Cloud-based Driver's Analysis

Student project

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***Abstract*—The goal of this article is to describe the early stage prototype of the system being able to constantly monitor and record car's usage as well as to evaluate its driver's performance. The solution is capable to gather information from various vehicle's sub-systems through the OBD II protocol and utilizes a Windows Phone 8 device to transmit those data (together with a complementary GPS position) to the Windows Azure computing cloud in which the subsequent analysis takes place.**

***Index Terms*—cloud computing, ELM 327, OBD II, vehicles monitoring, driver's profile**

I. Introduction

ONE of the industrial sectors which is under the constant influence of computer science is the automotive industry. The role of systems preventing vehicle from unintentional lane change or being able to park a car without driver's assistance are gradually changing their role from being a technical innovation to become a required (safety) standard. Furthermore, new possibilities emerge to integrate car's electronics with everyday objects like computers, tablets or smartphones.

Since 1996 (United States) and since 2001 (European Union) all automotive vendors were inclined to sell vehicles equipped with the OBD II interface (or equivalent). Its main purpose is to gather data from various vehicle's sub-systems which opens a range of possibilities a further analysis.

The idea behind the project described in this article is to create a modular system which could be used in order to analyze driver's performance based on information obtained from their vehicle and complementary data about car's GPS position.

The developed solution consists of the following modules:

1. ELM327 adapter (ref. [3]) which is directly connected to the OBD II interface. This module is responsible for sending raw data directly to the transmitting device.
2. Mobile device responsible for collecting and transmitting the raw data from vehicle's subsystems and information gathered from embedded sensors such as GPS or accelerometer. Those data (currently in the form of JSON objects) are sent to cloud services through the HTTPS protocol.
3. Cloud services whose main purpose is to collect data from the mobile client and insert them to the SQL Azure database.

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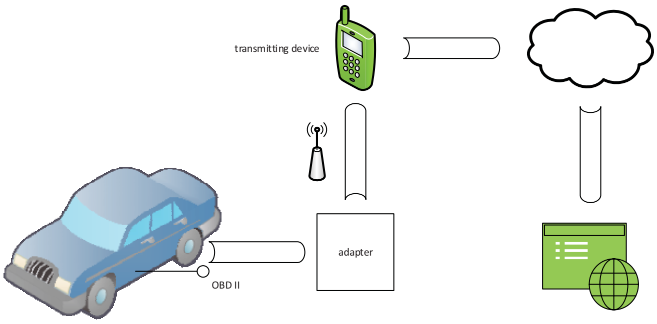

Fig. 1. Solution's overview.

A. Driver's profile

The term "driver's profile" which will be used in this article can be treated as a product of various factors determining overall driver's performance. The most representative analysis has been performed in domains of eco driving, reckless driving, tendencies to excessive speeding, driver's behavior while entering slow zones as well as the change of driving style induced by weather conditions.

B. Data gathering

For the purpose of initial testing the analysis has been performed on the group of four drivers (males in the age ranging from 20 up to 48 years). The dataset consisted of almost 1000 data records (each one reassembles one read operation performed on the vehicle's onboard computer).

II. Collecting and Transmitting Devices

As it was presented in the Figure 1, two electronic devices are responsible for data gathering and transmission. The first one is an ELM 327 adapter that reads vehicle's data via OBD II protocol and converts them into easily readable format. The second device is a smartphone which is responsible for transmitting those data (together with a complementary GPS position) to the Windows Azure computing cloud in which the subsequent analysis takes place.

There exist several possibilities to implement a communications protocol between those modules:

1. Using serial port connection.
2. Applying RS232-USB adapter and serial port emulation on a target device.
3. Using wireless technologies (Bluetooth/Wi-Fi).

The first solution cannot be applied since modern computers or smartphones are not equipped with a RS232 interface. The second one requires that a transmitting device supports so called USB host mode (i.e. acts as the USB host, powers the bus, and enumerates connected USB devices) which is a rare feature of modern smartphones as well. This leaves only a wireless technology as an option and since OBD II adapters are mainly utilizing Bluetooth transmission standard this technology has been selected. It is worth mentioning that although Bluetooth technology should implement a uniform standard of data transmission, it still causes many compatibility issues (mentioned in the last part of the article).

