

# mTADA: Mobile Tracking and Advanced Driver Assistance

*Alexiei Dingli and Christopher Bartolo*

Department of Intelligent Computer Systems

Faculty of ICT, University of Malta

Msida, Malta

alexiei.dingli@um.edu.mt, chris@chrisbartolo.com

**Abstract**—Safe driving requires knowledge of the surrounding traffic environment. Such knowledge will enable the driver to predict possible dangerous situations and events. Driver distraction and reckless driving are two cases, which reduce the ability of a driver to perceive these situations. This is the reason why Advanced Driver Assistance Systems (ADASs) are being introduced. In this paper, we will tackle how mobile devices may help out in ADASs. Many companies, such as BMW and Audi have been developing their own ADASs, but offer them as optional accessories at an additional cost, being available only with new vehicles. The aim of the system we are developing is to help out in decreasing the amount of motor vehicle accidents by developing a low cost solution, which can be easily downloaded to and installed on a mobile device, and which may be used on any vehicle. The final results prove that the system was quite successful during tests, with many people claiming that they would use such a system on a regular basis.

**Keywords**—active driver assistance, driver behaviour, motor accidents, driver safety

## I. INTRODUCTION

In this section, we will introduce the subject matter of the paper. We will first identify the problem, and then we will continue to explain the major causes of motor traffic accidents.

### A. The Challenge

Road traffic accidents have become one of the leading causes of death. This costs countries billions of dollars a year for damages, insurances, and health bills. The most worrying, though, is the fact that the increase of these accidents has brought the cause up to the same ranks as HIV/AIDS, Malaria and Tuberculosis, and most communities are still practically ignoring it. Lord Robertson from Make Roads Safe argues that every six seconds we have another reason to work with campaigns such as Make Roads Safe as an international community. Make Roads Safe present statistics claiming that 1.2 million people are killed, with a minimum of 50 million people left injured, every year. They predict that by 2015, “road crashes will be the leading cause of disability for children aged four and above in developing countries” [1]. L.G. Norman argues that accidents are or will become the number one cause for deaths, mainly in highly industrialized nations where roads

are crowded with vehicles. He continues to argue that road traffic accidents can be considered as the new epidemic. The paper by L.G. Norman was published in 1962, which only goes to show that the situation of road traffic accidents has not been improved as dramatically as was needed and still has a lot of work to be done [2].

Many drivers are over-optimistic, over-confident, and make above-average biases, leading to excessive risk taking, a delay in the uptake information, and social norms of bad driving, which lead to a high number of traffic accidents. These accidents also lead to moral hazards for damages, which are usually covered by insurances, as many damages are not paid for by the drivers, which make and take the risks. Knowing this, drivers are willing to take more risks. We can easily see that many accidents can be easily avoided. Most accidents are caused by the victims themselves, caused by human errors, such as “imperfect perception, insufficient attention, and inadequate information processing” [3].

### B. Major Motor Accident Causes

Cause 1: Alcohol; Alcohol is one of the most well-known and most advertised causes of accidents. There have been many campaigns launched to tackle this cause and increase the awareness of such health issues. In fact, the amount of accidents caused by drunk driving has been declining in many countries throughout the past few years [4].

Cause 2: Fatigue; We all know that we need to sleep seven to nine hours a day to optimize our performance, and to be able to concentrate and work. It is not a matter of choice. The longer we remain awake, the more we feel the need to sleep and the harder it gets to resist the urge to do so. By not sleeping the right number of hours, we are becoming more prone to extreme short term sleepiness, which could easily lead to chronic sleepiness. Sleepiness reduces the person’s reaction time, vigilance, alertness, and concentration, hence resulting in impairment of attention-based activities. These activities include driving. Sleepiness reduces the speed at which information is processed and the quality of all decision-making, badly affecting any driving activity. A study was held by the Sleep Research Centre in the United Kingdom on how drivers are affected by fatigue. The study reported a finding which indicates that 20% of all accidents are caused by driver fatigue on long, monotonous roads [5].

Cause 3: Distraction; Driver distraction is when a driver pays attention to other activities while driving. It is another major problem, which is also well-known to be one of the biggest causes of road traffic accidents. Most widely used in campaigns is the risk of driving while using mobile phones and in fact fines issued by police due to the use of mobile phones while driving have been increasing rapidly during the past few years. However, research in the area has proved that road traffic accidents related to driver distraction are actually being caused by other methods and other forms of multitasking. Distraction impairs the driver's decision-making and observation skills, making him take worse decisions about how to control his vehicle's and surrounding vehicles' safety [6].

