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F. J. Ruiz, N. Agell, J. A. Ortega (Eds.)
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ARTEMISA: Architecture of an eco-driving assistant based on the anticipation

V.Corcoba Magaña[1], M.Muñoz Organero[1], A. Fernández-Montes[2], J. A. Ortega[2]
[1]Dpto. de Ingeniería Telemática.
Universidad Carlos III.
Leganes, Spain
vcorcoba@it.uc3m.es, munozm@it.uc3m.es,
[2]Departamento de Lenguajes y Sistemas Informáticos
Universidad de Sevilla
Spain
afdez@us.es, jortega@us.es

Abstract

This paper presents the architecture of an eco-driving assistant. The assistant evaluates the fulfilment of classic eco-driving advices such as: maintain a constant speed, driving at high gear, slow down smoothly and so on. In addition, the assistant issues advices based on the anticipation. Anticipation is the key of eco-driving. The assistant is capable of detecting traffic signs beforehand and it checks if the speed is suitable for not having to slow down sharply. In addition, the system proposes an optimal average speed according to the conditions of the road.

To model the environment where the vehicle is moving, we use an Android mobile device. These devices are ideal due to to their multiple network connections (Bluetooth, UTMS and WIFI) and sensors (camera, acceleration sensor, GPS and so on). To obtain the vehicle's parameters (speed, fuel consumption, RPM, etc.), we use the diagnostic port (OBD2).

The proposed system can improve fuel consumption and safety. In addition, it is independent of the type of vehicle.

1 Introduction

The number of vehicles has increased in recent years. As a result, it has increased the fuel consumption and the emission of gaseous pollutants. The emission of gaseous pollutants causes more deaths than traffic accidents. On the other hand, the energy resources are limited and the increase in demand causes them even more expensive.

In this context, many solutions have appeared that seek to reduce fuel consumption and greenhouse gas emissions. There are solutions based on the reduction of the weight of the vehicle, improvements in aerodynamics, improvements in the engine, etc. Among these solutions, there is one that has gained great importance in recent years: the Eco-Driving. Eco-driving is a driving technique that saves fuel regardless of the technology. This driving technique consists on applying set of rules such as: Maintaining constant speed, driving at a high gear, driving at 90 Km/h maximum, avoiding speeding up and slowing down sharply and so on.

Applying the eco-driving rules, we may save between 10 and 25% of fuel [Muraki and Kanoh, 2008][Barbé and Boy, 2006][Mierlo et al., 2004][Koskinen, 2008]. However, the percentage of fuel economy will depend on the type of vehicle. For example the hybrid vehicles only save 10% [Lindfeldt et al., 2010]

There are a lot of research studies on eco-driving. Some authors try to find parameters that affect fuel consumption and determine how they influence fuel consumption. [Ericsson, 2001], suggested that to save fuel we should avoid heavy acceleration and high speed driving. [Johansson et al, 2003] proposed maintaining low deceleration levels, minimizing the use of 1st and 2nd gears, increasing the use of 5th gear, and block changing gears to save fuel. [Kuhler and Kartens, 1978], identified a set of ten variables that influence energy consumption and in the emission of greenhouse gases.

Other authors evaluate the effect of using an eco-driving assistant in the fuel consumption and distractions that may cause. [Boriboonsomsin et al, 2009] evaluates the suitability of eco-driving assistant to acquire knowledge about eco-driving. [Klauer et al., 2006] concluded that distraction due to secondary tasks like interacting with a mobile device contributed to over 22% of all crashes. [Riener et al., 2010] proposed a vibro-tactile notification system into the car seat (either in the safety belt or the seating), to warn about the current CO2 efficiency.

A way to address the eco-driving is to influence in the parameters that the driver controls at any time such as: speed, accelerations and gear. In [Saboohi and Farzaneh, 2009], the authors proposed a control strategy to drive efficiently. This control strategy determines the adequate speed and adequate gear at any given time. [Casavola et al., 2010] analyzed two algorithms to determine the most efficient gear for fuel saving at each time. [Barth and Boriboonsomsin, 2009] proposed an algorithm for deriving the recommended set vehicle speed, based on real-time measurements from a traffic measurement system. In [Ke et al., 2010], the authors proposed a Min-Max ant algorithm to find an optimized vehicle speed and acceleration with respect to fuel-efficiency.

