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Smart Application for Every Car (SAEC). (AR Mobile Application)

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Abstract Technology is continuously evolving at an exponential rate. Fast technological advances are being made, especially in the field of smart phones, that facilitate the conduct of our daily activities in many areas such as driving. The ever-increasing number of vehicles on roads increases the likelihood of traffic accidents, resulting in higher number of deaths and serious injuries to drivers, passengers, and pedestrians. Among the main causes of road accidents are over speeding, unsafe lane jumping, and failure to keep a safe distance between vehicles, to name a few. In an attempt to contribute to the improvement of road traffic safety, we have developed an Augmented Reality-based Smart Vehicle Driver Assistance application. The application is designed to enhance vehicle driver's safety, in particular, but is also considered to lead to incremental improvement of safety of road traffic. The application can run on both Android and iOS platforms and incorporates several beneficial features required by a vehicle driver such as monitoring of vehicle speed, warning the driver in case of lane deviation, detection of road signs, and to alert the driver if the vehicle is not being driven at a safe distance from the vehicle in front. In addition to providing information to improve safe driving, the application also helps the vehicle driver save parking location of the vehicle in order to efficiently identify the parking location when retrieving the vehicle. This feature is very useful at large and unfamiliar parking areas, such as at airports or one-off large public gatherings, especially in inclement weather. The application also includes other useful functions such as the payment of parking fees, storage of information regarding vehicle maintenance, and keeping the vehicle legal document up to date. The application uses the stored information to display reminders of the appropriate action that needs to be taken before it becomes overdue.

1. Introduction

Nowadays, smartphones are considered an integral part of our lives, and there is now a need for the development of more intelligent, concise, and effective human–computer interactive

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technologies [1–3]. Mobile technology has already been successfully applied to diverse fields of human activities such as education, healthcare, transportation, business, entertainment, and military to name a few. The ever-increasing productive use of smart applications is, in fact, a living testimony to the usefulness of this particular technology in our daily life.

Vuforia [4,5] is a software development kit (SDK), mainly used in the development and implementation of applications using Augmented Reality (AR). With the help of Vuforia libraries, applications envisage images and objects using the mobile device camera and enable interaction with the spaces in the real word. Vuforia supports the development of both Android and iOS applications. As will be seen later, we have used Vuforia for the development of our application.

Open Source Computer Vision Library (OpenCV) [6] is an open source computer vision and machine learning software library. It was built to provide a common infrastructure for computer vision applications. It is supported with all platforms available in the market. The OpenCV library supports more than 2500 optimized algorithms to improve the detection, identification, and tracking of objects. The OpenCV library has been used in our application to detect vehicles, streets and road lanes.

In addition, we have used the capability of Augmented Reality (AR) to insert and overlay digital information into the real world. AR essentially turns the environment around us into a digital interface by placing in real-time projection of virtual objects in the real world. There are many AR tools currently available in the market ranging from 3D viewers, reality browsers, to immersive interactive gaming [7]. There are many applications that benefit from AR technology and are being successfully used in several areas such as travel, shopping, medicine, education, gaming, and many more. Other AR-based applications are used to enrich camera displays with information based on the application's context, for instance, pointing the smartphone at a printed menu that would display the prices of the dish along with videos showing the dish being prepared. Recently, the use of AR technology has attracted attention in gaming, especially after the development of the popular Pokémon Go AR game that allowed users to catch virtual Pokémon hidden in a map of the real world. AR technology seems to have sufficiently matured to provide almost limitless uses of the technology. It is a rich, constantly evolving technology that offers almost endless possibilities [7]. Driving of road vehicles is considered to be one of the most common and essential lifestyle skills in the world. Unfortunately, vehicle accidents happen every day for several reasons. Vehicle accidents cause many injuries and also deaths and result in loss of billions of dollars for the governments in lost revenue [8]. Road accidents occur for several reasons, ranging from over speeding, careless traffic lane jumping, and failure to maintain safe distance between vehicles. According to the World Health Organization (WHO) global status report on road safety, published in 2018 [9], the number of road traffic deaths increased to 1.3 million in 2016. In Australia, for example, an increase in road traffic deaths from 2015 to 2016 was 8% and the over speeding was found to be the main cause of the increase in road traffic accidents [10]. In the USA, an increase of 4% in road traffic deaths was considered to be mainly due largely to over speeding [11]. In New Zealand, the number of road traffic deaths in 2018 was the highest since 2009 and statistics show that speeding was one of the main causes [12]. Furthermore, it has been found that the highest number of drivers who died in road traffic accidents was less than of 35 years. According to a study [13], conducted at Al-Ain Hospital, in UAE, the most common cause (67.1 %) of head injuries was related to road traffic accidents. Furthermore, the estimated mortality rate, involving road accidents, in the UAE is considered to be 37 per 100,000 of the population. This makes the road accident death rates in the UAE one of the highest in the world. A survey of 1007 drivers [14] conducted in the UAE identified the top five causes of road traffic accidents as over speeding (68%), tailgating (56%), distracted drivers being distracted (47%), frequent changes in the traffic lane (32%), and driving in the wrong traffic lane (18%). Many initiatives have been put into practice by the concerned authorities to reduce road traffic injuries and fatalities in road traffic. For example, Saves Life: a road safety technical package [15] was released in 2017 by WHO aimed at reducing the rates of road traffic deaths and injuries by 50% by the year 2020.

In response to all the issues mentioned above, we have proposed an important smart mobile application to assist vehicle drivers, with the aim of reducing vehicle accidents and ensuring safe driving.

However, some people consider the distractive nature of the use of smartphone, while driving, as one of the major contributors to road traffic accidents. Our application, as described in this paper, shows that smartphones can also be used to make vehicle driving a much safer and stress-free experience. In this paper, we propose an AR-based mobile application for both Android and iOS that is also supported by Android Auto and Apple Car Play. The Smart Application for Every Car serves as an important tool to assist drivers to manage the driving process and thereby adjusting their driving behavior; including but not limited to over speeding, traffic lane changes, and sign detection. The application also helps drivers in locating their parked vehicles. The app also provides other functions that will be discussed in more detail later in this paper.

The remainder of the paper is organized as follows. Section 2 discusses the related research work. The research methodology of the research is detailed in Section 3, while Section 4 introduces the proposed application with its architecture, functions, and features. An example illustrating the use of the AR-smart Vehicle Driver Assistant app is also provided in Section 4. Finally, Section 5 concludes this paper.