Cause 4: Behavior; The driving behavior of drivers reflects how the driver perceives situations and his decision-making skills when encountering different situations. Irresponsible driving behaviors have been given the term 'road rage' to describe them. Road rage is becoming increasingly popular especially with the young and middle aged population because of the stress, anxiety, anger, antagonism, and fear experiences on today's roads and traffic situations. Surprisingly, most problems which result from bad driving behavior are actually caused by the belief that the law cannot or will not do anything and would not take action about any fleeting transgressions [7].

## II. TECHNOLOGIES AND DRIVER ASSISTANCE

In this section, we the focus will be around around what has already been published related to driving assistance systems and the technologies used.

### A. Computer Vision

One of the most broad and vast research areas in computing is image processing. It involves not just filtering, but also compression and image enhancement. Computer vision is where image processing is used and implemented, and one of its main tasks is to understand what the image is actually depicting. This is handled by making use of complex algorithms to analyse the content based on recognition. All functionalities provided by computer vision such as reconstruction of 3D scenes, motion capturing and object recognition. The field of computer vision is rapidly growing, with microprocessors being improved and becoming more powerful [8]. The results of these improvements came with a number of computer vision libraries being made available, some of which are even open source and free to use, while others are commercial products. Some of the libraries we investigated were libCVD, openCV, Matrox Imaging Library and NI Vision [9].

### B. Advanced Driver Assistance Systems

These systems have recently become very popular, with many companies researching and developing their own versions. Their aim is to decrease the amount of accidents and decrease the gravity of consequences caused by accidents, while also making the driving experience easier and more efficient. These systems are intelligent systems,

and support the driver in performing one or more elements involved in the driving task [9]. A number of surveys have been conducted regarding ADASs, and the results conclude that 40% of traffic accidents can be prevented with their use. However, even though ADASs can prevent many accidents, injuries and fatalities, they are still rarely used. This is believed to be true because many people have yet to understand their usefulness [10].

As previously discussed, many manufacturers have been and are still developing and implementing their own ADASs. These companies include Mobileye, Nvidia, Continental, BMW, VolksWagen, and Audi. Many of the features which they have implemented include night vision, lane departure warning, curve and speed limit information, collision warning, adaptive cruise control, local hazard warning, lane change assistant, obstacle and collision warning and avoidance [11].

## III. TACKLING THE MAIN CAUSES

### A. Cause 1: Alcohol

The current idea to reduce the problem of driving under the influence of alcohol is to "separate drinking drivers from their vehicles" [12]. This can be done by installing an ignition interlock device on the vehicle, which is connected to the starting system. The setup is connected to a breathalyzer, which enables or disables the ignition interlock device. When the driver needs to drive, he is required to blow into the breathalyzer tube [12]. Smart Start Inc. is a company based on Irving, TX, and has developed ignition interlock devices for vehicles and also for homes [13].

### B. Cause 2: Fatigue

VolksWagen and Smart Eye AB have developed their own solutions to tackle this cause. VolksWagen group have developed an attention control system, which includes a camera in the cockpit that monitors the driver's eyelids. When the system finds any signs that the driver may be tired, it makes a noise and requests the driver to take a break [11]. SmartEye AB developed the SmartEye Pro 3.0, which is a system that estimates head pose by using methods based on tracking of facial features and a three dimensional head model. However, they do not manufacture any algorithms to monitor the drowsiness [14].

### C. Cause 3: Distraction

A number of companies have introduced various systems and ideas to solve this cause. Many of these systems are not intelligent, providing feedback if, for example, the driver is intentionally changing lanes. Some of the best solutions are those presented by Mobileye. Their main solution is a camera-based safety solution, which helps out in accident prevention and mitigation. It notifies the driver on lane departure with visual and audio warnings and measures the distance between the tires to the lane markings on both sides of the vehicle [15].

#### D. Cause 4: Behavior

Companies developing driver behavior monitoring include Teltonika and Cellocator. These two companies offer vehicle tracking hardware with in-built algorithms based on accelerometer values. They take into consideration over-speeding, acceleration and braking, while also detecting, processing, logging and reporting a wide set of events concerned with hazardous driving behavior [16][17].

