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AN OBD-II BASED VEHICULAR DATA TRACKING SYSTEM FOR FUEL CONSUMPTION AND EMISSIONS IMPROVEMENT

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Abstract. *Due to recent concerns about climate change as well as the rise in the mean global temperature, it happened in December 2015, in Paris, the 21st Conference of the Parties of the UNFCCC (United Nations Framework Convention on Climate Change) to set an agreement to reduce greenhouse gases emissions. Since the Automobile Industry is responsible for a large amount of CO2 and NOx emissions, a small reduction would be significant, helping UNFCCC country members to achieve its Nationally Determined Contribution (NDC). For that purpose, in this work, it will be identified and analyzed factors that contribute in the process of greenhouse gases emissions and fuel consumption related to the user's way of driving. Within this context, a real-time vehicular data tracking system will be developed to analyze CAN bus signals through an OBD-II port, available in new vehicles produced in Brazil after 2010. The purpose of this system is to evaluate the vehicle real operation characteristics and gear shift strategies to obtain significate reduction in fuel consumption and gases emissions. An Android application will be developed presenting relevant information for the user to improve its way of driving and the vehicle energy efficiency. This system, therefore, will allow drivers to keep on track of its vehicle performance as well as help to reduce the effects on climate change in a long run. Since most recent vehicles are being produced with onboard multimedia units, the system implementation would imply a low cost for automobile companies..*

Keywords: Tracking System, OBD, Vehicular Emissions, Fuel Consumption, Smartphone

1. INTRODUCTION

With the growing concerns with climate changes and also the increase in the mean temperature of the planet due to greenhouse gases, it was held, in Paris, the 21st Conference of the Parts of UNFCCC (United Nations Framework Convention on Climate Change), also known as the Paris Agreement. The treaty aims to regulate measures to reduce carbon dioxide emissions starting from 2020. Brazil compromises to reduce greenhouse gases emissions in about 37% until 2025, and 43% until 2030, when comparing with the year of 2005. (Source: ITAMARATY).

According to the Ministry of Science, Technology and Innovation, in 2012, the Energy sector (fuel based processes) was responsible for 37% of the amount of CO2 emissions, with 47,5% of this amount is a direct consequence of automobiles usage being, therefore, one of the main sources of CO2 emissions in urban areas.

In order to evaluate the impact of vehicular emissions, standardized driving cycles were defined and regulated by Environmental Protection Agencies. These driving cycles were set to simulate real world driving conditions (urban areas, highways, aggressive driving, etc.), acting as a normative way for a new vehicle homologation, before entering the market. The most important cycles nowadays are the FTP75 (in the United Sates) and the NEDC (in Europe).

In the other hand, studies shown that normative cycles are not very well correlated with real world conditions, resulting in estimation errors for fuel consumption and gases emissions in dynamometer testes. According to Tzirakis and Zannikos, 2014, road modifications, fleet changes, fuel changes, driving behavior, local legislation, and others, have a great influence in vehicle’s speed profiles. These differences suggests that standardized tests should be modified locally, in order to become a better representation of the real world driving. Yet, several studies suggests the use of new technologies (cellphones, internet, wireless connections, etc.)as a tool to obtaining real world driving conditions, contributing for a better estimation of fuel consumption as well as greenhouse emissions. The accessibility of these new technologies and information’s transmission speed is making them essential in daily activities due to its variety of applications, and becoming a tendency in the industry.

Regarding the automotive industry, companies are investing in connected systems, using smartphones and multimedia as a head unit. However, none of this systems stands out in the matter of the integration between vehicular connectivity and vehicle performance, being used as entertainment systems and comfort control.

For that purpose, this project aims to integrate connectivity platforms with the vehicle activity, in order to reduce fuel consumption and CO2 emissions. In this way, the low cost solution would be available for users worldwide with benefits for the economy and, also, breaking the effects of the greenhouse effect, the major objective of the Paris Agreement.

2. METHODOLOGY

2.1 Real Time Vehicle Tracking Data

Vehicle data information is available through a bus which connects all vehicle control units, and it is called the CAN Bus (Controller Area Network). All vehicle’s electronic signals traffic through this bus, addressed by an hexadecimal code indicating each different signals.

