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The use of Smartphones to assess the Feasibility of a Cooperative Intelligent Transportation Safety System based on Surrogate Measures of Safety

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Abstract

The future of road transportation is going to be shaped by connectivity and autonomous driving. Connected and autonomous vehicles are expected to increase safety and reduce traffic congestion. Once all the vehicles are connected and geo-localized there might still be a need to integrate a different level of autonomous vehicles on the road: from the human driven vehicle to the fully autonomous vehicle. While surrogate safety measures have been extensively considered to estimate the risk of accidents due to improper driving, there has been no attempt to use them to help drivers achieve a better driving style. This paper presents an experimentation on the idea to warn drivers when they are driving in such a way (owing to their interactions with other vehicles) that could potentially lead to an accident. In the proposed system the driver is warned of the risk of collision by the combined use of localization (GPS) gathered information and the application of road safety indicators such as Deceleration Rate to Avoid a Crash, Time To Collision and others. The experimentation involving car-following vehicles showed the feasibility, with existing technologies, of using surrogate measures of safety to assist the driver in keeping a better driving trajectory. Once connected vehicles are introduced on the market, the presented results can be a base to develop commercial smartphone applications that will allow users of "not connected" old vehicles to also take advantage of real time driving assistance for a safer use of the road.

Keywords: Smartphone applications; ITS; Cooperative web services; Surrogate safety measures, Traffic safety, Road safety

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1. Introduction

Advanced driver-assistance systems (ADAS) are systems which are designed to help drivers in a way that should also increase traffic safety. Since most accidents involve human mistakes ADAS systems have been developed to assist drivers in the adoption of safer driving styles, thereby reducing possible mistakes. Already developed ADAS systems have been extensively made available to assist drivers in the car-following driving task and usually are based on computer image, radar image processing and Lidar data processing. The applied systems are not yet based on Vehicle to Vehicle communication (V2V). V2V systems require the introduction of new (sometime expensive) technologies on new vehicles. With the introduction of connected vehicles and a real implementation on the field of V2V technologies new ADAS systems might be introduced that will be able to take into account also satellite localization data and more complex interactions between vehicles such as, for example, the kind of interactions that can happen in a long platoon of vehicles. In this new scenario, surrogate safety measures, which have been considered extensively to estimate the risk of accidents due to improper driving, might be used to help drivers achieve better driving styles.

Surrogate safety measures indicators evaluate the interactions among vehicles in traffic, highlighting the occurrences of unsafe situations. At the end of the 1960s, Perkins and Harris (1967) [1] introduced the concept of traffic conflict for the first time. Baker in 1972 [2] described traffic conflict as the situation in which a driver tries to avoid a potential accident, or a situation of danger, through the application of an evasive maneuver (braking, lane change, or acceleration).

These indicators have been studied for several years, in different approaches, using real data of vehicle trajectories (Oh and Kim 2010 [3], Guido et al. 2010 [4], Guido et al. 2013 [5]) or micro-simulation of traffic (FHWA 2003 [6], Saccomanno et al. 2008 [7], Astarita et al. 2012 a [8], Astarita et al. 2012 b [9]). The indicators of road safety provide a causal or mechanistic basis to explain the complex interactions, dependent on time and vehicles, with an aggregate approach (Hayward 1971 [10], Minderhoud and Bovy 2001 [11]; Huguenin et al. 2005 [12]).

Meanwhile many Cooperative ITS systems have been developed applying smartphones; in [13, 14, 15, 16] smartphones are used for the evaluation of traffic parameters, and in [17, 18, 19, 20, 21, 22, 23] smartphones are used in a cooperative way to assess and reduce fuel consumption.

This paper intends to introduce a cooperative ITS to improve traffic safety, which can be useful for traditional "not connected" vehicles, following results of other researches [24, 25, 26, 27] where smartphones are used to improve traffic safety.

The safety measures can be classified into three different categories according to the method adopted to estimate the risk: measurements as a function of the reaction time, measurements as a function of the braking power, and safety indexes.

In this work, the safety levels are assessed in terms of:

- Time to Collision (TTC), that is, the time that, in the different phases of the conflict, a vehicle needs to collide with another vehicle, if they maintain their current speed to the projected collision point. When there is an ongoing conflict, the TTC value varies over time, and the critical measure of the severity of conflict becomes the minimum value of TTC. Its formula is the following:

$$TTC_f = \frac{d}{V_f - V_s} = [s]$$

- Deceleration Request Avoid Collision (DRAC), defined as the maximum deceleration request in order to avoid the impact, obtained from physics without considering the frictions. Its formula is the following:

$$DRAC_f = \frac{\left(V_f - V_s\right)^2}{2 * d} = \left[\frac{m}{s^2}\right]$$

where V_f represents the speed of the vehicle taken into consideration, V_S the speed of the vehicle which precedes it, and d is the distance between the two vehicles

2. Proposed system

To evaluate the interactions among vehicles, and then identify the potentially unsafe traffic conditions, we experimented a system that uses smartphone sensors to detect coordinates and speed of vehicles. The accuracy of the measurements obtained through the devices was evaluated acceptable for these types of measure from previous tests (Guido et al. 2012 [28]) coupling professional high frequency GPS receivers and different commercial smartphones.