### IV. AIMS AND OBJECTIVES

ADASs aim to prevent motor accidents mainly caused by distractions, drowsiness and behavior. In this work, our main goal is to provide a low-cost driver assistance system without the need of installing any additional hardware and which works on any vehicle. In order to produce such a solution, we have investigated a number of existing solutions.

We aim to provide an easy to use, and an easy to understand interface, which notifies the driver of dangerous events based on priorities (sorted according to their importance) without distracting the driver. The notifications we aim to provide the driver with are related to over-speeding, driver distraction and drowsiness, lane departure, oncoming obstacles, and suggested speeds for oncoming curves.

### V. DESIGN

A system has been developed and released. In this section, we will go through the system's design and the chosen platform.

#### A. Mobile Platforms

Mobile devices have improved radically, especially with the progress of the internet on these devices. This caused the usage of smartphones and their services to "become more and more popular" [18]. Some of these services include Location Based Services and transport information services. "Mobile Services make life easier, simpler and more effective" [18]. There are a number of Mobile Platforms available for mobile devices, including Android, Windows, iOS, WebOS, Symbian, and RIM [18].

Developing the system to work on a commonly used mobile platform will satisfy one of the aims we set out to achieve – we have tried to produce an easy to use application, which can be installed and made use of by anyone of any age.

The system was developed on the Android platform. It is the mobile platform, which is on the rise, has the highest market share and is one of the easiest to develop on since applications can be developed using JAVA.

#### B. ADAS to Android mobile application

A lot of time was spent researching existing driver assistance systems and solutions, which are available to the general public. All the systems found are powered by quite powerful hardware, specifically designed and built for the use of ADASs. The systems also have plenty of sensors

installed around the vehicle, such as RADAR infrared sensors, and cameras with night vision enhancement technologies. For our implementation, we made it a point not to use any third party hardware peripherals, and use only the built-in hardware sensors provided by the device, which made it harder to implement.

Analyzing the causes and how they have been previously tackled, all of them require additional hardware, such as breathalyzers. In our implementation, we developed workarounds, which make use of estimates. This will satisfy one of the aims, which states that we will try to provide a low cost solution with no need to purchase and install any external devices. However, for causes such as drunk driving, workarounds could not be developed since there is no actual control over the vehicle.

##### 1) Tackling Cause 1: alcohol;

As previously mentioned, developing functionality to tackle this cause is close to impossible without third party external peripherals. One of the ideas which came to mind was to implement an accelerometer sensor listener, which analyses user activity patterns and checks the driving behaviour. This however would turn out to be very inaccurate, and can only be used to warn the driver not to drive. Warning a person under the influence of alcohol not to drive would prove to be close to useless. This is because as previously explained, alcohol encourages a competitive behaviour, which will only encourage the driver to be dangerously daring.

##### 2) Tackling Cause 2: fatigue; and cause 4: Behavior

The methods to tackle driver fatigue and driver behavior are very similar. The idea is to analyse the user activity patterns to identify the status of the user. The data is collected from the device's in-built accelerometer sensor, and then filtered to achieve the data needed. The current implementation identifies the status of the user, whether walking, driving, or standby. It also identifies any sharp 'hits' exerted on the device, such as pot holes in the road, harsh turns, harsh braking and harsh acceleration. However, the implementation assumes that any sharp 'hits' are only harsh braking or harsh acceleration, and does not understand the difference between the others (harsh turning, etc.). To tackle fatigue, the current implementation constantly provides feedback to the driver by both audible tones, and by speaking out instructions. This keeps the driver attentive and pesters him if he is driving too fast and therefore recklessly. The implementation to continually give feedback to the user will also help to satisfy the third aim, which states that we will provide the user with warnings to reduce his possibility of being in a traffic motor accident.

Other parts of the implementation include a curve detection and notification function, which analyses the road the vehicle is currently on, and using digital maps, extracts and calculates the angles of the rest of the road in front. The algorithm then takes the user's speed from the GPS sensor, and compares the angles to the suggested speeds. These implementations will help reduce motor accidents, which

occur due to over speeding in curves by notifying the user earlier to give him time to take preventive action.

