Artemisa: Early Design of an eco-driving assistant

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Abstract

Eco-driving is becoming a very important topic in recent years since aspects such as environmental pollution, energy conservation, global warming and user safety depend on it. To save fuel, it requires a combination of vehicle design principles (including aerodynamics, engine optimization, fuel type and vehicle weight) and that the driver adopt an efficient driving style.

This paper presents an eco-driving assistant that evaluates the driver's driving style from the standpoint of fuel consumption. Then, based on the assessment provides advice to adopt eco-driving habits. Eco-driving assistant will facilitate that drivers learn the techniques of efficient driving.

We solution runs on mobile devices with Android OS requiring minimal HW inside the vehicle. Furthermore, analyze better driver's driving style than other solutions because it takes into account environmental variables that influence in the fuel consumption.

1 Introduction

Vehicles are important energy consumers and major emitters of pollutant gases. The vehicle pollution produce causes more deaths than road traffic accidents [Spanish SPT, 2011; IDES, 2006]. Reducing energy consumption is therefore a priority for governments, vehicle manufacturers and users.

Energy savings in vehicles depends mainly on two factors: the vehicle and the driver. Regarding the vehicle factor, manufacturers have taken a series of measures to reduce energy consumption:

- Aerodynamic design with less air resistance
- Reduction in the fuel consumption of the engine and in CO2 emissions
- Use of hybrid engines (petrol / electric)
- Vehicle weight reductions that requires less power to move

In order to improve the driver factor, eco-driving assistants are designed to provide appropriate advices that stimulate the application of eco-driving principles and facilities their learning.

Eco-Driving assistants tend to involve an extra cost to the vehicle, since they require the use of extra hardware and software. In addition, these solutions do not model successfully the driver´s driving style because they don´t consider environmental variables such as the state road, the road characteristics and weather conditions.

This paper proposes an early design of an eco-driving assistant which is being implemented and validated inside the Spanish funded ARTEMISA project. This solution tries to minimize the on-board hardware and software requirements.

Artemisa´s eco-driving assistant is based on the use of a mobile device running the Android OS [Android OS Developer, 2011] where the eco-driving assistant is executed. Also, we will use a Bluetooth module that connects to the vehicle´s diagnostic port. This Bluetooth module allows sending the vehicle telemetry to the smartphone.

Eco-driving assistant uses the information obtained through the diagnostic port with the smartphone´s information (Sensors, GPS and Internet connection) to accurately model the driver´s driving style from the point of view of energy consumption.

This approach can be used on any model of vehicle and does not require any special device installed in the vehicle. Moreover, its cost is reduced, the Bluetooth module costs about 50 $ and Android Smartphone 100 $.

2 STATE OF THE ART REVIEW

The concept of eco-driving [Knowledge Platform Eco-Driving, 2011] has acquired a great importance and relevance in recent years due to the increase in the automotive fleet size and its influence on climate change.

The objective of the eco-driving is to reduce energy consumption by applying a set of rules based on physics that seek to reduce the demand for power.

These rules do not require a technological support but the cooperation of the driver. The problem is that driving is a very complex task in which there are multiple objectives such as safety, speed, etc. Sometimes, the objectives could come in conflict [Young et al., 2011]. For example, if the driver wants to arrive early at its destination, he will increase speed coming into conflict with the aim of reducing energy consumption.

On the other hand, many drivers are unaware that by applying a set of rules on driving can reduce energy consumption, so that, the motivation and learning are fundamental in the eco-driving process.

For the driver to learn the efficient driving techniques, we can use an eco-driving assistant. There are several studies like [Boriboonsomsin et al., 2009] that value the suitability of eco-driving assistants to make the user acquire a more efficient driving style.

The use of efficient driving techniques has a positive impact on fuel saving as has been demonstrated in many studies such as [Mierlo et al,. 2004].

There are also several proposals to analyse which variables affect fuel consumption. [Kuhler et al., 1978] introduced a set of ten variables. These variables are used in laboratories for consumption and emissions of vehicle fuel. Other authors such as [André, 1996; Fomunung et al., 1999] increased the number of parameters or replaced some of them to improve results. The drawback of these proposals is that they do not take into account the environment where the vehicle circulates that often has a significant influence on energy consumption.

