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In-Vehicle Augmented Reality Traffic Information System: A New Type of Communication Between Driver and Vehicle

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Abstract

In order to improve driving safety and minimize driving workload, the information provided should be represented in such a way that it is more easily understood and imposing less cognitive load onto the driver. Augmented Reality Head-up Display (AR-HUD) can facilitate a new form of dialogue between the vehicle and the driver; and enhance intelligent transportation systems by superimposing surrounding traffic information on the users view and keep drivers view on roads. In this paper, we investigated the potential costs and benefits of using AR cues to improve driving safety as new form of dialog between the vehicle and the driver. We present a new approach for marker-less AR Traffics Signs Recognition system that superimposes augmented virtual objects onto a real scene under all types of driving situations, including unfavorable weather conditions. Our method uses two steps: hypothesis generation and hypothesis verification. In the first step, Region Of Interest (ROI) is extracted using a scanning window with Haar cascade detector and AdaBoost classifier to reduce the computational region in the hypothesis generation step. The second step verifies whether a given candidate and classified into vehicle and non-vehicle classes using edge information and symmetry measurement to verify them. We employ this approach to improve the accuracy of AR traffic information system to assist the driver in various driving situations, increase the driving comfort and reduce traffic accidents.

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Keywords: Augmented Reality; Region Of Interest; Driving-Safety, Head-up Display, Camera Calibration, Traffic Information; OpenCV.

1. Introduction

In recent years, the use of the automobile as the primary mode of transportation has been increasing and driving has become an important part of daily life. Every accident is one too many, especially when it results in injury or even loss of life. Given that the global volume of traffic has increased to around one billion vehicles, road safety has become a key challenge for society, industry and politicians [1]. The rapid growth of technology has propelled novel ways in which drivers senses may be augmented. Steering a vehicle has become a challenging task and this is underpinned

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by the fact that more than 80 % of vehicle accidents are caused by driver errors. Cooperative systems, which allow vehicles to communicate with each other to achieve a common goal, are widely recognised. Intelligent Transport Systems (ITS) concern the use of information and communication technologies applied to transport infrastructure and vehicles.

A number of solutions have previously been proposed in the automotive industry which typically concentrate in the collection of vehicular and traffic information without effective prioritization of their significance. Safe automobile driving requires drivers to process large amounts of dynamic information under time pressure. However, drivers can attend to only a small percentage of visual stimuli at once. To address this problem, i.e., to mitigate driving problems caused by excessive information, we propose to working on ways to make it easier to see navigation instructions without taking your eyes off the road. Our visions are placed in future scenarios where we assume novel interfaces to be context aware and natural to effectively convey information when it is safe to do so, i.e., when they do not increase the information overload of the driver. We place the information at exactly that point in the drivers field of view where it belongs and is required.

One such technology is that of Augmented Reality (AR) which offers the ability to provide drivers with a variety of information in an unobtrusive manner. Head-up displays (Huds) project information directly into the field of vision, so the driver does not have to look down at the instrument cluster. HUD technology in a combination with (AR) delivers a potential to overcome existing bottlenecks for increasing information needs in modern cars. Augmented Reality based Head-Up Displays (AR-HUD) are emerging as a next-generation in-vehicle display technology, potentially reducing drivers mental workload and divided attention across roads and dashboard information. AR-HUD technology has the potential to increase attention to cued elements without adversely affecting attentional resources and reducing the ability to respond to environmental information outside the focus of attention [2].

In a world that is becoming increasingly complex, the AR-HUD relieves the burden on the driver because what the drivers eyes see is directly connected with explanatory information. In the area of vehicular safety, this aims to reduce road accidents through driving assistance systems.One of the solutions to prevent these accidents is to provide information on the surrounding environment to a driver when driving a vehicle, traffic signs recognition, lane deviation warnings, and safety distance indication, as well as forward collision warnings, among other automated functionalities. In both instances, the ability to recognize signs and their underlying information is highly desirable. This information can be used to warn the driver of an oncoming change, or in more intelligent vehicle systems, to actually control the speed and/or steering of the vehicle.

