Visualizing risk areas using augmented reality glasses as advanced driver-assistance system

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Enhancing Perception of Risk Objects for Car Drivers Through Augmented Reality Glasses

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ABSTRACT

In complex driving scenarios, drivers often face the challenge of making quick decisions regarding the safety of crossing intersections or entering roundabouts. These decisions, prone to human error, can compromise road safety and driving efficiency. The recent advancements in augmented reality (AR) glasses hold significant potential for assisting drivers in avoiding such dangers. Unlike traditional AR heads-up displays (HUDs), AR glasses provide a larger field-of-view. While previous research has proposed various driving-assistance concepts using simulated displays, only a few have explored actual implementation or experimentation with real AR glasses. This study introduces a novel concept of visualizing risks through AR for driving assistance systems. We have designed and implemented two different interfaces specifically tailored for real AR glasses, integrating them into a driving simulator system. To evaluate the effectiveness of AR glasses in driving assistance, we plan to conduct experiments based on this platform in the future.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**.

KEYWORDS

driving assistance system, augmented reality, driving simulator, interaction design

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1 INTRODUCTION

Human drivers often face challenges in accurately estimating surrounding vehicle dynamics due to various factors [6, 7, 10, 12, 15]. Augmented Reality (AR) technology, with its ability to overlay digital information onto the real world, holds immense potential for providing warnings or suggestions regarding dangerous objects or areas. While AR technology has seen widespread adoption in entertainment, medicine, education [7] and robotics [13], the automotive industry has also explored its potential by integrating it into Augmented Reality Heads-Up Display (AR-HUD) systems [14]. These AR-HUD systems already implement driving-assistance features such as navigation, lane-keeping assistance, and front collision warning. However, the limited Field-of-View (FOV) of AR-HUD, which only covers the driver's sight of the front lane, makes it challenging to provide warnings for objects in a wider angle around the driver, such as pedestrians suddenly entering the road. While a full windshield display holds promise for covering a larger area, its implementation remains at the conceptual stage and is hindered by numerous technological challenges.

In recent years, wearable AR devices, specifically AR glasses, have experienced rapid development, offering an alternative solution. AR glasses, capable of tracking human gaze and following the user's line of sight, provide a much larger FOV. They have the potential to display relevant content on objects in other lanes, sidewalks, or traffic signs. Some car manufactures have attempted to connect AR glasses with in-vehicle systems to provide similar features as AR-HUD. However, most of these attempts remain conceptual, and driving simulator studies often rely on projectors or virtual reality (VR) to simulate AR displays. There is a lack of empirical studies that utilize real AR glasses for driving assistance features.

In this study, we propose a novel concept of visualizing risks through AR glasses for driving assistance systems. To validate our concept, we have designed and implemented two distinct interfaces that are specifically tailored for real AR glasses. These interfaces have been seamlessly integrated into a sophisticated driving simulator system, allowing researchers to evaluate the effectiveness of AR glasses in various driving scenarios. By conducting experiments based on this platform in the future, we aim to gain valuable insights into the practical application of AR glasses for driving assistance and further validate their potential for enhancing road safety and driving efficiency.

2 RELATED WORK

The integration of AR technology in the automotive industry is gaining standardization due to its potential to enhance driver cognitive efficiency [8], reduce mental workload [1–3, 11], and improve task performance [8]. Currently, AR cues can be displayed to drivers through three different methods: AR head-down display (AR-HDD), where AR content is presented on a screen overlaying camera information; AR head-up display (AR-HUD), where AR content is

*Both authors contributed equally to this research. They proposed the basic concept together. Derck implemented of Carla simulator, designed and implemented the interface 1 and 2; Chao designed the system structure, supported interface 1/2, HoloLens implementation, and risk calculation algorithms.

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Figure 1: The system structure and the apparatus

projected onto the windshield or another transparent plate; and head-mounted display (AR-HMD), where AR content is displayed in AR glasses.