Otherwise, there are in the market several commercial solutions that attempt that the driver acquires habits of efficient driving. Nissan has designed a system [Eco-Pedal, 2008] that suited the acceleration depending on the circumstances. If the driver exerts on a gas pressure exceeding the recommended one, he is alerted by a warning light that was accelerating incorrectly.

Garmin has developed a program called [EcoRoute Garmin, 2011] for their GPS devices to get the most economical route in terms of fuel economy. This software also has a scoring system that rewards good driving style from the point of view of energy saving.

In addition to these proposals, [Audi EcoTraining, 2011; Fiat Eco-Drive, 2011; HondaEcoAssist, 2011] also have eco-driving assistants. These solutions use data from vehicle sensors to assess the driving style from the energy efficiency point of view and then deliver efficient eco-driving tips. The problem is that they are dependent on vehicle model and are usually offered as an extra.

Another type of solution to minimize fuel consumption is the proposal of [Ford and Google Cloud Prediction, 2011]. They propose to predict the behavior of the driver to minimize energy consumption.

Vehicle will act as a data acquisition system and it will send the captured data to Google. Google using historical driving data and the Google Prediction API can predict certain aspects during the displacement of the vehicle allowing the optimization of the powertrain.

This solution, based on cloud computing, presents a serious problem since the vehicle´s data are very sensitive and could be used by an attacker for bad purposes. On the other hand, this solution is being developed for Ford vehicles and it is not valid for other vehicles.

3 Driving Style Modeling

To analyze the driving style of the driver, we will use multiple parameters. All these parameters can be classified into three classes according to the means by which they are acquired:

- Data obtained through the diagnostic port
- Information obtained through the Internet
- Data obtained through the sensors and the GPS in the mobile device

3.1 Data obtained through the diagnostic port

To obtain the parameters related to the vehicle we will use the sensors supplied by the vehicle. Sensors communicate with the ECU using a wired bus (CAN, LIN or MOST) or a wireless interface (RF or Bluetooth) although the latter is less common due to the power consumption of wireless networks and related security problems. We can obtain the data captured by the sensors in the vehicle through the diagnostic OBD2 port.

OBD2 is a standardized interface [Godavarty et al., 2000] whose origins come from the need for a mechanism of self-assessment which offers a reliably report on vehicle emissions and that can inform the driver about the malfunction of some elements in the vehicle. Since 1996, the OBDII is a legal requirement for new vehicles in the USA and since 2000 in Europe (Directive 98/69EG) for petrol cars, since 2003 for diesel cars and since 2005 also for trucks.

An Android Mobile device can capture the data coming from the diagnostic port (OBD2) using a Bluetooth Adapter as [OBDLink, 2011] that plugs into the diagnostic port. Bluetooth Adapter acts as interpreter converting diagnostic OBD2 port signals to serial data.

OBD2 provides numerous data about engine control unit and other unit of the vehicle as TCM, ABS, etc. To access this information, we will use an identifier called PID (hexadecimal digits). Each variable (speed, gear, Fuel consumption) of the system has assigned its own PID.

The process to get the value of a variable is as follows:

- The mobile device sends a PID to Bluetooth adapter
- The Bluetooth adapter sends the PID to the vehicle's bus
- A device on the bus recognizes the PID and sends the value for that PID to bus
- The Bluetooth adapter reads the response, and sends it to mobile device

3.2 Data obtained from INTERNET

Current chipsets for mobile devices usually integrate GPS, WiFi, UMTS, Bluetooth and GSM technologies in a low cost way providing multiple ways for the mobile device access to the Internet.

Using Internet and data location (Latitude and Longitude) obtained by the GPS or mobile triangulation network service, we can get information about the environment (road type, road state, weather conditions, etc.) that affects energy consumption. This information is normally available in XML, so we can process it easily since Android Os provides a XML API.

3.2 Data obtained through the sensors and the GPS from the Mobile Device

Mobile devices with the Android operating system have a multitude of sensors that can obtain the temperature, slope, atmospheric pressure, light, orientation, etc. To access this information, Android provides the following classes included in the package android hardware:

- Sensor: representing a sensor
- SensorEvent: that represents a sensor event and provides information about the type of sensor, time-stamp, accuracy and data provided by the sensor
- SensorManager: which provides access to the sensors on the device

Android allows us to obtain highly relevant parameters for the assessment of the driving style from the standpoint of fuel consumption without having to install additional sensors in the vehicle.