To avoid collisions with stationary obstacles, other moving vehicles, or pedestrians, drivers have to be aware of the possibility of a collision and be ready to start braking early enough. In addition, when following other vehicles, drivers need to keep a safe distance to allow for proper braking. An understanding of how drivers maintain such a safe distance, the type of visual information they use, and what visual factors affect their performance is clearly important for improving road safety [3]. This is an important next step against driver distraction and sensory overload in the future. This will increase safety on the roads and build trust in existing vehicle systems and new driving features such as automated driving. There are two main problems to solve before the widespread usage of AR. First, the problem of rendering and merging virtual objects along with the high quality video stream. Second problem can be stated as a problem of finding a transformation of virtual scene into the perceived by the human scene [4]. It requires that virtual objects are placed in the correct 3D position, orientation and comply with the human eyes scale factor. For every frame of video stream the virtual objects have to be placed in a correct position and orientation and rendered again [5].

Recent studies have investigated how augmented reality displays impact older drivers performance [6,7,8]. They found that AR cues in general helped older drivers to detect hazardous target object of low visibility. Another interesting method was introduced by [9] that examines multiple methods for visually depicting occlusion in outdoor AR, varying opacity, stroke, and fill settings. The study found that users have difficulty discerning more than a few levels of occluded objects, even though AR graphics opacity appears to be promising as an effective layering and ordering cue. However, most case studies were conducted with prototypes and driving simulators due to difficulties to conduct safe use cases [10].

The proposed research describes a novel approch to localizing and traking vehicles with respect to the egolane, a 3D AR-HUD for animating traffic signs lane tracking and forward vehicle detection to handle challenging conditions, i.e, road traffic signs, lane occlusion by a forward vehicle, varing illumination and lane change. This paper describes interactions, opportunities, and challenges associated with applying AR interfaces in the automotive domain. This approach takes advantage of wireless communication techniques to facilitate continuous positional and orientation data transfer between moving vehicles and an AR animation. Another important issue was the study of conventional traffic signs, in terms of rules for placement and visibility, types of traffic signs and the migration of these to in-vehicle display. Here we proposed new signs and develop 3D models of these signs as well as other road infra-structures.

2. In-Vehicle AR-HUD System for Providing Driving-Safety Information

In-vehicle or roadside AR-HUD system have the potential to improve safety by providing drivers with advance warning of changes in the route geometry. The present study proposes a mark-on-windshield warning system for vehicles that allows the driver to see potentially hazardous objects in front of the vehicle by projecting information directly into the drivers field of view, without taking his eyes off the road. The proposed system is expected to help drivers by conveniently providing safety information and allowing them to safely avoid forward obstacles. The primary goal of this study was to determine the costs and benets of dynamic conformal AR cues to alert experienced drivers to potential roadway hazards. We predicted that these AR cues would not interfere with the perception of non-target. By merging all the information from drivers, cars, and infrastructure into a common database, the basis for an improved interaction between the involved parties could be established.

In this paper, we propose a novel concept of an in-vehicle AR-HUD system that displays navigation information directly onto the vehicles windshield, superimposing it on the drivers view of the actual road. AR-HUD based vehicular safety information system that provides warning information allowing drivers to easily avoid obstacles without being visually distracted. We integrate AR-HUD based lane, traffic signs and vehicles tracking for driver assistance, this novel approch adds valuable safety functionality and provides a contextually relevant of the on-road environment for driver.

2.1. Vehicle-to-Vehicle Traffic Information System

With the rapid development of driverless cars, unmanned aerial vehicles, and other automated systems, AR systems have the potential to communicate with other vehicles to improve tracking performance and make better prediction or detection of critical events. The present study focusing on systems that allow the vehicle to become a partner in the drive by monitoring a cars surroundings, warning the driver of danger, and even taking control of the car in some situations. Vision is important to driving and driver safety worsens with visual attentional decline. The section presents approach used for the investigation of AR presentations and determination of the best way to present visually concealed hazards. To maintain a safe distance behind other vehicles and avoid collisions, the proposed system informs and warns the driver of detected obstacles using various mounted devices. It uses sensors or cameras to monitor the distance between your car and one in front.

Vision-based vehicle detection follows two basic steps: Hypothesis Generation (HG) where the locations of possible vehicles in an image are hypothesized, generating candidates with respect to a vehicle by using the AdaBoost learning algorithm. And in the second stage Hypothesis Verification (HV), verify the correctness of the vehicle candidates provided by the HG stage by verifying the candidates according to symmetry measurement and horizontal and vertical edge analysis.

During the HG step, the system scans each window of the input image and extracts Haar features of that particular window, which is then used to compare with the cascade classifier. Finally, only a few of these sub-windows accepted by all stages of the detector are regarded as objects. The detection process takes an image as input and gives at the output the regions that contain the Region Of Interest (ROI). The false alarm rate of the Haar cascade detector without hypothesis verification is higher but eliminates most of the non-object regions.

