Context-Awareness Mobile Devices for Traffic Incident Prevention

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Abstract—Several techniques have been developed in last years by automotive industry in order to protect drivers and car passengers. These methods, for instance the automatic brake systems and the cruise control, are able to intervene when there is a dangerous situation. With the aim to minimize these risks, in this paper we propose a method able to suggest to the driver the driving style to adopt in order to avoid dangerous situations.

Our method is basically a two-level fuzzy systems: the first one is related to the driver under analysis, while the second one is a centralized server with the responsibility to send suggestions to drivers in order to prevent traffic incidents.

We carried out a preliminary evaluation to demonstrate the effectiveness of the proposed method: we obtain of percentage variation ranging from 85.48% to 88.99% in the number of traffic incidents between the scenarios we considered using the proposed method and the scenario without the proposed method applied.

Index Terms—Intelligent transportation system, Context-awareness, Traffic congestion estimation, Traffic safety, Fuzzy system

I. INTRODUCTION

The 2015 global status report on road safety, reflecting information related to 180 countries, indicates that the total number of the road traffic deaths has plateaued at 1.25 million per year, with the highest road traffic fatality rates in low-income countries. In the last three years, 17 countries have aligned at least one of their laws with best practice on seat-belts, drinkdriving, speed, motorcycle helmets or child restraints. While there has been progress towards improving road safety legislation and in making vehicles safer, the report shows that the pace of change is too slow. This is the reason why urgent actions are needed to achieve the ambitious target for road safety reflected in the newly adopted 2030 Agenda for Sustainable Development: halving the global number of deaths and injuries from road traffic crashes by 2020.

According to the World Health Organization, road traffic injuries caused an estimated 1.25 million deaths worldwide in the year 2010 i.e., one person is killed every 25 seconds.

Only 28 countries, representing 449 million people (7% of the world’s population), have adequate their laws addressing all five risk factors (speed, drunk driving, helmets, seat-belts and child restraints). Over a third of road traffic deaths in low- and middle-income countries are among pedestrians and cyclists. However, less than 35 percent of low- and middle-income countries have policies in place to protect these road users.

As a matter of fact, speed typically is the major factor in many accidents. However, not all accidents are caused by speed and not all accidents are preventable. Many accidents can be prevented and in those that are not preventable, the damage could be mitigated.

For instance, in order to reduce the accidents percentage it is important to drive according to road conditions: drive slower when the weather is bad, road surfaces deteriorate in rain, ice or snow. The ability to stop quickly greatly reduces when the roads are not perfectly dry.

Another good driver practice is to avoid other vehicles, i.e., to avoid driving next to another vehicle in case it has to swerve to avoid an animal or debris that may be in the road.

It is also important to check out at intersections as many accidents happen here: always slow down and look both ways at intersections. Several drivers assume the other vehicles will stop just because the light is red, while there is always someone trying to get through the intersection during a yellow light.

From these considerations, it seems clear that the adoption of a polite driving style can be a deterrent in traffic incident.

Considering this scenario, in this paper we propose a method with the aim to reduce traffic incidents. Our method is based on real-time driving style identification. Using fuzzy logic-based techniques, the proposed method is able to make sense of the driving style that drivers are adopting. The main assumption behind our approach is that in a scenario
several cars are running on the same track, we expect that drivers exhibit a similar driving style. Once one or more drivers present driving style very different by the one of the remaining drivers, the propose method communicates with these drivers in order to invite them to adapt their own driving style following the most of the drivers. This is the reason why we consider the proposed approach as context-awareness: as a matter of fact, depending on the type of road, the proposed method is able to identify the driving style to be adopted by drivers in order to avoid traffic incidents.

Basically the proposed method is composed by two components: the server, with the ability to define the best driving style for each road and the client, with the ability to evaluate the driving style of the driver under analysis: this task is performed on the mobile user of the driver that is able to gather a set of features available on all cars since 1996. For each road, the driving style of all involved drivers are sent to the server component: the server side is able to send suggestions about the driving style to involved drivers with the aim to minimize incidents and congestions.

Basically, the centralized server has in charge to make the cooperation between several cars involved in the same road, in order to avoid traffic incidents and congestions.

The paper is organized as follows. Current state-of-the-art literature is described and discussed in the next section, while in Section III the proposed method is described. The proposed approach has been applied in Section IV in order to evaluate the effectiveness of the proposed method. Finally, concluding remarks and future work are given in Section V.

II. RELATED WORK

In last years, several methods have been deployed in the automotive context with the aim to prevent and/or detect traffic incidents using the widespread mobile technology. For instance, authors in [8] designed an Android-based application able to monitor the vehicle through the On Board Diagnostics interface, being able to detect accidents. The application considers the G force experienced by the passengers in case of a frontal collision, typically used together with airbag triggers to detect accidents.