2. Related work

2.1. Related research papers and applications

Several research efforts have been made either as research papers or in the development of smartphone applications taking full advantage of smartphone technology in terms of its sensing capabilities, high resolution cameras, and internet connectivity in traffic accident detection and in assisting vehicle drivers to drive safe. Several researchers have focused on vehicle accident detection and reporting or generating alert warnings of these accidents. For example, in [16], a smartphone application was developed to help with accident detection and also to inform drivers in case of traffic accidents to avoid congested areas and select alternative routes. Similarly, Khot et al. [17] developed an application that reports traffic accidents to the nearest emergency service and warns drivers about the accidents in order to select an alternative route and avoid traffic delays. The authors in [18] suggest an Android-based smartphone application to monitor vehicles and, in case of accident detection, alert the pre-defined individual or a government agency via email or SMS about the details of the accident along with a call to the emergency services. On the other hand, other researchers have focused their work on how to ensure safe driving and prevent vehicle accidents by suggesting proactive smartphone applications. The application proposed in this paper, falls in the second category.

We have conducted a systematic analysis of the available mobile applications and research papers dealing with vehicle driver safety, by exploring Websites, the Google play and the Apple Store. We have found several contributions made in the field of road traffic safety with the main purpose of providing a comprehensively safe and stress-free driving experience. Several mobile applications have been developed to tackle the related issues with the aim of reducing the number of road traffic accidents. The following is a summary of some of these applications.

An application proposed in [19] implemented a smart system to detect and report car accidents automatically in an instantaneous manner. In this app, data is collected from the mobile phone and analyzed using a Dynamic Time Warping (DTW) and Hidden Markov Models (HMMs) that establish the accident severity, notifies the location of the accident to the official responders, and provides access to vehicle driver's medical data. The developers of the application argued that the application will reduce the emergency response time, which, in turn, will lead to a reduction in road traffic deaths. An investigation conducted by the USA Transportation Department found that 23% of car accidents were caused by the vehicle driver's involvement in texting (either sending or reading text messages) while driving. The authors in [20] proposed a smart mobile application that blocks the driver's mobile phone when the specified driving speed limit is exceeded. The only option left open to the driver is making of emergency calls. Another mobile application described in [21] focuses on the detection of driving pattern and analysis of human driving behavior, such as acceleration, deceleration, and changing traffic lanes. The application also detects obstacles such as bumps or potholes and then alerts the driver. In addition, the application uses the acidometer and smartphone GPS sensor (Gyroscope) to detect road abnormalities and driving behavior by analyzing data collected from the sensors and processing them via a fuzzy system. Alerts are issued when the driver exceeds the prescribed speed limit of a road. The application also makes an automatic call or an SMS message is sent to registered relatives to inform them if the driver is involved in a traffic accident. The application is said to be cost-effective as it makes use of the sensors instead of having separate sensors installed on the vehicle itself for the same purpose. However, the application has limited features and misses other important functions, such as maintenance of safety distance, detecting road signs, and providing vehicle parking assistance.

AR GPS Drive/Walk Navigation [22] is another mobile application that uses the GPS and a camera to implement an AR vehicle navigation system. The driver is led directly by the virtual path displayed on the camera preview screen that is easy to follow. The app also has an option for video recording if the driver wants speed recognition and alert warning in case of exceeding the speed limit. An audio instruction facility is also available to guide the driver to his/her destination. The developers of the application claim that their application is intuitive and easy to use, and thus helps to reduce the risk of being distracted by the driver. The application has been criticized by the users, for its complex and poor user interface. The application has also been criticized, in user feedback on Google Play, for frequent loss of GPS connection, heavy load on mobile phone battery, and poor display of AR features.

An AR system using Head-Up Display (HUD) is proposed in [23] for the main purpose of reducing traffic accidents at night. The (HUD) alerts the driver about road traffic in real time by means of audio alerts or beeps. The vehicles augmented reality system collects real-time road traffic information, then analyzes the situation before providing the best action to take back to the driver on the screen in order to assist avoiding an accident. The system uses a layered architecture. The data are collected from mobile sensors and cameras. Then, this is passed over to a second layer that extracts the needed information, which is used by a third layer to provide the driver with the feedback on how to deal with the current situation. Other features of the application include lane assistance, handling sharp turns, and display of other visual warnings on the screen.

Augmented driving [24] is an iOS AR application that allows drivers to be more involved in the driving process. This includes features such as real-time evaluation of driving pattern, safety distance monitoring, traffic lane assistance, and the issue of warnings in case of over speeding. The application also features functions such as video recording and display of driving information and status such as current speed and driving route. The application has useful features. However, the experience of users with this application has been shown, as reported in the Apple Store, to be unsatisfactory. The shortcomings reported include flawed features, misleading information, poor user interfaces, and the distractive nature of app that may lead the driver to wrong actions.

myDriveAssist [25] is another application that uses the smartphone camera to detect speed limit, signs, and warns the driver if the speed limit is exceeded. It also warns the driver ahead of time (ten kilometers) in case another vehicle is moving in the wrong direction. The application also alerts the driver in case the driver is driving in the wrong direction and provides remedial action to avoid collision. Users' reviews of the application indicate that the application does not recognize all the road signs.

Car DVR & GPS navigator [26] is a vehicle DVR and GPS navigator combined in one application to help vehicle drivers drive safely. The application uses the smartphone camera to record the trip, in addition to using AR technology to assist the driver get to the target destination efficiently. Another feature included in this application is the monitoring of vehicle speed.

RoadAR [27] is an application developed to help drivers to recognize road traffic signs and monitor vehicle speed by showing the current speed of the vehicle and GPS information. The driver can also use the application to record the trip and share it on YouTube. Another useful feature of this application is that it allows the user to select the preferred language to interface with the system. However, one major issue related to this application, as reported by users, is the frequent crashing of the application along with overheating of smartphone batteries.

A project implemented by Istanbul Municipality is a mobile application named “IBB CepTrafik” [28]. This application generates real-time road traffic information using live traffic cameras and announcements about Istanbul city. The app also presents online weather status and information regarding the traffic conditions in various parts of the city on hourly basis. One of the interesting features of this application is the optimization of traffic on Road Network in the city and the issuance of recommendations regarding the shortest and easily accessible route to the destination. The application is similar to Google maps for direction detection, but does not support road sign detection, vehicle speed monitoring, and other features discussed in applications previously described in this paper. The app is designed for a specific city that is in Istanbul, Turkey.

OnRoad [29] is another application that provides assistance to vehicle drivers, but in a different way. The developers propose an Android application that monitors multiple parameters related to the car engine, such as the RPM, fuel status, and throttle position. The main objective of this application is to help the driver improve fuel consumption.

Another application is proposed in [30]. The application helps users to manage a range of features and services related to their vehicles. The proposed application reminds users about the renewal of their annual car pollution certificate. The application enables drivers to manage vehicle scheduled and nonscheduled maintenance activities such as general check-ups and tire pressure checks, respectively. It helps to explore new cities located around the user easily. The application has the capacity to play music based on the mood of the driver. The application provides other services such as car object detection, travel pattern, and helpdesk.

Several other applications have been proposed, but none of these seem to offer a full range of desirable functions centered on driver safety and presentation of reliable real-time information. Most of the other applications either have limited features that do not work as intended, display inaccurate information, or suffer from poor user interface.

