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Low-Emission Driving Assistants: Experience from MODALES

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Abstract

The H2020 project MODALES has implemented a mobile app for low-emission driving, which takes the role of personal assistant to the project's end-users. This app profiles a user's driving style and recommends attitudes to adopt or avoid. Using a mobile app makes it possible to reach a large number of users easily and at a low cost, thus enabling experimentation and awareness campaigns to be conducted on a wide range of configurations (e.g., car types, engines, geographical areas). This technical paper gives an overview of how this app works and shares this experience for other projects and activities. The presentation of this paper at the ITS Europe Congress will also include a **live demonstration of this app and of the tools developed within the project** to reduce vehicle emissions by changing driver behaviour.

Keywords:

Human-centred computing; Ubiquitous and mobile computing; Low-emission driving; On-Board Diagnostic.

Key objective:

Using a system embedded in a car, such as a smartphone, to collect useful driving data and to provide recommendations for low-emission driving behaviour.

Background on sensing systems and sensors:

Recent technological advances in communication technology and mobile computing have provided new ways to understand driving behaviour. These new tools require setting up in-car sensing systems to collect relevant data and process it. Detections performed by such sensing systems can be divided into two categories: **participatory sensing** and **opportunistic sensing**, preferred in most projects and where the data collection process is performed automatically and based on sensors. For instance, tri-axial accelerometers have been used alone for several decades to monitor human movement and estimate energy expenditure.

Sensing applications can usually address three detection levels depending on existing data-sharing policies (Lane et al., 2010): the **individual** level, the **group** level and the **community** level.

Depending on the detection level, different data protection and privacy degrees need to be adjusted, thus requiring the definition of rigorous data treatment systems. The usage of smartphone sensors to analyse driver behaviour is persistently shown in the literature and is mostly focused on the individual level. Therefore, the key challenge for conducting such research is selecting the most suitable sensors accepted by the driver (i.e., data collection process should be convenient to the end user, non-intrusive, and should not breach user privacy).

With this in mind, Table 1 below presents a comprehensive analysis to identify potential data collected through smartphones and OBD-II interfaces that can be used to analyse driving behaviour and to show user acceptance of the technology (Faye et al., 2017, Hong et al., 2014, Júnior et al., 2017).

Table 1 - List of smartphone and OBD data for the Driver Behaviour Analysis

Device	Sensor	Data	User Acceptance of Technology
Smartphone	Accelerometer	Acceleration, vibration, and tilt	High
	Gyroscope	Orientation details, rotation, and direction like up/down and left/right	High
	Barometer	Air pressure	High
	Network traces	Passive network data left by Wi-Fi, Bluetooth and cellular nodes	High
	Compass	Magnetic fields	Medium
	Camera	Facial Images	Low
	Microphone	Loudness of sound	Very low
	GPS	Location	Low
OBD-II dongle	-	Real-time parameters: Engine RPM, speed, pedal position, airflow rate, coolant temperature, Engine load, Throttle percentage.	Medium
		Vehicle Identification Number (VIN)	
		Status of “Check Engine” light	
		Emission readiness status	
		Oxygen sensor (maximum and, minimum voltage output, and switching rate)	
		Diagnostic trouble codes (DTCs)	
		Number of miles driven	
		Number of ignition cycles	

The mobile assistant implemented in MODALES:
MODALES' mobile app for low-emission driving aims to assist users throughout their journeys, providing recommendations as they travel and in ways that do not interfere with their driving (e.g., when stationary at a traffic light or in the form of sound notifications).

Technically speaking, the app adopts a modular approach, which allows several small components to be developed independently and then interact with each other to provide a unique driver experience. This approach facilitates collaborative development and validation. The app has been developed for Android and iOS, using the Flutter framework to avoid working on two code bases. Flutter is Google's SDK for crafting beautiful, fast user experiences for mobile, web and desktop from a single codebase. In order to prevent breaches of privacy, most of the processes operate locally on the mobile phone. Furthermore, the local computation allows the system to operate even without Internet connectivity.