A. *Communication with car*

The ability to read the data from the vehicle using a circuit-based ELM327 adapter depends on many factors. The most important one is the type of the Engine Control Unit (ECU) installed in a particular vehicle as it provides data to the diagnostic connector applying one of many possible hardware protocols (like SAE-J1850, ISO 9141-2, ISO 14230-4, etc.). Another issue is the number of parameters which can be obtained from various vehicle's subsystems. To be able to read anything using the OBD II interface, it is necessary to send to the controller information about requested parameter ID (PID). Unfortunately, none of vehicles manufacturers is obliged to support all PIDs (ref. [5]).

In addition to obtaining values of various parameters, the ELM 327 adapter also allows to perform basic vehicle diagnostic including reading fault (error) codes or information stored in the car computer's memory at the time of any anomalies – for example the erroneous signal from any sensor (which is often signalized by the "check engine" dashboard control).

B. *Windows Phone Application*

The requirement set towards the transmitting device is (apart from data transmission) to perform an initial data processing (such as packaging) as well as compression, which significantly reduces the transmission cost. The mobile device is also the source of additional information (such as a GPS position). The applied Windows Phone 8 platform provides a very mature programmer's API and a stable environment for hosting a mobile app responsible for fulfilling the aforementioned requirements.

III. Eco Driving

The term "eco driving" stands for energy efficient use of vehicles, i.e. low fuel consumption, modern driving culture, making a best use of available technology in the car and decreasing CO2 emission. It may also be defined as a set of rules, which should enable the follower to achieve the aforementioned goals.

1. Anticipating traffic flow ("smooth driving") which means increasing scope of action, smooth changes of distance between other vehicles, maintaining adequate velocity and optimal use of car's gearbox, i.e. making use of neutral shift or letting the car roll in gear with clutch engaged.
2. Maintaining steady velocity at low RPM value (i.e. avoiding as much as possible rapid increase of velocity which results in high RPM and highly increased fuel consumption). It is recommended to use throttle gently to maintain low RPM on each gear (which enforces faster gear change) and to avoid unnecessary speed peaks or abrupt braking.
3. Shifting gears up early for the purposes of low fuel consumption. It is assumed that gears should be changed at 2000 RPM (diesel engine) and respectively before exceeding 2500 RPM for gasoline units.

The aforementioned rules can be perceived as the core ones. Of course, there are many more, which are related for instance to car's hygiene (i.e. keeping dead weight away, maintaining proper tire pressures, etc.).

The correlation which has been applied on the test data has been made between throttle position, current RPM and speed. A conclusion that driver does not comply to eco driving rules could be drawn in the following cases:

1. Rapid increase of RPM – suggestion to change a gear.
2. Maintaining high RPM (accordingly for fuel type in car if such information is available).
3. Strong throttle pressure (over 2⁄3 of maximum value).
4. Rapid increase of vehicle's speed.

TABLE I
EXAMPLES OF (NON)ECO DRIVING BEHAVIORS (REF. [1])

RPM	Speed	Throttle
786	0 km/h	24.7%
1587	24 km/h	58.9%
1878	31 km/h	41.1%
1987	56 km/h	43%
2123	63 km/h	51%
2348	70 km/h	50%
2489	79 km/h	78%
3120	89 km/h	81%

The example where eco driving rules have been obeyed is depicted in the fourth row of Table I (RPM / speed / throttle position = 1878 / 31 km/h / 41.1%). On the contrary, in the eight row (RPM / speed / throttle position = 2489 / 79 km/h / 78%) one can observe increased RPM value along with excessive throttle pressure. It implies that gear should be changed to reduce the RPMs and that an immediate release of a throttle is suggested. In general rows from one to four are examples of obeying eco driving rules, whereas rows from five to eight depict situations where those have been violated.

