Gamification and driving decision support using the sensors of vehicles and smartphones

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Abstract

Vehicles are not just a means of transportation anymore, but they are also moving entities that collect and transmit a great amount of data, captured by sensors from the internals of the vehicle and from its environment as well. These data extended with smartphone sensors can be a stable base for smart car-based infocommunication systems. There are two main interfaces to extract the data from a vehicle: OBD-II (On-board Diagnostics) and CAN bus (Controller Area Network bus). This paper introduces an advanced measurement tool, called ObdCanCompare. The purpose of this tool is to provide an environment to compare these data streams in real time and conclude how and which interface can be used for derivation of driving decisions. It also enables creating business intelligence reports using the SensorHUB-based backend, which is our data collection and service development for sensor networks, smart devices and cloud-based backend environments. Results show that the OBD-II interface is quite accurate compared to CAN bus, in order to demonstrate this we have created the Social Driving application as a socio-cognitive ICT pilot application that displays vehicle data to users from OBD-II and enables to compare usage statistics of different drivers in the network as a socio-cognitive gamification.

Keywords: OBD-II; CAN; SensorHUB; VehicleICT; driving decision; gamification; socio-cognitive ICT

1. Introduction

Nowadays, more and more devices, sensors and gadgets are getting connected to the Internet in the IoT (Internet of Things) world. One such sensor set is a vehicle itself, which began to be used in the smart vehicle-based solutions in recent years. However, a vehicle is a complex system, it is not trivial, how its different data is sent to the Internet. In the transmission, two interfaces can be utilized: the OBD-II port (only used for maintenance) and the CAN bus system (used for communication between the internal systems).

We can connect to both interfaces with adapters, then the converted data streams can be uploaded to the Internet via a computer or a smart phone. It is possible to obtain parameters like engine speed, vehicle speed, temperatures, pressures, engine runtime, trouble codes etc. Using these values we can calculate other complex parameters as CO_2 emission or fuel consumption which are important to help eco-driving, make predictions about air pollution and derive decisions to guide the drivers.

A previous research [13] introduced a measurement tool and its environment from collecting parameters from vehicles. By using one smartphone with this tool, it was possible to collect the data only from one interface in the same time. The major disadvantage of the previous system was that if we were interested in both data streams at the same time, we had to use two phones: one for the OBD-II port and another one for the CAN bus. Although with this setup it was not possible to compare the data streams from the interfaces, this function was only available using the SensorHUB backend. Continuing the research and improving this tool we have created ObdCanCompare to make these data collectable with only one smartphone and make comparable in the same time on the screen of the smartphone (and also in the backend).

Our main motivations are to add more comparable parameters to ObdCanCompare from CAN bus and also to prove that OBD-II is as good as CAN bus for our developments. Because the CAN bus gateways are car-specific, it is more expensive and more difficult to install in the engine compartment or behind the dashboard. Meanwhile the OBD-II port is easily accessible in most of the vehicles and OBD-II adapters are inexpensive, same for every car and can be bought easily. In further research and development, the resources of SensorHUB will be also used to extract consequences from the processed data sets for predictions about further values and usages which are interesting for other related research disciplines including the intelligent decision technologies.

In this paper we introduce the improvements and features of ObdCanCompare. We also determine the further possibilities of the tool using the SensorHUB framework to extract and derive other parameters. We introduce our first results and an implementation of a socio-cognitive gamification application called Social Driving, where we use the SensorHUB backend to compare the parameters (CO_2 emission, fuel consumption, etc.) of the drivers and return the rank of the driver. At the end of each month the most eco-driving users can gain coupons or discounts at fuel stations or other partners.

The rest of the paper is organized as follows. Related works can be found in Section 2, then Section 3 introduces the SensorHUB Framework and VehicleICT implementation. Section 4 presents the improvements and functionality of ObdCanCompare and Social Driving. Finally, Section 5 concludes the paper and proposes further research areas.

