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Co-operative ITS: ESD a Smartphone Based System for Sustainability and Transportation Safety

Vittorio Astarita[a], Demetrio Carmine Festa[a], Pasquale Giofrè[a], Giuseppe Guido[a] and Domenico Walter Edvige Mongelli[a]*

[a]*Department of Civil Engineering, University of Calabria, Arcavacata di Rende (CS) 87036, Italy*

Abstract

Co-operative Intelligent Transportation Systems (C-ITS) are emerging rapidly due to recent development in Global Navigation Satellite System GNSS systems and mobile internet. The main goal of these systems is to improve traffic conditions and safety level on the road networks. With the rapid growth of smartphone technologies and mobile internet, C-ITS based on smartphone may contribute increasingly in vehicle data collection and in traffic safety and sustainability issues.
This paper, extending previous research results, explores the possibilities of using smartphone applications coupled with a central server GIS (Geographic Information System) web system to contribute to traffic safety and to reduce fuel consumption. The idea of a co-operative system in which GPS (Global Positioning System) enabled smartphones are capable to acquire individual vehicle's kinematics is extended to take into account both safety and fuel consumption issues. Information in the system is shared on a web server for promoting more sustainable and safe driving styles. The co-operative system allows drivers to examine information about their individual driving style and consumptions allowing a better use of the road. Road operators can use the system to find critical points on the network and to promote traffic safety.

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Keywords: cooperative systems; smartphone; sustainable transportation, fuel consumption; traffic flow.

* Corresponding author. Tel.: +39 0984494020; fax: +39 0984494020
E-mail address: domenico.mongelli@unical.it

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1. Introduction

Co-operative Intelligent Transportation Systems (C-ITS) are being imposed on the market due to low cost of technological implementation. As defined by the European Commission, co-operative systems for road traffic management can be considered as a systems in which “road operators, infrastructure, vehicles, their drivers and other road users will cooperate to deliver the most efficient, safe, secure and comfortable journey. The vehicle-vehicle and vehicle-infrastructure co-operative systems will contribute to these objectives beyond the improvements achievable with stand-alone systems”.

Co-operative ITS can provide information to the road operators that can operate with an updated real-time knowledge of the traffic condition reducing risks for travelers and allow drivers and vehicles to communicate with each other.

In the latest years different technologies have been applied to co-operative systems and Europe has contributed supporting research projects[1,2,3,4,5,6].

As smartphones are spreading and becoming more and more connected, co-operative ITS in the future might be based more and more on smartphone use for different applications and there is a possibility to use smartphone to extract useful information on traffic speeds and in general on traffic conditions. New concepts in mobile phone use may emerge to sustain traffic safety and a better organization of people and vehicle movements; some of this new concepts will be based on the co-operative concept allowing people to gather information and efforts into new and more sustainable intelligent transportation systems.

One of the mechanism to gather position and speed information from smartphone are GNSS systems like Galileo, GPS and Glonass. In fact, GPS equipped smartphones represent today a low-cost means to measure travel time[7] and traffic flow conditions[8]; moreover they can be used to evaluate traffic safety[9] and path choice[10]. Herrera et al.[11] and Chen et al.[12] proposed traffic flow parameters estimation using GNSS sensors on normal mobile phones. Zhou et al.[13] presented traffic forecasts based on a fleet of GPS equipped cars. Others[14] proposed mobile phones as a means to control car dynamics for insurance companies. Many cooperative systems are becoming mainstream such as BlaBla Car and Uber. Salin[15] presented a mobile phone based cooperative system for pedestrian and bicycle users.

The objective of this paper is to present a co-operative smartphone based system named ESD (EcoSafetyDrive). In ESD smartphones units (on-board) are used to collect information on vehicle dynamics with the aim to establish better use of the road in terms of sustainability both from the point of view of traffic safety and reduction of fuel consumptions.

ESD collects information on all trip from the GNSS module of smartphones. Position, speeds and acceleration are stored for personal analysis of the diver and for a common shared co-operative use in the driver community. Moreover the same information can be used by road management agencies to better manage traffic control and to identify dangerous road spots.