The vehicle candidates from the AdaBoost algorithm, which may include vehicle objects and false alarms, are used in horizontal and vertical edge analysis. After ROI are determined, the second stage is HV. In this stage, all hypotheses are verified by we must verify whether the candidates are vehicle or not. Different views of a vehicle, especially rear/frontal views, contain many horizontal and vertical structures, such as rear-window, bumper, etc. The ”Canny edge detector is used to detect the edges in the grayscale image of the ROI. Next, we apply vertical symmetry axis detection into contour edge images to build the potential regions where vehicles may be presented.

(a) Input (b) Candidate ROIs

(c) Hypothesis Verification (d) Vehicle Detection

Fig. 1: Proposed vision-based vehicle detection system

The system draws data from the vehicle's camera and combines it with the vehicle's dynamics data, which is used to create a model of the external view of the car as seen from the driver's perspective. In addition to showing your current speed, the system can overlay information on the road specifically where it is most relevant to the driver, such as the distance to the car in front, when to make a turn, or even upcoming driving conditions[?] .

2.2. Vehicle-to-Infrastructure Traffic Information System

Future navigation systems may show infrastructural information by an AR system. AR cues may offer a promising means to improve driver safety, potentially reducing response time and increasing hazard detection likelihood. By deploying an on-board camera-based driver alert system against approaching traffic signs such as stop, speed limit, unique, danger signs, etc.By using such technology, vehicles are able to reduce the lockto-lock steering wheel travel as a function of the vehicle speed. For example, if a car suddenly stops on the freeway or around V2V blind corner, it can warn other cars to slow down before they even see the danger. This will lead to fewer road fatalities and less severe injuries. In addition, the support provided by intelligent vehicles will decrease the stress level of all traffic participants and lead to a more pleasant overall driving experience.

Traffic Sign Detection. In the detection step, the distinctive features of traffic signs shall be considered. Since traffic signs are normalized in specific colors and shapes, it is convenient to use those features to decide the candidate signs. The goal of our detection stage is to identify image regions that may contain a traffic sign. To ensure a high system performance, we focus on fast detection methods. We have based our research on one of the most outstanding approaches in object detection for real-time applications of the last decade i.e., the Viola-Jones face detector framework[11]. The first phase of the system deals with the detection of traffic Signs using a scanning window with Haar cascade detector for each image of the input stream (target images), which eliminates most of the not-objects. Nevertheless, in order to make the traffic sign detection more robust to pixel noise or low contrasts, the texture based detector will be the responsible of post filtering these ROI and will give us the definitive detections.

Verification System Based SURF Features. In verification phase, a SURF detector was used to perform traffic signs detection in candidate areas. For any object in an image, there are many 'features' which are interesting points on the object[12]. In the training stage, SURF features are extracted from all training samples, using a dense grid. Since we are interested in the sign contents, and only descriptors that do not fall outside the sign contour are taken into account. Our system exploits SURF features, which have shown a high robustness to varying recording conditions. Then a candidate image is matched by individually comparing each feature of the candidate with the special database; the selection is made based on the classifier used and the features are matched based on ANN. Even with all the robustness of the SURF matching, some points could be wrongly correlated, resulting in outliers. To remove these bad matches, the tracker was improved with a technique that is able to validate key-points orientations; Random Sample Consensus (RANSAC) robust method is used.

If the recognition is complete, a multiclass sign classifier takes the positive ROI and assigns a 3D traffic sign to each one. Correct and timely recognition of road traffic signs is necessary to ensure a safe journey. AR-based Traffic Sign Recognition (AR-TSR) may help drivers receive important information regarding the signs, even before their eyes can actually see them, in an easy and comprehensible way.

2.3. Pose Estimation and Augmentation

Pose Estimation . In marker-less AR-HUD, the problem of finding the camera pose requires significantly more complex and sophisticated algorithms, e.g. disparity mapping, feature detection, extraction, matching and classification. Camera calibration allows combination of virtual world and real world objects in a single display. In case of images or videos, the relative position of an element on a screen can be calculated from camera parameters and relative position information of the camera with respect to the element.

