

Real-Time ADAS Visualization Using DL-GSA-Based Computer-Generated Holography

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Abstract

This study investigates the integration of Computer Generated Holography with Advanced Driver Assistance Systems for applications in augmented reality head-up displays. By utilizing the Deep-Learning Gerchberg-Saxton Algorithm (DL-GSA), the research achieves real-time holographic projection with multi-depth visualization, allowing for dynamic 3D AR-HUD displays.

To ensure accurate holographic visualization, ADAS data undergoes coordinate transformation, aligning sensor-captured information with the driver's perspective. A custom optical system, equipped with a single spatial light modulator (SLM) and spatial multiplexing, enables precise and immediate projection of road conditions.

The results indicate the feasibility of using CGH-based AR-HUDs to enhance driving safety by providing an immersive interface that aligns critical ADAS information with the driver's natural viewpoint.

Author Keywords

Computer-Generated Holography; Holography; Deep Learning; Unsupervised Learning; ADAS; AR-HUD.

1. Introduction

This study mainly focuses on integrating Computer Generated Holography (CGH) with Advanced Driver Assistance Systems (ADAS).

In our previous research, the Deep-Learning Gerchberg-Saxton Algorithm (DL-GSA)[1-2] was successfully applied to CGH, achieving remarkable results. By leveraging deep learning, the generation time of the GS algorithm was significantly reduced. This advancement enables CGH to achieve real-time hologram generation and demonstrates its potential for applications in augmented reality head-up displays (AR-HUD).

Meanwhile, an Advanced Driver Assistance System (ADAS) [3] is a collection of electronic technologies integrated into vehicles to enhance safety and improve driving efficiency. It uses sensors, cameras, and radars to monitor surroundings, provide alerts, and even take control in critical situations. Common features include adaptive cruise control, lane-keeping assist, automatic emergency braking, and blind-spot monitoring. These systems can also integrate with the Electronic Control Unit (ECU) to reduce accidents and enhance the driving experience.

The integration of ADAS and DL-GSA would enable CGH-based AR-HUD systems to achieve dynamic, real-time calibration, thereby facilitating real-time visualization of road conditions and enhancing their practical functionality.

2. Methodology

ADAS Coordinate Transformation

ADAS can capture road condition information surrounding the vehicle. However, integrating this information with a CGH-

based AR-HUD requires addressing the displacement caused by differing perspectives. Since the viewpoint of ADAS sensors differs from that of the driver, ADAS data cannot be directly applied to CGH. The coordinate information from ADAS must undergo a transformation to convert the sensor's perspective into the driver's viewpoint. This transformation ensures that the CGH output is correctly aligned with the driver's perspective, enabling accurate projection of calibrated information onto the optical system.

DL-GSA

The DL-GSA algorithm, based on the Fresnel Transform (FrT) [4-6] (Eq.1), enables real-time generation of holographic images for AR-HUD systems. Using FrT, light propagation is precisely calculated, facilitating accurate holographic projections. The algorithm employs a Convolutional Neural Network (CNN) to predict the optimal complex field for the target image, which is then propagated through the Fresnel transformation to generate a holographic phase mask. A custom loss function refines the model by comparing the reconstructed image with the original input.

$$E'(\xi, \eta) = \frac{j}{\lambda z} e^{-j\frac{2\pi}{\lambda} z} e^{-j\frac{\pi}{\lambda z} (\xi^2 + \eta^2)} \iint_{-\infty}^{\infty} [E(x, y) e^{-j\frac{\pi}{\lambda z} (x^2 + y^2)}] e^{j\frac{2\pi}{\lambda z} (x\xi + y\eta)} dx dy \quad (1)$$

In addition to real-time generation, the DL-GSA algorithm supports multi-depth training to produce holograms at varying depths and imaging distances. This adaptability enhances its practical application in dynamic AR-HUD scenarios by enabling the visualization of 3D spatial information.

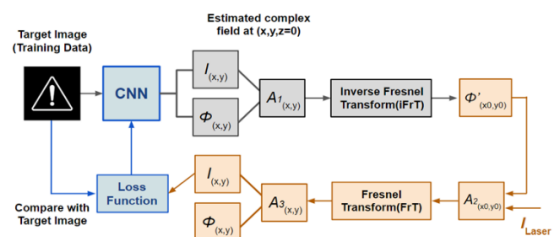


Fig. 1 DL-GSA Training flow.

Optical System

In this study, the optical reconstruction system for computer-generated holograms is designed to utilize a single spatial light modulator (SLM) for reconstructing holographic images computed through the DL-GSA algorithm, with spatial multiplexing serving as the enabling technique. The system employs a collimated laser beam at a wavelength of 640 nm as the experimental light source. The optical path is directed through a beam splitter (BS) to the SLM, which modulates the input data and generates the holographic image, subsequently projected onto a diffuser. To optimize system performance, a penetrating mirror is integrated to reduce spatial footprint while facilitating the dynamic enlargement of the reconstructed images.

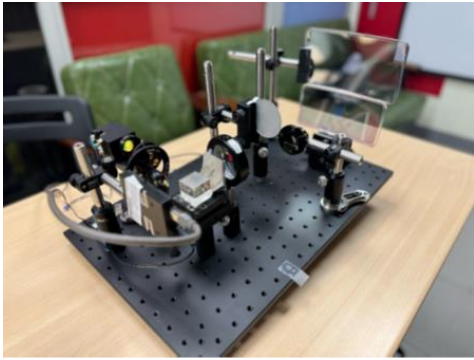


Fig. 2 Optical reconstruction system.

3. Results

In this study, ADAS plays the role of providing road condition information, which is then subjected to coordinate transformation. The transformed coordinate data is subsequently utilized by the SLM for real-time imaging modulation. Figure 3 illustrates an example of the integration of the optical system and the algorithm, where the reconstructed holographic image contains authentic optical depth information and enables real-time road condition calibration. This demonstrates the feasibility of a CGH-based AR-HUD system.



Fig. 3 Experimental results of CGH reconstruction.

4. Discussion

Our integration of CGH with ADAS, represents a promising development for next-generation AR-HUD. By utilizing the DL-GSA, we achieved significant reductions in hologram generation time, enabling real-time holographic visualization. This advancement is critical for in-vehicle applications, as timely and accurate information is essential for ensuring driver safety.

We addressed the challenge of aligning ADAS sensor data with the driver's perspective through coordinate transformation, ensuring that all holographic information is calibrated to the driver's field of view. This method not only enhances the driver's ability to intuitively perceive critical information but also creates an immersive experience by integrating multiple depths of visualization.

While the results are promising, future work may focus on further optimizing the spatial footprint of the optical system, improving resolution, and minimizing latency to enhance practical usability.

5. Conclusion

In this study, we successfully demonstrated the feasibility of integrating Computational General Holography (CGH) with Advanced Driver Assistance Systems (ADAS) for real-time AR-HUD applications. By employing our DL-GSA, we achieved dynamic, multi-depth holographic visualizations that provide an accurate and immersive representation of road conditions. Our innovative optical reconstruction system uses an SLM with spatial multiplexing to project ADAS information that is accurately aligned with the driver's viewpoint. These advancements showcase our commitment to enhancing driving safety and comfort by developing a seamless, real-time interface that connects vehicle systems with drivers, ultimately leading to safer and more intuitive driving experiences.

6. Acknowledgements

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7. Reference

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