3) *Tackling cause 3: Distraction;* Tackling this cause is a combination of all the functionalities and methods used to tackle the other three causes. We tackled driving distraction with the idea that we need to constantly pester the driver to keep his attention and focus on the road ahead. The alerts and warnings used in the previously described functionalities already do a big part of the job. The additional methods to tackle this cause have not been fully implemented. However, the essential, most difficult parts have been implemented for proof of concept.

The system makes use of the camera to analyse the lane markings and oncoming obstacles, and tries to estimate (since only one camera is available) the distance between the host vehicle and the obstacle linearly in front. The current implementation can also detect obstacles on neighbouring lanes, which then can be used to provide feedback to the driver if there is a possibility that an obstacle is beside the host vehicle while changing lanes. All the functionalities combined help reduce the risk of motor accidents by alerting the driver and catching his attention if he is distracted.

### VI. IMPLEMENTATION

The system has been developed in a modular fashion, where each feature is developed in its own separate module. The main modules are the user interface, the activity analyser, the lane processor, the obstacle processor, the directions and curve detector, the GPS location module and the call catching module. It is important to note that our aim was not to develop all features which are available in other existing ADASs, but to give an idea of what can be achieved with a mobile device and how it can help out in this area.

The GPS sensor will be used for geolocation purposes, to record location, speed and acceleration. The 3G connections provided by the device will be used to connect to the server, and the accelerometer will be used to analyse the driver's activities.

#### 1) The service and the main thread

The system has been divided into two main parts: the main thread and the service. The main thread handles the Graphical User Interface (GUI) of the application: the camera view, the car information views, the destination selection and map view, and other small, low memory intensive threads, lane processing and obstacle processing. The service is a background thread, which controls other small background threads. It handles the text to speech, the activity analyser, the GPS location listener, curve detection, turn by turn navigation, location tracking, warning logging and notifications, incoming call blocker and the SMS sender.

#### 2) The activity analyser

This feature analyses the device's accelerometer and GPS information to determine whether the user is walking, driving, or standby. It is mainly used in conjunction with the incoming call block. If the user is in 'standby' or 'walking' mode, the incoming call block is switched off. If the user is in 'driving', the incoming call block is enabled. In Figure 1, we can see the process for analyzing the user's activity.

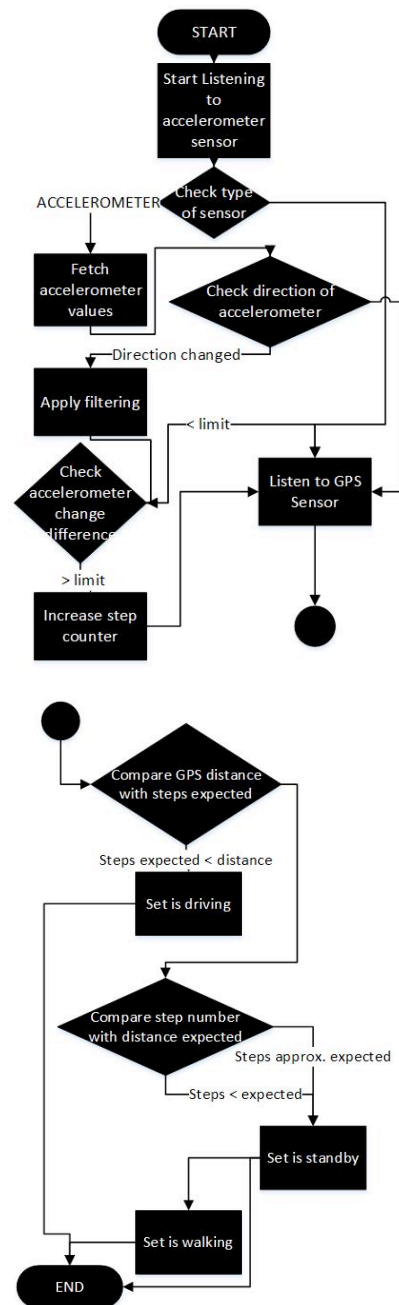


Figure 1: The Activity Analyzer process

### 3) Lane processing

The lane processing algorithm took a lot of time to figure out; much longer than expected. Many implementations were tried and tested, until a good output was achieved. The main problems were caused because of the faded out lane markings in Malta. Also, many roads do not have lane markings. The result achieved by the lane processing algorithm can be seen in Figure 2.