AR-HDD, which displays Camera-View Augmented Reality on a screen, is widely adopted by car manufacturers for applications such as navigation or ADAS due to its lower cost and relative ease of implementation. However, it has been reported that AR-HUD performs better in navigation tasks because it eliminates the need to glance away from the road [5]. Leading HUD manufacturers in the automotive industry, such as Bosch, Continental, and Panasonic [9], have successfully entered the market by developing bright tablet-sized windscreen projectors for AR-HUD systems. However, these windshield displays are limited in size and, consequently, in capability. Emerging advancements in AR technology by companies like WayRay[1] and EyeLights[2] offer potential solutions to overcome these limitations by enabling full AR windscreen integration in future vehicles, enhancing both user experience and road safety. Nevertheless, challenges persist in realizing a full windshield display, as it poses greater technical difficulties compared to AR-HUD systems [4]. It is important to note that even with a full windshield display, it cannot cover the entire area within the driver's line of sight, as blind spots still exist in the side of the vehicle and the A-pillar area.

In the near future, upcoming developments in personal AR devices will allow further advancements in the automotive industry to utilize AR for driving assistance by superimposing images onto the full windscreen. Some developments and concepts of AR-HMD have been proposed [3][4]. Currently, the technology is already being explored in driving simulators for the proper integration of its potential benefits. However, challenges such as the degree of interference to the driver's field of view or cognitive load remain. Additionally, more research needs to be conducted regarding the potential applications.

[1]https://wayray.com/
[2]https://eye-lights.com/
[3]https://www.progress.audi/progress/en/sid-odedra-head-of-ui-ux-design-talks-about-the-audi-activesphere-concept.html
[4]https://www.engadget.com/2015-04-09-mini-augmented-vision.html

3 SYSTEM STRUCTURE AND APPARATUS

By combining the capabilities of the driving simulator and the HoloLens device, we aimed to create an immersive and interactive AR experience that could effectively visualize the risk areas in real time.

3.1 Driving Simulator and ROS connection

A static driving simulator was implemented for our study. The hardware of the simulator consists of three LCD display panels, each with a diagonal of 126cm and an individual resolution of 1920x1080. Furthermore, the simulator setup also features a set of 500W surround sound speakers, to simulate vehicle sounds, and a Logitech G27 steering wheel with pedals. For the software the open-source driving simulator software Carla[5] was used with the modifications of Python API. The software is well integrated with various compatible modules such as scenario runner and carla ROS bridge that allows the execution of repeatable complex test driving scenarios with real-time data communication.

3.2 HoloLens

The open-source MRTK[6] library was used to develop the AR application to be deployed on the HoloLens 2. The application receives real-time simulation data via ROS, performs the calculations to determine the dimensions of the risk areas, and displays the risk areas in AR. To ensure proper alignment between the virtual world of the driving simulation and the HoloLens display, we employed a Vuforia marker. This marker acted as an anchor point, allowing us to establish the screen position within the HoloLens world.

4 AUGMENTED REALITY UI DESIGN

4.1 Risk calculation formula

To effectively visualize the risk within the AR glasses, it is crucial to assess the likelihood of a potential collision. In our study, we consider objects not only within the same lane but in any direction, necessitating a comprehensive approach to risk calculation.

Initially, we consider traffic objects as point-like representations, and assume that they maintain their current velocity vectors. Using

