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Co-operative ITS: Smartphone Based Measurement Systems for Road Safety Assessment

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Abstract

Co-operative Intelligent Transportation Systems (C-ITS) are attracting a lot of attention, and many resources are devoted to the development of new platforms integrating vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. The main goal of these systems is to improve safety level on the road networks through a new intelligent services available on-board supporting smarter driving. Due to the rapid growth of smartphone technology and smartphone worldwide sales, C-ITS may have a great contribution from its applications in vehicles data collection. Worldwide sales of smartphones totaled 968 million units in 2013, according to Gartner Inc., exceeding annual sales of feature phones for the first time. This study presents a new co-operative systems based on a client/server platform in which client units are GPS-enabled smartphones capable to acquire individual vehicle’s kinematics to be shared on a web server for road operators and users analysis. The cooperative system allows drivers to watch detailed information about their individual driving style and global statistics on their trips. On the other hand, road operators can analyze the whole database to highlight critical points on the network (where unsafe behaviors occur more frequently) and to reward users with safer driving style. This study underscores the usefulness of the smartphone technology for improving C-ITS and assessing potential safety problems.

Keywords: road safety; co-operative ITS; smartphone.

1. Introduction

Co-operative Intelligent Transportation Systems (C-ITS) are rapidly growing thanks to the diffusion of low cost communication technologies. The most common communication cooperation on the road includes vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems.

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 provide several information about the vehicles and the road conditions to the road operators with the purpose of reducing the risk on the road network; furthermore, vehicles can communicate with each other and/or with the infrastructure increasing the quality and the reliability of information available about the state of the vehicles and the road environment.

In the latest years researchers have analyzed various application fields of C-ITS; a great effort has been made to improve the co-operative systems by using mobile radio networks, wireless communications technologies, and integration among traffic, communication and multi-user driving simulator framework.

Many activities have been started worldwide to develop new co-operative ITS improving traffic control and management. Europe has contributed to their development through political initiatives supporting research projects on co-operative systems such as COOPERS, CVIS, Safespot, COMeSafety, EuroFOT and Drive C2X.

Nevertheless, only recently researchers are trying to integrate vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications filling the current gap between the two approaches as in Walkie-Talkie project.

Due to the rapid spread of smartphone technology, co-operative ITS may receive a great support from its applications in vehicles data collection. If correctly designed, special applications for mobile devices can improve safe and comfortable mobility, and can lead to social and economic benefits, reducing the cost of the co-operative devices.

In fact, GPS equipped smartphones represent today a low-cost means to measure travel time, acquire instantaneous vehicle speeds, estimate safety performance on the road, estimate route choice models. Herrera et al. proposed a traffic monitoring system based on GPS smartphone sensors taking advantage of the extensive coverage provided by the cellular network in many urban jurisdictions. Chen et al. proposed a traffic information prediction system based on GPS-equipped probes reporting in real-time. Zhou et al. proposed a traffic flow analysis and prediction process based on GPS data of floating cars. In Handel et al. a framework is presented to deploy a smartphone based measurement system for road vehicle traffic monitoring and usage based insurance. Salin introduced a cooperative system for vulnerable road users based on mobile device.

The purpose of this study is to present a co-operative road safety management system (SafeCityDrive) based on a client/server platform. Client units are based on GPS-enabled smartphones (on-board) used to acquire individual vehicle instantaneous speeds and acceleration profiles. Instantaneous speeds and acceleration profiles are real-time shared on the server, and stored for road operators or personal analysis. SafeCityDrive is capable of capturing user’s behavior in each trip he made, and tries to educate drivers to a better driving style through the competitiveness among them improving safety on the road networks. Once the information are stored on the server, road operators manage the data and analyze the performance of the road network, especially in some critical control points (e.g. intersections, black spots, work zones). The cooperative system allows operators to reward users with more disciplined and safer driving.

The remainder of this paper is organized as follows. Section 2 introduces a new methodology for road safety assessment based on smartphone measurement systems. Section 3 describes the client/server platform and the mobile application implemented for this study. Section 4 summarizes the major conclusions of the study and suggests directions for future work.

2. System analysis

The system is based on the sharing of vehicle tracks data acquired by a mobile technology and sent by users to a central server that processes and organizes them according in the various points of interest. The system is therefore composed of two parts: 1) a client, composed by a mobile device, such as smartphones, tablets, etc., which collects the data, and 2) a central web server, based on the coupled Linux-MySQL-PHP, which processes them and returns statistics in graphical form. The operation flowchart is detailed in Figure 1. The specific app (SafeCityDrive) installed on the mobile device can trace drivers during daily trips by storing the location information obtained by the
use of GPS chips, now available on all mobile devices. Furthermore, it provides information regarding the driving style evaluating speed and acceleration profiles time by time from the GPS.

