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# Automatic accident detection with multi-modal alert system implementation for ITS

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ABSTRACT

The rapid technological growth is now providing global opportunities to enable intelligent transportation system (ITS) to tackle road accidents which is considered one of the world's largest public injury prevention problem. For this purpose, eCall is an initiative by European Union (EU) with the purpose to bring rapid assistance to an accident location. This paper[1] presents HDy Copilot, an application for automatic accident detection integrated with multimodal alert dissemination, via both eCall and IEEE 802.11p (ITS-G5). The proposed accident detection algorithm receives inputs from the vehicle, via ODB-II, and from the smartphone sensors, namely the accelerometer, the magnetometer and the gyroscope. An Android smartphone is used as human machine interface, so that the driver can configure the application, receive road hazard warnings issued by other vehicles in the vicinity and cancel countdown procedures upon false road vehicle crash detection. The HDy Copilot is developed for Android OS as it provides open source APIs that allow access to its hardware resources. The application is implemented, tested and connected to an IEEE 802.11p based prototype. The generated results show that the application successfully detects collisions, rollovers, performs the eCall along with sending Minimum Set of Data (MSD) and Decentralized Environmental Notification Message (DENM).

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## 1. Introduction

Despite the progress that automotive industry has achieved in producing safer and more efficient vehicles over the last years, road vehicle crashes are still high and more than 26 000 people died on the roads of the European Union (EU) in 2013 [1]. According to EU statistics 1 054 745 road vehicle crashes were recorded in 2013 causing 1 387 957 injuries in 2013 and this is the lowest number since the last 10 years [1]. To address these concerns, new technological capabilities are being introduced in automobiles. With the vehicular communication systems development, the ITS concept is emerging which targets innovative services for traffic management to ensure safer roads and well connected and coordinated transport networks. Currently, ITS is strong research topic in the vehicular communications scientific community. A great number of universities, institutes, vehicle manufacturers and telecommunication companies are researching and developing solutions to be deployed at a large scale. The need for standardization is a concern, in order to unite and direct the research efforts. Therefore, the European Telecommunications Standards Institute (ETSI) and the Institute of Electrical and Electronics Engineers (IEEE) have already published standards to be followed in this research field.

With the development of vehicle communications, it is expected that communications between vehicles will provide more information to drivers about their surroundings, thus allowing them to make better decisions, resulting in the increase of their safety and efficiency. With more information drivers can decide the best route to take, or even carefully approach a certain location within their route, knowing that the location is marked as unsafe. Today, high-end automobiles offer some limited ITS services, such as turn-by-turn GPS navigation systems, accident detection systems, as well as traffic, weather and entertainment applications built-in on vehicle's on-board computers. But these service are normally associated with high costs or in most cases, are

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**Table 1**
ASI and Theoretical Head Impact Velocity (THIV) scale values [7].

| Impact severity level | Index values |
| --- | --- |
| A | ASI $\leq 1.0 \wedge$ THIV $\leq 33$ km/h |
| B | ASI $\leq 1.4 \wedge$ THIV $\leq 33$ km/h |
| C | ASI $\leq 1.9 \wedge$ THIV $\leq 33$ km/h |

**Table 2**
Abbreviated Injury Scale [8].

| AIS value | Injury characterization |
| --- | --- |
| 0 | No injury |
| 1 | Minor |
| 2 | Moderate |
| 3 | Serious |
| 4 | Severe |
| 5 | Critical |
| 6 | Maximum/fatal |

manufacturer-specific and cannot be used in all vehicles. On the other hand, in older and lower end automobiles, smartphones are used to provide almost the same features and services. Therefore, smartphones are playing a vital role and offer valuable solutions that can be integrated with any vehicles.

Transportation safety, pollution reduction and time/costs efficiency are some of the most important goals to achieve in ITS. As referenced in [2], the benefits can be grouped into the following three categories: transport efficiency, environment preservation and safety increase. Therefore, this paper addresses the safety increase only, notably automatic accident detection, emergency assistance and road hazard warning dissemination.

### 1.1. Vehicular accident detection

Road vehicle crash scenarios that often inflict more severe injuries are: collisions and rollovers. When involved in a road crash, a vehicle can have a frontal, lateral, rear or even diagonal collision. Any of those directions are possible so, in order to develop an effective Autonomous Accident Detection (AAD) mechanism, all those types of accidents should be detected.