The Can Bus is a serial communication protocol developed by Bosch and announced at the International Conference of SAE (Society of Automotive Engineers), in Detroit, Michigan, in 1986. This network defines an efficient and reliable standard of communication among vehicle’s sensors, actuators, controllers and other nodes to applications in real time (Li, 2008).

This protocol follows the standard ISO 11898 and fundament in the concept CSMA/CD with NDA (Carrier sense multiple Access/ Collision Detection with Non-Destructive Arbitration). During its operation, all modules verify the system state, analyzing messages sent with higher priority (Soares, 2012).

In a way to detect problems and to standardize emission tests, it was created the standard OBD (On-Board Diagnostic), in the United States. Nowadays, all vehicles which support the OBD-II standard adopt the standard diagnostic code and communication interface (ISO J1979) and the communication among the OBD and the Can Bus (ISO 15765). Then, all available control units data can be collected externally from the OBD port.

With the wireless connection, Bluetooth, the low cost connector ELM327 (Fig. 1) is capable of collect and transfer data to a dedicated application, where the users are capable of tracking the vehicle information by the use of a mobile unit, defined by ISO J1979.

Figure 1. Commercial Connector OBD ELM327

2.2 Fuel consumption Optimization and CO2 emissions

Some parameters that can be obtained from the OBD-II port are mentioned in studies indicating its relations with fuel consumption and pollutant emissions. Among them, the vehicle speed, engine speed, acceleration and deceleration gradient, brakes and gear shift seems to be the most important, suggesting that the driver behavior has a significant effect in the vehicle’s energy efficiency (Vaezipour et al, 2015).

With respect, the work done by Araújo and de Castro, 2012, aims to create a mobile application giving to the users hints to obtain a better vehicle’s efficiency. They showed after a set of testes a relation of the number each hint was given, resulting that gear shifting was the most common, This results suggests that gear shift optimization should be applied and considered as the first step to improve the vehicle’s performance, reducing fuel consumption and also CO2 emission.

To identify the parameters to be analyzed a standardized driving cycle test FTP75 was run in a dynamometer laboratory, The vehicle used was the Fiat Mobi, and data acquisition was done using the company’s apparatus for a direct CAN Bus data track, and also with a mobile application connected to the OBD-II port, Torque Pro.

The first set of tests were used as a preparatory phase to obtain relevant information about the vehicle's performance, building the model for the system. Then, the optimization algorithm, suggested by Blagojevic et. al., 2012 was applied to a real world test, in order to validate the model. Since the data obtained through the CAN bus has an acquisition frequency of 250Hz, depending on the information wanted, a large amount of data can be analyzed without information loss. In the other hand, the comparison with the data obtained through the OBD-II port, with a frequency of 1Hz, is needed to be sure no relevant information will be missing.

3. RESULTS AND DISCUSSIONS

3.1 Preliminary Phase and Firsts Results

From the results of Araújo and de Castro, 2012, indicating that gear shift time is one of the most important issues regarding fuel consumption and also CO2 emissions, the first step is to identify the active gear. Since the transmission ratio has a direct relationship with vehicle speed and engine speed, it is represented by Fig. 2, showing a well-defined escalation, sufficient to identify the active gear by OBD-II data.