[5]https://carla.org/
[6]https://github.com/microsoft/MixedRealityToolkit-Unity

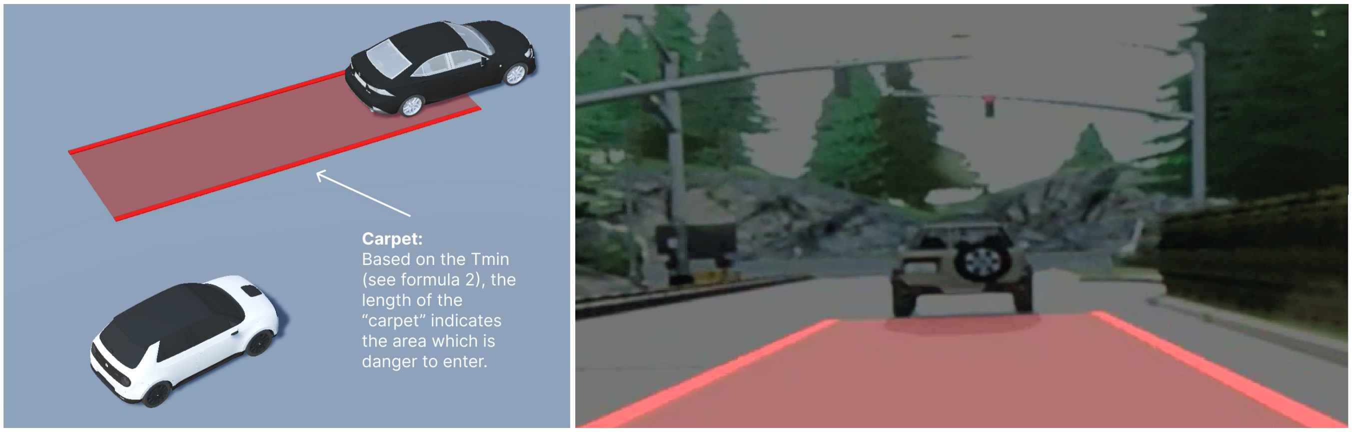

Figure 2: Design 1: The carpet

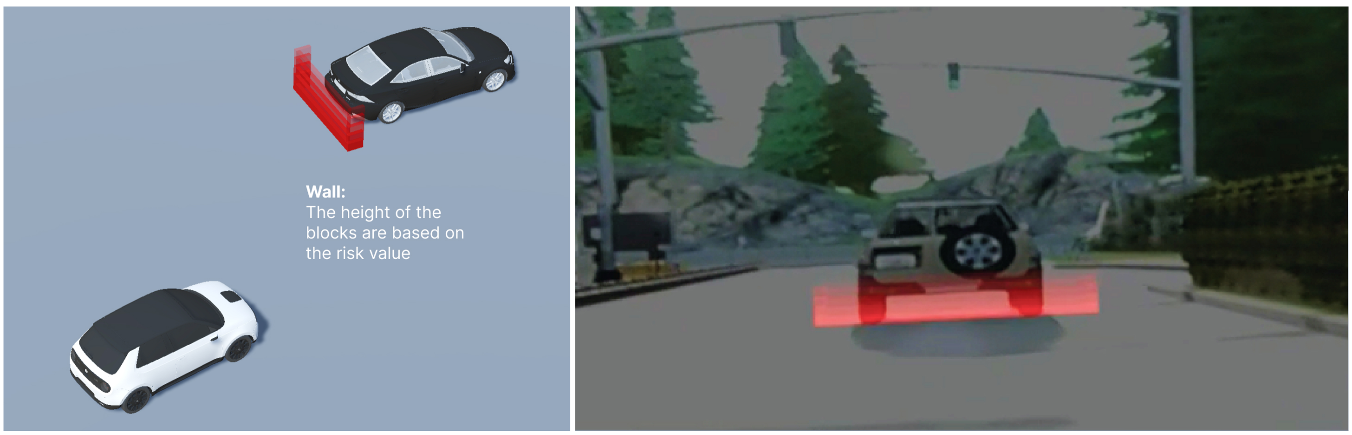

Figure 3: Design 2: The wall

this information, we can determine the time ($t_{min\_distance}$) in the future when the ego vehicle and another object will be closest to each other. This time can be calculated using the following formula:

$$t_{min\_distance} = -\frac{\triangle\vec{p} \cdot \triangle\vec{v}}{\triangle\vec{v} \cdot \triangle\vec{v}} \tag{1}$$