![process flowchart](image)

**Fig. 1. SafetyCityDrive process flowchart**

At the end of the trip the mobile application sends the information to the web server, via HTTP protocol. The web server processes the data in order to store only the information needed by the management staff of the road network. The web server then allows users to access information on two levels, the outer with stronger security constraints is dedicated to drivers who can use it to display detailed information about their individual driving and global statistics on their driving behavior, and to participate to contests that will reward the best drivers. The other level is instead devoted to road operators and allows them to manage some control points on the network, where users’ behavior is checked. Detailed statistics of all checked passes are available at these points, and road operators can use these statistics to decide how to reward the best drivers. When the managing staff inserts a new control point on the network, information from the drivers are sent and stored in the co-operative platform as a vehicle crosses the control point section. Subsequently, the server gives the driver a positive or negative score in terms of its driving behavior. A positive score is assigned if the speed at the control point is less than or equal to a threshold established by managing staff, otherwise a negative score is assigned. The sum of the positive and negative points is then used to determine the ranking of the driver relative to other users of the system. The user can also decide whether to take advantage of its accumulated points to buy prizes that road operators can make available to encourage the use of the co-operative system and improve the approach of the drivers at critical points in the road network. The basic concept of the SafetyCityDrive system is therefore to progressively educate drivers to a better driving style through the playful competition among them. The gaming interaction among different road users becomes the key to improve road safety, because in this way drivers are stimulated to improve their driving style by a voluntary participation in a fun activity. The system is therefore to be considered a container of information that is crowd sourced, and such as social networks, thanks to the playful competitiveness generated among drivers.

### 3. Client/Server platform

The app that runs on mobile devices is currently only available on Google Android (Figure 2), but its development is already planned for Apple's iOS and Microsoft Windows Phone. The Graphical User Interface makes it easy to use the app, as the driver, before starting the trip, only needs to run the app; the app will then provide by itself all the necessary operations to track the vehicle on the road.
The mobile application allows users to collect a series of parameters such as position, acceleration and speed via the GPS chip embedded on the device itself. In addition, through a colored bar, users can constantly monitor their driving style strictly correlated to the estimation of the acceleration and speed profiles obtained by the GPS chip. At the end of the trip the application can show statistics regarding the trip directly on the display of the device. Information are available on average speed, maximum speed, travel time, etc. Finally, to complete the process, users can transfer the data of the trip to the web server that will process them. The web server has two types of access, the first one for drivers, and second one for the road operators. The web server, allows the drivers to store and analyze trips in a simple and effective way, giving the chance to easily examine the main driving parameters for each trip (Figure 3).
Users can then decide how to visualize trips, whether individually or in aggregate form, and also query the web server in different ways. The trips can be displayed directly on the map with an indication of the critical points (Figure 4) identified by the management staff, or by choosing other available parameters, supplied by colored dots. This feature allows users to understand immediately where driving was incorrect or dangerous.

![Fig. 4. A trip displayed on map and critical point (web server)](image)

Travel data can also be displayed on a common graph lines (Figure 5) that provides more information than standard data visualization on the map.

![Fig. 5. Speed profile (web server)](image)

The system therefore allows to keep under control driving errors and to improve driving trip after trip. Drivers have also the option to visualize aggregate information on the map, querying the web server on a group of trips, rather than on a single trip. This kind of elaborated visualization allow users to understand whether, over time, they improve or not in their driving style. The other access system to the web server is dedicated to road infrastructure managers; by accessing the data uploaded by all the users, they can visualize statistics on the road network and, specifically, at the control points. This information could be useful to design measures dedicated to the improvement of the road infrastructure and establish policies for road safety assessment.

4. Conclusions

This paper has presented a co-operative Intelligent Transportation System based on mobile smartphone technology in which users share their driving style on a client/server platform for making safer their trips on the road.
networks. The major assumption is made that individual vehicle’s kinematics can be acquired by on-board GPS-enabled smartphones (client units), and then shared on a platform (server) useful for road operators analysis. A designed app for mobile devices (SafeCityDrive) implemented for this co-operative road safety management system is capable of capturing users behavior in terms of speed and acceleration profiles during their trips. The analysis and the management of these data made by road operators, especially in specific critical points of the networks (e.g. intersections, black spots, work zones), allow to identify potentially dangerous users behaviors and, at the same time, to reward users who adopt the best driving behavior. SafeCityDrive promotes the educational process towards a better and safer driving style through the competitiveness among drivers.

Notwithstanding the preliminary limitations of this study, the proposed C-ITS has yielded some promising results. Future development of this work should be addressed to raise the penetration market for the app and formalize the partnership with road operators in order to make SafeCityDrive more efficient in safety assessment on the road networks.

References