The proposed system mainly consists of multiple client devices (drivers' smartphones) and a central computer that can receive and interpret signals received.

On the server side, the system has been implemented with a computer that is able to acquire data, to process them and send them back to the various devices. The computer used was an Intel ® Core ™ i7-2670QM with a frequency of 2200 MHz, 8 GB of RAM and a network card Realtek PCIe GBE Family 8168. A specific application named "UNICAL FALCO Road Safety" has been developed to compute and manage data coming from the devices. The application is able to capture the incoming data from the various devices, process them and finally retransmit them in a summarized form to the same device.

On the client side, the basic idea is to run an application that can gather the positional information and the speed information provided by the device and to send it to the central computer through standard 3G wireless phone data system.

The data required for the calculation of safety indicators are: the positions of vehicles, the time stamps(t) obtained by GPS, and the vehicle speeds (v). The computer application receives the data (Figure 1) with the Protocol GET / POST directly on the IP network card of the computer.

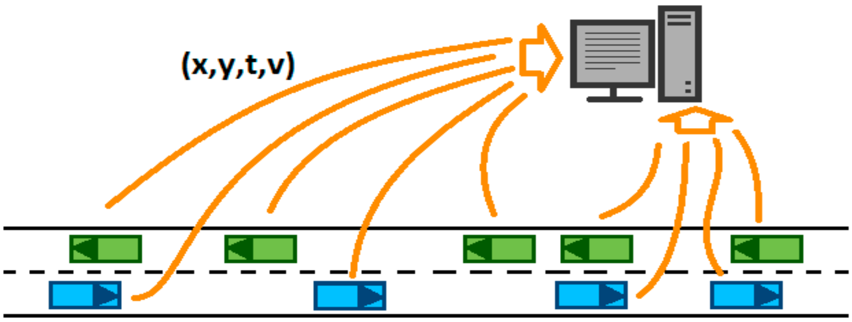

Fig. 1. Parameter transfer from vehicles.

Then the FALCO system searches for vehicles that, moving in the same direction as the vehicle processing the request, are ahead of it, and performs the calculation of DRAC and TTC road safety indicators and safety distance which is obtained as the sum of two contributions, the distance covered by the vehicle at an initial speed V during the time needed to perceive the presence of the obstacle and to actuate the brakes, and the stopping distance, which is the distance traveled by the vehicle from the moment when the brakes are actuated to the moment in which it stops (calculations in the system are performed according exactly to Italian standards DM 2001 [29]).

Once all the parameters are calculated, the server returns in real time (Figure 2) to individual devices connected to the system the values of the safety indicators and the safety distance. Other general static information on dangerous and specific point on the road can also be transferred.

The mobile unit then is able to provide a warning to the driver if the driving style does not respect calibrated thresholds on the received parameters. In the experimentation we assumed that driving is safe when DRAC is not more than 3.3 m/s^2, TTC is not less than 1.5 s and the safety distance with the leading vehicle is not less than what is established by Italian standards.

Moreover the system can give a warning based on recent or historical-based measurements of DRAC and TTC when the driver is approaching an area where safety violation in specific black spots of the road were observed. In other words drivers are warned not only when their personal driving style triggers an established threshold but also when they are approaching a "dangerous" area where many "unsafe" occurrences are observed on the same day or many "near crashes" are registered on a consistent historical database. This feature allows the system to be used even when the participation is not yet so widespread as to give a reasonable probability that a generic user will have a leading vehicle also participating in the cooperative system.

Warnings in this case will be effective to alert the driver of approaching dangerous road spots and not related to the driver interaction with other drivers.

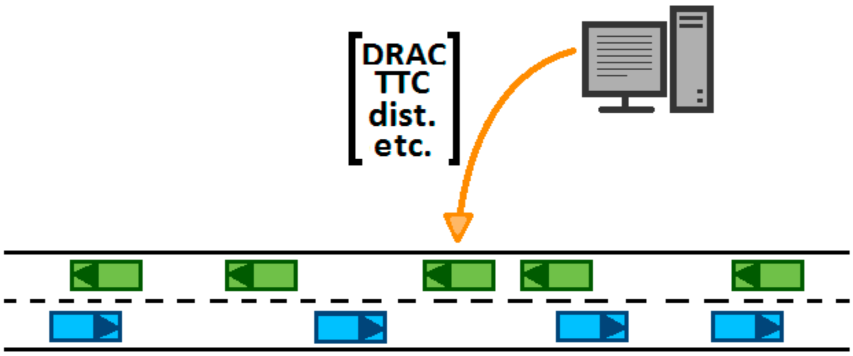

Fig. 2. Indicators transmission to vehicles.

