Night Time and Low Visibility Driving Assistance Based on the Application of Colour and Geometrical Features Extraction

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Abstract. The present work shows an application to detect cars in night environments as a means to assist the car driving through HSV (Hue, Saturation, Value) colour extraction and geometric modelling. The developed algorithm has been implemented in smart devices through the platform Android. The detection and tracking of vehicles are implemented in low visibility environments such as night time, raining or snowing conditions; the different tests carried out confirm high performance rates of detection (p = 95.2 %). The information provided by the different sensors of the smart devices have been used to generate virtual information in a real driving environment (Augmented Reality) in order to complement the functionalities of the purposed solution. This information consists of visual, vibratory and auditory warnings that detect possible collisions and dangerous driving situations.

Keywords: Color extraction · Geometrical features · Smart devices · Augmented reality · Assisted driving

1 Introduction

According to the Global Status Report on Road Safety 2015 published by World Health Organization (WHO) [1] each year around 1.2 million people die by traffic injuries around the world and 1 million people lives are affected with permanent health issues due to this cause. The traffic crashes increases in low visibility conditions such as night time, raining and snowing. The proportion of tools that help to reduce the risks caused by these conditions are a current priority and the motivation of this work.

In addition, a study carried out in [2] the automation of the driving improves the capability of reaction in car incidents and generates security to the drivers. These statements are confirmed by the simulations carried out in [3] where it could be confirmed that the risk of collision decreases in an 80.7 % when the systems that provide early warning in an event of collision are present. The majority of the assistance in driving systems has been developed to be applied in daytime or in good lighting conditions [4] without considering other kind of conditions. The required information to assist the automatic driving is mainly obtained from the driving

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environment through different kinds of sensors, which include the optical ones. The video cameras provide visual information of the driving environment and the algorithms extract information of interest that let identify traffic signals, pedestrians, pavements, traffic lights etc. Currently the smart devices provide other information different than visual that helps in the detection task and generates the timely warnings to avoid vehicle collisions and accidents.

This work shows a warning system to avoid vehicle collisions in low visibility environments, especially in night conditions, through the detection of vehicles by identifying the tail lights and using the sensors of the smart devices. The system guarantees an effective detection and the processing rates are very low as the tracking is continuous and the warnings are activated in real time. Also, the system is easily noticed as produces both visual and sounding warnings. The final result has been the generation of augmented reality through the introduction of virtual information in actual driving in night time environments. The development has been based on tools of free access and has led to create a specific APP that can be applied to Android devices.

The present article consists of the following sections. In the Sect. 2 related works to this work are commented. In the Sect. 3 the method and materials used in the development of the application are explained. In the Sect. 4 an extensive set of tests with their respective results are shown. In the Sect. 5 the main conclusions and future work are shown.

2 Related Works

The night vision systems have been used in the task of cars detection but they are unaffordable for many users due to their high cost [5] and are of limited efficiency as their use increases the risks of collision, especially when they are out of place or wrongly located [6]. In addition, the computational cost generated by this kind of sensors during the data processing is high. In [7] for example, neuromorphic vision sensors are used to classify and detect cars and trucks but the time of the processing of information can reach up to 200 meters making difficult the detection task in real time.

The approach of this implementation is based on the detection of cars acquiring the characteristics of their tail lights and the geometric relation between them. Some works showed in the state of the art use these characteristics to carry out detections in night time stages. In [8] a method for the detection of vehicles considering the variation of intensity levels of grey of the tail lights is presented, also an estimation of the distance from the monitor vehicle to the target vehicle considering the geometric relation established in [9] and a virtual horizon is presented. In [10] the detection of light of the tail lights using the space of colour L*a*b is done allowing the detection of vehicles in low visibility conditions. Also in [11] the distance between two tail lights as a source of information to the detection of cars in night time is considered; these detections do not take place in real time but through videos recorded previously. In the same way in [12] the tail light is segmented through a multilevel threshold histogram as a previous stage to the detection of vehicles and the estimation of distances. Following the same line in [13] a series of sensors to assist in the night time driving are implemented. The vehicle is detected through the identification of its tail lights. The monitoring and presentation of warnings take place in real time at the rate of 10 fps. In the same way in [14] the brightness of the tail lights is used to establish the geometric relations and temporary space in the detection and tracking of cars in night time, in this case the system is not implemented in real time. In [15] the implementation of the whole net of sensors and cameras to acquire information from both the external and internal, which refers to vehicle elements, driving scenarios are shown. These sensors are not embedded on an only platform.