The app is broken down into three separate modules:

- A **data collection module**, which considers data from *(a)* OBD-II (e.g., engine rpm, vehicle speed), *(b)* phone sensors (e.g., accelerometer, wireless traces) and *(c)* the user. Using an OBD dongle would be optional to provide end-users with a standalone application and another – more accurate and detailed version – relying on additional data. The lack of data induced by the absence of OBD leads to less accurate estimates, but still valid. Phones should, if possible, be fixed in the car using a car holder, thus allowing the user to have a comfortable view of the phone's interface and for the proper recording of accelerometric data, i.e., using a stable reference in space.
- The data mentioned above is used as input to a **scoring module**, making it possible to create a local representation of the user's profile and distinguish different behaviours previously identified via laboratory tests and state-of-the-art reviews. This scoring module can compute, on one side, a real-time acceleration profile, and on the other side, a time series of scores, using a classification approach. Input data comes from OBD dongle and phone sensors, while ground truth data would be provided by the user and independent data such as GPS.
- Finally, a **recommendation module** will advise the user to adopt attitudes depending on his/her perceived behaviour. Based on the two sub-scores explained above, the mobile app generates two types of recommendations:
    - **Active recommendations**, which are presented to the user while driving. The user's driving style is analysed in real-time and transcribed into an acceleration score. The user interface and possible actions are be limited, so these recommendations need to be simple to preserve the user's safety. Active recommendations require local data processing and storage.
    - **Passive recommendations**, which are given to the user after a trip. A report is generated, including textual recommendations, statistical analyses and contextual elements. This

feedback allows drivers to learn from bad driving habits and improve their emissions reduction. Passive recommendations mean that data processing and storage will be outsourced to an external server.

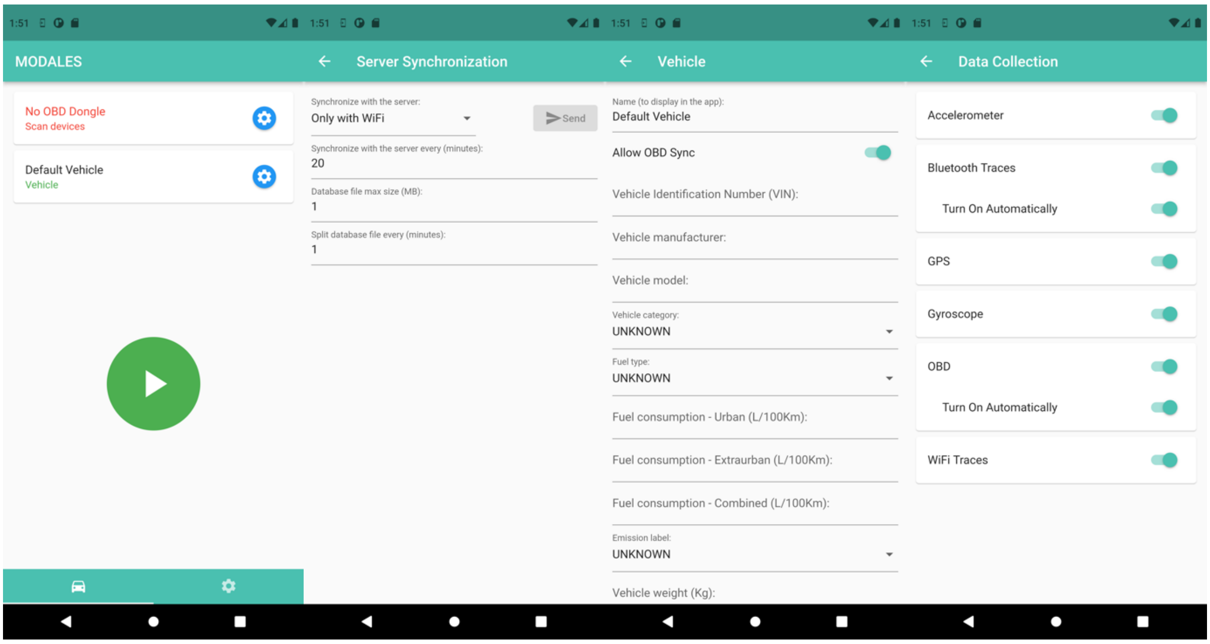

Figure 1: Screencaps of the app's data collection module

A larger view: the project's dashboard:

For each app user, anonymous indicators are transmitted to a **web dashboard** to collect usage statistics and performance metrics. The latter allows the authorities and the public to understand the benefits of the mobile app and view statistics by region or type of user. The web dashboard aggregates the data and presents them in various graphical representations to assist decision-making.