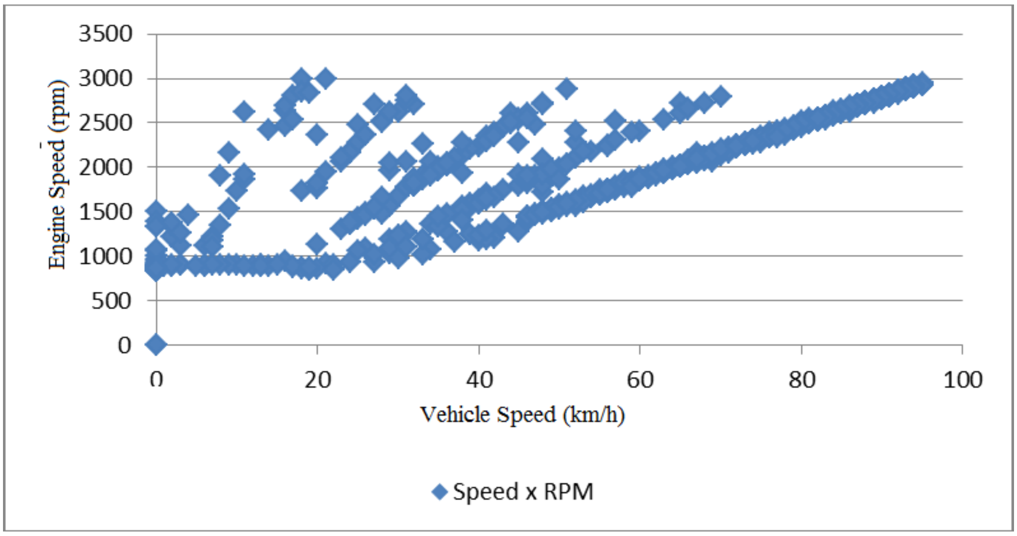
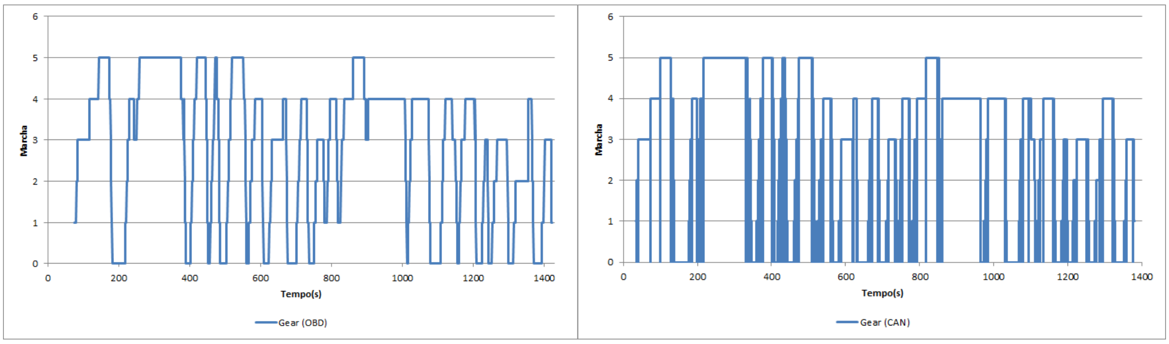


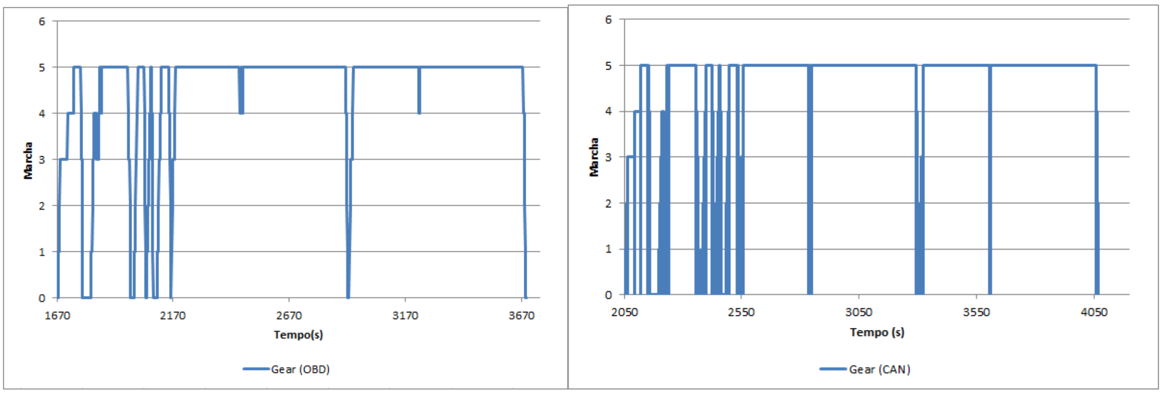
Figure 2. Relationship between engine speed and vehicle speed for active gears identification

Despite the well-defined relationship shown in Fig. 2, real world previous tests showed much more data between the intervals. So it is needed to determine a certain range the defines each gears correctly. Taking it into account, and since FTP75 tests have signals attesting the active gear, the result is compared by the two acquisition systems. Figures 3 and 4 shows the correlation between the OBD data and the FTP75 and Highway cycle data by CAN bus.