2.2. Research contribution

The main contribution of the current research paper is to propose a comprehensive AR based mobile application that helps in reducing road traffic vehicle accidents and keep vehicle drivers safe by monitoring the vehicle speed, sign detection, traffic lane deviation, safe distance between vehicles by providing audible and visual warnings. In addition, other useful features such as assistance in finding the vehicle once it is parked, paying parking tickets, reminding the vehicle registration renewal, and exploring vehicle engine parts. The usability of the application has been thoroughly considered in the design and implementation process of AR-vehicle driver assistant app, which has led to the development of user-friendly interfaces and ease of use of the application.

3. Methodology of the research conducted

The flowchart in Fig. 1 illustrates the research methodology and describes the related application development process.

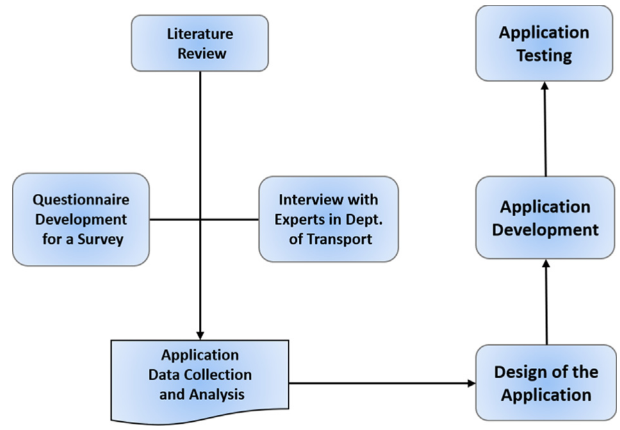

Fig. 1 Research Methodology flowchart and the proposed application development process.

Research started with a thorough literature review process. The latter was carried out in stages, in itself. First, the related research studies and scientific papers were collected and reviewed. Secondly, the available technical applications were collected, investigated, tested, and analyzed. Thereafter, an online questionnaire-based survey was developed and carried out. The data obtained from the survey, was then analyzed appropriately (as detailed in Section 4). Finally, an interview with domain experts was conducted and the opinions and comments of the participants were collected and analyzed.

As shown in the figure, at each stage the data was collected, processed, and analyzed to arrive at the main conclusions of the research and the potential contributions. On the basis of the knowledge thus gleaned, the subject application was designed and implemented. Finally, the application was tested and evaluated by a number of users. The comments and feedback provided by the user group were then used to upgrade the application in order to provide an almost flaw-free and user-friendly app.

4. The proposed application

This section provides a detailed description of the functional attributes of the proposed application and the ways in which it assists drivers to make their driving task safe, efficient, and stress-free. Table 1 summarizes the symbols and abbreviations used in this paper.

4.1. Application system analysis

Gathering application requirements is one of the most important stages in the Software Development Life Cycle (SDLC). The requirement elicitation for the establishment of performance requirements of the application was conducted with due diligence including as to how the proposed application will be used and how it will interface with users. The requirements elicitation also was aimed at getting to know various problems users face while driving their vehicles. The performance requirements were collected through a survey in which users were able to submit their responses, online, through a soft copy of the survey. The size of the user survey population was 100 people. The surveyed population was selected from

Table 1 List of acronyms and symbols.

AR	Augmented Reality
CTH	Current True Heading
DTW	Dynamic Time Warping
GPS	Global Positioning System
HMM	Hidden Markov Models
HSV	Hue, Saturation, and Value
HUD	Head-Up Display
OpenCV	Open Source Computer Vision
RPM	Revolutions Per Minute
SDK	Software Development Kit
SDLC	Software Development Life Cycle
TH	True Heading, variable used in the detection of lane deviation
X	variable used in the detection of lane deviation
Φ	Latitude
λ	Longitude
R	Earth's radius

a group of people with valid UAE driving licenses. A summary analysis of the data collected through the survey and feedback is discussed in the following paragraphs.

The analysis of the survey data showed that the highest number of responses (39.44%) were received from drivers with 2–5 years of driving experience followed by (29.58%) of drivers with 6–10 years of driving experience. The least number of responses (15.49%) were received from drivers with driving experience exceeding 10 years. Furthermore, the main problems that people while driving were analyzed and investigated. (46.48%) of the participants found themselves having difficulties driving in harsh weather conditions, while (59.15%) of the drivers found it difficult to drive at night. Almost half of the respondents (46.48%) found it difficult to resist over speeding, followed by (32.39%) of drivers who found it difficult to drive alone. A small number of respondents suggested other problems they face, such as parking.

More than (60%) of the participants were found to have accidents due to the driving problems mentioned earlier. A large number of participants (89%) believed that the development of an appropriate mobile application would help them overcome their driving difficulties. Their view was based on the positive experience of mobile applications they have used in other areas of their life. While (11%) of the participants did not consider the application to be of great value.

4.2. Application system design

The proposed app is developed using the Unity platform and is based on AR technology, which is a powerful tool to represent data in 3D models and reduces the cognitive load on the driver. Thus, enhancing and providing a richer driving experience. In addition, Unity platform uses C# as programming language. The app, therefore, runs on smart devices (phone/tablet), which, in turn, operates on both Android and iOS platforms. The architecture of the application is shown in Fig. 2. Vehicle drivers are required to register / log into the application. Once logged successfully, the application becomes available for use.

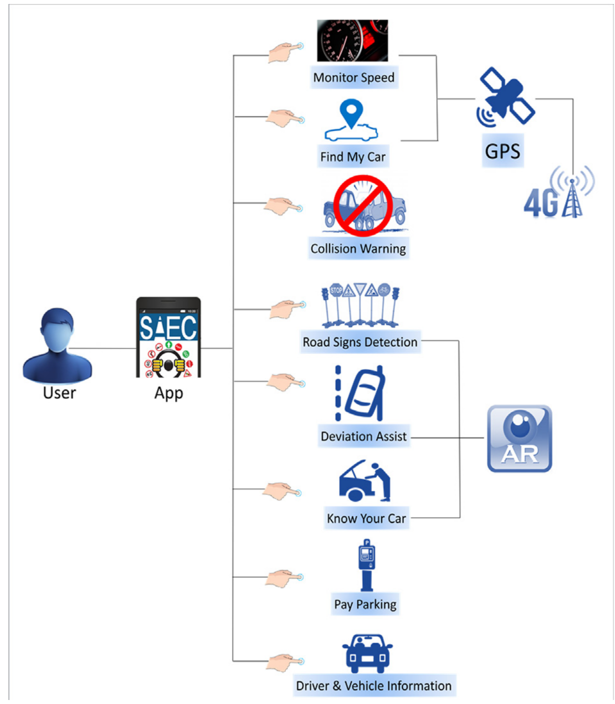

Fig. 2 The application architecture.