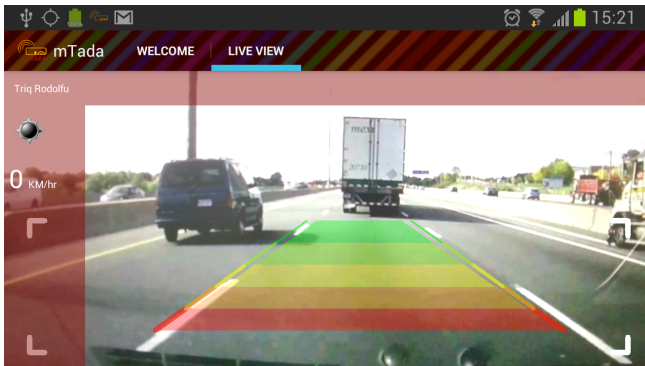


Figure 2: The result achieved from the lane processing algorithm

### 4) Obstacle processing

The obstacle processing algorithm which has been designed and implemented for the paper has to be improved and worked on. The algorithm implemented is one which has been adapted from the algorithm proposed by Shane Tuohy in his dissertation paper: Real Time Distance Determination for an Automobile Environment using Inverse Perspective Mapping in OpenCV.

### 5) Directions and Curve detection

For this feature, we needed to set up a special server with map data. We set up a CentOS 6.0 64bit server and installed a number of applications such as Mapnik, osm2pgsql and Routino. These applications are used for mapping functionalities such as routing. We downloaded the map data from an open source, free to use server: Open Street Maps. We then implemented some methods using PHP and postgresql queries to retrieve road data, such as road names and road points, which make up the road. The road points are sent to the application installed on the device, which in turn analyses them and calculates the difference between each angle. It then issues both visual warnings and sound warnings to the driver depending on the speed of the vehicle and the strength of the oncoming curve. An example of a warning given by the curve detection can be seen in Figure 3.

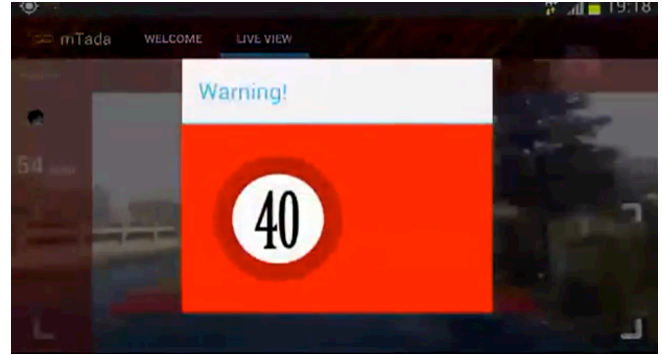


Figure 3: A curve detection speed warning

### 6) Incoming calls and SMSs

The main purpose of this feature is to reduce driver distraction. It listens for any incoming calls, and can be set to either answer the call and send it to loud speaker, or block any incoming calls, and send an SMS automatically to the caller, with a message saying that the other user is driving.

## VII. RESULTS AND EVALUATION

The system was made available on Google Play, free of charge. We created a website which enabled users to register and receive a username and password. As soon as we released the system for private testing, we sent out an email to all registered users to inform them that they could start testing it. We had some limitations, such as the fact that user must be located in the Maltese Islands to be able to test it out. After installing the application on the user's mobile, the mobile had to be installed on the dashboard of a vehicle, with the camera facing towards the road in front.

We evaluated the system in two ways. As explained above, we allowed users to download it and test it on their own. For the second method, we chose a number of individuals from different age groups and went on test drives with each one of them individually.

### 1) Private testing

The website for registering and downloading the application was launched on [www.m-tada.com](http://www.m-tada.com). After given some time to evaluate, each user was sent a short questionnaire. The questionnaire was filled and submitted by twenty-one people, 48% being between the ages of eighteen and twenty, 33% being between the ages of twenty-one and twenty-five, 5% being from the age group of twenty-seven to thirty-five and the last 14% being older than thirty-five. Six of the applicants have been in a motor traffic accidents, four admitting that it was their fault, mainly caused by driver distraction and driver drowsiness. One of the applicants also said that the accident was partially caused because of driver behavior. Eleven people said that they never considered making use of ADASs, while four never felt the need, and the other six may have considered them. Also, four of the applicants did not know that many modern vehicles come with driver assistance options, while two never considered it.