2. Related works

In [3] the authors introduce their platform called DrivingStyles. The architecture integrates both data mining techniques and neural networks to generate a classification of driving styles by analysing the driver behaviour along each route to achieve a symbiosis between smartphones and vehicles through its OBD-II port. Their final goal is to assist drivers at correcting the bad habits in their driving behaviour, while offering helpful tips to improve fuel economy.

In [4] the authors propose an Android-based application that monitors the vehicle through the OBD-II interface, being able to detect accidents. Their proposed application estimates the G-force experienced by the passengers in case of a frontal collision, which is used together with airbag triggers to detect accidents. The application reacts to positive detection by sending details about the accident through either e-mail or SMS to predefined destinations, immediately followed by an automatic phone call to the emergency services. Experimental results using a real vehicle show that the application is able to react to accident events in very low time, validating the feasibility of smartphone based solutions for improving safety on the road.

In [7] the authors define and design an embedded solution to support drivers in driving process. It can obtain real-time vehicle data, such as vehicle speed, engine speed, coolant temperature, instant fuel consumption, etc., from CAN bus and through this information to provide services to drivers. By Android-based mobile devices and an embedded circuit, they can collect, store and analyse the various vehicle information and then use these data to provide back-end services to drivers. Vehicle information is transferred to a mobile device which, using internet connection transmits them to a server.

The major difference between previous researches, results and our work is that we have proposed an accurate OBD-II and CAN bus comparison tool, we have improved its capabilities and now we show how the tool works in real environment and we compare data transmitted from the car via OBD-II and CAN bus.

3. Background: SensorHUB

In this paper, we focus on the comparison of the OBD-II data and CAN data. For this, we used the resources and services of the SensorHUB framework and its automotive subsystem, the VehicleICT framework.

The SensorHUB framework supports data collection and service development to utilize sensor networks, smart devices and cloud-based backend environments.

The architecture of the SensorHUB concept is depicted in Figure 1. The whole system contains the following areas [8]:

- Sensors, data collection, local processing, client side visualization and data transmission.
- Cloud based backend with big data analysis and management.
- Domain specific software components.
- Applications, services, business intelligence reports, dashboards.

3.1. Vehicle as a set of sensors

During the driving of a vehicle every important value can be seen on the dashboard: speed. RPM, fuel level, coolant, other indicators. Nowadays we can use HUD (head-up display) or GPS device or board computer also. These devices can use the data bus of the vehicle or their own sensors. With special adapters we can also connect to communication buses.

The two main options are the OBD-II diagnostic interface or the inner CAN bus network infrastructure. Figure 2a shows a Bluetooth adapter which can connect to the OBD-II interface. The connector can be found in all car made after 2005 near to the pedals or to the steering wheel. Inside the adapter there is an ELM327 chip which converts the OBD-II stream for the RS-232 serial port. USB and Wi-Fi implementations are also available.

In Figure 2b a CAN bus gateway is presented. This device based on FMS standards [13] (Fleet Management System) was made by the Inventure Inc. [2] mainly for fleet management for trucks so a lot of special parameters are available like pedal positions, tachograph data, driver identification, etc. However these gateways are car-specific, more expensive than the OBD-II adapters and also their installation is more difficult in a vehicle.

Collecting data from these two interfaces with our smartphone via Bluetooth stream is simple with a client application. In our environment the application will be the ObdCanCompare. Using a smartphone we can also acquire some other interesting parameters extracted from its sensors. Some options are: GPS (longitude, latitude, GPS time, and altitude), accelerometer (acceleration, deceleration), camera (record the way), light sensor, proximity sensor, magnetometer, etc. Complex parameters can be calculated with special formulas, as the CO_2 emission or fuel consumption.