(a) (b)

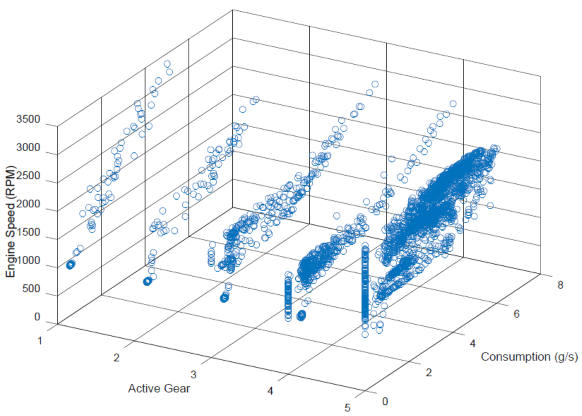
Figure 3. Active gears obtained by (a) OBD-II port data e (b) CAN bus – FTP75



(a) (b)

Figure 4. Active gears obtained by (a) OBD-II port data e (b) CAN bus – Highway

In order to perform the optimization algorithm suggested by Blagojevic et. al., 2012, performance maps were obtained through the FTP75 standard test. Parameters as Engine Load, Fuel Consumption, Torque, Engine Speed, Vehicle Speed and Throttle Position were acquired and their relationships for each gear is shown in Fig. 5. Also, Figure 5 (c) shows the increase in fuel consumption as it reaches the maximum torque for each gear.



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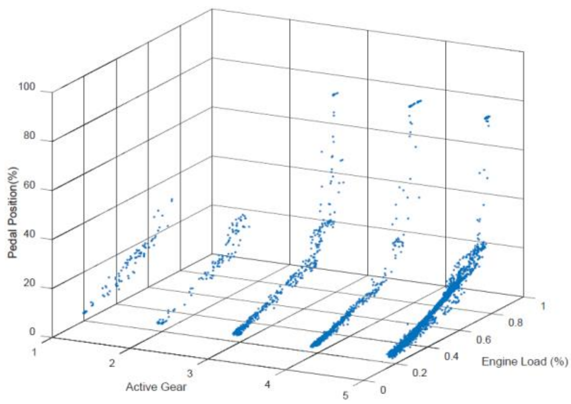

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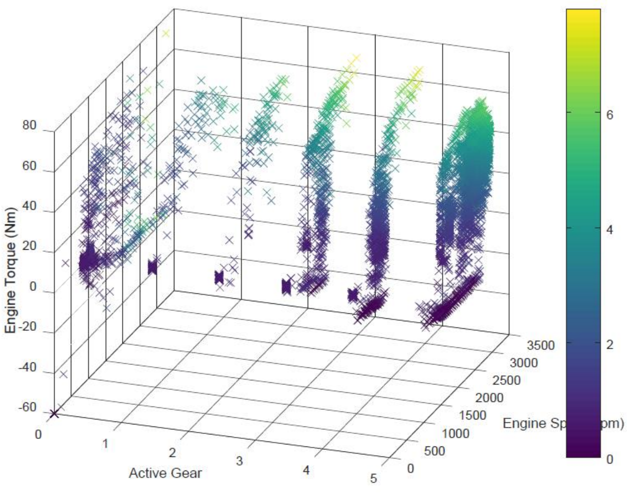

(c)

Figure 5. (a) Consumption vs Engine Speed; (b) Engine Load vs Throttle Position; (c) Torque vs Engine Speed vs Fuel Consumption

3.2 Optimization Model

The aim of this project is to validate the gear shift optimization algorithm suggested by Blagojevic et. al., 2012, but with different speed limits. The algorithm takes into account only parameters that can be obtained from the OBD-II port and, so, it can be use as a real time advice for the users to change gears earlier, minimizing fuel consumption and CO2 emissions.