The mathematical model used is the projection transformation, which is expressed by equation 1 where λ is the homogeneous scale factors unknown a priori, P is 3×4 projection matrix, $x = (x, y)$ is homogeneous coordinates of image features, $X = (X, Y, Z)$ is homogeneous coordinates of feature points in world coordinates, $K \in R^{3\times3}$ is the matrix with the camera intrinsic parameters, also known as camera matrix, the joint rotation-translation matrix $[R|t]$ is the matrix of extrinsic parameters, $R = [r_x r_y r_z]$ is the 3×3 rotation matrix, and $T = [t]$ is the translation of the camera.

$$x = PX = K[R|t]X \tag{1}$$

The projection matrix, P is the key to creating a realistic augmented scene using the intrinsic parameters of the camera, the dimensions of the video frame, and the distances of the near and far clipping planes from the projection center. In our method, we assume that the intrinsic parameters are known in advance and do not change, and this is reasonable in most cases.

$$\begin{aligned} P &= \overbrace{K}^{\text{Intrinsic Matrix}} * \overbrace{[R|t]}^{\text{Extrinsic Matrix}} \\ &= \overbrace{\underbrace{\begin{pmatrix} 1 & 0 & x_0 \\ 0 & 1 & y_0 \\ 0 & 0 & 1 \end{pmatrix}}_{\text{2D Translation}} * \underbrace{\begin{pmatrix} f_x & 0 & 0 \\ 0 & f_y & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{\text{2D Scaling}} * \underbrace{\begin{pmatrix} 1 & s/f & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{\text{2D Shear}}}^{\text{Intrinsic Matrix}} * \overbrace{\underbrace{(I|t)}_{\text{3D Translation}} * \underbrace{\left(\begin{array}{c|c} R & 0 \\ \hline 0 & 1 \end{array}\right)}_{\text{3D Rotation}}}^{\text{Extrinsic Matrix}} \end{aligned} \tag{2}$$

In order to integrate virtual objects into real-world seamlessly, AR system must own ability to recognize and track its desired environment. However, marker-less techniques are still challenging and very potential to be explored, in purpose to develop a seamless AR experience. Inside the final *augmented view*, virtual objects were well aligned with real objects in position, orientation, and scale without any visual inconsistency. The vehicle surrounding along the predicted host path and the expected positions of traffic signs were modeled in 3D, then a projection to the image plane resulted in a ROI.

AR technology may serve as a safety countermeasure for drivers with visual attention impairments.

Projection Based Augmented Reality. In this final stage, the projection of virtual objects is easily accomplished once the pose is known. Having calculated the camera interior orientation and the camera exterior orientation for a video frame, the 3D can be drawn at the right position, with the proper scale, orientation and perspective in the scene of the real world. With the complete set of camera parameters, virtual objects can be coherently inserted into the video sequence captured by the camera, so that synthetic traffic signs may be added to increase safety.

Table 1: Recall and Precision Results for Traffic Sign Detection

Testing	vehicle images	TP	Precision (%)	Recall(%)
Video 1(front)	517	484	93	95
Video 1(rear)	327	311	95	92

Finally the registration matrix is calculated using the above homography and the virtual objects are rendered on the real scenes using OpenGL. Thus, the appropriate conversions were made for the proper combination of the results obtained using OpenCV and OpenGL and the consequent right augmentation of the real world scenes.

3. Experimental Results

To evaluate the performance of the proposed algorithm, we implement the proposed Traffic Information System using the hardware environment of Intel (R) Core (TM) i5 (2.5 Hz) and the software environment of Windows 7, Visual Studio 2010 using OpenGL and OpenCV Library. Our research has focused on the design of novel AR systems that leverage the emergent standard for vehicular communications, in the form of vehicle-to-vehicle and vehicle-to-infrastructure traffic information system. This system can successfully detect objects that are in front of the car and they reflect information such as your speed, driving warnings or navigational directions on the inside of the windscreen to make it easily viewable without taking your eyes off the road.

3.1. Object Detection Evaluation

3.1.1. Vehicle Detection

We applied our method to vehicle detection, and we demonstrate the improvement in robustness of the system in various lighting and weather conditions. The database used to train the detectors was collected from [13],and our own images. With the OpenCV HaarTraining tools, we get the classifier of the front and rear of vehicles with resolution of 32×32. pixels to 64×64. pixels. A total of 3,000 vehicle images were used in the training procedure and 4000 non vehicle. The experiment is conducted in various experimental environments, the results of the vehicle recognition are shown in Table1.

The system showed good performance in terms of recall, precision and false positive rates even in bad lighting conditions. Information from the adaptive cruise control assures you that you are driving the correct distance from the car in front of you and gives you an early warning if you are not.

3.1.2. Traffic Sign Detection

The database used to train the detectors was collected from German Traffic Sign Recognition Benchmark (GTSRB) dataset [14], the Belgian Traffic Signs dataset (BelgiumTS) [15], and our own images. Our training data set consists of 4500 interest traffic signs and 6000 non traffic signs. The sizes of traffic sign examples are in range from 20×20 to 222×193 pixels.