IV. Reckless Driving

The term "reckless driving" has its legal explanations in countries such as United States or Canada (an example can be found in Mississippi's code (ref. [4]): "Any person who drives any vehicle in such a manner as to indicate either a willful or a wanton disregard for the safety of persons or property is guilty of reckless driving."

Furthermore, the term is also widely used in automotive industry not only in collocation with breaking the rules of safety on the road but also misuse of the vehicle itself (i.e. the usage which is non-adequate to current environmental conditions). As there are many situations which may be treated as reckless behavior, the description will concentrate only on those which could be captured applying the realtime data analysis.

One of examples is directly connected with weather conditions and ignition of the car. During frost the so-called "cold engine" is a moment just after ignition during all the mechanisms need tens of seconds to warm up, as it may result in potential breakdown of elements if car starts moving rapidly. Moreover, it is strongly recommended to treat car's engine "gently" during first couple of minutes because driver should wait until coolant acquires working temperature and engine warms up. This means avoiding rapid acceleration and maintaining low RPMs during first minutes of the ride.

If there are sensors in the car which can measure temperature of air going directly to the engine (ODB II standard defines it as the "air intake temperature") it may be deduced whether the weather conditions outside allow rapid acceleration or not. An example of data corresponding to improper behavior just after ignition during winter is shown in Table II.

TABLE II
EXEMPLARY DATA (OUTSIDE TEMP. = -15 °C), REF. [1]

RPM	Speed	Throttle	Uptime
889	0 km/h	27.3%	0:00
1258	0 km/h	28.9%	0:07
2350	12 km/h	53.4%	0:14
2650	36 km/h	43%	0:21
4800	79 km/h	91%	0:28
3535	89 km/h	48%	0:35

One can observe that the driver waits less than 14 seconds and initiates a movement of the car, along with relatively strong throttle pressure and medium RPM value. Afterwards it is also visible that rapid movement is initiated, along with very strong throttle pressure and high RPM – which is identified as potentially harmful for the machine.

V. EXCESSIVE SPEEDING

The purpose of this method was to check how often driver exceeds the allowed speed limits. To perform such analysis, data from vehicle's onboard computer about its current speed, and information about current location from the transmitting device are correlated with geolocation data. For those purposes the OpenStreetMap service has been utilized.

The other possibility offered by correlating onboard data with geolocation information is to determine driver's behavior approaching the points classified as "slow zones" – i.e. places where driver should reduce vehicle's speed. Examples of such points may be crossroads with stop signs, crossings or railway crossings. The method should check if driver has reduced vehicle's speed when approaching such a point and present a percentage value of how often driver is behaving properly in such situations. The algorithm applied in this cases is as following:

1. Find a slow zone point.
2. Find five readings proceeding a given point.
3. Check if the speed has been decreased.
4. Repeat for all slow zone points.
5. Evaluate the percentage value when speed has been decreased approaching the "slow zone".

The data gathered from test group suggest than more than 60% of drivers constantly exceeds allowed speed limits, together with not adjusting vehicle's speed while entering "slow zones".

VI. WEATHER CONDITIONS

The purpose of this analysis is to determine if driver's behavior adapts accordingly to the weather conditions on the road. To evaluate such a case, information about driver's behavior on the same road, in two or more different weather conditions is necessary. This allows to observe the change in driving style (for example higher or lower driving speed) in relation with change of weather conditions, such as temperature, wind speed, precipitation or humidity.

The analysis performed on the given data set involved comparing the readings of speed and RPM values for two data sets collected on the same road, on a different date, with different weather conditions but using the same car driven by the same driver. The comparison can be presented in form of the following line charts (Fig. 2 and Fig. 3).