However, we have to take into account that sensors depend on the model of SmartPhone and the version of Android. For example, until Android 2.3 not be offered support for the pressure sensor. To find out which sensors has a mobile device, we can use the getSensorList method include in the SensorManager class. In figure 1, we can see the Data Adquisition System.

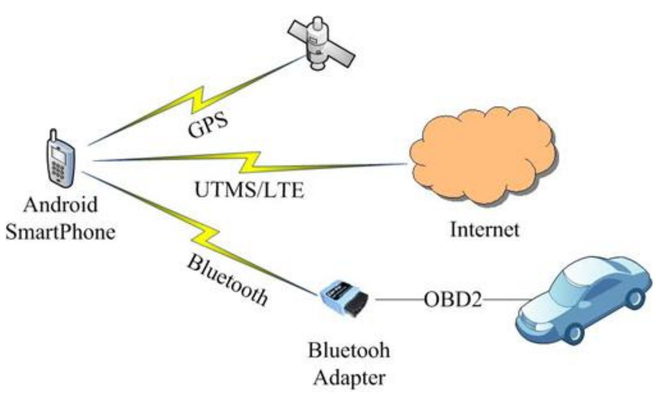

Fig. 1. Data acquisition system.

4 Eco-driving Assistant Architecture

The analysis of the driving style and the generation of recommendations is a very complex problem due to the large number of variables involved. We propose a solution based on the use of an expert system which runs on a mobile device with Android OS.

Current mobile devices have around 1GHz processors sometimes even two cores (TEGRA) which are able to perform complex tasks. However, its computational performance is not yet comparable to a PC processor. Furthermore, battery and memory consumption can be a problem. To resolve this problem, we propose divide the system in two modules: a client module and a server.

Client module is responsible for obtaining the data that are used to detect bad ecological driving habits. Also, it will check the eco-driving rules provide for the server to determine what eco-driving tips must be shown.

Client hardware consists on an Android mobile device and a Bluetooth Adapter module. Bluetooth Adapter is connected to the diagnostic OBD2 port and it will send vehicle data (Gear, Speed, Trip Distance, ect) to the Android mobile device thought Bluetooth.

Server is responsible for generating the eco-driving rules using a classification algorithm as J48. This solution is intended to release the client of this task which is computationally expensive. We describe the client and server components in more details in the following sub-sections.

4.1 Client

Client will use databases to store profiles, eco-driving rules and information acquired by the system data acquisition. To create and manage databases, we use SQLite which is integrated in the Android OS. The databases we use are the following:

User profiles: store the user specific information registered in the system

Vehicles profiles: store vehicle information such as the model and the main characteristics of the vehicles. This information allows us to use the eco-driving assistant on multiple vehicles

Eco-driving Rules: store the eco-driving rules obtained from the server or created by the user. Each rule will be associated to one or more users and to one or more vehicle profiles to allow personalize the system.

Facts Database: stores the data obtained by the data acquisition system. Its format is:

ValueAttribute_1, …, ValueAttribute_i

The attributes are the set of variables (speed, gear, weather conditions, ect…) whose values are obtained by the data acquisition system. When the value of the attribute is not known we insert a question mark instead.

Facts database only store data in the last ten minutes due to the limitations of Smartphones. Therefore, we have to progressively remove the oldest entries.

The client module also comprises the following software components:

Data acquisition System: This component runs as an Android service. An Android service is a component of an application used to perform an operation without the user having to interact with it. Data acquisition system obtained the following information:

- Data from the vehicle´s diagnostic port (acceleration, gear, speed, etc...) which is sent to the mobile device via Bluetooth from the Bluetooth Adapter module.
- Weather data from the Smartphone´s sensors or web service.
- Location data from the GPS receiver on the mobile device or from the network connection
- State of the road (traffic, incidents) and characteristics of the road obtained through Internet.

The obtained data will be stored in a database called Facts Database. Android uses SqlLite3 as database management system and provides several classes to manage transparently the database.