Nowadays the miniaturization of the components has allowed that the smartphones mechanisms include sensors such as GPS, accelerometer, gyroscope, camera and others embedded on the same platform. These sensors provide useful data to establish position, location, acceleration and visual information. This data has been used in applications of driving assistance applications such as iCarBlackBox, Drivea, Augmented Driving, iOnRoad and Car Safe available in Android and IOS platforms. These applications have been developed to reach a good performance in controlled conditions but they make mistakes when lighting variations take place [16].

3 Materials and Methods

3.1 Materials

Multiple tools of software and hardware have been used in the detection and collision warning approach. Software tools have been chosen taking into consideration free access environments that guarantee functionality such as Open CV version 2.4.8 libraries on the operative system Android 4.4 Kit Kat. For the programming environment Eclipse, running on an Intel Core i5@3.1 GHz computed has been used. The tests have taken place in different smart devices, which characteristics are shown in Table 1.

Table 1. Technical characteristics of the smart devices.

Characteristic	Type 1	Type 2
Operating system	Android v2.1	Android v4.4
RAM	576 MB	2 GB
Processor	1 GHz	2.2 GHz
Display	3.7” (480 × 800 pel.)	4.95” (1080 × 1920 pel.)
Sensors	Accelerometer, GPS	Accelerometer, GPS
Camera	5 MP (2592 × 1944 pel.)	8 MP (3264 × 2448 pel.)

3.2 Method

In the developed application the accomplishment of the following requirements has been verified, they are: the execution of different kinds of Android terminals, the detection of different sorts of cars, the extraction of information of spatial location of the cars in the scene and the presentation of the parameters speed, precision, areas and calculation of the lighting centre of the vehicles’ headlights. In addition, the system shows the visual and audible warnings screen, a friendly environment for the user and

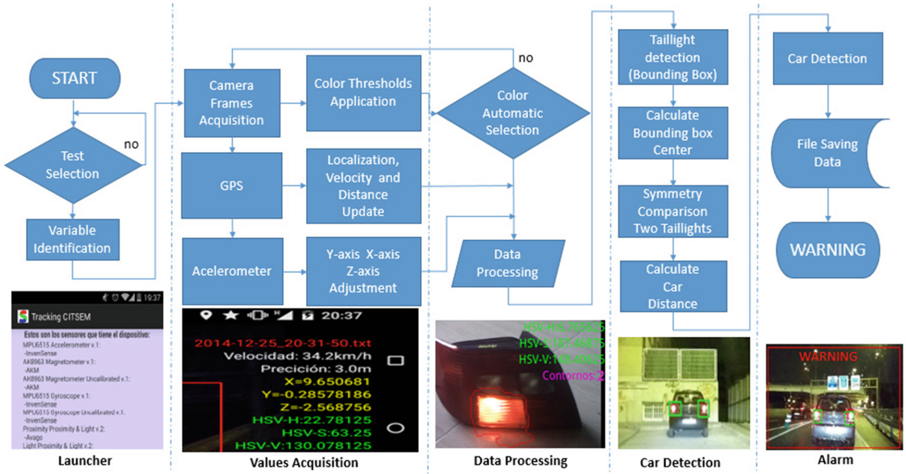


Fig. 1. General diagram of the driving assistance system.

avoids an adverse impact on the experience of processing data or when the system stops working momentary. Figure 1 shows the whole diagram of the system.