The paper is organized as follows. Section 1 gives a general description of the system. Section 2 describes the main functions of the system. Sections 3 and 4 give more details on the safety module and on the fuel consumption modules. In Section 5 a summary of results and implications for future researches are discussed.

2. General description of the system

The proposed ITS system is built upon the gathering of driving tracks data, obtained by widespread smartphone technologies, and the successive elaboration and sharing of the relevant information among users of the system. Data are voluntary collected by users and transferred to the central elaboration unit of the system; the central unit elaborates information and creates a structured geolocalized database that can be interrogated by users. The information acquired from the database can be useful for the single user for personal use or for a shared use of data. Users on the platform are encouraged to share and cooperate.

ESD system originates from the combined application of mobile phone module and a central computational unit. ESD mobile application module collects and disseminate information in real time. The mobile phone application can collect satellite established positions of vehicles along a path and transfer this information to the central system. The central unit can elaborate information and give it back in a structured form in many different ways: by web interface and mobile phone applications and also according to the geographical position of the receiver. ESD system combines the “smartness” and computing capabilities of new mobile devices applications with a centralized Web-GIS Elaboration Unit.

The mobile device used in ESD can be any kind of mobile device that has GNSS capacity and that can collect data.The central server is based on a Linux-MySQL-PHP platform, that is able to process information and give back to users detailed information in graphical form. The operation flowchart is represented in Figure 1.

The mobile ESD application is able to save tracks of vehicles by memorizing position and speed obtained by the use of GNSS chips, currently embedded on most of mobile phones. Moreover it can provide alarms connected with the specific vehicle dynamic in real time.

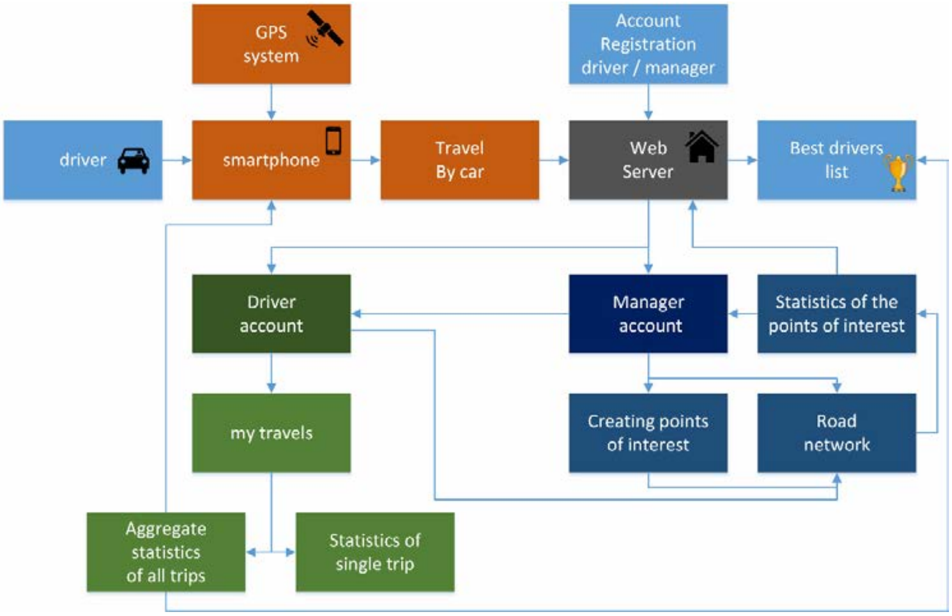

Fig. 1. ESD system process flowchart.

At the end of a trip the vehicle users can transmit all information to the central Unit, via standard internet protocol. The central Unit can elaborate data in order to extract information useful to road operators. The central Unit with WEB-GIS capabilities allows drivers to access detailed information about their own trips; on the other hand operators can access information that once treated and filtered does not contain any more private information regarding single drivers.

