Development of Dynamic Information Fusion Interactive System on Direct-view Transparent Display in vehicle application

Hong-Ming Dai, Tzu-Yi Yu, Chien-Ju Lee, Yu-Hsiang Tsai and Kuan-Ting Chen

Electronic and Optoelectronic System Research Laboratories, Industrial Technology Research Institute, Chutung, Hsinchu, Taiwan 310, R.O.C.

Abstract

In this research, we have developed dynamic information fusion interactive system with transparent display applied in the mobile field. The dynamic information fusion interactive system integrate four main technologies: gaze tracking, relative position acquisition, fusion information mapping and visual field tracking adaptive information generation. For the part of visual field tracking adaptive information generation, we let the position and numbers of fusion information change as the user's field of view varies to help users to use this system more comfortably and intuitive. By integrating those technologies, we can achieve an AR-based interactive system on direct view transparent display. And the accuracy of the information fusion is greater than 80%. Such a system can provide passengers with location-based interactive information of virtual and real integration in the mobile field.

Author Keywords

interactive system, transparent display, visual field

1. Introduction

In recent years, transparent display and its applications play an important role in display technology for the next-generation. There are two types of transparent display technologies, head-mounted projection and large-area direct-view types. We can exploit these two kinds of transparent displays to help us to achieve augmented reality applications with existing sensing and positioning technology. We can get the gaze direction of user on display and get the projection area of background object on display. Then show the corresponding virtual information on the screen which the region overlapped by them[1-2]. For the head-mounted display type, users must wear the heavy head-mounted devices on the head. It is not comfortable to use for a long time. But its technology for fusing the virtual information and background object is more easy to achieve because it just need to consider the part of background object's projection relations with screen[3]. That's why we can see so many kinds of this type of products are sold in the market nowadays. On the other hand, for the large-area direct-view transparent display type, it can help users to realize augmented reality interaction without wearing any devices. It's more friendly and intuitive for users. But it is more difficult to deal with information fusion because we should consider both parts' relation with screen, background object and user's gaze direction. Therefore, the development and application of direct-view transparent displays have gradually expanded. This type of display technology is seen as an essential part in the smart life that can realize a mixed reality interactive system. For example, smart retail application, smart education and entertainment field, smart medical application and mobile applications have strong demands for this novel technology. In particular, the demands for mobile application have grown explosively. The era of autonomous vehicle is coming, people wants to do something in the cars during the ride. In the previous years, Audi showed its tour service for passengers in the sedan. It helps passengers to introduce the history and scenery while cars is passing the different tourist spots by voice commentary. In 2020, Spanish tour bus provided location-based information for passengers on smart windows, such as travel messages. Smart windows became more and more significant in the future, especially for smart life.

In direct-view transparent display applications in the mobile field, users see both the scene behind the smart window and the virtual information on the smart window mapped on the scene according their gaze direction. The position of the virtual information gradually moves as the car moves and user moves. In such application, there are two issues that must be considered. The first one is how to get the object's position exactly while the object is moving relative to car and get its project area on the screen. The second one is how to show the information correctly when the field of view for user is changed. When users move forward and backward slightly or move left and right a little, they possibly see the entirely different objects through the smart window. So we should change the corresponding virtual information quickly. For the first problem, we have proposed a transparent display interactive system based on transparent display and GPS technology to get the roughly position of object relative to the smart window. As for the second problem, we have proposed an method which names visual field tracking adaptive information generation. This method helps system doing fusion calculation and showing the corresponding information for background objects to users more efficient when they move to change their position relative to smart window. We calculate the users' visual field by their eye position relative to smart window with AI recognition module firstly. Then we check which objects are inside the visual field secondly. Display the corresponding information on screen finally.

2. Proposed Interactive system

We would briefly introduce the proposed dynamic information fusion interactive system, including basic system structure, identification modules for user and object, fusion information calculation, visual field tracking adaptive information generation method and transparent display device. This is a prototype of dynamic information fusion interactive system for vehicle applications. User can see the background objects and their corresponding information or introduction through the smart window which is made of transparent display while car is moving. The position and numbers of virtual information vary for generating a better fusion information as the car moving and user shifting.

2.1 System Structure

Figure 1 shows example of the system structure of the proposed dynamic information fusion interactive system. The system peripheral has at least one camera, one GPS and transparent display. It would do face identification and gaze tracking on user via in-camera device. Getting the position relative to the transparent display via GPS receiver. Then show the fusion information via transparent display on the corresponding area by the user's sight.

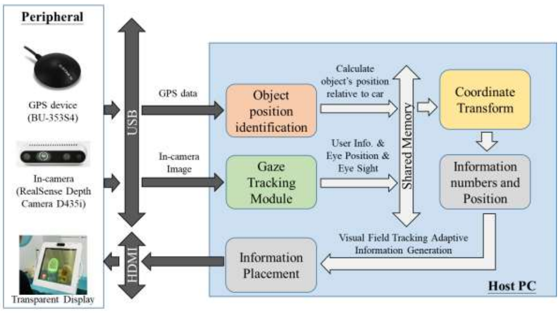

Figure 1: The proposed dynamic information fusion interactive system structure.

2.2 Identification Module

In the identification module, we divided it into two parts to discuss: one is user identification, the other one is object position identification.