Summarising the system includes the following modules:

- **The Launcher and Test.** The launcher executes the application using the "Activity Splash Screen" function. The application menu is shown by the "Main Activity" function. On the other hand the calibration and operational tests of the accelerometer, GPS and the camera are executed. In this first part of the process an identification label is assigned to each of the functions of the sensors through a variable.
- **Acquisition of Values and Updates.** In this module the information of each of the variables is acquired. The GPS can serve as an example. In the GPS the coordinates acquire the location and the variables of speed and precision are updated, also the location changes taken place in the device are registered. In relation to the accelerometer a horizontal adjustment of the smart device is done allowing to obtain a spatial location of the smart device in a continuous form in relation to the 3 coordinate axis (x, y, z). On the other hand a register of the HSV values previously defined as thresholds according to a colorimeter study is done.
- **Data Processing.** In the data processing the function "Location DAO" is used to make a comparison. Here a comparison of the values of the thresholds corresponding to the outline bright and the colour of the tail lights in relation to the values obtained in whole image. The data inside the thresholds is automatically selected establishing regions of interest known as ROI's. The ROI's are labelled and the necessary variables for the detection of the corresponding outlines of those ROI's are initialized. In relation to the GPS an automatic register of the changes happening in the GPS signal is done continuously. In the same way continuous adjustments and registers of the spatial location of the smart device through the data collected by the accelerometer take place.

- **Car Detection.** Here the outlines of the ROI's are established. A bounding box is assigned to each ROI, a symmetry analysis between each of those ROI's is done and their values of areas, centres and dimensions are compered. Finally an analysis of the spatial location of the ROI's is done taking into consideration a framework. In other words it can be said that the ROI's are evaluated in relation to the virtual horizons. In this way a couple of ROI's that are symmetrically equal or almost equal and spatially aligned are obtained. These couple of ROI's correspond to the vehicle tail lights. In addition the values of the increase or decrease of the distance from the centre of the framework to the target vehicle are calculated through Euclidean distance and registered in other file. Also the increase or decrease of the obtained speed is registered by the smart device located inside of the car used in the test.
- **Warning.** Once the target vehicle is detected, its spatial location is recorded in a file, a new label is assigned and a continuous tracking of the different frames that are video frames takes place. The approaching or distancing of the target vehicle will generate different values of distance in relation to the vertical limits of the framework. The warning of the dangerous approaching is effectively generated when the decrease of distance values surpasses the established limits. This means that the target vehicle is approaching the framework and there is a risk of imminent collision. The warning is reinforced when it detects an increase of the speed obtained by the phone. In addition, audible and vibration warnings take place in order to make the system suitable to people with special needs. Figure 2 shows how the application works.

Fig. 2. The application shows information about the velocity, distance, spatial location, HSV colour components, detections and warnings in real time.

3.3 Colorimetric Study

The colorimetric study carried out in this work has allowed to define the values of HSV aligned to the tail lights bright and to the red light around that bright. The reason why this space of colour has been chosen is because of the high level of true positives (TP) and the low false positives (FP) obtained against to the models RGB and YCrCb from different tests developed. The lighting changes generate important problems of detection, especially in the RGB model due to a modification of any of the channels that affects in general, the global calculation and therefore the values of the thresholds should be valued continuously. On the other hand although the YCrCb model shows a better respond in processing time, the detection rates in relation to HSV are lower.

The model HSV allows the visual information to be more easily interpreted because separates the luminance from the chrominance. These sources of information refer to the colour tone (H) and saturation (S). The H values are acquired from the highlight of the reds that are presented in the tail light outlines. The S parameter is captured from the white colour of the intensity light. In the same way the two parameters, H and S, let adjust the component value (V) to the maximum tail light bright.

The intensity of the light emitted by the tail lights in cars are regulated under global standards that car manufacturers should follow. Therefore their values are kept constant and the thresholds that allow detecting these values should be of common use. The next step is to find the value of HSV in the tail lights outlines and in the bright. The HSV value rank considering 8 bits vary from 0 to 255, the decimal value obtained then is transformed into a binary value due to calculation reasons. For the conversion of RGB into HSV the maximum values of RGB have been considered in the way that $M = \max(R, G, B)$ and the minimum values $m = \min(R, G, B)$. From these two considerations S and V are given by:

$$S = \frac{M - m}{M}, \tag{1}$$

$$V = \frac{M}{255}. \tag{2}$$

Where V is the result of the max (R, G, B) that is the maximum value that the pixels could have up to 255. The component V is generated by the bulb of the tail lights. The component H, between the values 0 to 255 or 0–1, if the components have normalized. The values change in function of the angle θ that varies from 0 to 360º. This angle is formed between the two lines of the primary colours RGB. Due to conventional reasons the colour red has been chosen as one vertex, other vertex is formed by the white colour and finally the third vertex is formed by the green or blue. The value of H is expressed according to the relation shown in (3).