3.2. VehicleICT

VehicleICT platform is the vehicle related implementation on top of the SensorHUB framework, which supports connected car domain related application and service development. [11] It utilizes the capabilities of the SensorHUB and provides a vehicle domain related layer with several reusable components and features. This means that the VehicleICT itself can be considered as a test environment that verifies the different aspects of the SensorHUB framework. [5] Figure 3 introduces the architecture of the solution with the following areas:

1. Smart Client Environment (ObdCanCompare),
2. SensorHUB service bus,
3. Reporting Agent (Pentaho),
4. Data Center (Hadoop).

4. Contribution - Case study: ObdCanCompare and Social Driving

We implemented the ObdCanCompare application, which is suitable for receiving parallel Bluetooth data streams both from the OBD Bluetooth adapter and from the Inventure Inc.'s FMS Gateway CAN adapter as well, displaying them on the screen of the smartphone and transmitting the data to the SensorHUB server. On the screen it is possible to analyse data with the built-in real-time comparative charts, dashboard-like displays and text displays.

4.1. Measurement environment

Before implementing ObdCanCompare two or three smart phones needed for the measurement environment. One phone used for the OBD-II Bluetooth stream and another one for the CAN bus stream. To access the backend internet collection also needed. After implementing ObdCanCompare the needed device number was reduced to one smartphone and receiving parallel Bluetooth data stream became possible as it is presented in Figure 4.

4.2. Business intelligence reports

On the infrastructure side, the data collected from the vehicles are aggregated, processed and loaded into a data store. This is a state-of-the-art data storage cluster, equipped with the Apache Big Data Stack (Hadoop) [9]. From its Data Lake we can also make custom ETL (Extract-Transform-Load) processes to get the necessary dataset. Based on the measurements it is possible to generate business intelligence reports for example with Pentaho Business Intelligence system: tables, comparative charts and maps, or with Big Data techniques obtain more complex conclusions. Figure 5 shows examples for maps in the reports.

The analysis shows, that the OBD and CAN bus data are similar to a certain extent. Some features like engine RPM or speed correspond roughly, but a number of additional parameters, including derived values significantly differ. Based on these report generator system we created the analytic system of our Social Driving application.

4.3. Social Driving – a socio-cognitive gamification application

Based on the OBD-II interface we have implemented an application for community usage, called *Social Driving*. The original concept behind the application is to create a service that integrates connected cars in a social context, in order to help the users to be a better driver and to utilize the car sensor data in the level of urban society. Besides, users can compare their performance values with each other. The inevitable connection between cars and air pollution had triggered the basic idea. Eco-friendly driving could help to save fuel, which affects not only the environment, but the wallet of the drivers too. In order to help users to drive eco-friendly, the analysis of the information focuses on carbon-dioxide emission and fuel efficiency. [15] As a future plan we are also working on connecting the application to the current smart city conceptions.

We have designed the solution on top of the SensorHUB backend which collects and aggregates the information from the drivers, and emit the aggregated values back to the driver's smartphone. Figure 6a shows the fuel usage and Figure 6b shows the CO_2 emission comparing the actual value of the driver to the aggregated value of all users.

A conception for the application (which is currently in alpha testing phase) is to make contracts with companies connecting to the vehicle domain (fuel stations, parking companies, etc.). They will be able to mark areas as geofences in the city and if the user drives to this area, a push notification can be sent to the smartphone with a coupon to a product or service at the company. This service is using the proximity service implementation in the SensorHUB backend. The coupon is a QR code, what can be easily used for discount coupon widely as it is presented in Figure 6c.

The users can also follow each other (with anonymized names or nicknames) on the livemap and there they can watch if there any new geofence-based coupon has been created. Livemap is shown in Figure 6d.

