Collision Detection System Using Mobile Devices and PANGEA

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Abstract. In the last decades the cost of manufacturing sensors has decreased greatly, making it possible to apply many different artificial intelligence techniques to improve the quality of our lives, one of them being the reduction of deaths in traffic accidents. Such misfortunes are usually caused by the long waiting period between the occurrence of the accident, the calling of the emergency service and their arrival. The goal of this work is to design an intelligent platform that detects a traffic accident automatically and which requires no interaction on the part of the people involved. We will design a low-cost hardware that will be suited to all types of vehicles. The sensors and medical services will be interconnected by a multi-agent system of virtual organizations (PANGEA).

Keywords: Wi-Fi · Smartphone · Emergency service · Embedded sensors · PANGEA

1 Introduction

Several scientific studies [1, 2], have proved that most deaths in traffic accidents,70%, occur between 20–30 min following the accident. It often happens that when an accident occurs the time taken to notify emergency services is too long [3]. For this reason, in many cases, nothing can be done to save the life of the injured. The main objective of this work is to reduce the response time of emergency services through the use of a low cost hardware. The architecture designed will increase the victim's chances of survival by providing medical help as early as possible. This could significantly reduce the percentage of deaths in the coming years. The latest statistics [4] on the use of new technologies indicate that in Europe, 96% of the adult population has some type of mobile phone.

In addition, the figures in [5] reflect that 80% of users who have a mobile device also have a data connection plan, this explains why we have chosen Smartphone as the central element of connection between the damaged vehicle and the medical services. The use of the driver's Smartphone in our system means that it is not necessary to buy additional data services, reducing costs. The Smartphone will not only send emergency alerts, but will also be able to detect the strength of the collision with its own sensors,

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without the necessity of incorporating additional hardware in the vehicle. To evaluate the case study, a mobile application will also be designed for the emergency services, in this way the ambulance drivers will be able to receive emergency calls. This application will show the most optimal route to the place of the accident, depending on the state of the roads and traffic at that time. The connection between the hardware sensors located in the vehicle and the driver's Smartphone will be made via Wi-Fi. All information relevant to the accident such as the geographic location and the outside temperature of the vehicle, is sent remotely to a central server. This information is stored in a database so that it can later be used for data analysis. For example, it is possible to check the geographical areas where most accidents occur or on what type of roads do accidents occur; whether they are primary roads, secondary roads etc.

The rest of this article is organized as follows: the background section provides an overview of similar works on the subject, Sect. 3 includes a case study and the proposal, finally Sect. 4 presents the results and conclusions.

2 Background

After an in-depth review of the state of the art and due to a European regulation that will be in force by 2020, automobile companies are currently developing a system called eCall [6]. By installing sensors in the vehicle, this system has the ability to determine the severity of an accident [7]. At the time of the accident, the system records a voice message from the injured, which is directly heard in the alarm center [8, 9]. The request for help can also be activated manually in cases of slight gravity, by pressing a button that is inside the vehicle. In case the system detects that the vehicle has collided, this procedure is performed automatically.

The eCall system is aimed at being the solution adopted by most companies and government agencies involved in the automotive sector [9, 10]. However, many end-users reject the service as it implies additional costs for a data service from the automobile companies.

This solution is not universal because not all drivers will be able to pay monthly sums for the service. Creating a universal system is the incentive of this work. Another disadvantage that has been found in this system is that eCall will only be available for new vehicles from 2020.

It is still being discussed whether the person who must assume the cost of the system is the final driver of the vehicle or are the concessionaires that sell the cars. This system requires a complex installation during the manufacture of the vehicle, because of this, manufacturers have to modify and reconfigure their production robots which implies high adaptation costs in the manufacturing processes.

The system presented in this work aims to make the solution independent of the vehicle manufacturer, this solution can be deployed in both four-wheel and two-wheel vehicles, and is suitable for both new vehicles as well as the current ones, regardless of the year of manufacturing.

The eCall system is not fully automatic, as it will require human supervision; an operator who will be in charge of notifying medical services manually. These procedures can easily be improved with technology. The following will explain how we obtained a solution that significantly improves upon the performance of eCall and one which can be used by the majority of people involved in the automotive sector.