Preprocessing Module: It is responsible for generating a single instance from the data stored on the facts base in the last ten minutes.

To obtain the instance we will calculate the arithmetic mean for each attribute of the facts base, if the attribute is a numeric type. In case that the attribute is nominal, we will choose the most frequent value.

Preprocessing module and inference engine don´t run continuously because occasional actions that negatively influencing energy consumption must not be penalized. For example, if a man crossing the road incorrectly, we have to stop suddenly even if it is a mistake from the point of view of efficient driving.

Profile Manager: Responsible for creating, viewing, modifying and deleting user and vehicle profiles. This component allows the customization of the eco-driving assistant and its use in different vehicles. Profiles are stored in a database called profiles. This database will contain two tables: “User Profiles” and “Vehicle Profiles”.

Rules Manager: Allows us to create, view, modify and delete eco-driving rules. Also, we can download or update eco-driving rules from server via Internet Connection. Eco-driving rules are stored in a database called “Eco-driving-rules”.

Session Manager: Allow us to identify the user who is using the system. The aim is that multiple users can use the eco-driving assistant. Once the user has identified, the assistant may retrieve user preferences as eco-driving rules, vehicle profiles, etc.

Evaluation Module: It is responsible for evaluating whether it is satisfied the premises of the eco-driving rules, in which case will be shown the consequent of the rule (eco-driving advice).

The rules will have the following format:

If attribute_1 = X, attribute_2 = Y and attribute_3 = Z,
… attribute_n = T then eco-driving_tip_1.

Example: If speed = 130 and desviationSpeed = 15 then advice_1

This example expresses that if a vehicle circulates at 130 km/h and standard deviation speed value is 15, eco-driving assistant must be displayed the driving tip one. The advice one indicates that the user have to reduce speed because circulate at high speeds increases fuel consumption since is needed more power engine.

User Interface: Distraction is one of the major causes of traffic accidents. The use of non-driving devices such as mobile phone, GPS or eco-driving assistant has many negative effects if handled while driving or we divert too much attention to them.

To avoid these adverse effects, User Interface component will display with a clear typographic the eco-driving tips on screen. Also, we store a report with the eco-driving advices. Therefore, driver could see eco-driving advices when the car is stopped. Report is associated with the user's profile.

On the other hand, we will convert a random eco-driving advice to voice using TTS API provided by Android since version 1.6. All the eco-driving advices are not converted to voice because it demonstrated that the sounds distract the driver.

4.2 Server

On the server will have two databases: knowledge base and eco-driving rules database.

Knowledge base: It is a SQLite database that contains the knowledge (also called training set) extracted from the manuals about efficient driving or experts.

The format of the instances stored in the knowledge base is as follows:

ValueAttribute_1,ValueAttribute_2 ,......, Class

Attributes are the set of variables (speed, gear, weather conditions, etc.…) whose values are obtained by the data acquisition system. When the value of the attribute is not known, we insert a question mark instead. Class represents an eco-driving advice. Below, we will show an example of the instance of the knowledge base.

?,?,?,?,?,?,?,?,?,?,?,?,?,3000,?,?,?,?,?,2

This example expresses that if a vehicle circulates with 3000 R.P.M must be displayed the driving tip two. The advice two indicates that the user have to shift gears because circulate at high revolutions increases fuel consumption.

Eco-driving Rules Database: save the eco-driving rules generated by the generator module rules will be described below. These rules are to be provided to the client. Client uses these rules to evaluate the driver's driving style and therefore show the eco-driving tips.

The server module is divided into the following components:

Knowledge module: It allows that experts in eco-driving insert knowledge in the Knowledge base. Experts will have to indicate the premises values (attributes of the expert system) and the eco-driving advice to be applied (class).

However, it is not necessary to indicate the value of all attributes contemplate in the expert system because the classification algorithm (c4.5) handle training data with missing attribute values.

Rules generator: It is responsible for generating eco-driving rules using the knowledge stored in the knowledge base. The rules will be stored in the "Eco-driving rules" database.

To obtain the eco-driving rules we propose to use the C4.5 classification algorithm. This algorithm usually produces good results and does not need to know the value of all attributes of the system. In the future, it would assess the use of other algorithms.