#### 1.1.1. Collision detection

A collision generates a sudden change of speed and happens when an object slam into another object resulting in a sudden variation of speed. The severity of the collision depends on the direction, orientation and speed of both the colliding objects. If the objects are moving in the same direction and with different orientation, the collision will be more violent than moving in the same direction and orientation. This means that, when the relative speed among objects increases the collision will be more severe. This variation of speed over time $\left(\frac{\partial v}{\partial t}\right)$ is called acceleration. The acceleration generated during vehicle crash is an important parameter to consider in collision/accident detection systems. Authors such as Weiner in [3], Thompson et al. in [4] and Kumar et al. in [5], in their work on accident detection systems, used the 4g $\left(g = 9.8\ m/s^2\right)$ threshold above which road vehicle crash takes place. Thompson et al. also show that smartphone falls and harsh car breaks are unlikely to surpass the 4g threshold, which proves that this threshold acts as a correct filter for false detections. European road restraint systems are used to reduce the severity of road vehicle crashes when vehicles leave the road. To achieve this, these systems are evaluated based on the European standard EN1317 [6,7]. This standard is based on the Acceleration Severity Index (ASI) and Theoretical Head Impact Velocity (THIV). Table 1 presents the ASI scale values.

The ASI scale measures a collision impact severity and is divided into three levels. Impact severity level A is the less severe while C is considered the most severe. This means that on level B and above, there is the risk of serious injury. Minor injuries can be categorized in terms of Abbreviated Injury Scale (AIS) for values under 2 and serious injuries for AIS values over 2 (see Table 2). Studies performed by Gabauer et al. in [9] and Shojaati in [8] demonstrate the relation between ASI, Head Injury Criteria (HIC) and Abbreviated Injury Scale (AIS). Both, HIC and AIS, are metrics used to describe and quantify the injury severity of a vehicle occupant. To determine ASI, a tri-axial accelerometer is required to measure longitudinal $(A_x)$, lateral $\left(A_y\right)$ and vertical $(A_z)$ acceleration components.

#### 1.1.2. Rollover detection

A rollover happens when a vehicle rolls over it's main axis. To detect such rotations, it is necessary to analyse the rotation of the car's three main axis over time. Vehicle's rollovers are often more dangerous, causing more severe injuries and more damage to the vehicles. Therefore, ITS research is focusing more in rollover detection and proposing systems for real time rollover detection.

### 1.2. eCall

In 2013, there were 26 000 fatalities in European Union (EU) roads and this was the lowest number since 2001 [10]. The time an injured person receive proper care from the Emergency Medical System (EMS) is related to the probability of death and trauma [11]. According to Henriksson et al. [12], death and trauma rates can be reduced if there is a quicker response from the EMS. A quicker reaction can be obtained if help is requested immediately after the road vehicle crash occur. In addition, if the exact location of the road vehicle crash along with other extra information is provided to the EMS an immediate and better response is possible.

The European Commission, in an attempt to provide faster response from European EMS, declared the mandatory deployment of eCall in passenger cars and light duty vehicles from 2017 [13,14]. eCall is an automatic accident detector that in the presence of road vehicle crash automatically requests help to the EMS through the European 112 emergency number. When a vehicle crash occurs, the car system performs an eCall that is composed by the voice call and a Minimum Set of Data (MSD) that is also transmitted, through the Mobile Network Operator (MNO), to the most appropriate Public Safety Answering Point (PSAP). The solution adopted for the MSD transmission, is an in-band modem that transmits data in the voice channel. The MSD should contain information to help speed up the EMS arrival to the vehicle crash location. According to the eCall Driving Group recommendations [15], the MSD [16] should be sent in a 140 bytes packet.

The main aim of the proposed system is to speed-up the integration and implementation of eCall and accident detection mechanisms. In addition, this work provides a cost effective and portable solution compared to the manufacture specific. Furthermore, our other main concern and contribution was to improve the reliability by sending the emergency messages via two independent networks (cellular and IEEE 802.11p).

The rest of the paper is organized as follows. Section 2 describes related work reviewing some commercial applications and relevant research projects. The system architecture and implementation are presented in section 3, together with IT2S ITS-G5 platform, the application's graphical user interface and details of the accident detection algorithm. Section 4 describes the system validation with special emphasis on the robustness tests. Finally, section 5 summarizes the main conclusions of the paper and unveils some future work.

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