,100
0,125	0,000	0,875	0,000
0,286	0,000	0,429	0,286
0,571	0,000	0,000	0,429

Table 2 – Transition matrix

And the emission matrix the following (Table 3):

0,900	0,000	0,000	0,000	0,100	0,000
0,300	0,200	0,000	0,250	0,000	0,250
0,429	0,143	0,286	0,143	0,000	0,000
0,125	0,000	0,000	0,000	0,375	0,500

Table 3 – Emission matrix

After the reading of emissions sequence measurements, the model determines the probable state (table 4).

Actual State Probabilities, defined by nine HMM models									
	HMM1	HMM2	HMM3	HMM4	HMM5	HMM6	HMM7	HMM8	HMM9
More probable state	2	2	1	3	3	3	3	4	3
State 3	$P_{1,1}$	$P_{1,2}$	$P_{1,3}$	$P_{2,1}$	$P_{2,2}$	$P_{2,3}$	$P_{3,1}$	$P_{3,2}$	$P_{3,3}$
State 4	$P'_{1,1}$	$P'_{1,2}$	$P'_{1,3}$	$P'_{2,1}$	$P'_{2,2}$	$P'_{2,3}$	$P'_{3,1}$	$P'_{3,2}$	$P'_{3,3}$

Table 4 – Outputs of Actual States

It generates the probability of the system to be in one of the possible four states. The next step consists in the application of the Forward / Backward algorithms to find the occurrence probability of different states.

The model stops with forecast, where is generated the most probable sequence of future emissions and the corresponding states for each HMM model, until two periods after the actual remote sensing reading.

6. Integrating systems

Figure 8 shows a real configuration that integrates the several terology pieces. One thing concerns with this design that is its simplicity, friendliness, and low cost of all system, as can be observed in that figure. The central system is based on a Linux Server running apache web server and PostgreSQL database [15]. All system is available through IPv4 connectivity from the acquisition system level to the Linux Server and SMIT clients. Data acquisition can be done using special low cost hardware, as also by high performance acquisition systems like National acquisition hardware using LabView (connections to SMIT server is also obtainable by IPv4 connectivity), and Ethernet PLC's. It is also available on the SMIT Server, a Fax server (Hylafax), and a TCP/IP server for reception of data acquired from different acquisition hardware, using UDP packets with acknowledgement.

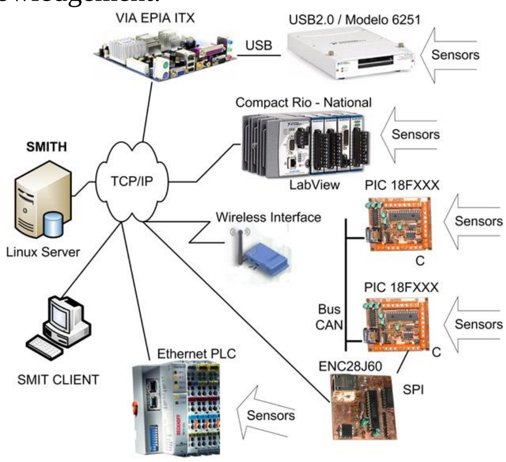

Fig. 8 - An integrated system for terology with on-line data reading

Nowadays, SMIT has or is being to have, new adding like the followings:

- Wireless communication to IP devices to receive measurements from any MO, like Wind Generators, Diesel engines, or any others;
- On-condition modules to predict planned interventions based on variables that are regularly measured being by remote way, by physical connecting or by human reading.

7. Conclusion

The paper shows a new methodology to measure, read, transmit and manage emission data from vehicles with internal combustion engines. The concept that is the base of all development presented is the Environmental Centred Maintenance (ECM).

A new maths model is proposed to reach that goal, a Hidden Markov Model that is used to predict the on-condition maintenance interventions.

All developments are supported by an information system called SMIT and a mix of hardware-software technologies using IP devices and GSM networks to transmit signals.

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