Assumptions. *The user shall have an Android lollipop (or later version) or iOS 6 (or later version). The user must give the location privileges of the app. On the other hand, the application uses GPS technology, and it also requires internet connectivity in order to provide real-time feedback, which enables drivers to manage speed of their vehicles, receive warning alerts in case of over speeding, and assistance towards maintaining the necessary safety distance to avoid collisions. It also helps vehicle drivers save their vehicle location when parked to facilitate easy retrieval. In addition, AR, along with Vuforia and OpenCV technologies, is used to detect road traffic signals in order to provide the relevant information to drivers and alert them in case of lane deviation. Furthermore, AR was also used to view the different parts of the vehicle engine.*

In addition, the app also has the ability to store and provide other important information related to the driver and the vehicle.

The specific information related driver could include his/her personal details whereas in the case of vehicle, the information could comprise of vehicle registration, maintenance schedule and ownership details. Vehicle information is maintained by saving the data during the vehicle registration process. Later, the user can update this information as and when required. Another interesting feature of the application is that it supports two most widespread languages, i.e., English and Arabic, which makes it available to a wider section of the public.

4.3. The application features

The features and functions of the application are summarized in the following subsections.

A. Register/ Login/ Logout: This allows users to register and then to log in and logout from the mobile application.
B. Drive mode: This function launches the mobile device camera as and when directed to the road or street. It helps the user make driving a stress-free experience by providing information through the multiple features such as collision alert warning, sign detection, speed monitoring, and helping to maintain the required safety distance. To use these features, the mobile must be mounted on the vehicle dashboard. Below is a description of each related feature:

12. **Sign detection:** The advantage of this function is that it detects traffic signs in advance while driving to audio relay the information to the driver. This function uses an adjusted face detection algorithm, where the target in this case is the street signs. The method used is the haarcascade with OpenCV based on machine learning. In the first phase, several images of street signs of the UAE (around 50 each) were gathered and then edited using Adobe Photoshop software to separate foregrounds from backgrounds. In the second phase, the haartraining classification algorithm [31] was run on these images to produce a haarcascade.xml file, which was used with Unity OpenCV to detect signs [32,33]. Moreover, the detection algorithm used in our application is a modified face detection algorithm taken from the Unity Asset Store [32], combined with [33], and converted to C# code. For each frame, the following steps (Fig. 3) were repeated until a given sign was detected.

1. Cut the image into two halves with a vertical line (only the right half is needed since the UAE follows right-hand driving).
2. Convert the image to grayscale.
3. Check the grayscale image with the haarcascade.xml file using the OpenCV function detectMultiScale().

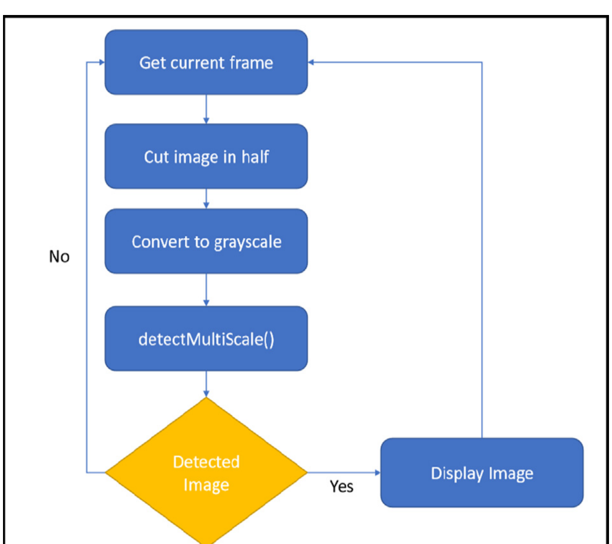

Fig. 3 Sign detection flowchart.

4. If there is a detection, a display of a predetermined image is made, otherwise go to step 1.

22. **Lane and sharp turn detection:** The deviation assist function is built into the proposed application to ensure the safety in so far as staying within the road lane is concerned. The deviation assist produces an audible and visual warning, displaying a red-bended arrow in case of lane deviation, as shown in Fig. 4. The application first detects the road/street lane [34] by taking the following pseudocode steps:

1. Convert the frame image taken by the mobile camera to grayscale.
2. Then, convert the greyscale image into HSV (Hue, Saturation, and Value) color space. After that, apply a mask to the original image to get the required pixels (yellow and white).
3. Apply Gaussian blur filter to suppress noise in the images to enhance the resulted edge detection.
4. Apply the Canny edge detection algorithm, which is an image processing methodology that is utilized to detect edges of an image while suppressing noise.
5. Finally, draw a polygon on the resulting edges.

The second part of the algorithm detects whether the driver has taken a sharp turn. An arrow is then displayed to indicate the vehicle position. The arrow is coded. It is displayed in green when the driver is keeping the lane, and it turns red when the driver deviates from the lane or takes a sharp turn. The polygons drawn in the lanes in the first part of the algorithm are the target of this color change as shown in Fig. 4.

1. The built-in Compass class in Unity is used to get the true heading.
2. The true heading is rounded to the nearest Xth part of the 360 degree circle (the 360 degrees circle is divided into X parts; in our case, we have taken the X equal to 8 degrees).
3. Save the true heading in a global variable (we call it TH).
4. The following steps are then repeated in a continuous loop as long as the mobile camera remains logged and the scene function is in operation to capture image frames.
   a) Obtain the current true heading and save it in a local variable CTH.
   b) No action is taken if the absolute value of the difference (TH - CTH) is less than X. Otherwise, TH becomes CTH rounded to the nearest Xth, and the color of the arrow is changed to red.

B3. **Speed monitoring:** This function enables the user to view the real-time speed of the vehicle and get an audio alert in case of over speeding. The over speeding alert is issued by the application by comparing the real-time speed of the vehicle with the applicable road speed limit. The speed display and thus the overspeed audio warning depend on the GPS signals in order to calculate the latitude and longitude of the current position of the vehicle which is then utilized to calculate the distance [35]. The calculated distance was then divided by time using the haversine formula as shown in the following pseudocode:

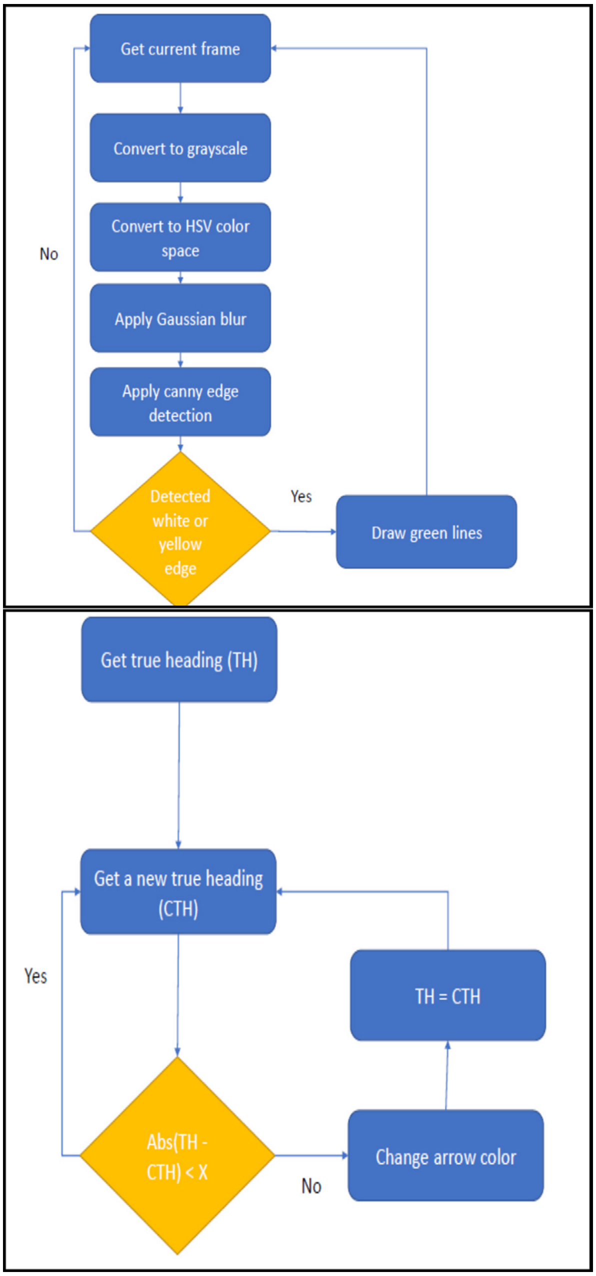

Fig. 4 Lane and sharp-turn detection flowchart.

a) Calculate $\varphi1$ and $\lambda1$ at t1, $\varphi2$ and $\lambda2$ at t2
b) $a = \sin^2(\Delta\varphi/2) + \cos\varphi1 \dot{s} \cos\varphi2 \dot{s} \sin^2(\Delta\lambda/2)$
c) $c = 2\ \mathrm{atan2}\ (\sqrt{}\ a, \sqrt{}(1a))$ *
d) $d = R\ c$
e) $v = d/\Delta t$

where φ is latitude, λ is longitude, R is the radius (mean radius = 6,371 km) as shown in Fig. 5.

This function is repeated when the difference between the current frame and the latest frame, at the time when the last calculation was made, is greater than or equal to 3 s (in our case, 3 s gave us the best result).

B4. **Safety distance assistance:** This function comes into force whenever the mobile camera is switched on. The objective of this feature is to capture and detect 3D large images, such as of other vehicles in front of the camera, using Vuforia libraries. Once an object is detected to be nearer than the regulatory imposed distance (in our case from 2 to 5 m depending on the quality of smartphone camera), then an audible alert is generated to warn the driver that the regulatory distance limit requirement has been exceeded. The feature enables drivers to maintain the safety distance between two vehicles, as required in most countries, thereby minimizing the risk of potential crashes.

C. **Save vehicle location:** The life we live is complex, fast, and busy. Therefore, it put us under considerable pressure. Most of the time, we work against time. Under the circumstances, it is quite common for people to forget where they have parked their vehicle, especially in the case of vehicle parking facilities adjacent to large shopping malls and unfamiliar parking places such as airport hubs.

This function of the application helps the user save the vehicle's parking location. Once parked, the user can save the location using the mobile GPS feature. This function works by saving both the latitude and longitude of the vehicle parked location using the GPS, which can be used later as a reference in the 'Find My Car' feature. SAEC also uses the smartphone magnetometer and the gyroscope to direct the vehicle user to the parking location of the vehicle in the form of a compass.

D. **Find my car:** This function is used by the user to locate the vehicle from the last saved GPS position (with the save my car location function). The application, when deployed, checks if a location has already been saved, if the location has not been saved, then an alert is displayed and the user is moved back to the main screen. Otherwise, the application switches on the device GPS and displays a virtual compass towards the coordinates

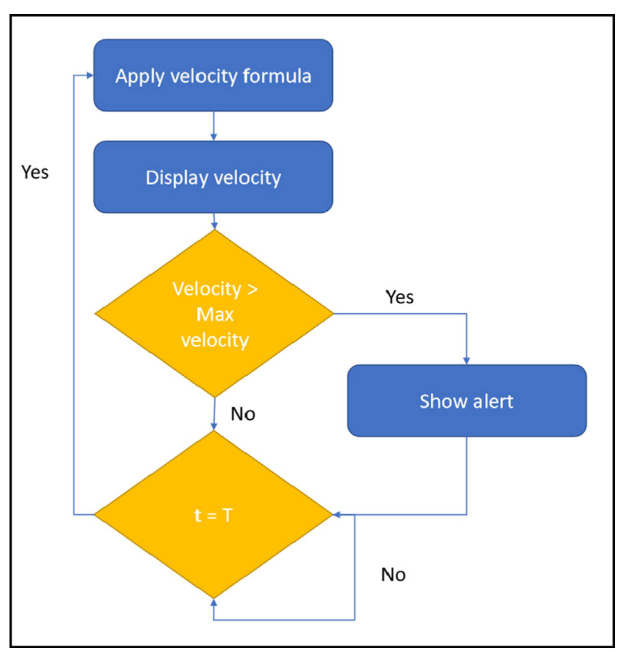

Fig. 5 Speed monitoring flowchart.

of the saved location. The virtual compass spins in a loop until the user arrives at those coordinates. This function provides both audible and visual guidance to the user to get to the location of the parked vehicle. The audible alert sound increases as the users get closer to the parked vehicle. The availability of GPS signal needs to be checked frequently based on the longitude and latitude, when the user is walking towards the target destination, to enable calculation of the remaining distance to the parking location and to update the rotation of the arrow.

E. **Add/Remove driver information:** This facility is used to allow the user to save his/ her driving license information and to be able to check traffic fines by first connecting to the traffic police website (in our case, Ministry of Interior, UAE), which holds the related information. In addition, drivers are alerted, through the application, regarding the validity and renewal requirements of their driving licenses when the validity of their driving license is close to the expiration date.

F. **Add/Remove vehicle information:** This function facilitates the storage and retrieval of vehicle information. The information includes vehicle plate number, registration information, and other related information which then can be used to keep track of any due action that needs to be taken such as the planned maintenance services, vehicle registration validity period, and due date for renewal of vehicle insurance. Vehicle information saved can be retrieved and used to pay for vehicle parking fee in UAE. This is achieved through the pay parking feature of the application.

G. **Know my car:** This feature of the application enables the user to learn about various parts of the vehicle. Once selected, the app AR camera is switched on, which then need to be pointed towards the part of interest. The app then displays a 3D model of the selected part. In addition, the app also provides detailed information about the selected part.