These functions and services are a good base for socio-cognitive ICT. As the most important features of this field: focus on cognitive capability, a generic perspective, various temporal scales and the context of emergent functionality are appearing in our application and conception. It realizes the sensor-bridging and sensor-sharing communication where cognitive entities on both ends use the same sensory modality to receive information what is not only transmitted, but also transformed to a different, more appropriate sensory modality of the receiving cognitive entity. [14]

Social Driving can be customized for company usage, where the properties of employees can be reported to the employer. The reports can include tables and charts about the employee with the following values: GPS coordinates, vehicle speed, engine speed, fuel consumption, CO_2 emission, etc. Figure 7 and Figure 8 shows example charts of the reports. From the reports ranks can be made and for example the most eco-driving employee could get reward or premium. This could realize a socio-cognitive gamification between the employees in a company with positive output: the users would be more eco-drivers, they would care the environment, finally they would also profit from the situation.

5. Conclusions and future work

Measurements with longer measuring time show that the engine and vehicle speed values are almost the same from the OBD-II and CAN bus interfaces as presented in Figure 9. Differences can be observed only for shorter (10-20 s) measuring time.

The main difference between the two interfaces is the sampling frequency. The frequency of the OBD-II port is 1 Hz. while the frequency of the CAN bus could be higher however it was limited to 5 Hz in our measurement setup (as the limited throughput for uploading samples) [13]. Another difference is the amount of parameters. The FMS-based CAN bus provides some other interesting parameters which unavailable on the OBD-II interface like fuel level, total used fuel, total vehicle distance (mileage) etc. but also provides fleet management and truck specific parameters like tachograph data, driver identification, etc. which are not necessary for us. Parameters of both interfaces can be used as the basis for derived parameters.

Comparing the OBD-II and CAN bus data, we can say that for a basic smart car-based solution such as our connected car-based social application Social Driving, it is sufficient to use the OBD-II port with its 1 sample/s rate and limited selection of parameters as the important parameters are available and they are almost as accurate as the CAN bus measurement results. Of course for professional solutions, such as fleet management systems, the CAN bus-based solution is a better choice.

Currently we work on analysis algorithms and calculating parameters more accurately like fuel consumption, CO_2 emission and other interesting comparable parameters.

We would like to use the received data sets as input values for a machine learning environment to predict with prediction algorithms, decision trees or time series analysis about the values of parameters in the future to help eco-driving, make predictions about air pollution and also to help the drivers with recommendations for their route and driving style to make better decisions. For this purpose Weka data mining software [12], the Hadoop-based Sparkling Water [6] and Apache Spark MLlib [10] seems promising.