For this purpose, the investigating parameters, those to be acquired in real time through the OBD-II port, were:

- Calculated Load Value: *L(%)*
- Throttle Opening: *Ø (%)*
- Engine speed: *n(rpm)*
- Vehicle speed: *v(km/h)*

In order to minimize fuel consumption, the maps presented in Fig. 5 were used to obtain fixed parameters which characterize the above mentioned criterion. Such parameters include:

- Minimum engine speed for each gear n_{min};;
- Engine speed at maximum torque for each gear n_{Mmax};
- Initial throttle position $\emptyset_0$
- Maximum calculated load value L_{iconst} at the maximum throttle opening value $\emptyset_{iconst}$ in the constant speed mode in each gear;
- Minimum calculated load value L_{max} at the minimum throttle opening value $\emptyset_{max}$ at the maximum acceleration mode;
- Limit values for $L/\emptyset$ for each gear at the acceleration mode;
- Engine speed and vehicle speed ratio for gears identification;
- Transmission intervals for determining current gear.

With the above mentioned criterion parameters obtained, the first step is to determine which gear is currently engaged, as it was done in Fig. 3 and 4. Assuming that the first gear is only for starting, when engaged, this gear will only be recommended below 3000rpm, recommended by Eco Driving strategies (SenterNovem, 2005) to minimize unnecessarily fuel spent. If this engine speed is exceeded, then the second gear is recommended and shown to the driver.

If no gear is engaged, the model checks for higher motion speeds (above 40km/h). Since no gear is engaged, the throttle opening must be at minimum position, otherwise fuel is unnecessarily spent. If the vehicle speed is less than 40km/h, no gear will be recommended. In the other hand, the third gear will be set as a minimum gear needed and, then, the highest gear available will be recommended, if the engine speed is above the minimum determined previously for each gear.

If a gear is engaged, the first test checks for idle motion, in other words, for idle position of the throttle. For a positive answer, no gear shift is needed. If not, another test is performed, checking for an approximately constant speed mode, comparing the limits L_{iconst} and $\emptyset_{iconst}$ set for each gear. If true and the engine speed is less than the minimum determined for the current gear, a downshift will be recommended, unless the second gear is engaged. In this case, the second gear will be kept. Otherwise, if the engine speed is higher than the minimum determined for the current gear, the highest gear available will be recommended, checking the availability regarding its engine speed minimum criteria.

For the acceleration mode, it is checked if the vehicle is performing a maximum acceleration mode by comparing the engine load and throttle position with L_{max} and $\emptyset_{max}$. If that so, the recommended gear will be the one operating the closest to the maximum torque speed. If the vehicle is not at maximum acceleration mode, the vehicle speed is checked. For speeds above 80km/h, the highest gear (fifth) will always be recommended.

For speeds above 40km/h, the third gear will be set as minimum required and, than some checks are done. For the fourth or fifth gear engaged, will be checked If the engine load and throttle position ratio is above the limits previously determined. For a positive answer, the gear shift is not recommended. Otherwise, upshift and downshift will be recommended, respectively. If the third gear is engaged, the same procedure is done and the upshift will be recommended if L/∅ ratio is less than the previously defined.

For speeds below 40km/h, on the other hand, if the third gear is engaged, a downshift to gear 2 will be recommended if L/∅ ratio is less than the previously defined for the current gear. Otherwise, the minimum engine speed limit will be verified, recommending the second gear for low engine speeds.

In order to validate the optimization model, a real world test was performed and provided by FCA, as a standard test defined by the company. The active gears and the recommendation gears throughout the test is shown in Fig. 6.