H. **Pay parking:** This function can be activated once the driver is in park and saves the current position of the vehicle. It allows the user to pay for the parking fee regardless of their location within the UAE (in our case, the feature only works in Dubai and Abu Dhabi). Vehicle number plate information is required to pay the parking fee. The required information is already stored as explained earlier in the Add/Remove Information section. The result of this operation is a text message generated by the app, containing details about the vehicle plate, date, and time.

4.4. An illustrative example

In this section, an illustrative example is given to show how the application works and the interfaces that result from user interaction with the application. Note that not all interfaces are shown here due to space limitations.

The screen shown in Fig. 6 appears when the user first launches the application. On the login screen, the user must enter the username and password to gain access to the application. The user can create a new account by selecting 'Sign up for the application". In case the user has forgotten the password, the option 'Forgot my password" can be used to reset the password.

Fig. 7 the main screen after the user has successfully logged in to the application. A rotating wheel displays the 7 main options of the application, 'Driving mode', 'Find your vehicle', 'Park your vehicle', 'Pay parking', 'Know your vehicle', 'Driver information', and 'Vehicle information'. As explained earlier, the drive mode assists the driver in managing vehicle speed, and keeping within the traffic lane, as shown in Fig. 8. The other options of the user interface are the safety distance and the sign detection as illustrated in Fig. 9. The user can choose the preferable option by clicking on the camera icon which enables switching between the interfaces. When the vehicle gets too close to the leading vehicle, an audible collision warning alert is generated. Road signs are detected and displayed as they appear on the road. In addition, the application keeps monitoring the vehicle speed and produces an audible warning alert when the speed limit is exceeded. The arrow in the middle of the screen is used to indicate the lane deviation. A green arrow, displayed on the screen, indicates that the vehicle being kept in in traffic lane. However, when the arrow turns red, this indicates to the driver that the vehicle has swerved off its intended path.

By selecting the 'Park My Car" option, the application directs the user to the screen shown in Fig. 10. The user then clicks the 'Save' button to save the vehicle's current location, as explained earlier. The application uses GPS technology to collect the accurate location and save it. Once that step is completed, the user is asked if he or she is willing to pay the parking fee. If the 'yes' option is selected, then the application takes

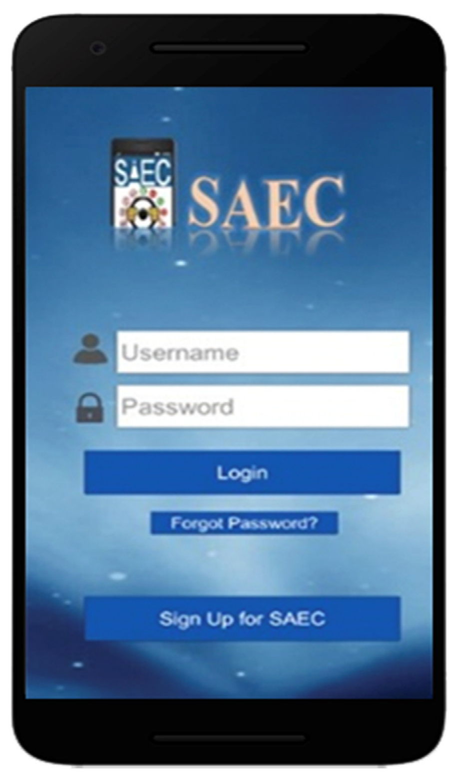

Fig. 6 The application login screen.

Fig. 7 The application main screen.

Fig. 9 Drive mode screens (sign detection and collision warning).

Fig. 8 Drive mode screens (lane detection and speed monitor).

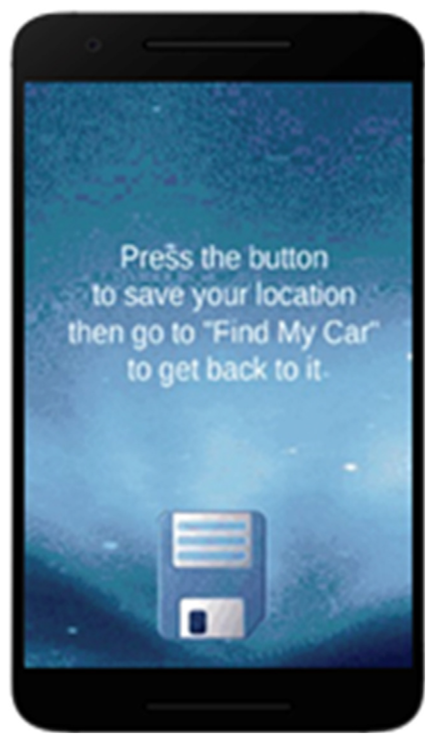

Fig. 10 "Park My Car" screen.

the user to the 'Pay Parking' screen, shown in Fig. 11 with the two possible interfaces depending on the city (Dubai or Abu Dhabi in our case).

Note that vehicle information is already stored in the system. The user only needs to select the number of hours to pay for. Once the vehicle is parked and the time is approaching the expiration time of the ticket, an SMS is generated and sent to warn the user. In case the user wants to extend the time for vehicle parking, the application displays again the corresponding Pay Parking screen, depending on the vehicle location (city). The selection of the "Find My Car" option directs the user to the screen shown in Fig. 12. An arrow pointing to the direction of the vehicle is displayed and changes depending

Fig. 11 "Pay Parking" screen.

on the direction of motion. Additionally, the distance between the user and the saved location decreases/increases depending on the distance to the saved vehicle's location. The application produces a continuous audio beep that becomes louder as the user gets closer to the saved location of the vehicle.

Fig. 13 illustrates the interfaces for the options 'driver information', 'vehicle information' and 'know my car" options. Driver information includes all personal data, license number, traffic code number, issue date, expiration date, and the location where the driving license was issued. The button 'Check fines' will direct the user to the traffic website to check whether there are any fines issued to him/her. The vehicle information screen displays all the information related to the vehicle such as plate number, vehicle registration, location, expiration date, and vehicle details. In addition, the user has

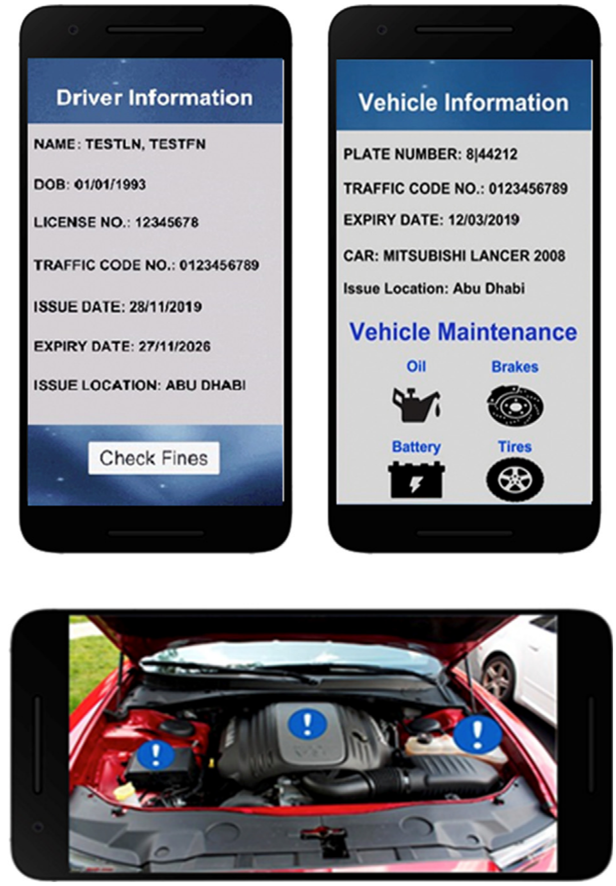

Fig. 13 Driver information, vehicle information, and "know my car" screens.