Researchers in [9] describe how mobile devices can automatically detect traffic accidents using accelerometers and acoustic data, with the aim to immediately notify a central emergency dispatch server after an accident in order to provide situational awareness through photographs, GPS coordinates, VOIP communication channels, and accident data recording.

Miao et al. [10] model the severity of injury resulting from traffic accidents using artificial neural networks and decision trees. They applied them to a data set obtained from the National Automotive Sampling System (NASS) and the General Estimates System (GES). Their experiment results reveal that in all the considered cases the decision tree outperforms the neural network. Furthermore, the data analysis also shows that the three most important factors in fatal injury are: driver’s seat belt usage, light condition of the roadway, and driver’s alcohol usage.

Anderson et al. [11] estimate the likely effect of reduced travel speeds on the incidence of pedestrian fatalities in Adelaide, Australia. The study was based on the results of detailed investigations of 176 fatal pedestrian crashes in the Adelaide area between 1983 and 1991. The smallest estimated reduction in fatal pedestrian collisions in the selection presented was 13%, for a scenario in which all drivers obeyed the existing speed limit. The largest estimated reduction was 48% for a scenario in which all drivers were travelling 10 km/h slower.

Researchers in [12] propose a method to detect an accident at any place and any time and report the same to the nearby service provider: the service provider arranges for the necessary help. In the scenario described by the authors, accident detection and reporting system can be placed in any vehicle that uses a sensor to detect the accident. They consider a microcontroller that takes decisions on the traffic accident based on the input from the sensors. The transmitter module, which is interfaced with the microcontroller, will transmit the accident information to the nearby Emergency Service Provider (ESP). This information is received by the receiver module at the so-called service provider control room in the locality under analysis. The transceiver module used has a range up to 100 meters under ideal conditions. The service provider can use this information to arrange for ambulance and also inform police and hospital.

A summarization related to the performance of four machine learning paradigms applied to model the severity of injury that occurred during traffic accidents is given in [13]. The authors consider neural networks trained using hybrid learning approaches, support vector machines, decision trees and a concurrent hybrid model involving decision trees and neural networks. From the experimental evaluation, their results reveal that, among the machine learning paradigms considered, the hybrid decision tree-neural network approach outperforms the individual approaches.

III. THE METHOD

In this section we present our method to assist drivers in order to reduce traffic congestion that, as highlighted into the introduction, can be symptomatic of incidents.

In Figure 1 the high-level architecture is depicted: two actors are involved in our method: the ecosystem of several cars under analysis and a centralized server.

As shown in Figure 1, the cars appear on the server sending information about own driving style (i.e., aggressive, not-aggressive, polluting, not-polluting), the server collects these data from the several running cars and analysing the context
current road related it sends to the cars involved suggestions. The server, analysing the cars behaviours, sends information ad-hoc for each car involved in order to suggest to the driver how to change the driving style with the aim to reduce possible traffic incidents (i.e., different cars whether are exhibiting different driving style will receive different suggestion to address the own driving style).

In order to compute the driver behaviour we consider two features gathered from the On Board Diagnostics (OBD) i.e., the vehicle’s self-diagnostic and reporting capability that is mandatory from 1996 [14]. As a matter of fact, OBD permits the communication between the plethora of electronic devices (for instance, the centralized locking system, the air conditioning control, the traction control and the antilock braking system) inside the modern vehicle [15], [16]. Modern automobiles contain upwards of 50 electronic control units (i.e., the so-called ECUs) networked together [17], [18], [19]. In order to compute the driving style we consider two features available from OBD: the actual speed and fuel consumed as described in Table I.

To infer the driver behaviour we resort to the fuzzy logic rules considering the widespread application on fuzzy rules in automotive context [5], [20], [21], [22]. As a matter of fact, the first notable application was on the high-speed train in Sendai in Japan, in which fuzzy logic was able to improve the economy, comfort, and precision of the ride [23]. Fuzzy Logic has also been used in recognition of hand written symbols in Sony pocket computers, flight aid for helicopters, controlling of subway systems in order to improve driving comfort, precision of halting, and power economy, improved fuel consumption for automobiles [24].

We consider that the actual speed and the instantaneous fuel consumption can assume two different state:

- **up**: when the next instance (i.e., the value) of the feature assumes a value superior to the previous one;
- **down**: when the next instance (i.e., the value) of the feature assumes a value inferior to the previous one.

We define the following drive behaviours according to the up and the down state. The behaviours are expressed in terms of fuzzy IF-THEN rules: the rule base of the proposed fuzzy system is defined as follows:

- **if** (speed is high) and (fuel is high) then (driver is aggressive);
- **if** (speed is low) and (fuel is high) then (driver is polluting);
- **if** (speed is high) and (fuel is low) then (driver is not-polluting);
- **if** (speed is low) and (fuel is low) then (driver is not-aggressive).