3. Validation of the proposed system

The proposed system has been experimented in the area of the University of Calabria and the validation was done in two stages: the first letting vehicles move in a predetermined area and evaluating both the data exchange and the display of information on mobile devices, while the second was focused on the comparison of the data displayed on the phones and those obtained by processing the trajectories of individual vehicles by the server.

More precisely four vehicles were n considered, one behind the other, on a 4 km stretch of road with a normal style of driving, recording position information of themselves and their motion characteristics.

While driving, it was possible to display (to the drivers) the information sent by the server about the safety distance with the leader vehicle and the other safety indicator values. The results were also post-processed and plotted to verify whether the events on the road were adequately registered (Figure 3 and 4).

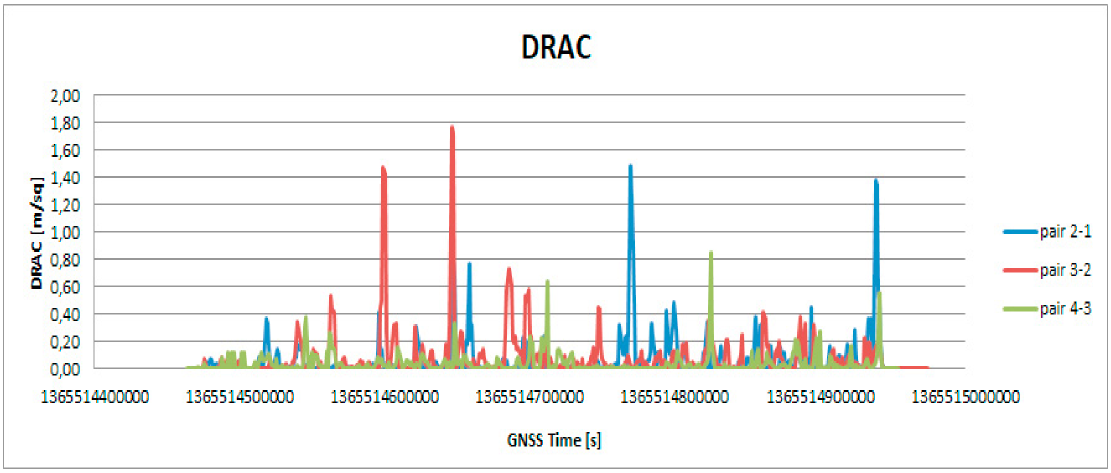

Fig. 3. DRAC values over time.

Fig. 4. Individuation of high risk zones according to DRAC values (The static information can be effective in warning drivers approaching black spots when leading vehicle is not connected).

4. Conclusions

In conclusion, we can say that the proposed experimentation established the feasibility of a warning system for smartphones that could be a valid aid to driving safely once "connected" vehicles become widespread.

For this reason, the application has been designed as user-friendly and simple so that the generic user would find it easier to accept this innovation as something useful to adopt and promote .

The possibility of obtaining safety maps like that shown in Figure 4 could provide an enormous help to focus in on high risk zones suggesting solutions and offering a new direction to traffic safety research and infrastructure management. Furthermore, the measures obtained from this system, which also can function as a traffic monitoring system, based on the techniques described in this article, can inform system users about the traffic on the network in real-time. This information could be provided in various ways, such as directly on mobile devices, on the Internet, on special information boards at the roadside, etc.; the possibility of accessing this information would allow drivers to avoid or postpone trips in cases of traffic congestion.

Warnings given to drivers that are approaching “dangerous” areas in terms of past “near crash” events can also be very useful to promote better driving styles and increase traffic safety.

A real-time warning system based on past events has the advantage of being applicable even if the evaluation of TTC and DRAC suffers from errors in GPS measurement, since it would be based on averages taken over time. Average values can give hints if a certain road spot is dangerous or not even when the single measurements may not be so accurate. The law of large numbers would guarantee that the averages accurately describe the situation even if the single measurements may suffer from inaccuracies.

This work is just a preliminary work that highlights the possibility of real time elaboration of surrogate safety measure data to obtain an increase in road safety alongside other benefits of traffic forecasting and congestion prevention. The experimentation was conducted only in a car-following situation and in the future, when connected vehicles become widespread it will be possible to extend the idea to other traffic situations such as, for example, overtaking maneuvers, pedestrian crossing (TTC with a pedestrian or cyclist that is going to cross a road carrying a smartphone; possibly this system would have avoided the Arizona Tesla killing of 18 March 2018[30]) and other specific situations where it can be useful to have real time information on cinematic parameters of road users.

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