Fig. 12 "Find My Car" screen.

the option 'Vehicle Maintenance' that can be used to view details about vehicle maintenance like what has been done in the last vehicle service and the due date of the next mileage service. The 'Know My Car' screen uses an AR camera to help the owner to obtain information about various vehicle parts. When the camera detects the engine compartment, it displays exclamation marks on the parts of the engine through the camera view, while showing a brief detail on each of the components displayed.

Table 2, as given below, summarizes the features of our proposed application compared to those discussed in Section 2. In addition to the features mentioned in the table, our proposed application has extra features related to vehicle registration to remind the vehicle owner about vehicle registration ahead of the expiration date, vehicle maintenance schedule, and information on vehicle engine.

4.5. Major impacts and benefits of the proposed application

The main results of this research paper are the development of a smart mobile application that includes several interesting features that vehicle drivers benefit from. With sign detection, lane deviation assistance, and safety distance monitoring features, these result in saving lives, reducing road accidents, and improving driving behavior. Consequently, this will have a great impact on reducing traffic deaths and financial losses

Table 2 A compartive summary between the proposed application and others existing.

Ref.	Apps	Technology	Traffic Sign Detection	Lane Deviation Warning	Safe Distance Warning	Speed Limit Warning	Parking Location Saving	Platforms
26	Car DVR & GPS navigator	AR	No	No	No	No	No	iOS, Android
25	myDriveAssist	AR	Yes	No	No	Yes	Yes	Android
22	AR GPS DRIVE/WALK NAVIGATION	AR	No	No	No	Yes	No	Android
29	iOnRoad	AR	No	Yes	Yes	Yes	Yes	iOS, Anroid
24	Augmented Driving	AR	No	Yes	Yes	Yes	No	iOS
27	RoadAR dashcam & speed camera	AR	Yes	Yes	Yes	Yes	No	Android
	SAEC	AR	Yes	Yes	Yes	Yes	Yes	iOS, Android

to traffic departments, insurance companies, and individual properties. Additionally, the proposed application saves vehicle drivers time by helping them find their vehicle once parked, warning them about the due date of vehicle registration ahead of time, and paying parking tickets through the application. Moreover, the application has been tested.

5. Conclusions and future work

Driving is no longer considered a luxury any more, it has become a necessity of our daily life. The high rates of deaths and injuries caused by road traffic accidents are mainly triggered by vehicle drivers who do not abide by traffic rules such as exceeding the speed limit, not keeping in their traffic lanes, not maintaining a safe distance from the vehicle in front, and getting distracted while driving, just a few to name. In an effort to contribute to saving lives by assisting vehicle drivers in preventing fatal road traffic accidents, we have proposed and developed an AR-based vehicle driver assistant application. Our proposed application is comprehensive and has several interesting features. The application assists the driver in monitoring the vehicle speed and generates audible and visual warnings in case the road speed limit is exceeded; it also helps drivers by recognizing and displaying road signs, also warns the drivers in case of lane deviation or fails to keep safe distance to the vehicle in the front.

The application includes other useful features such as enabling drivers to save the location of their vehicle when parked for easy retrieval later, information related to the vehicle maintenance, registration, and information on driver.

In the future, new and efficient techniques such as the one suggested in [36] may be used to help detect, with high accuracy, objects such as road signs and vehicle in front of the driver to avoid collision. We plan to extend our application to include a facility to warn the driver about the traffic signal ahead, especially when it turns red to slow down to prevent any collisions. Furthermore, we plan to make our application serve as a teaching tool to educate drivers and improve their driving behavior and style by rewarding them for good driving.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Y. Sun, C. Xu, G. Li, W. Xu, J. Kong, D. Jiang, B. Tao, D. Chen, Intelligent human computer interaction based on non-redundant EMG signal, Alexandria Eng. J. 59 (3) (2020) 1149–1157, https://doi.org/10.1016/j.aej.2020.01.015.

[2] H. Duan, Y. Sun, W. Cheng, D.u. Jiang, J. Yun, Y. Liu, Y. Liu, D. Zhou, Gesture recognition based on multi-modal feature weight, Concurr. Comput.: Pract. Exp. 33 (5) (2021), https://doi.org/10.1002/cpe.5991.

[3] Y. He, G. Li, Y. Liao, Y. Sun, J. Kong, G. Jiang, D.u. Jiang, B. o. Tao, S. Xu, H. Liu, Gesture recognition based on an improved local sparse representation classification algorithm, Cluster Comput. 22 (S5) (2019) 10935–10946, https://doi.org/10.1007/s10586-017-1237-1.

[4] Vuforia, Getting started with VUFORIA engine in Unity | VuforiaLibrary, n.d. [Online] Available: https://library.vuforia.com/articles/Training/getting-started-with-vuforia-in-unity.html [Accessed: 18 December-2021].

[5] M. Baldwin, Vuforiaia augmented reality (AR) SDK Review. Vuforia Augmented Reality (AR) SDK Review, 2014. http://augmentedrealitynews.org/ar-sdk/vuforia-augmented-reality-sdk-review/.

[6] About. OpenCV. 2020. https://opencv.org/about/ [Accessed: 4-November-2021].

[7] How Augmented Reality Works, Retrieved December 20, 2019 from Augment: "How Augmented Reality Works", Augment, 2016, n.d. [Online]. Available: http://www.augment.com/how-augmented-reality-works/. [Accessed: 20-December-2019].

[8] The most common causes of car accidents in Australia | QBE AU, Australia, 2017. [Online]. Available: https://www.qbe.com/au/news/the-most-common-causes-of-car-accidents. [Accessed: 20-December-2019].

[9] Global status report on road safety 2018: summary. Geneva: World Health Organization; 2018 (WHO/NMH/NVI/18.20). Licence: CC BY-NC-SA 3.0 IGO).

[10] Car Accident Statistics 2019 - Car Research & Statistics Budget Direct, Budget Direct, 2019. [Online]. Available: https://www.budgetdirect.com.au/car-insurance/research/car-accident-statistics.html. [Accessed: 20-December-2019].