$$H_1 = arc \cos \frac{(R - G) + (R - B)}{2 * \sqrt{(R - G)^2 + (R - B)(G - B)}}. \tag{3}$$

Where $H = H_1$ if $B \leq G$ and $H = 360^\circ - H_1$ if $B > G$. After the tests have been carried out, the average value of HSV obtained for the detection of tail lights bright is H = 42, S = 71, V = 255 and for the detection of the red colour of the outline is H = 62, S = 2, V = 55. These values have presented the highest rate of TP taking into account that multiple evaluations have been carried out at 15, 10 and 5 meters.

3.4 Geometrical Features in the Detection of Cars

The geometric features considerate for the detection of cars are the following: symmetries, distances, areas, geometric centres, shapes in a way that makes possible to identify a car in the scene.

The detection process starts with the matching between the thresholds of the values HSV found and the ones present in the scene, in this way is how the detection of the ROIs is done. Taking into consideration the characteristics of the ROIs such as the area measured in number of pixels, the centre, the maximum and minimum dimensions of height and width are calculated to locate the ROIs in the scene. Also a framework is implemented that represents the visual horizons as in Fig. 2 and descripted in the Sect. 3.1. The framework is related to a resize of the screen and allows efficiency in the processing due to the fact that carries out an initial rejection of the ROIs that are not inside of this. Also in order to ensure the detection of cars and to reduce the false positives, 4 regions of occurrence (R) are established. These regions are formed by dividing the framework in a way through which the vanishing point of the scene forms a series of triangles in perspective taking into account the lower vertex of the framework. It is necessary to indicate that this vanishing point is inside of the line of the virtual horizon. The R are weighed (W), so W will be higher where there is a higher likelihood of vehicles presence. This relation is presented as:

$$W_3 > W_1; W_3 > W_2; W_3 > W_4 \tag{4}$$

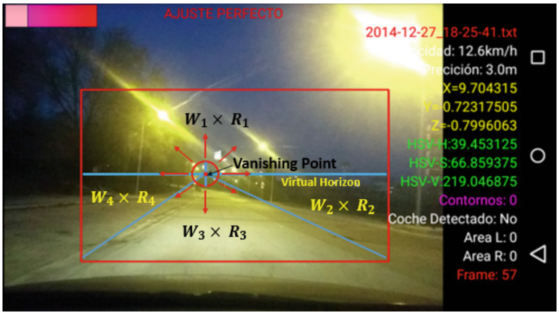
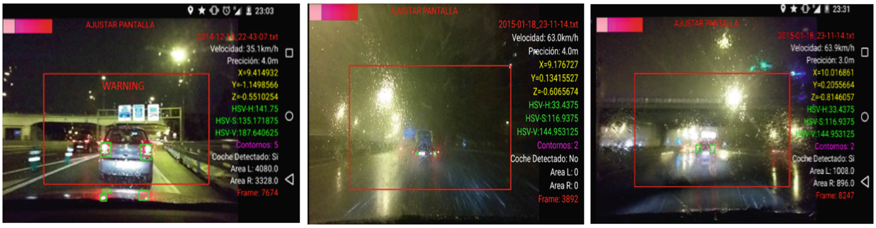


Fig. 3. Zone of detection probabilities based on regions and weights

The R vary according to the vanishing point spatial location in different places determined by the coordinates x, y. This proposal has resulted effective according to the evaluations carried out in different environmental conditions and are presented in the Sect. 4. The R_3 in general is the one with the highest occurrence of detections including when the vanishing point is moved near to the ends of the virtual horizon. The graphical description is shown in Fig. 3. On the other hand the virtual horizon and the upper and lower ends of the framework serve as a reference of the couple of bounding box that contains the tail lights to establish their alignment and effective detection as it is shown in the Sect. 3.