Users can analyze trip information regarding each single trip they have loaded on the system and see on a web generated map where and when they can improve driving style in terms of both more economical and more safe driving style. The system will show in detail where risky behaviors were adopted and where fuel consumption reduction would be possible. The system also allows to share information with other users and create a framework for driving style contests that would be designed to motivate a better use of the car. Road administrations are allowed by the platform to create contests and give awards to the best drivers according to the needed and desired driving styles on their road networks. For example, the road administration can set virtual speed monitoring points and can give awards to drivers that keep speeds the more regular and adherent to the administration expectations. In this way road administrations and public agencies can promote the use of the co-operative system and develop the driving styles at specific black spots in the road transportation system. The main rational in the ESD system is to increasingly train car users toward the adoption of improved driving behaviors by a motivating mechanism instead of punishment and restrictive interventions. Gaming interaction among drivers thus develops into a solution to enhance driving styles and traffic safety. This can be successful as drivers are motivated by an intentional contribution in an enjoyable activity. The ESD system in practice is a crowd sourced driving information data base with social and gaming characteristics, and with a capability of analyzing driving tracks from both point of view of safety and fuel consumption.

3. Functions of the system and data collection

The ESD mobile application allows users to simply manage fundamental functions. Users only need to start the application before the trip, then the app will collect data such as position, speed, acceleration and road grade from the GNSS chip system. Users are then informed by a coloured bar about fuel consumption rate and risky behaviors according to acceleration and speed profiles. The interface is designed to keep the attention of the driver on the road. After a trip, general information on each single trip can then obtained from the mobile app that has also a map view showing the position of incorrect driving maneuvers. Among the information displayed for each trip there are: an estimation of trip fuel consumption, an estimation of the cost of fuel, average speed, time of travel, maximum speed, percentage of correct and incorrect driving style. Once the information is transferred on the server, even more detailed information can be showed on the map relative to each single driving track or to the preferred combination of driving tracks.

Fig. 2. Mobile application for Google Android system.

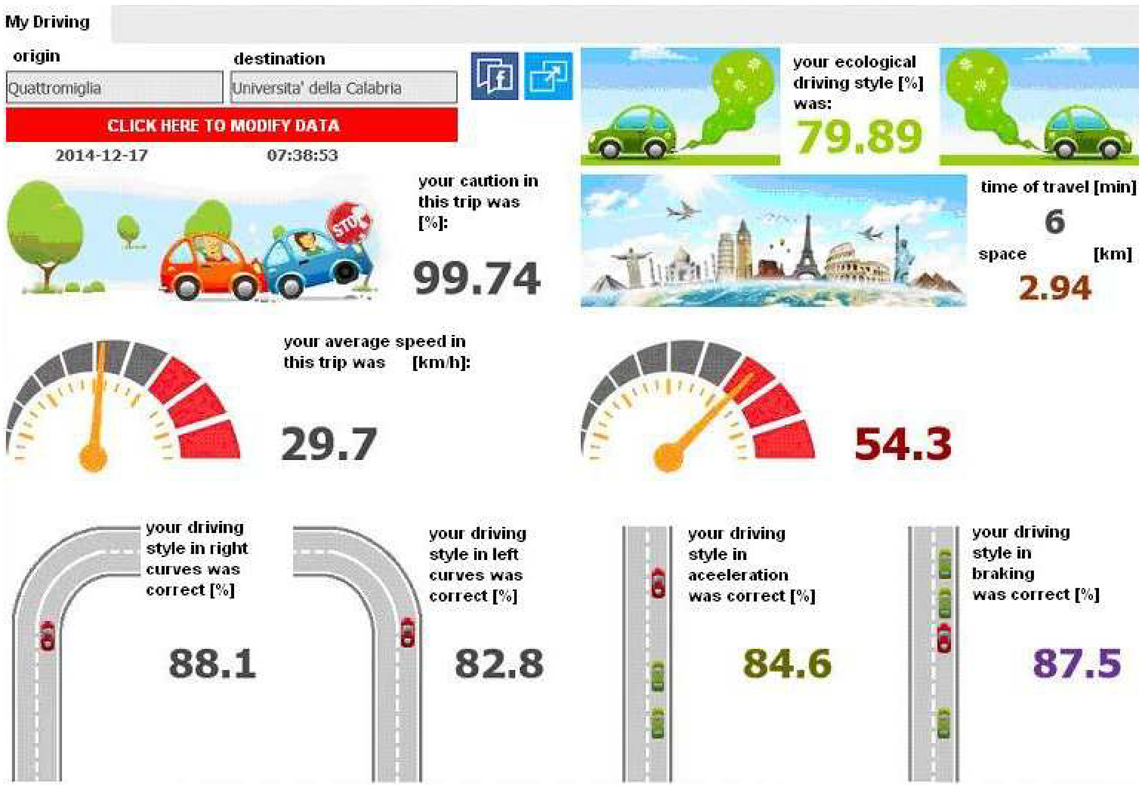

Fig. 3. Personal web page – Single trip information (web server).