With the questions regarding the application, three of the applicants did not have a compatible device and therefore could not make use of it. The others who managed to make use of the system, found the notifications and warnings it provided very accurate, with 15 claiming that it helped them improve their driving behavior, and another three saying that they do not know if it helped. The last question in the questionnaire asked whether the applicants would buy such an application. Fourteen of the applicants said they would, while three said no. One of the applicants comments that he would prefer the basic application to be made free of charge, with only additional features being put up for optional purchase.

### 2) Individual test drives

We went on test drives with 7 people of different age groups. We carefully analyzed their reactions to the feedback provided by the system to determine their compliance and acceptance of it. The device we used was a Samsung Galaxy S3 with Android version 4.1.2. It had an average frame rate of 10 frames per second.

Age group 1: 18-20; We tested 2 different people. Both were very compliant and accepting of the system, and drove very cautiously. They did their best to avoid being provided any feedback from the system. One of the participants said that he complied to the system as it made him feel safer. He said that since he is still a beginner, he is still used to following instructions given by the instructor, and he felt that the system was replacing him. He also claimed that the curve detection and warning system helped him travel along roads, which were new to him.

Age group 2: 20-30; The person from this age group drove very cautiously and slowly. He was given close to no feedback at all. When asked how he felt driving with the system, he said that he obeyed it because he did not want to be pestered by it, and also wanted to make the best of it. He used it to aid him while driving. He also claimed that he thought that the visual warnings defeated the scope of auditory warnings as it would take your eyes off the road unnecessarily.

Age group 3: 30-40; The person from the third age group ignored most of the warnings provided to him by the system, and only complied to it when it seemed to be the only choice he had. He gave us the impression that he did not comply because of pride and ego. We later asked him why he did not comply, and he simply answered that he wasn't interested in being given any feedback. He also said that he wouldn't mind having such a system in his vehicle, as long as he could choose the type of warnings and what warnings he would be given.

Age group 4: 40 -50; For this age group we went on 2 different test drives, a female and a male. The female claimed that she finds driver assistance system useful, and makes use of them regularly. She said that they help her in heavy traffic roads, and high speed roads. When using the system, she said that the warnings were very helpful and quite accurate. The male did not want any feedback given to

him. Out of pride, he went to the extent of doing exactly the opposite of what the system suggested him to do. He constantly criticized the system and said that the only feedback he wants is to know if there is a speed camera up ahead. He also claimed that he also ignores feedback from passengers as he is a very good driver because of his experience he gained over the years.

### 3) Results

At first glance, we can say that the system, although still requiring a lot of work, was very effective with the majority of the users. The system provided the users with accurate warnings. Most of the warnings were regarding high speeds when approaching curves in the road. The system pestered the drivers, encouraging them to drive cautiously and slowly while approaching these curves. A limitation in evaluating such a system is that the best way to evaluate it would have been to have a higher number of test drives and users evaluating it. We couldn't analyze exactly the number of near-collision situations, and how much of them would have been reduced with the aid of our system. We also believe that as can be seen from the test drive with age group 1, assistance needs to be given from the beginning of a driver's experience. Starting to provide assistance to experienced drivers will only encourage a competitive attitude and show one's pride and ego.

## VIII. CONCLUSIONS AND FUTURE WORK

### 1) Improvements over existing systems

We tackled two main points, which we aimed on improving over existing systems. One of these is that existing systems are very costly, because they require the driver to purchase external devices unless the vehicle has existing sensors. These devices then need to be installed by an auto mechanic, and set up by an auto technician or engineer. To buy a vehicle with pre-installed ADASs also is very costly as each feature is an 'optional', which has to be paid for extra. An existing system which works on mobile phones, as mentioned previously, Mobileye, also needs the user to purchase external devices and install them in various locations around the vehicle. The solution mTADA, which we have developed however does not need any external devices, but only makes use of the sensors provided by the host mobile phone itself. Another improvement is that the application also provides audible feedback with the voice of a human being, while also categorizing the different types of warnings according to the gravity of the situation. The system also provides driver behavior feedback while providing turn by turn navigation instructions, which no existing system currently provides.

### 2) Future Work

Plenty of ideas had been brought forward for the system proposed, however due to time restrictions it proved very difficult to even research them. In this section, we will be identifying the main ideas and explaining how they could be implemented and their possible uses.