4 The Experimental Tests and Evaluations

The experimental tests have been carried out, firstly, in a laboratory to extract the values of HSV, establish outlines and estimate distances. Afterwards different tests have been carried out in real conditions taking into consideration the detection of vehicles in urban and interurban routes at night time when raining slightly and heavily and when snowing as it is shown in Fig. 4.



(a) (b) (c)

Fig. 4. Tests carried out under different climatic conditions: (a) detection when raining slightly (b) detection when raining heavily (c) detection when snowing.

The confusion matrix is used for the validation of the precision of the detection and therefore for each of the tests the values of the TP are acquired when a vehicle is predicted and the prediction is right; the values of the FP are acquired when the system registers a detection when actually there is not one; the values of true negatives (TN) are acquired when a vehicle is not predicted and the prediction is right and the values of false negatives (FN) are acquired when the system does not register a detection but the detection exists. This appreciation can be quite subjective, however, taking into consideration that the evaluations have been carried out in a laboratory by observing each pre-recorded video frame of a total of 500 and externally, it can be said that the evaluations are more reliable. In the external validations have been used more than one evaluator and two cars in a coordinated way. From the obtained data, the calculation of: false positive rate $FPR = \frac{FP}{FP+TN}$, the Dice index $DI = 2.0\left(\frac{pxr}{p+r}\right)$ that allows to calculate the precision grade of the detections, Jaccard Index ($JI = \frac{TP}{TP+FP+FN}$) that valuate the right detections against the mistakes, Manhattan ($Mh = \frac{TP+TN}{TP+FP+FP+FN}$) carries out a global evaluation of the detections, the values of the precision of the system ($p = \frac{TP}{TP+FP}$) and recall ($r = \frac{TP}{TP+FN}$) has been done. Where the closer the value is to 1, the higher the refinement grade is. The evaluation results are presented in the Table 2.

The results show that the overall detection index (DI) is 94. 81 % in night time driving conditions. On the other hand the ID is 82.44 % in low visibility driving conditions when snowing. Taking into account the adverse and the low visibility conditions that the experimental environment shows, generally it is observed that the

Table 2. The results of detections in different weather conditions.

Weather conditions	Average velocity (Km/h)	TPR/r	FPR	P	JI	DI	Mh
Night (good conditions)	73	0.9441	0.0457	**0.9520**	0.9014	**0.9481**	0.9489
Night + Light rain	57	0.9347	0.0477	0.9204	0.8648	**0.9275**	0.9458
Night + Hard rain	25	0.8474	0.0893	0.8576	0.7428	**0.8524**	0.8862
Night + Snow	24	0.8244	0.1071	0.8244	0.7012	**0.8244**	0.8669

proposed solution is effective as it is completely developed to be used in real time in contrast to [7, 13]. In addition, the result of precision of a 95.20 % is included in the ranks reached by [14] with the difference that the presented system is implemented on a platform with a limited resolution capacity considering that a better resolution of the optical sensor guarantees better results and it is totally accessible, compact and handheld.

5 Conclusions and Future Work

The present work shows a developed application in the operating system Android, which purpose is to provide a tool that helps the driving especially in night time scenarios when the visibility is limited. The system accomplishes with all of the stages for the technological implementation. It begins with an analysis of the requirements, it goes through the functional design of experimental tests and it reaches the validation of the obtained results. Here also it is shown how the integration of the obtained information by the different sensors of the smart device, the application of specific thresholds in HSV, the use of geometric relations of different kind allow the precise detection of the cars tail lights. Also it is important to mention that the strategy to eliminate the false positives through the extraction and weigh of the zones of occurrence has resulted effective. The precision of the detection of cars is of a 95.20 %. This percentage shows high chances to generate warnings related to possible collisions. Finally the virtual information of speed, distance and warnings generated to be applied in real driving conditions known as augmented reality makes of this application a highly practical and useful tool. The promising results obtained let make future developments associated with the traffic sign recognition and take automated driving decisions in low visibility conditions.

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