As previously stated, in order to gather speed and fuel consumption in real-time we consider the data from the OBD, while the fuzzy logic rules verification in order to compute the driving style is performed on the driver mobile device/infotainment system available on the car. The device is in charge to obtain the OBD feature using the bluetooth interface, to infer the driver behaviour and to send/receive information from the server [19]. To send the OBD features, the OBD diagnostic connector is need: this connector is able to obtain real-time data from the OBD car interface and to send the data using the bluetooth connection to the device [16].

The server basically exhibits a web service able to accept the information about the driver behaviours running a road. The server, relying on the information received by the several cars under analysis and additional metadata obtained crawling a web mapping service that offers an API that allows maps to be embedded on third-party web services (for instance, Google Map⁴ or OpenStreetMap⁵), is able to compute to percentage of occupancy lane, as defined in Table II.

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### TABLE I

<table>
<thead>
<tr>
<th>Feature</th>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>speed</td>
<td>km/h</td>
<td>The actual speed of the vehicle</td>
</tr>
<tr>
<td>fuel</td>
<td>ml/s</td>
<td>The instantaneous fuel consumed by the vehicle</td>
</tr>
</tbody>
</table>

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### TABLE II

<table>
<thead>
<tr>
<th>Feature</th>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>occupancy</td>
<td>%</td>
<td>The occupancy of the lane</td>
</tr>
</tbody>
</table>

From the definition explained in Table II, a value of 100% related to the occupancy would indicate vehicles standing bumper to bumper on the whole edge. As for the speed and fuel features obtained from the car, we consider that the occupancy can assume two different state:

- **up**: when the next instance (i.e., the percentage) of the occupancy assumes a value superior to the previous one;
- **down**: when the next instance (i.e., the percentage) of the occupancy assumes a value inferior to the previous one.

We define the following suggestions according to the the up and the down state. The suggestions sent by the server are expressed in terms of fuzzy IF-THEN rules: rule base of the proposed fuzzy system is defined as follows:

- **if** (occupancy is high) then (aggressive and the not-polluting drivers should decrease their speed);
- **if** (occupancy is low) then (not-aggressive and the polluting drivers should increase their speed).

We highlight that the suggestions are sent by the server to the drivers in according to the context of the road in exam and of the behaviour style of drivers that are running the road.

Contextual information measured by a vehicle are applied as input variables to the fuzzy system [25]. The fuzzy system aims to measure the traffic congestion level as the output variable. For this, the Mamdani fuzzy inference system [26]

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⁴https://www.openstreetmap.org/
⁵https://maps.google.com/
is considered, which basically consists of four parts: Fuzzification, Fuzzy rule base, Inference engine and Defuzzification.

Fuzzification: in the fuzzification step, the crisp input values are transformed to fuzzy sets through the fuzzy membership functions. The output of this step is the membership grades of input variables related to the fuzzy sets. The proposed two-level fuzzy system defines basically two different states (i.e., up and down).

Inference Engine: the inference engine examines fuzzy rules with the aim to evaluate their output degrees. After this, the aggregation of the rules output is performed in order to compute the output fuzzy set. The max-min [27] aggregation is considered in the proposed method.

Defuzzification: this represents the process of providing a quantifiable result in Crisp logic, given fuzzy sets and corresponding membership degrees: basically it represents the process able to maps a fuzzy set to a crisp set [28]. It is typically needed in fuzzy control systems: as a matter of fact, these will have a number of rules able to transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets [29]. In order to find the geometrical center of the output variable we consider method described in [26].

IV. PRELIMINARY EVALUATION

In order to evaluate the proposed method, we consider the SUMO (i.e., Simulation of Urban MOBility) open source simulator [30], [31] with the aim to simulate road traffic. We evaluate the proposed system in an urban environment related to a city of the south of Italy with a speed limit of 50 km/h. The flow rate is 1800 vehicles per hour i.e., every 2 seconds a vehicle enters in the simulation environment. The vehicles are distributed uniformly across the urban path. We consider different traffic congestion levels by decreasing the speed limit on the urban road. In this simulation, the vehicles are supposed to be able to travel at the maximum speed limit we impose.

The vehicles are distributed uniformly across the urban roads. We infer different traffic congestion levels by decreasing the speed limit on the roads. Three simulation scenarios are defined with different traffic congestions:

- Scenario A: in this scenario, the maximum speed limit is set to 50km/h. The vehicles travel in a free flow state. In this situation, there is sparse traffic congestion and vehicles can travel freely at a high speed.
- Scenario B: in this scenario, the speed limit is 20km/h. There is low traffic congestion in which vehicles travel at a lower speed.
- Scenario C: in this scenario simulates a high congestion state, i.e., traffic jam, on the highway. This traffic state is made by setting the speed limit to 10km/h. In this situation, vehicles travel at a very low speed.