Bug fixes - The first work to be done on the system would be to fix the existing known bugs. These include the bugs related to the turn by turn navigation and finding a solution for the harsh braking and acceleration algorithms.

Obstacle detection and tracking - Obstacle detection has already been implemented, however as explained in the testing section, in real-life scenarios a lot of false positives are also being detected due to the different road shades, glares and the need for further pre-processing on the image feed to help identify the vehicles in dark situations.

Lane departure warnings - On fixing the obstacle detection and tracking algorithm the lane departure warning system can be enabled as the basics for this feature have already been implemented. By getting the obstacles from the image and tracking them, it would be possible to analyse whether there are any possible vehicles in blind spots, at the sides of the vehicle. Doing so will make it possible for the system to provide feedback when the host vehicle is deviating from the lane and a vehicle might be on the other lane.

Driving behavior - Another idea is to improve the user activity algorithm to be able to analyze the driving patterns to deduce the driving behavior of the user. This data then can be used to offer constructive criticism to the user based on these patterns. Another idea was that after deducing the driver behavior, feedback is provided to the user on how to reduce fuel consumption – eco driving.

Settings screen - A number of people provided additional comments and feedback in the questionnaire. The idea we liked the most was to have a ‘settings’ screen, which would allow the user to customize the user experience, and deactivate certain functionalities such as lane detection and tracking.

Map data - Another idea would be to have the map data downloaded and stored on the device instead of requesting the data every few seconds. This would help to reduce data costs and to preserve battery life. To accomplish this, however, the application would have to store the logs in internal memory, and then upload them to the server as soon as a valid connection is found.

Web application and traffic data - A part of the system which we did not manage to work on was a web application, which provides real-time data of the location of the mobile and real time logs. The application would enable many possible uses, such as vehicle tracking for businesses, and also driver analysis for personal use. With the implementation of this real-time system, it would enable the possibility of crowd-sourced traffic analyses and indication systems. This system would be able to analyze the data being transmitted by the devices, consider the different speeds on the different roads to estimate where there would be possible traffic. It could also be improved to indicate where there would be an accident. In fact, another possibility for future work on the system would be to implement collision detection, which would automatically

notify the authorities to take action, and neighboring traffic to avoid the road.

### 3) Conclusions

Road traffic accidents are a major problem, which takes major toll on life in all countries, mainly in industrialized areas and developing countries. The major causes of such accidents are alcohol, driving behaviour, fatigue and driver distraction. When tackling a cause like driver distraction and driver behaviour, it is very difficult for the driver to actually acknowledge that he is doing something wrong since there is no good source for feedback except for passengers or being in a near-accident situation. To solve this, we attempted to develop a system, which pesters the driver, keeping his attention and focus on the road, while also providing feedback based on his behaviour, such as excessive speeding, harsh braking and harsh acceleration.

We did extensive research, and presented the most relevant information. Based on this information we developed a system, which we named mTADA: Mobile Tracking and Advanced Driver Assistance. We implemented mTADA on the Android mobile platform so that it can be easily installed and used by a majority of the population. The system does not make any use of any third party peripherals but only makes use of the sensors already available on the device – GPS sensor, accelerometer, back camera and the touch screen. We managed to implement lane tracking and detection, curve detection, a turn by turn navigation system, and a warning system. However, we encountered some problems while tackling the obstacle detection algorithm because of different colours in the roads. We also encountered some small bugs during testing, which we have mentioned in the testing section previously and pointed out as future work in the previous section. To top it all off, after fully testing the system, we evaluated it in a real world scenario and it proved to be useful. Many people who we questioned claimed to have found it useful, and claimed that they would make use of such an application on a regular basis. We also went on test drives with people from different age groups and analysed their reactions, acceptance and compliance towards the system. Younger age groups were more compliant and accepting of the system, while males from older age groups did not want to be provided feedback, and were neither accepting nor compliant.

We found that the system development was quite difficult at first without making use of external devices, especially in night situations. We managed to design and implement a number of workarounds to tackle most of the 4 main causes. However, the system still has a number of bugs to be fixed, and a number of features and functionalities to be implemented. Even in the current state the system managed to achieve the results we set out to achieve, together with the aims and objectives we identified at the beginning of this paper.

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