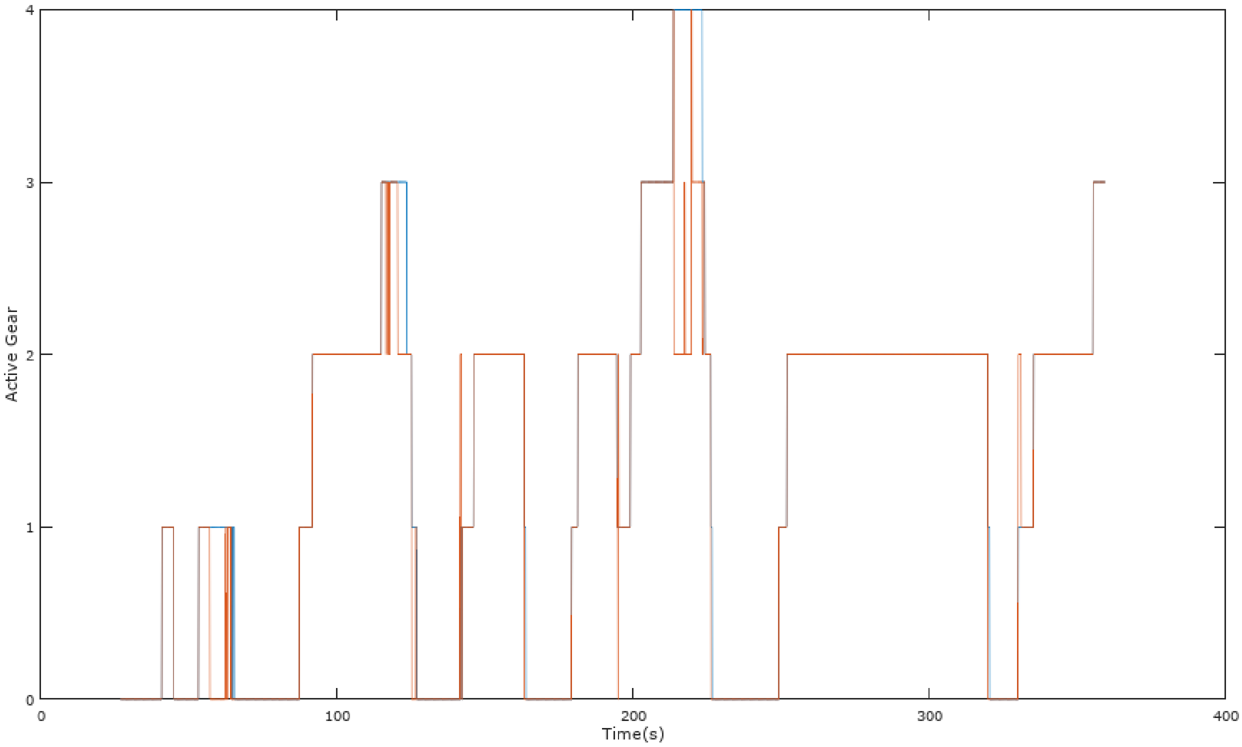

Figure 6. Recommended Gear vs Active Gears

Regarding that the real world test provided by the company was done by a well-trained driver, and no information was given about the availability of an external gear shift indicator, the model identifies the gear shift patterns correctly comparing to the actual engaged gear, despite little differences probably provoked by the driver's behavior. For a better evaluation of the algorithm, several standardized tests should be run to correctly identify the procedure differences when no gear shift strategy is applied.

According to the data shown in Fig. 5(a), it can be obtained extrapolated values for the new fuel consumption according to the recommended gears. By doing so, no significant differences were obtained, resulting in 7325 grams of fuel.

The result presented in Fig. 6 is not sufficient for the model validation, but proved to be a potential tool for obtaining the gear shift indicator by available data through the OBD-II port. It is shown several gear shift recommendations, both upshift and downshift, but, since the driver do not have a feedback information by this specific strategy, the same gear is kept and, then, returning to the gear's operation condition limits specified by the algorithm. A different set of tests need to be held, overpassing the engine speed limits usually recommended for gear shifts in order to evaluate the model's response.

Yet, a dedicated mobile application for live data acquisition (OBD-II data) and analysis is still under construction and, also, another set of tests are programmed to be held for the model's validation.

4. CONCLUSIONS

The proposed system prove to be a potential tool for live data tracking and analysis, obtaining the gear shift indicator by available OBD-II data, with no loss of relevant information. However, more tests should be run in order to validate the optimization algorithm presented in the literature.

An Android application is being developed to present relevant information to the user, applying the gear shift strategy and also Eco Driving strategies to reduce fuel consumption and CO2 emissions. In addition, driver's interaction with the application should be evaluated in order to not disturb the user's attention to the traffic which may lead to a risk for life.

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