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Figures

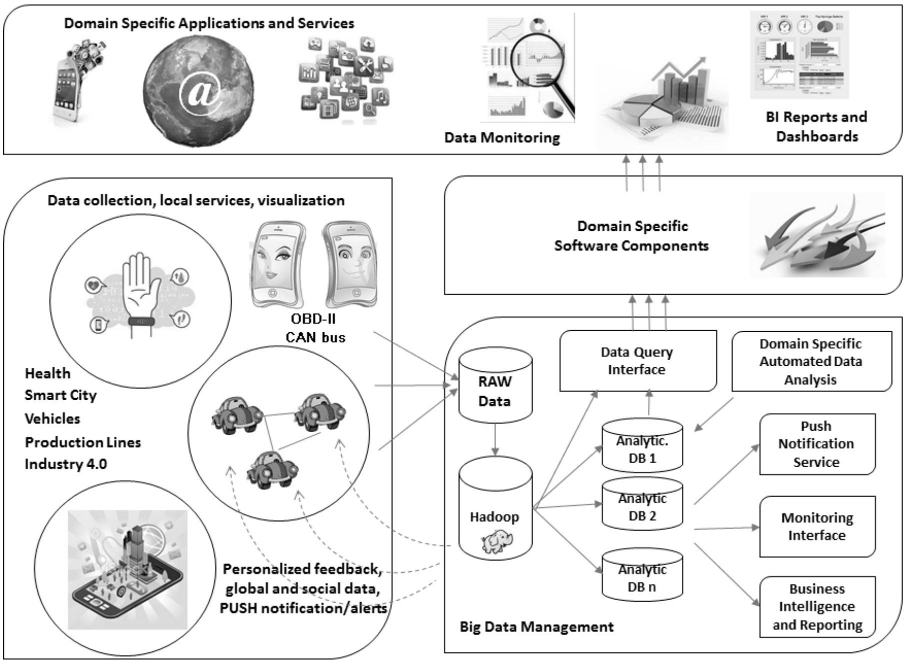


Figure 1: The SensorHUB framework

(a) OBD-II adapter (b) CAN bus gateway

Figure 2: Devices for smart cars

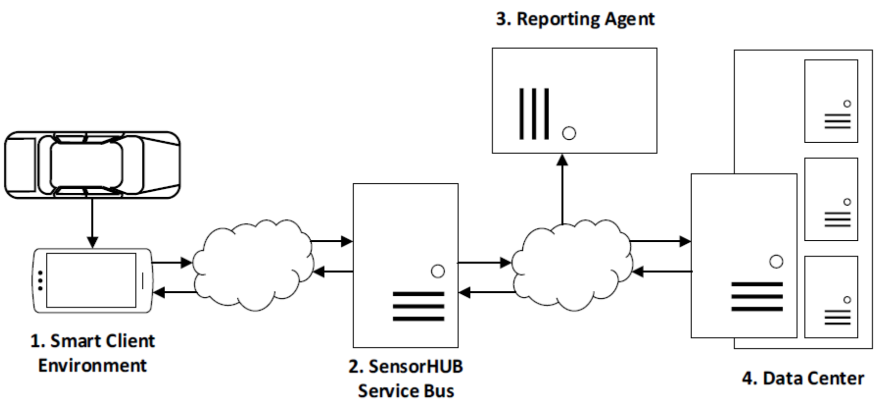


Figure 3: The detailed architecture of the VehicleICT as an implementation of the SensorHUB framework