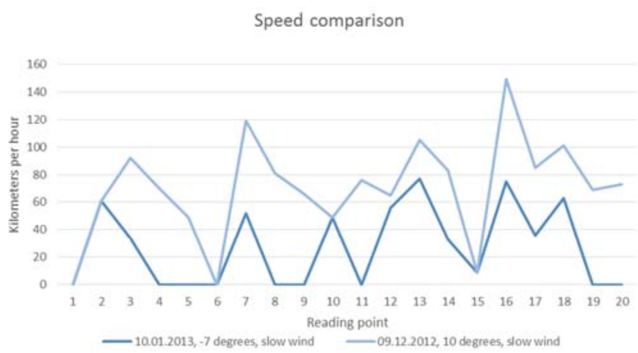

Fig. 2. Speed comparison (ref. [2]).

The first data set used in comparison was made on the 12th of December 2012, when the weather conditions were rather good, the temperature was around 10 °C, wind speed of 3 m/s with low humidity, and no snow or rain on that day.

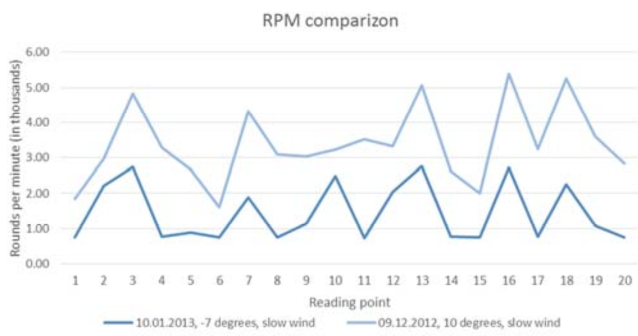

Fig. 3. RPM comparison (ref. [2]).

The second data set was taken on the 10th of January 2013, when the weather conditions changed drastically, the temperature was around -7 °C, wind speed was equal to 8 m/s, the humidity was high and it was snowing. The weather conditions in the second data set, were classified as harder, requiring more careful driving.

The two readings were taken at approximately the same hour, on the same week day, to minimize the difference in the traffic conditions on the road.

Charts clearly present that the driver decreased the vehicle’s speed together with RPM value. One of the possible fields for further improvement is to verify if the change in driver’s behavior is directly and solely connected to different weather conditions (it could be also related to the current situation on the road).

VII. Encountered Difficulties

The system development was impeded by various technological problems. Some of them were fairly simple to overcome, and some were practically irresolvable (bearing in mind project’s assumptions). It is worth mentioning that the biggest problem concerned Bluetooth related issues, specifically connection with ELM 327 adapters. The Bluetooth technology is interpreted differently on various smartphone devices which caused software failure on certain models. Also, the connectivity issue became an obstacle in case of usage of different ELM 327 adapters coming from various manufacturers (some of them has worked properly only with certain vehicles).

The biggest issue encountered in this project was frequency of data collection. The sequential command execution mechanism implemented on ELM 327 adapter combined with Bluetooth connectivity problems resulted in the fastest possible times of each cycle of about 2 up to 3 seconds. Whereas it gives some image of what type of a driver the system is dealing with (especially with large sets of data), real-time monitoring is almost impossible, as 2 seconds in case of critical situations (rapid acceleration, sharp breaking, etc.) is way too big time span to give accurate results.

One of the possible solutions to the above problems is to use a newer device, which slowly begins to enter to the Polish electronics market (namely the STN 1110). According to the manufacturer's declaration, the system is based on microcontroller about ten times faster and is equipped with larger and faster FLASH and RAM memory. This may potentially mean that the impact of the aforementioned problems can be greatly reduced

Another limitation was connected with the availability of the sensors in tested vehicles. As the software was tested mostly using cars with production dates ranging from 2004 to 2006, the OBD II accessible data was limited to mainly basic information about speed or RPM values.

VIII. Conclusions

Analysis of the data, portrayed one important variable being missing – i.e. information about the current traffic which may strongly influence the conclusions. For the purpose of minimizing such influence, the analysis has been performed on the data sets collected at roughly the same days of the week and hours, to approximate the same traffic conditions on the road.

Nevertheless, one can clearly see the potential of a developed solution which could be a form of vehicle’s black box, recording and informing about driver’s performance, as well as backing up information about the journey. The application of such systems can be related to reconstructions of various situations happening on the road, as well as provide useful data for car insurance companies.

References

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