Here, $\triangle\vec{p}$ represents the relative position vector from the ego vehicle to the other object, and $\triangle\vec{v}$ represents the relative velocity vector. If the value of $t_{min\_distance}$ is less than zero, it indicates that the closest point in time has already passed, and a future collision is unlikely. Conversely, if $t_{min\_distance}$ is greater than zero, we can calculate the minimal distance (D_{min}) between the ego vehicle and the other object. Since each object has its own volume, we consider $D_{min} < 5$ as an indication of a collision. However, if there is sufficient time for both the ego vehicle and the other vehicle to adjust their velocities, the collision is also unlikely to occur. Therefore, when the additional condition $t_{min\_distance} < 5$ is satisfied, the risk visualization will be displayed.

Using the aforementioned formula, we have devised two distinct designs to portray the collision risk projection according to user preferences. These designs alter the shape of the graphic based on the value of $t_{min\_distance}$ between the ego vehicle and the other vehicle. The differentiation lies in the direction of the shape transformation: design 1 stretches horizontally, while design 2 stretches vertically. Depending on the relative orientation and the direction of the collision risk, these designs can be displayed on either the front or the back of the other vehicle.

4.2 Design One: the Carpet

The visualization of this design consists of a red plane accompanied by two slightly elevated edges (Figure 2). To determine the length of the "carpet," it is calculated by multiplying the speed difference with the time taken to reach the minimal distance. Alternatively, if the time to minimal distance exceeds 2, the length is obtained by multiplying the speed difference with a factor of 2:

$$L_{area} = \begin{cases} \triangle v * t_{min\_distance}, & \text{if } t_{min\_distance} \leqslant 2 \\ \triangle v * 2, & \text{otherwise} \end{cases} \tag{2}$$

4.3 Design Two: the Wall

A different concept presents the risk in a vertical direction. The "wall" consists of a collection of transparent blocks stacked together

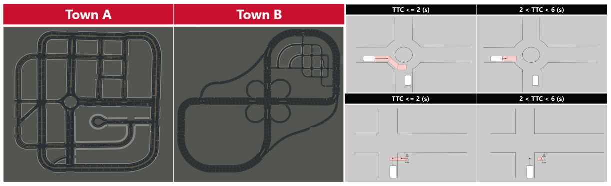

Figure 4: The maps and scenarios

(refer to Figure 3). Due to varying heights of the blocks, the upper sections of the wall exhibit greater transparency. This design approach ensures that the wall does not obstruct the view of the leading vehicle. The height of the wall (H_w) is calculated according to the following formula:

$$H_w = \begin{cases} h_{obj} * (t_{min\_distance}/2), & \text{if } t_{min\_distance} \leqslant 2 \\ h_{obj}, & \text{otherwise} \end{cases} \quad (3)$$

where h_{obj} is the object's (car or pedestrian's) height.

5 SCENARIOS AND USER STUDY PLAN

To assess the effectiveness of the AR visualization designs, we devised and implemented several scenarios within two maps of the driving simulator (Figure 4 left). These scenarios, such as includes entering the roundabout or pedestrian jump into the road (Figure 4 right) with the variations of velocity of the surrounding traffic participants, were designed to simulate traffic situations where the proposed concept hypothetically aids the driver by dynamically displaying the risk area.

6 CONTRIBUTIONS AND FUTURE WORK

This study proposes a novel concept of using AR glasses to visualize risks in driving assistance systems. We address the limitations of existing AR-HUD systems, which have a restricted Field-of-View (FOV), by leveraging the larger FOV of AR glasses. We have designed and implemented two interfaces tailored for real AR glasses, integrated into a driving simulator system. Through future experiments, we aim to evaluate the effectiveness of AR glasses in various driving scenarios and validate their potential for enhancing road safety and driving efficiency.

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