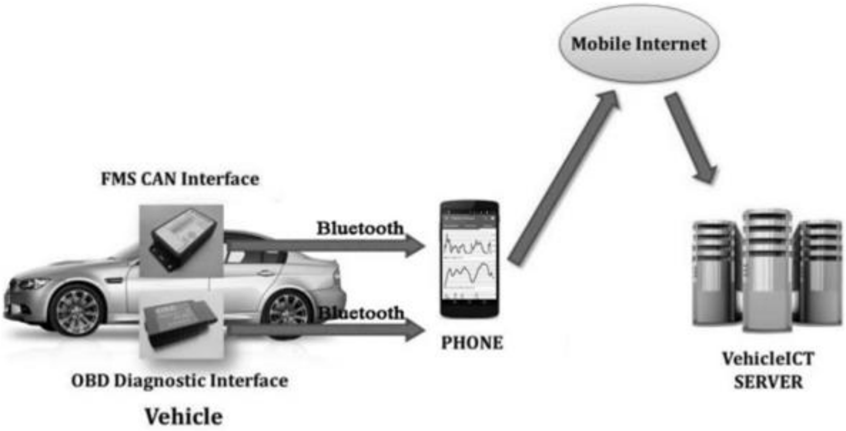
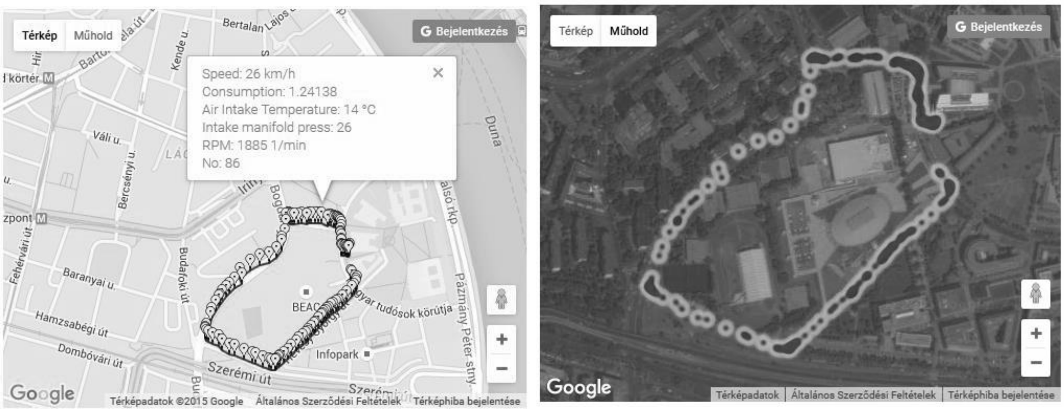
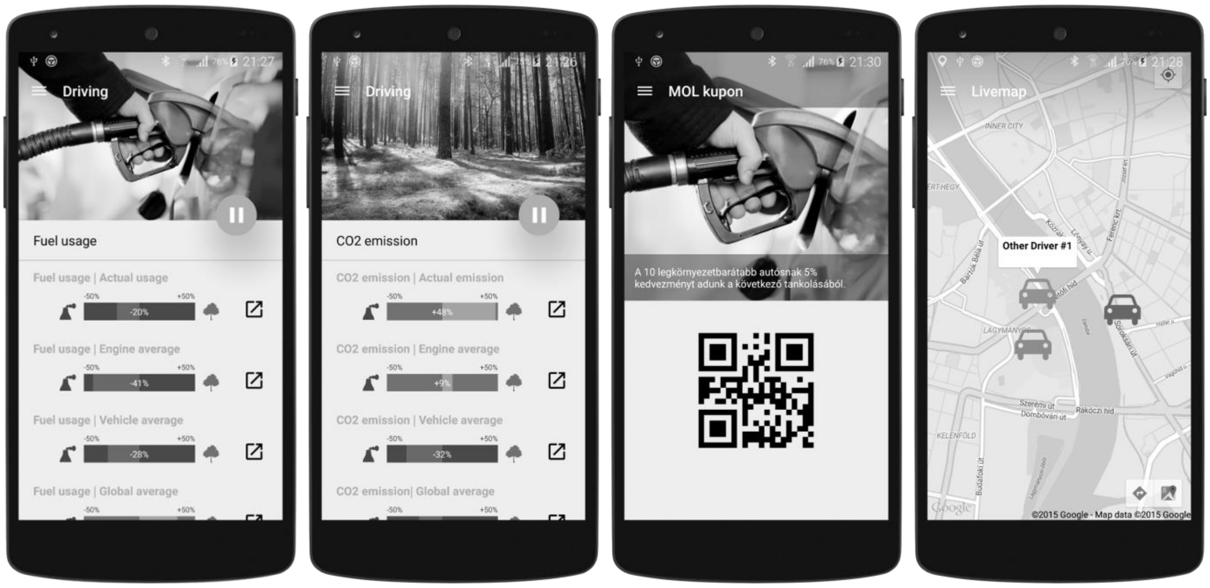


Figure 4: Measurement environment with ObdCanCompare



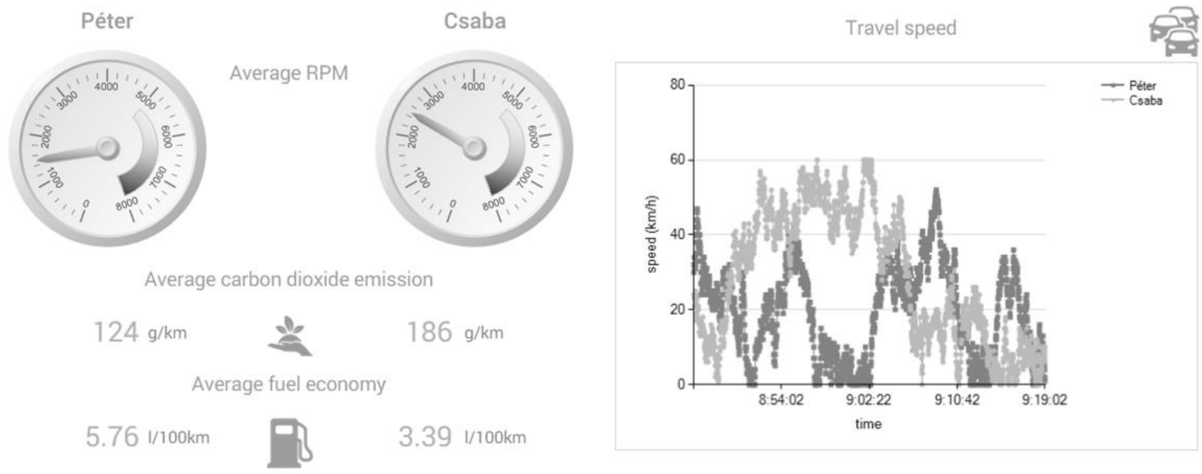
(a) Interactive map with values (b) Static map