[11] USDOT Releases 2016 Fatal Traffic Crash Data, NHTSA Public Affairs, 2017. [Online]. Available: https://www.nhtsa.gov/press-releases/usdot-releases-2016-fatal-traffic-crash-data. [Accessed: 20-December-2019].

[12] Monthly overview of crash statistics, Transport.govt.nz, 2019. [Online]. Available: https://www.transport.govt.nz/assets/Uploads/0585ae9f7f/2018-12-December.pdf. [Accessed: 20-December-2019].

[13] J. Bell, Road accidents account for almost 70% of head injuries at one UAE hospital, The National, 2013. [Online]. Available:

http://www.thenational.ae/uae/health/road-accidents-account-for-almost-70-of-head-injuries-at-one-uae-hospital. [Accessed: 20-December-2019].

[14] Top 5 Causes of Car Accidents in the UAE, Kippreport.com, 2014. [Online]. Available: http://www.kippreport.com/fcs/top-5-causes-of-car-accidents-in-the-uae/. [Accessed: 12- March-2019].

[15] World Health Organization, Save lives: a road safety technical package. World Health Organization, 2017. License: CC BY-NC-SA 3.0 IGO https://apps.who.int/iris/bitstream/handle/10665/255199/9789241511704-eng.pdf.

[16] Thompson, J. White, B. Dougherty, A. Albright, D.C. Schmidt, Using smartphones to detect car accidents and provide situational awareness to emergency responders, in: Proc. International Conference on Mobile Wireless Middleware, Operating Systems, and Applications, 2010, pp. 29–42. doi: https://doi.org/10.1007/978-3-642-17758-3_3.

[17] I. Khot, M. Jadhav, A. Desai, V. Bangar, Go Safe: Android application for accident detection and notification, Int. Res. J. Eng. Technol. 5 (5) (2018) 4118–4122.

[18] J. Zaldivar, C.T. Calafate, J.C. Cano, P. Manzoni, Providing accident detection in vehicular networks through OBD-II devices and Android-based smartphones, in: Proc. IEEE 36th Conference on Local Computer Networks, 2011, pp. 813–819. doi: 0.1109/LCN.2011.6115556.

[19] F. Aloul, I. Zualkernan, R. Abu-Salma, H. Al-Ali, M. Al-Merri, iBump: Smartphone application to detect car accidents, Journal of, Comput. Electr. Eng. 43 (2015) 66–75, https://doi.org/10.1109/IAICT.2014.6922107.

[20] S. Kadry, Safe drive-in smart city, in: Proc. 2016 Smart Solutions for Future Cities, Kuwait, 2016, pp. 1–7. doi: 10.1109/SSFC.2016.7447879.

[21] N. Akhtar, K. Pandey, S. Gupta, Mobile application for safe driving, in: Proc. 2014 Fourth International Conference on Communication Systems and Network Technologies, Bhopal, 2014, pp. 212-216. DOI: 10.1109/CSNT.2014.49.

[22] AR GPS DRIVE/WALK NAVIGATION. (n.d.) (2012, June 11). Retrieved from Google Play Store [online] Available: https://play.google.com/store/apps/details?id=com.w.argps&hl=en. [Accessed: 18-December-2021]

[23] B. Park, J. Lee, C. Yoon, K. Kim, Augmented reality and representation in the vehicle for safe driving at night, in: Proc. 2015 International Conference on Information and Communication Technology Convergence (ICTC), Jeju, South Korea, 2015, https://doi.org/10.1109/ICTC.2015.7354791.

[24] Augmented Driving, 2014, Retrieved from iTunes [online] Available: https://itunes.apple.com/us/app/augmented-driving/id366841514?mt=8 [Accessed: 18-December-2021]

[25] myDriveAssist, n.d. (2015, November 5) [online] Available: https://m.apkpure.com/mydriveassist/com.bosch.mydriveassist [Accessed: 22-January-2022].

[26] Car DVR & GPS navigator, n.d. (2014, November 6) [Online] Available https://cor-car-dvr-amp-ar-navigate.soft112.com/ [Accessed: 22-January-2022].

[27] RoadAR dashcam & speed camera, n.d. (2015, July 8) [Online] Available http://www.roadar.ru/ [Accessed: 22-January-2022].

[28] E. Dılek, Y.E. Ayözen, Smart mobility in Istanbul with "IBB CepTrafik", in: Proc. NOMS 2016 IEEE/IFIP Network Operations and Management Symposium, Istanbul, 2016, pp. 1273–1278. doi:10.1109/NOMS.2016.7503002.

[29] A.V. Khanapuri, A. Shastri, G. D'souza, S. D'souza, On- road: A car assistant application, in: Proc. International Conference on Technologies for Sustainable Development, 2015, pp. 1–7, https://doi.org/10.1109/ICTSD.2015.7095903.

[30] A. Kodre, K. Tikone, M. Sonawane, P. Jare, P. Shinde, Smart and efficient personal car assistant system, in: Proc. 2nd International Conference on IoT in Social, Mobile, Analytics, and Cloud, 2018, pp. 12–17. doi: 10.1109/I-SMAC.2018.8653752.

[31] Tutorial: OpenCV haartraining (Rapid Object Detection With A Cascade of Boosted Classifiers Based on Haar-like Features) - Naotoshi Seo, Note.sonots.com, 2016. [Online]. Available: http://note.sonots.com/edit.php?SciSoftware%2Fhaartraining. [Accessed: 20-December-2019].

[32] OpenCV for Unity - Asset Store, Assetstore.unity.com, 2016. [Online]. Available: https://assetstore.unity.com/packages/tools/integration/opencv-for-unity-21088. [Accessed: 20-December-2019].

[33] E. Sommerlade, V. Pisarevsky, S. Turkmen, A. Alekhin, "opencv/opencv", GitHub, 2018. [Online]. Available: https://github.com/opencv/opencv/blob/master/samples/cpp/dbt_face_detection.cpp. [Accessed: 20-December-2019].

[34] G. Ballew, OpenCV for Lane Detection in Self Driving Cars, Medium, 2017. [Online]. Available: https://medium.com/@galen.ballew/opencv-lanedetection-419361364fc0. [Accessed: 20-December-2019].

[35] C. Veness, Calculate distance and bearing between two Latitude/Longitude points using haversine formula in JavaScript, Movable-type.co.uk, 2016. [Online]. Available: https://www.movable-type.co.uk/scripts/latlong.html. [Accessed: 20-December-2019].

[36] D.u. Jiang, Z. Zheng, G. Li, Y. Sun, J. Kong, G. Jiang, H. Xiong, B.o. Tao, S. Xu, H. Yu, H. Liu, Z. Ju, Gesture recognition based on binocular vision, Cluster Comput. 22 (S6) (2019) 13261–13271, https://doi.org/10.1007/s10586-018-1844-5.