In the simulated scenarios, every vehicle records its actual speed and instantaneous fuel consumption at 5 second constant intervals. In each scenario, we considered 1000 sample vehicles to validate the proposed method. The vehicle feature values are obtained in real-time i.e., while the simulation is running.

We present the simulation results below: we consider the three scenarios without the application of the proposed method and the same three scenarios with the application of the proposed method.

In order to evaluate whether the proposed method is able to prevent traffic incidents (the scenarios in which we apply the proposed method) we need to change the vehicles state while the simulation is running. To perform this task we consider TraCI (i.e., Traffic Control Interface)\(^6\): it basically permits to have access to a running road traffic simulation, allowing to retrieve values of simulated cars and to manipulate their behaviour in real-time while the simulation is running. In order to implement the proposed methodology in the SUMO simulation environment, we developed a set of scripts using the Python language (this library supports all TraCI commands)\(^7\).

We obtain that in the three scenarios generated by SUMO (without the application of the proposed method) we obtain a traffic incident number equal to 172 (for the Scenario A), 124 (for the Scenario B) and 109 (for the Scenario C). Considering the three scenarios with the proposed method we obtain a decreasing number of traffic incidents i.e., 23 for the Scenario A, 18 for the Scenario B and 12 for the Scenario C.

Table III shows the results of the preliminary evaluation we performed:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>#Incident_1run</th>
<th>#Incident_2run</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>172</td>
<td>23</td>
</tr>
<tr>
<td>B</td>
<td>124</td>
<td>18</td>
</tr>
<tr>
<td>C</td>
<td>109</td>
<td>12</td>
</tr>
</tbody>
</table>

with \#Incident_1run we indicate the number of traffic incidents for the three different considered scenarios without the application of the proposed method, while with \#Incident_2run we indicate the number of traffic incidents using the proposed method.

The method we proposed, as demonstrated by the results showed in Table III, obtains following performances in the analysed scenarios:

- a decrease of the number of traffic incidents from 172 to 23 relating to the Scenario A;
- a decrease of the number of traffic incidents from 124 to 18 relating to the Scenario B;
- a decrease of the number of traffic incidents from 109 to 12 relating to the Scenario C.

In order to give statistical evidence about the effectiveness of the proposed method, Figure 3 shows the histograms of

\(^6\)http://sumo.dlr.de/wiki/TraCI/Protocol
\(^7\)http://sumo.dlr.de/wiki/TraCI/Interfacing_TraCI_from_Python
the three different evaluated scenarios (A, B and C) with the #Incident_1run (red histograms) and #Incident_2run (blue histograms).

We compute the percentage incident variation between #Incident_1run and #Incident_2run for each considered scenario, obtaining:

- a percentage incident variation equal to 86.63% between #Incident_1run and #Incident_2run for the Scenario A;
- a percentage incident variation equal to 85.48% between #Incident_1run and #Incident_2run for the Scenario B;
- a percentage incident variation equal to 88.99% between #Incident_1run and #Incident_2run for the Scenario C.

To summarize, we obtain of percentage incident variation ranging from 85.48% to 88.99% in the number of traffic incidents between the scenarios using the proposed method and the scenario without the application of the proposed method.

V. CONCLUSION AND FUTURE WORK

With the aim to preserve road safety, in this paper we propose a method able to reduce traffic incidents.

The proposed method considers a two-levels fuzzy system: the first level is related to the mobile device of the driver, while the second one is represented by a centralized server. The fuzzy system on the mobile device of the driver, using the bluetooth interface, is able to gather a set of two features available on all cars since 1996 and it computes a driver profile while the car is running. The information about the driver profile is sent to the second fuzzy system, i.e the centralized server that is able to analyse in real-time the occupancy lane percentage in order to establish whether different drivers should change their driving style to prevent traffic incidents.

We perform a preliminary evaluation of the proposed method using the SUMO traffic simulator, considering thee different scenarios: for each scenario evaluated the proposed method is able to decrement the number of traffic incidents. In particular, we obtain of percentage variation ranging from 85.48% to 88.99% in the number of traffic incidents between the scenarios using the proposed method and the scenario without the proposed method.

As future work, we plan to perform an exhaustive evaluation of the proposed method. As a first step, we will test the method using different cities and we will evaluate whether the proposed method is able to decrease the number of traffic incidents also in big and populated cities simulation.

In addition we plan to extend the proposed method also to pedestrians: considering that the driver behaviour is identified...
using the mobile device, we can take into account also the pedestrian behaviour in order to mitigate pedestrian incident in an ecosystem able to prevent traffic and pedestrian incident.

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