5 Functional Description Of The Artemisa´s Eco-driving Assistant

In this section, we describe the process that is performed to obtain eco-driving advices on the client. Furthermore, we explain how the server gets the eco-driving rules.

5.1 Client Functional Description

The first step of the client is to get enough information to model the driver's driving style from the point of view of energy consumption. The information is gathered by the module data acquisition system through the mobile device, Internet and vehicle´s diagnostic port. The data collected are stored in the database of facts. Samples are taken every second.

In parallel, every 10 minutes is run the preprocessing module and then, the evaluation module. Preprocessing module generates a single instance from the data collected in the last 10 minutes that are stored in the facts base. The resulting instance will be evaluated by evaluation module using the eco-driving rules.

The consequent of eco-driving rule whose premises are met will be the eco-driving tip that are not fulfilling the driver and therefore have to show.

Evaluation module does not run continuously because occasional actions that negatively influencing energy consumption must not be penalized.

Finally, user interface module will convert to voice a random eco-driving tip, show all eco-driving tips on screen and store an eco-driving report. In figure 2, we can see a diagram of Client.

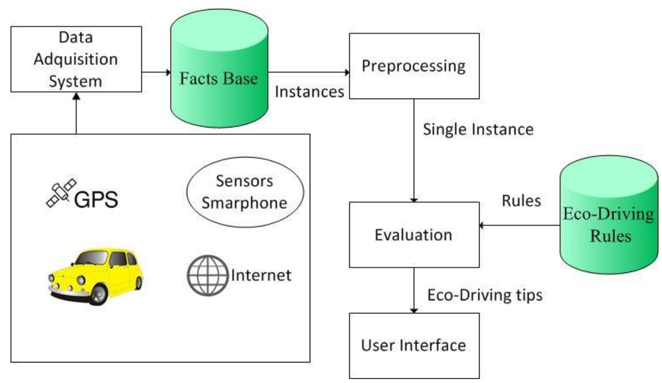

Fig. 2. Client Functional Description.

5.2 Server Functional Description

To obtain eco-driving rules, server uses the c4.5 algorithm. This algorithm build decision tree using the knowledge stored in the knowledge base and the gain information concept. Eco-driving rules are generated from the decision tree.

The classification algorithm will run each time that experts introduce knowledge in the knowledge base.

Generate the rules does not require any information from the client. In this case, the only data that travels over the network are eco-driving rules, so there are not security problems unlike the solution proposed by Ford. In figure 3, we can see a diagram of Server.

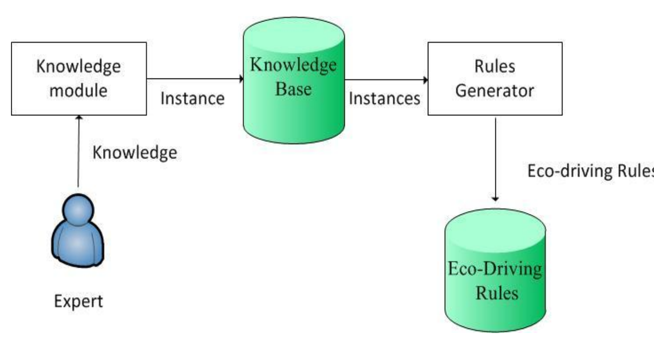

Fig. 3. Server Functional Description.

Conclusion and future work

In this paper, we have proposed an eco-driving assistant to help the driver to adopt an efficient driving style.

Unlike other proposals presented, Artemisa´s eco-driving assistant takes into account environmental variables that influence fuel consumption. The aim is to evaluate the driving style assessment as accurate as possible, in order that the eco-driving tips shown are really useful and not discourage the driver.

Furthermore, we solution is cheap, compared to others that requiring the installation of additional hardware components in the vehicle and. On the other hand, it is independent of vehicle model.

In the future, we plan to improve the system by establishing an interconnection network of vehicles that allow us to know the precise path of the vehicle that precedes the driver and its traffic flow to be able to anticipate events. Anticipation is a key factor to achieve efficient driving.

It would also be interesting to analyze various algorithms to see if they produce better results than the proposed algorithm (C4.5) to generate eco-driving rules.

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