In this paper, we propose an eco-driving assistant to help the driver for adopting an efficient driving style. The assistant will warn the user when it does not comply with the basic rules of eco-driving. Also, it recommends an optimal average speed. The eco-driving assistant runs on an Android mobile device. These devices are suitable due to its multiple connections and sensors. However the presented architecture could be run on another platform.

2 Eco-driving Assistant

[Artemisa Project, 2012] aims to save fuel by modifying the behavior of the driver. To do so, we can use static eco-driving advices or dynamic eco-driving advices. Some static advices are: not to drive fast, not accelerate sharply, driving at high gears, maintaining speed constant and so on.

Dynamic Eco-driving advices are those which take into account the current conditions such as: traffic density, vehicle speed, weather conditions, traffic accidents and so on.

The proposed eco-driving assistant takes into account these two types of advices. The effectiveness of eco-driving assistant attendees to modify the behavior of the driver has been widely proven**.**

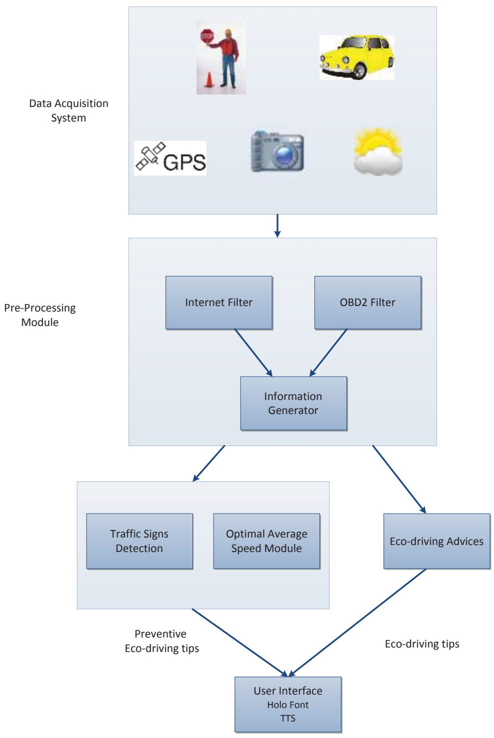

Figure 1. Architecture of eco-driving assistant

In Figure 1, we can see a schema of the proposed system. Eco-driving assistant has the following components:

- Data Acquisition System: this component is responsible for obtaining information about the vehicle and the environment. The information obtained will be used to determine what eco-driving advices should be issue.
- Preprocessing Module: this component is responsible for filtering the data collected by the data acquisition component and generating additional information by analyzing the data collected.
- Eco-driving advices: this module is responsible for evaluating the driver driving style and based on this evaluation issuing eco-driving advices, so that, the driver will change the negative aspects of his or her driving style. For example: If the driver brakes sharply, the eco-driving assistant will issue: You should slow down smoothly.
- Predictive advices: this module predicts in advance situations that cause an increase in fuel consumption to warn the driver. Also, it indicates that actions should be taken to prevent such situations.
- User interface: this module is responsible for presenting the eco-driving advice and warning the user.

2 Data Acquisition System

Data Acquisition System obtains the value of all variables that influence fuel consumption or that can help to predict the actions to be performed by the driver to save fuel. It uses as information sources the following means:

- Internet: State of the road and weather conditions
- Camera: Traffic Signs Detection
- GPS: Vehicle Location
- OBD2: Vehicle speed, RPM, fuel consumption and travel distance

Internet information
Traffic Density and Weather Conditions are obtained from the [DGT, 2012] web service and [AEMET, 2012] web service. The information is provided in XML format. The Android XMLNull library is used for processing the file XML.