3 Case of Study

The architecture proposed in this work detects a traffic accident and alerts the emergency service as fast as possible. The most important components of the hardware designed are based on the use of an Arduino microcontroller with wireless technology and an accelerometer. The reduced size of the device and its wireless capability allow for its attachment to any dashboard or motorcycle in a simple way. This device is wirelessly connected to the user's Smartphone, taking advantage of the passenger's data connection so that no additional phone services have to be paid. For the system to be distributed and transmitting data efficiently, a multi-agent architecture called PANGEA [11–15] has been used. The main characteristic of PANGEA is that it allows to develop applications embedded in computationally limited devices in a simple way, through the use of IRC protocol, which is based on the exchange of simple frames based on plain text.

This multi-agent architecture, which has been developed by BISITE, is based on the use of virtual organizations that facilitate the distribution of tasks among the different elements that make up the system.

Figure 1 shows the different agents and the different virtual organizations that make up this case study. First is the virtual sub-organization called User's Car, it is in charge of managing the information coming from the interior of the user's vehicle. Coordinated by the agent with the coordinator role, it will collect the data coming from the hardware devices deployed in the system. The virtual sub-organization Remote Server will receive all the data registered by the sub-organization User's Car in real time and will analyze them, if it detects any type of problem, it will issue an alert through the agent with Alert role. Likewise, this sub-organization will store all data for study and analysis as well as for subsequent historical data reports. Finally, the sub-organization Emergency Unit, composed of the roles: Alerts, Location and Information, is the organization responsible for giving a quick response to an accident alert. This sub-organization is deployed in the intervention unit of the emergency service and will quickly handle the requests for help launched from the sub-organization Remote Server.

3.1 Sensor System

The systems for the detection of accidents operates in two parts, the first one is the sensor installed in the vehicle and the second is the acceleration sensor found in current mobile devices. Increased accuracy is the main advantage of sensors installed in the car because using just the mobile device can lead to false positives. Each of the two systems is detailed below:

The integrated hardware in the vehicle is based on the use of an ESP8266 microcontroller in combination with an inertial measurement unit, an 802.11n Wi-Fi

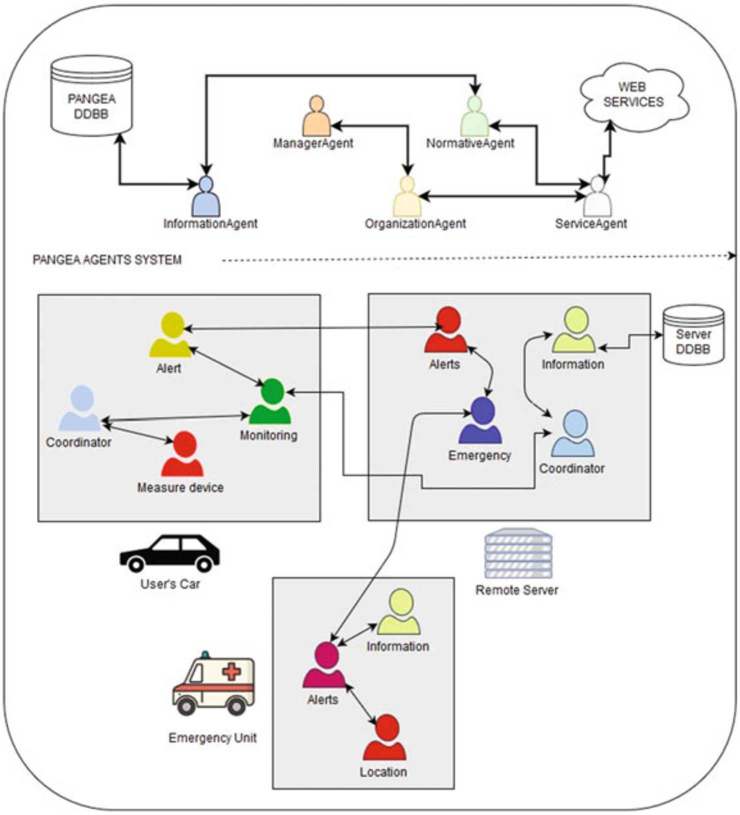

Fig. 1. Virtual organization of the system

wireless communication module, and a LIPO battery that makes the device autonomous. The cost of the prototype is remarkably low, less than 40 €.

The main element of the hardware designed is the inertial unit of measurement, which allows to control its tilting axes and the speed at which it moves.

Thanks to these parameters it will be possible to calculate when an accident occurred, this is because the sensor will be located in a compact place in which a change in the axes of inclination X and Y (Fig. 2) will indicate a collision, calculating the change in speed at its beginning and at its end. To detect an accident and make sure that it was a serious collision, it is necessary to observe a sudden change in the inclination of the axes as well as the speed of the vehicle 10 s after the collision is zero.