Users can then decide in detail how to display trips and make interrogations to the web server in different ways. Trips can be showed on the map with evidenced critical points (Figure 4). The features of the system allows users to find and learn intuitively when a specific driving style can be improved.

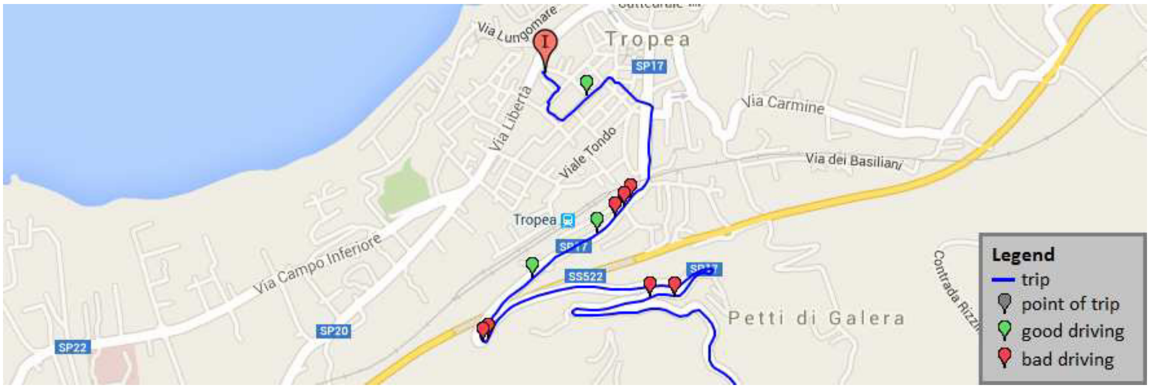

Fig. 4. A trip displayed on map and critical point (web server).

The ESD cooperative system is designed to reduce driving errors and to improve driving styles. The other function of the system is dedicated to public agency and road management that can access and analize aggregate data on the road network or on specific road location. The way information is structured in the system is useful to easy spot problems and to decide how to improve road conditions or make better management strategies for an increased safety.

4. Safety evaluation

Safety evaluation is based on the results of an Italian PON project: "M2M" Mobile to Mobility: Information and communication technology systems for road traffic safety (PON National Operational Program for Research and Competitiveness 2007-2013). The project M2M was aimed at every possible application of smartphones to enhance traffic safety. Results of this research[16,17,18] showed that driving styles can be considered more safe or less safe depending on speed and acceleration profiles obtained by the smartphone satellite positioning system.

When the point representing frontal and lateral acceleration is outside this defined diagram, the driver behavior is considered "unsafe". The number of instants in time in which lateral and frontal acceleration determine "unsafe" conditions on the total time of the trip gives an indicator for discriminating between aggressive and non-aggressive driving behaviors.

In the ESD system presented in this paper, acceleration values are used to warn drivers and to evaluate trip safety together with a speed based procedure.

The speed based procedure can be introduced when road operators establish in the ESD system desired speed for some specific control point. Drivers are then evaluated on both the acceleration profile and on adopting a speed that meets the administration expectations on the set of chosen control points.

Analyzing data on the ESD system relative to single trips or relative to aggregate statistics allows the drivers to correct driving style to meet both a better acceleration profile and the recommended posted speed limits.