Camera
Eco driving assistant uses [OpenCV project, 2012] library to take the photograph from the road. OpenCV is cross-platform, there are versions for GNU / Linux, Mac OS X , Windows and Android. It contains over 500 functions covering a wide range of areas in the vision process as object recognition (face recognition). This library makes internal use of Android native libraries to access to the camera.

Location
Geographical Coordinates are obtained through the GPS from Android mobile device or triangulation of antennas. Eco-driving assistant uses the geographical coordinates to determine the vehicle location. Vehicle location is used to obtain the road conditions. In addition, it also used to save the location of the detected traffic signs.

OBD2
Vehicle speed, RPM, fuel consumption and travel distance are obtained from vehicle diagnostic port (OBD2). OBD port [Godavarty et al., 2000][OBD2 Adapter, 2012], was proposed in 1984 and it is known as the standard OBDI. OBDI is strong mind focused on the assessment of the emission of gaseous pollutants from the vehicle. In 1988, OBD was improved and it was named as OBD2. OBD2 provides much more information than OBDI because its aim is not only to evaluate the emission of gas pollutants, but also to be able to do in-depth diagnostic about the operation of vehicle. This diagnostic vehicle port (OBDII) is included in most of today's vehicles.

To obtain the vehicle diagnostic values, we connected a Bluetooth adapter to the OBDII port and the adapter sends data to an Android Mobile Device. Figure 2 shows the data acquisition system.

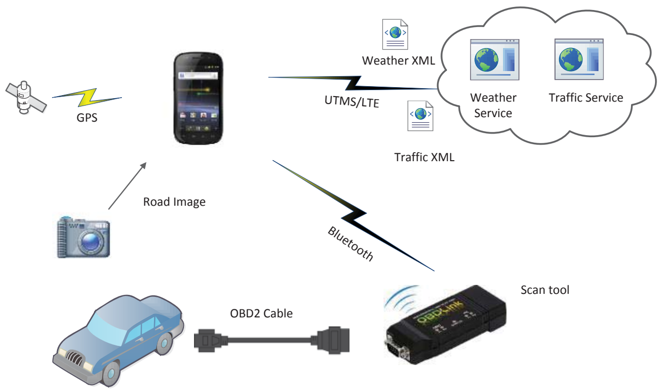

Figure 2. Data Acquisition System

3 Pre-Processing module

This module is responsible for filtering and extracting information from the data collected by the data acquisition system.

OBD Filter
On some occasions, the data obtained through the OBD2 port are unusual. For example, when the vehicle is stopped the travel distance value supplied by the diagnostic port is incorrect. This filter is responsible for removing the values that exceed a threshold.

Weather Filter
This filter is responsible for categorizing weather conditions into three classes: good, regular and bad.

Traffic Filter
This filter is responsible for categorizing the traffic density in three classes: smooth, moderate and heavy.

Image Interpolation
We resize the captured image 10x using cubic interpolation. Due to the limited processing capabilities of current mobile devices, we resize only the right half of the image. We resize this region of the image because in Spain the traffic signs are located on this side of the road.

Generation of information
We can obtain relevant information about the driving if we look at the data collected by the data acquisition system. For example, if we observe that the distance traveled remains constant over a period, we can deduce that the vehicle is stopped. If the vehicle is stopped for more than two minutes, we could issue an Eco-driving advice as: You must turn off the vehicle engine during prolonged stops.

4 Eco-driving Advices

This component assesses compliance with the following eco-driving advices:

- Vehicle Speed should not exceed 110 km / h
- Accelerations should not exceed 1.5 m / s ^ 2
- Slowdowns should not be less than -1.5 m / s ^ 2
- Driver must turn off the vehicle engine when vehicle is stopped for more than two minutes
- The driver is driving at low gear

5 Prediction Module

There are numerous studies on eco-driving, which states that the key to eco-driving is the anticipation. Our system analyzes the environment and it predicts whether the driver actions will cause an increase in fuel consumption or not. To achieve this goal, the system has two components:

Traffic Signs Detection
Sharp accelerations cause a considerable increase in the demand for energy, and therefore, an increase in fuel consumption. On the other hand, sharp slowdowns cause a great waste of energy.