As mentioned before, there is an alternative for users who choose not to install any type of hardware in their car, since an accident can be detected using solely the sensors that are embedded in their Smartphone, however, with lesser precision. Both systems can easily be installed in any type of vehicle once manufactured, regardless of the brand or the year of manufacture, having a great advantage over the eCall system which needs to be installed during the manufacture of the vehicle.

Fig. 2. Example of sensor output values during an accident

3.2 Monitoring and Alert System

Once an accident has been detected by the hardware attached to the vehicle or the sensors embedded in the mobile device an automatic response is generated. The application installed in the user's mobile sends an alert to the central server of the emergency service with data about the accident such as the exact time or geolocation of the vehicle involved in the collision. Once the request arrives, it is determined which ambulance is the closest to the place of the incident, and a notification is sent to the driver's application. The information collected from each accident is stored in a central database, and information on whether the health authorities have attended the place of the accident are added on as well as the time taken to go to the place, the severity… etc. The central emergency server is in charge of evaluating the alerts that have been sent from the different Smartphones of users after a traffic accident has occurred.

Ambulance drivers using this system must install the application that allows them to receive notifications as well as the mapping of the most optimal route, depending on the condition of the roads. This application receives data about the geolocation of the accident and automatically calculates the fastest route to reach it. From the central panel that is managed by the alarm center, it is possible to view the accidents that have already been taken care of by other ambulances or the accidents that need a higher attendance priority, this helps obtain a greater efficiency. Figure 3, is a general diagram of the different actors involved in the process.

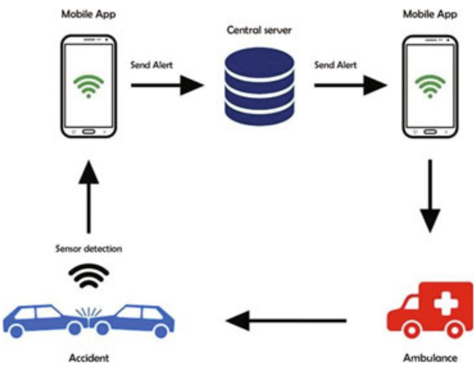

Fig. 3. Alert system diagram

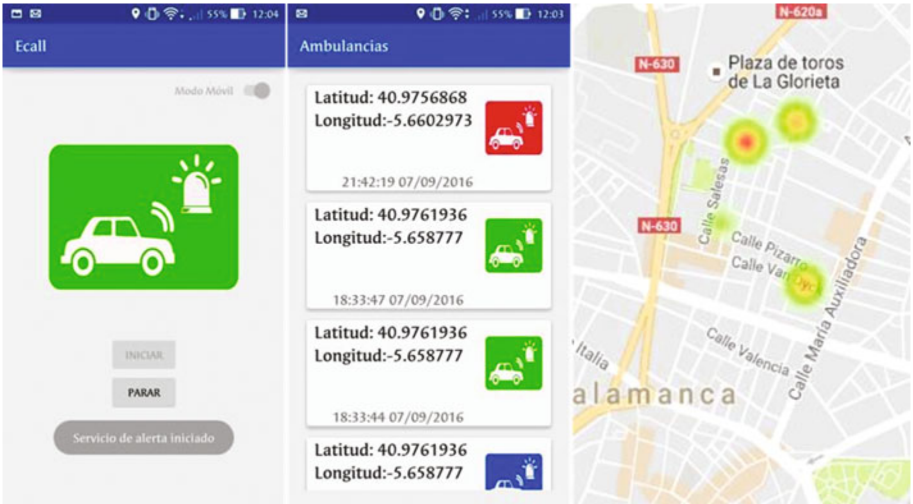

Fig. 4. **a** Sensor application, **b** Ambulance application, **c** Heatmap

4 Results and Conclusions

The use of the multi-agent architecture PANGEA, has allowed for the deployment of algorithms embedded in computationally limited devices. In order to validate the functioning of the system, we carried out simulations of accidents on some highways in the city of Salamanca, Spain. The simulations have been carried out in different parts of the city in order to check efficiency and correctness of the application that automatically establishes a route for the ambulance from its current location to the place of the accident. A central alarm management panel has been designed, it monitors in real-time the accidents occurring and also keeps note of those that have already been attended (Fig. 4). The application has been evaluated by people specializing in car security systems, and they claim that it is a more advantageous system than eCall. In driver's opinion this system is cheaper because it doesn't require buying any more phone services and it can be installed easily by the user and therefore no money is spent on its installation. The developed prototype also allows us to make statistics of the accidents, through a heat map we can view the zones where most accidents have occurred.

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