Figure 2: Screencap of the dashboard

The Web dashboard application is based on the received data from the mobile sensors and OBD dongles and indicators derived from them:

1. Vehicle emissions
2. Fuel consumption
3. Driver aggressiveness

The three indicators are time-based. Thus, the dashboard can also present the performance evaluation based on time.

Data specification:

We collect or compute factors that we consider necessary to offer recommendations to the driver. We divided these factors into four categories: environmental, vehicle, driver profile and driver behaviour. The environmental category covers everything outside the user control (e.g. weather and traffic conditions). The vehicle category describes the vehicle's state mainly in a static manner. Similarly, the driver profile category covers static aspects of the driver. Finally, the driver behaviour category includes factors that change continuously during a trip and define how the driver is performing. Some of these factors are be used to give recommendations while driving, others for recommendations offered after the trip is over, and others for impact assessment. Table 2 below describes the key metrics considered by the project's systems.

Table 2 – Data collected by MODALES' mobile assistant

Category	Factors that influence low-emission driving	How to get this data?				
		From OBD/J1939	From mobile sensors	From user Input	From car model	From external service
Environmental	Type of road		X			X
	Speed limit		X			X
	Road surface conditions		X			
	Wind					X
	Slope		X			X
	Congestion		X			X
	Light conditions		X			X
	Temperature					X
	Humidity					
	Raining					
	Snowing					
Vehicle	Vehicle type	VIN		X	X	X
	Engine type			X	X	
	Fuel consumption label			X	X	
	Emission label			X	X	
	Vehicle weight (empty vehicle)			X	X	
	Tyre information (brand/model, year)			X		
	Tyre pressure					
	Vehicle km			X		
	Use of retrofits					
Driver profile	Gender			X		
	Age			X		
	Use of vehicle			X		
	Driving experience			X		
Driving behaviour	Acceleration	PID90	X			
	Deceleration	PID90	X			
	Speed	PID13	X			
	Engine torque requirement	X				
	Engine rpm	PID12				

Conclusion and first results from the data collection campaign

User pilots are key aspects for testing with end-users and validating the development as well as for creating a large data collection system to profile a driver's behavior. Studies are deployed in the following sites: Leeds (UK), Helsinki (Finland), Barcelona (Spain), Thessaloniki and Athens (Greece), Romania (Bucharest), Luxembourg (several areas), Istanbul (Turkey), Nanjing (China). 25-30 people per site compose the sample group which consists of both private and professional drivers. In the first period of recorded driving (baseline), the drivers are not using any MODALES tool and this period will last 2-3 months, starting from January 2022. The second period will also last 2-3 months and the drivers have to use the MODALES tools (app on smartphones with an OBD reader installed). The data will be stored on the device and frequently sent by the user and/or the mobile device itself to a central server for filtering and time series interruption checks. The driver will be reminded to use the application through the social media and time related messages to his/her smartphone.

As the trials will have 25-30 vehicles per site and rely on volunteers, a perfect representation of different vehicle types as well as age groups, gender, driving experience and trip habits is not possible. The primary selection needs to be on the vehicle type, as for cars EURO-4 engine technology or newer ones are needed, but not less than five years old (older models cannot provide the required OBD data and newer models have cleaner engines and hence the advice from the DALED app would have less effect). For commercial vehicles, the fleets depend on the companies which agree to cooperate with MODALES on these trials (e.g Nestlé Hellas).

Prior to the trials, two ramp-up pilots have been performed in Barcelona and Luxemburg in 2021 as a preliminary experiment. Their purpose was to check the whole process in order to identify and solve possible issues the trials may encounter.

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