A large proportion of abrupt decelerations and unnecessary acceleration are due to the driver distractions. These distractions make the driver fails to comply with traffic signals that require or may require stopping.

The eco-driving assistant warns the user when the speed at which he or she circulates is not appropriate due to the proximity of a traffic signal that requires or may require stopping. The "adequate" speed is defined as the one that allows the vehicle to stop upon reaching the traffic signal without exceeding a threshold in the slowdown. We have set the threshold at 1.5 m/s^2. Greater decelerations make fuel consumption increase exponentially as we have observed in several tests.

Our eco-driving assistant detects three types of traffic signs: stop signals, yield and pedestrian crossing. To detect these traffic signs, we use the method proposed by Viola & Jones [18] that uses a cascade of strong classifiers. This proposal is the first object detection algorithm to provide competitive object detection rates in real-time.

Viola & Jones propose to detect objects based on the change of intensity. The method employs features that involve the sums of image pixels within rectangular areas. A learning algorithm, based on AdaBoost, selects a small number of critical visual features and builds a set of strong classifiers (cascade) using these features.

The efficiency of this method is due to:

- A new image representation for very fast feature evaluation.
- At any stage if a classifier rejects the sub-window under inspection, no further processing will be performed and it will continue on searching the next sub-window. So in the early stages, many sub-windows (the easiest) are removed with very little processing.

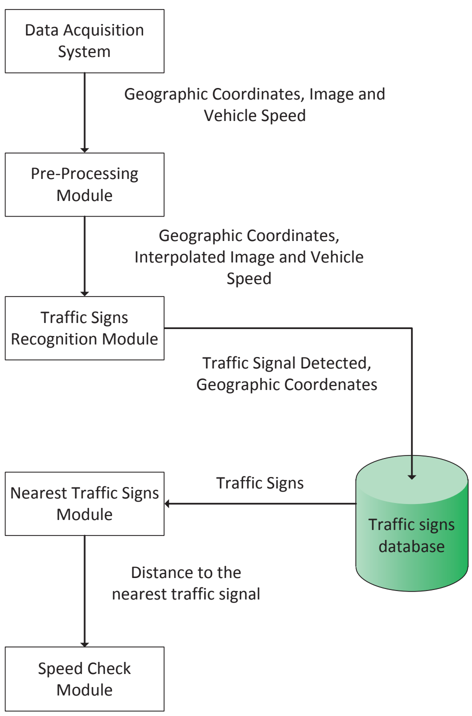

Figure 3. Schema of traffic signs system

In Figure 3, we can see a schema of the Traffic Signs Detection System. Our proposal uses as input variables: vehicle speed, vehicle location and interpolated image.

The detection module looks for traffic signs on the interpolated image using the method of Viola & Jones. It´s important to highlight that the set of classifiers is built on a PC due to low processing power of the mobile phone. Classifiers are saved on the Android mobile device as an xml file.

If the detection module detects any traffic signal, it will save its geographical coordinates in a nAndroid SQL database. The objective is to detect the traffic signs in advance because the system is only able to detect signals up to 20 meters distant due to the limitations of the cameras on mobile devices.

Then, the Nearest Traffic Sign Module gets the distance to the closest traffic signal. Finally, the Speed Check Module is responsible for checking if the current speed is appropriate using the current vehicle speed and the distance to the nearest traffic signal.

Optimal Average Speed Module

This module obtains the optimal average speed to minimize fuel consumption and increase safety. Although, vehicle speed is not the only parameter influencing in fuel consumption, it is one of the most decisive because it influences other factors such as acceleration, decelerations and security (control over the vehicle).

To get the optimal speed, this module uses an algorithm based on genetic algorithms (ASGA). ASGA defines the problem as a combinatorial optimization problem where the individuals are represented as vectors. Each position of the vector represents a section of the trip. In addition, the position of the vector contains an average speed value and travel time. For example, in Table 1, the 2-position of the vector indicates that the vehicle must run at 90 km / h and travel time is 200 seconds.