Due to the different appearance frequency of each type of sign and the high intra-class variability, we trained a detection cascade for each group of similar signs. We have trained three different cascaded detectors, one for each of the proposed interest traffic signs classes: Speed limit, Danger, and Unique signs. In order to get a high efficiency classifier, we have set the number of cascade stage to 13. The minimum hit rate is set to 0.995 while the maximum false positive rate is set to 0.5. The samples width and height were both set to 24×24.

To test the validity of our approach and to ensure a high diversity of road conditions, we have tested image sequences of different types, each one carried out in different days and with different weather conditions. An analysis presenting the performance rates of the TSR are described. The achieved detection performances are summarized in table 2 vs. the number of test images.

The experimental results of Table 2 demonstrate an excellent performance of our system. The results show that the proposed algorithm attains an average precision rate of 97.4 % and an average recall rate of 98.1 %.

Table 2: Recall and Precision Results for Traffic Sign Detection

Traffic Signs	Number of signs	TP	Recall (%)	Precision (%)
Speed limit	127	126	99	97.6
Danger signs	79	75	97.4	98.7
Unique signs	50	50	98	96

Fig. 2: Frames illustrating the insertion of virtual 3D object sign

3.2. Augmented Reality Tracking

AR cues may offer a promising means to improve driver safety, potentially reducing response time and increasing hazard detection likelihood. The stability of tracking is achieved with a temporal smoothing approach that determines the average pose from multiple estimations. Then, the mean pose over the last frames is used. Moreover, we improved the pose accuracy using a check validation process by computing several poses for each single target localization.

In this section, the results obtained during real-time tests performed with a fully equipped vehicle are presented. We started the evaluation of the AR tracking by superimposing 3D graphics on target images. To provide driving safety information using the proposed AR-TSR, various sensors and devices were attached to the experimental test vehicle, as shown in Figure 2.

Experimental results showed that the proposed method is significantly reduce the computational cost and also stabilizes the camera pose estimation process. A virtual object is attached to a real object for the augmentation purpose, the camera pose are used to superimpose virtual objects onto the real environment. The use of the object tracking process keeps the augmentation correct, which proves that pose estimation has been calculated accurately. Moreover, it is able to automatically recognize the scene and to identify the patch to be augmented, in spite of changing viewpoint and/or illumination conditions. Using the calculated pose matrix, a virtual 3D object is projected into the real world scene for augmentation purposes as is shown in Figure2.

The experiments confirmed that the system can accurately superimpose virtual textures or 3D object to a user selected planar part of a natural scene in real-time, under general motion conditions, without the need of markers or other artificial beacons. A virtual object is attached to a real object for the augmentation purpose. The use of the object tracking process keeps the augmentation correct, which proves that pose estimation has been calculated accurately. Indubitably, the speed of our system varies according to different conditions appearing in the video sequences and the complexity of virtual objects. AR system false alarms and misses did not impair driver responses to potential hazards.

4. Conclusions

Augmented Reality traffic information system can facilitate a new form of dialogue between the vehicle and the driver; and enhance intelligent transportation systems by superimposing surrounding traffic information on the users view and keep drivers view on roads. In this paper, we have proposed a in-vehicle AR-HUD system for providing driving-safety information that superimposes augmented virtual objects onto a real scene under all types of driving situations, including unfavorable weather conditions. Our method uses two steps: hypothesis generation and hypothesis verification. In the first step, Region Of Interest (ROI) is extracted using a scanning window with Haar cascade detector and AdaBoost classifier to reduce the computational region in the hypothesis generation step. The second step verifies whether a given candidate and classified into vehicle and non-vehicle classes using edge information and symmetry measurement to verify them. In-vehicle contextual AR has the potential to provide novel visual feedback to drivers for an enhanced driving experience and a new form of dialog between the vehicle and the driver. To provide driving-safety information using the proposed AR-HUD, drivers receive all important information before their eyes in an easily comprehensible way.

In the future, cars will be able to adapt their driving characteristics with impressive flexibility to either the environmental conditions or the wishes of the driver. When discussing AR or other advanced technologies that will be applied to the next generation of vehicles, it is critical to explore the deeper cognitive structure information and visualization for these different display types. The AR-HUD system enables the driver to see an augmented display of the status of driver assistance systems and the significance of this information in their direct field of view. This will increase safety on the roads and build trust in existing vehicle systems and new driving features such as automated driving.

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