Figure 5: Maps about test driving



(a) Fuel usage (b) CO_2 emission (c) Coupon (d) Livemap

Figure 6: Screens of Social Driving application

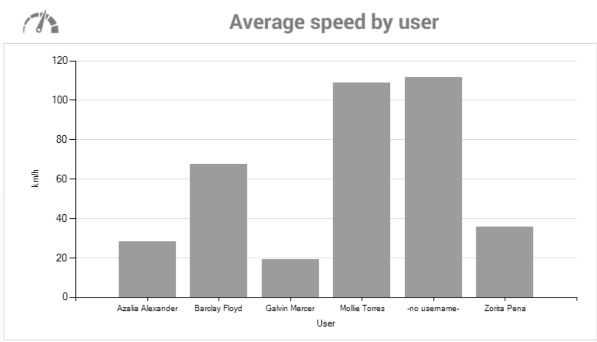


(a) Engine speed (RPM), CO_2 emission and fuel consumption (b) Travel speed

Figure 7: Comparing charts in Social Driving report

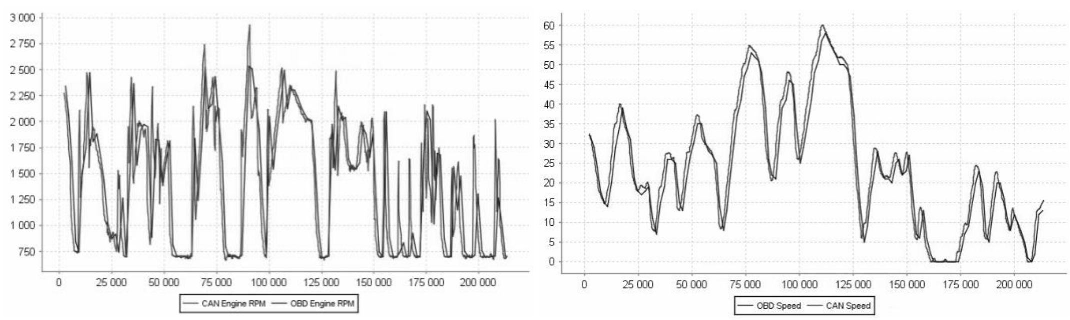
Total fuel consumption by user

User	Total kms	Avg. fuel economy	Fuel consumed
-no username-	0 km	13.08 l/100km	0 liter
Mollie Torres	2.53 km	5.64 l/100km	0.14 liter
Barclay Floyd	14.43 km	4.92 l/100km	0.71 liter
Zorita Pena	9.56 km	7.71 l/100km	0.74 liter
Galvin Mercer	9.1 km	5.76 l/100km	0.52 liter
Azalia Alexander	13.2 km	3.39 l/100km	0.45 liter



(a) Total fuel consumption by user (b) Average speed by user

Figure 8: Company charts in Social Driving report



(a) Engine speed (RPM) (b) Vehicle speed

Figure 9: Comparing charts in ObdCanCompare report