Table 1

Encoding of an individual for the ASGA Algorithm

Variables			
Stage	0	1	2
Speed	20	90	45
Travel time	500	200	300

The algorithm has as input parameters: speed, traffic flow, weather conditions, R.P.M and the number of estimated stops. The fitness function is defined as:

$$F_n = \left(\left(\left(\frac{N_{Stops}*1000}{S_{d\ Stops}}\right) * \left(\frac{V}{10}\right)\right) + \left(\left(F_w + F_T\right) * \ln V\right)\right) + F_C$$

where F_c is the estimation fuel consumption(L/100Km) given by Eqs.1, S_d is the section distance(meters), N_{Stops} is the estimated number of stops, F_w is a weather factor given by Eqs.2, F_T is a traffic density factor given by Eqs. 3 and v is the vehicle speed (Km/h).

$$F_C = F_m * ((RPM_E * P_m)/7024)v \quad (1)$$

where F_m is the fuel consumption measured using the test ECE-15 cycle. This cycle was introduced by the EEC Directive 90/C81/01 in 1999, v is the vehicle speed, P_m is the maximum torque value (Nm) and RPM_E is the estimated revolution per minutes at v vehicle speed.

$$F_w \begin{cases} 0 \ if\ weather = good \\ 0.05\ if\ weather = regular \\ 0.1\ \ if\ weather = bad \end{cases} \quad (2)$$

$$F_T \begin{cases} 0\ \ if\ weather = low \\ 0.05\ if\ weather = moderate \\ 0.1\ if\ weather = heavy \end{cases} \quad (3)$$

Figure 4 shows a schema of the ASGA algorithm.

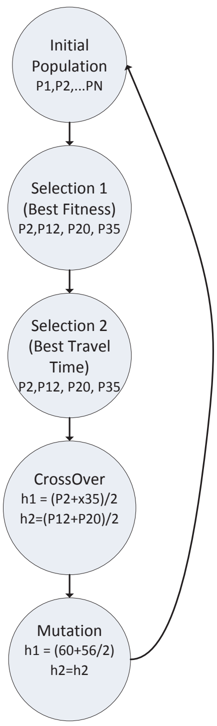

Figure 4. ASGA Algorithm

6 User Interface

Distractions to manipulate devices such as GPS or mobile are the cause of a large number of accidents (Mapfre, 2006). The user interface module is intended that the eco-driving advices are as least intrusive as possible.

User interface module is responsible for showing eco-driving advices with clear typographic, and also, it converts text to voice. Driver does not have to look at the screen.

We use the ROBOTO font to show the Eco-driving advices. This typography was introduced on Android 4.0 to improve visibility on devices with small screen. To convert the advices to voice, we use the TTS library that supports Android since version 2.1.

7 Conclusions

In this paper, we have presented the architecture of an eco-driving assistant developed inside the ARTEMISA project. The proposed eco-driving assistant evaluates eco-driving rules whose effectiveness has been widely tested. On the other hand, the eco-driving assistant is directly influencing the driver through the speed parameter.

In addition, the use of the assistant increases safety because the proposed speed for the vehicle is suited and adapted to the current conditions of the road. A large proportion of accidents of traffic are due to an inadequate speed

The proposed assistant runs on an Android mobile device. Today's mobile devices are suitable for modeling the environment due to to their multiple network connections (Bluetooth, Wi-Fi, UTMS) and sensors (GPS, Light Sensor, Accelerations sensor). In addition, the cost of implementing the solution is low. We can find Android mobile devices for less than $ 100. Furthermore, the proposed architecture could be easily moved to another platform.

As future work, we want to improve the eco driving assistant carrying out an exchange of information between the vehicles on the road. In this way, we can issue new eco-driving advices based on the anticipation. For example, if a vehicle is circulating at an unusual speed and it issues this information to vehicles that follow, these can shape slow-downs more smoothly.

Acknowledgments

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