Augmented Reality Head-up-display

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Abstracts

We developed an augmented reality heads-up display system in this study. That displays integrated messages including overlapped image of lane marking and information of preceding vehicles on 5 meters in front of windshield. The system will also be verified for its feasibility through software simulation and prototype production.

Keywords : Marking Detection, Augmented Reality, Virtual Image, Head-Up Display.

1. Introduction

Augmented Reality (AR) is what virtual images are integrated into the real world. In AR environment, human sensory perception enables to help integrate between virtual images and real world, and strengthens its effect of immersion. As a result, some scholars endeavor to apply Head-up Display (HUD) based on augmentation technology onto navigations for passenger and vehicles [1]. Among above studies, Marcus Tonnis indicated in 2005 that compared with plane-view display, AR display system proves more effectively to direct driver’s attention [2]. This research proposes an AR HUD system that enables to project driving information, including vehicle speed, speed limit, forward collision warning, and lane departure warning etc. onto windshield through virtual image projected by HUD system. Such AR system manages to achieve Augmented Reality performance by overlapping image displayed by system and actual lane view seen by driver through coordinate conversion technology between real world and projected images.

2. Experimental

Purpose of this research is to realize an augmented reality heads-up display system capable of overlapping displayed image with that seen by driver from actual lane. The whole structure consists of 2 parts:

I. Virtual image display: this unit is designed to project driving information onto windshield by way of optical machine system. Ensuring that image seen by driver overlaps with actual lane, imaging distance of virtual image is hereby set at 5 meters in front of windshield, where the size of view should cover vehicle up-front space about 4m×1m, as depicted at figure1. In order to put it into reality, this research proposes to apply reflective virtual imaging system in combination with dual-path structure as construction design, with overall structure that two sources of image are applied to embody dual-path structure, and enable to effectively minimize subsequent dimension of optical machine through intersected and overlapped dual paths. Consequently, virtual image magnified by concave lenses is projected onto windshield before reflective to human eyes in a fashion that a huge image is then readily presented in front of windshield (structure of optical machine as show figure 2). Above components are subject to initial design before they undergo further design and optimized process based on system requirement through the assistance of ZEMAX imaging design software. The specifications of system and imaging quality after optimization are depicted in figure 3 and sorted in Table 1.

II. Image process unit: this unit adopts Texas Instrument (TI) DFM6438 DSP as calculation platform to perform recognition of lane markings and conversion of virtual imaging coordinates. Our research applies 4 kinds of key marking characters as the approach of lane marking recognition: High-Grey Value, Edge Characteristic, Range of Lane Mark Width and Continuity to increase recognition accuracy. Please see Figure 4 for final processed images generated by lane marking recognition. For best overlapping result between virtual image and actual world, the image coordinates captured by video camera should convert coordinates of virtual imaging display. First, imaging
recognition is conducted in 2D images to acquire imaging coordinates of lane marking. Then 2D images can be converted into 3D projection display by way of formula 1 and formula 2 (virtual imaging conversion formula) so as to obtain overlapped position between lane marking projected on windshield and actual space (world coordinates) before corresponding relation is calculated between imaging coordinates and position of driver’s eyes. Detailed relation between virtual imaging display and video camera coordinate as per Figure 5.

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U_p = \frac{U_e H_e}{e_v m_b - v_c} - \frac{e_m m_b - e_v - e_u x_u}{e_v H_e} + U_{p0}
\]

\[
V_p = \frac{e_m m_b - v_e - e_p m_p y_e - e_p H_p}{e_v m_b - v_c - y_u}
\]

3. Result & Discussions

As shown in Figure 6 about system structure configuration chart, video camera, optical machine module (including source of image, concave lenses and combiner, and DSP module are installed on top of dashboard for driver to identify safety message of preceding vehicle and reminder message of integrated driving speed and speed limit. Integrated message screens will then be input to 2 units of small LCD Display monitors as part of basic structure of dual paths. Actual display performance of AR HUD system through experimental platform as presented in Figure 7, where the display area can cover up-front lane, clearly detect current location of up-front lane marking of travelling vehicle, warning message of safety distance away from preceding vehicle, integrated messages of driving speed and speed limit, and displayed image can be overlapped with screen of actual lane. The accuracy recognition rate of lane deviation warning system for good-quality roads such as Expressway reaches up to 98.2% and Highway reaches up to 98.6%; projected lane image perfect in line with actual lane represents a tolerance less than a marking width at ±15cm.

Vehicle up-front safety virtual imaging warning system developed by this research is purposed to integrate up-front safety system, virtual imaging display mechanism and coordinates conversion technology, which enables to project intuitive image information on windshield that offers driver the most real, three-dimensional viewing effect. In combination with image processing chip and feature searching approach, said system enables to identify lane marking of both side and position of preceding vehicles, and supported by algorithm of virtual image projection conversion, it surely will bring about virtual image warning functions of lane deviation and anti-collision with preceding vehicle.

Reference

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<th>Table.1 Specifications of Heads-up display</th>
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<td>Virtual image distance</td>
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<td>Virtual image Size</td>
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**Fig. 1** Diagram of the Head-up display to project augmented reality information in front of the windshield.

**Fig. 2** The optical system is composed of two image source, concave mirror, and two combiners.

**Fig. 3** Image quality of the optical system: (a) Geometric aberration; (b) Field curvature and distortion after optimization.

**Fig. 4** The result of lane marking detection

**Fig. 5** The relationship between virtual imaging display and video camera coordinate

**Fig. 6** AR-HUD test structure

**Fig. 7** Sample image demonstrating the performance of AR-HUD system