5. Fuel consumption evaluation

The ESD system fuel consumption module has been designed on the basis of the survey carried on in[19]. The survey has been designed to evidence user's desires and to analyze the demand for this kind of services. The fuel consumption module is able to estimate consumption data without the need to consult the car OBD (On-board diagnostics) data by considering acceleration and speed obtained from the smartphone satellite location system. In other words, fuel consumption is evaluated just by the vehicle dynamics. The procedure is easy to use and original. Details have been presented in[20,21,22]. In all these previous works the system was based on data coming from both the GPS and the car OBD; data coming from the car OBD port were necessary to calibrate consumptions rates as a function of speeds, accelerations and rode slope in ESD instead fuel consumptions can be evaluated for every car with an autocorrecting procedure on the base of the reported past consumptions. The user has to update the mobile app with the effective observed consumption values each time the tank is refueled. In this way the fuel consumptions estimations are based on real values and not on values coming from the car OBD. Recently, in some cases with some automakers, OBD values were shown to be not accurate.

The developed methodology works through a series of corrections obtained with an algorithm that consists in solving a set of linear equations by trial. The solution of the equations is done by requiring as boundary conditions, the initial level of fuel in the vehicle and by using a reference matrix for consumptions.

After completing some refueling (6 times) it is possible to evaluate correction factors for the reference consumption matrix (Figure 5).

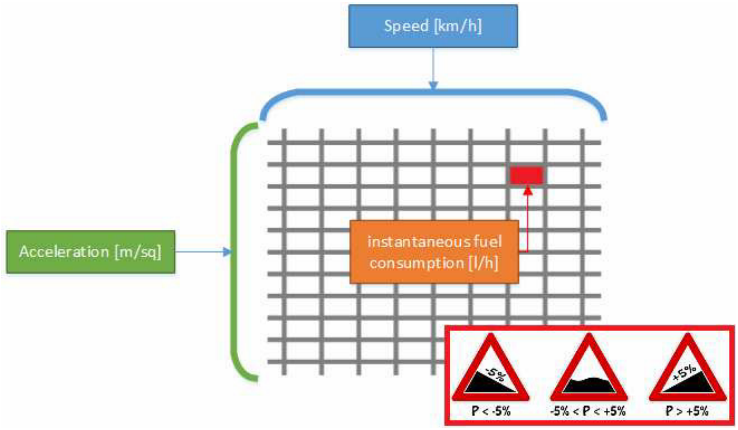

Fig. 5. Matrix of consumption as a function of three road slope categories.

The algorithm (Figure 6) takes into consideration the distance traveled as a function of the road slope and determine the correction factors evidenced by the completed trips. The system works iteratively adjusting the matrix with each trip and making consumptions estimates more and more accurate.

Fig. 6. Algorithm for consumption estimation.

The estimation of consumption is calculated as a function of the road slope. For the completed trips, paths are divided into three main categories of slope: uphill, downhill and flat.

In order to obtain a correction coefficient, the actual consumption rates need to be derived proportionally to the kilometers travelled in various slope conditions. The algorithm starts by calculating the difference between the theoretical and actual consumption assessed on refueling quantities. The difference is attributed for each of the three slopes as a function of the space travelled. A factor for the correction of the consumption matrices is obtained for each of the three slopes. A different reference consumption matrix is used for each of the three slopes. At the end of the instantaneous fuel consumption can be obtained for each of the three slope categories as a function of speed and acceleration.

6. Conclusions

In this paper it has been described a co-operative Intelligent Transportation System named ESD (EcoSafetyDrive) that is built upon mobile phone technology and data sharing, in which users can share information on trips with information on driving style and fuel consumption on a central informatics platform. The system can contribute to promote better driving styles in terms of traffic safety and fuel consumption, since it extends results of previous researches adding in fuel consumption evaluation and indications to reduce fuel consumption. Moreover information acquired with the system can be useful to identify dangerous road spots and dangerous driving maneuvers that originates from a lack in infrastructure design or management. The system allows to create a positive reinforcement of good driving behaviors by allowing authorities to assign awards to drivers that drive with a more safe and economical driving style. EcoSafetyDrive can thus be also applied to educate and motivate drivers for a better use of vehicles.

The proposed Co-ITS could become widespread and bring useful results if adequately promoted by public agencies. Future development will be addressed to reach the market and involve in a partnership road administrations and public agencies.

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