(1) User identification

The user identification module utilized the Intel RealSense's depth and RGB sensors to catch the image for doing feature tracking. With its stable measurement and high accuracy, helping the system to get the convincing 3D depth information of users as features for identification and training. The user identification module applied the machine learning method to get the identification results. Then send the results to the host system by shared memory. This module was written by Python and it exploited the Dlib library for training to get the recognition model.

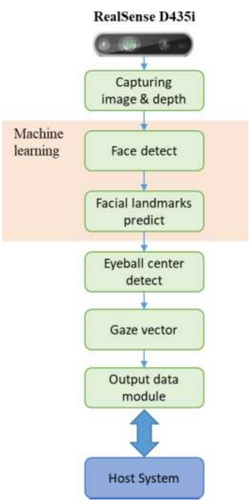

Figure 2: The flow chart of user identification module

(2) Object position identification

The object position identification module adopted the GPS receiver to get our position as latitude and longitude. Then calculate the relative position to the objects from our database. There are three major information from this database, the objects' name, their introduction and their absolute position in latitude and longitude from Google map. This module computed all of the objects' relative distance to the transparent display which position is from the GPS receiver by the basic mathematical formula we showed in figure 3. R is the radius of earth, ϕ_1 and ϕ_2 are the altitude of two points, λ_1 and λ_2 are the longitude of two points.

The GPS receiver read the data in the signal format of NMEA-0183, which protocol established by National Marine Electronics Association. There are so many types of data, including GPGGA, GPGLL, GPRMC and so on. We got the latitude and longitude of our position from GPGGA, which means Global Position System Fixed Data. To get the information of latitude and longitude, we should decode the raw data and do the simple mathematical transform.

$$d = 2R \times \arcsin\left(\sqrt{\sin^2\left(\frac{\phi_2 - \phi_1}{2}\right) + \cos\phi_1 \cos\phi_2 \sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right)$$

Figure 3: The formula of relative distance calculation

2.3 Fusion Information Calculation on system

After getting the users' gaze direction and objects' position relative to transparent display from user identification module and object position identification module, the host system would integrate them to calculate the appropriate position of fusion information on transparent display. Then show the virtual information by transparent display for user reading.

For the step of fusion information calculation, resolution transform, GPS data shifting and GPS signal instability should be considered. Because of the resolution difference between camera and transparent display, we must do the resolution transform to the same resolution basis when we got the gaze position of users from camera. GPS data shifting and GPS signal instability are common issues when we use GPS receiver to deal with some engineering problems. They can be solved by some algorithm which makes the signal more smoothly and convincible. After correction of resolution and GPS data, we think that we can get better results of fusion information which the virtual information is more accurate and closer the corresponding background objects.

2.4 Visual Field Tracking Adaptive Information Generation

In order to make the system more efficient and the accuracy of fusion information more accurate, we proposed visual field tracking adaptive information generation method. This method can help the virtual information to move smoothly and real-time while users are moving to change their view through transparent display. We calculated the visual field of user first, then adjust the position and numbers of virtual information as the user's visual field changed. The described situation is shown in figure 4.

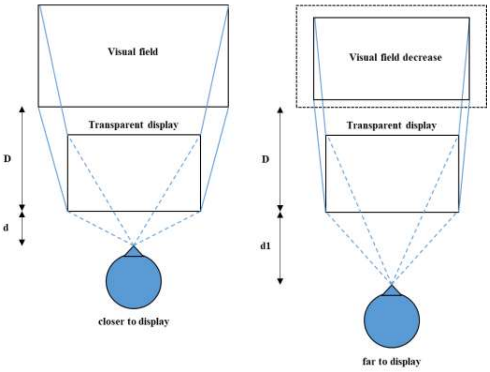

Figure 4: A schematic diagram of visual field vary while user moving forward or backward to transparent display

To solve the problem that we described above, we derived the formula as shown in figure 5 where X is the original position of virtual information, X' is the new position of visual field vary, d is the original distance of user to display, d_1 is the new distance of user to display while user moving forward or backward, D is the distance of display to object and Xc is the center position of the display. If the original position of virtual information, X, is greater than Xc, we use the formula (1). Using formula (2) for another situation.

$$X' = Xc + d1(d+D)(X-Xc)/d(d1+D), X>Xc \quad (1)$$

$$X' = Xc - d1(d+D)(Xc-X)/d(d1+D), X<Xc \quad (2)$$

Figure 5: The formula of the position shift of the virtual information as visual field vary

In order to simulate the application of dynamic information fusion interactive system on direct-view transparent display in the mobile field and conducted a quick verification for the visual field tracking adaptive information generation method. We recorded the actual scene out of the car side window and played it behind the transparent display screen. And we used pseudo-GPS data as the position of the objects from the scene. The users can see the virtual information on the transparent display corresponding to the background objects even they changed their visual field by moving after the we applied the visual field tracking adaptive information generation method on system. (As shown in figure 5). It also helps the system to get more accurate fusion results and reduce the computing loading by minimizing the quantity of computation.

Figure 5: Simulation application of dynamic information fusion interactive system on direct-view transparent display in the mobile field

3. Transparent Display Device

To achieve the application of dynamic information fusion interactive system in mobile field, we need a transparent display which transparency is same as car window. We utilized the 17 inch highly transparent AMOLED (active-matrix organic light-emitting diode) for this simulation application shown in figure 6. Its transparency is greater than 70% so that is suitable for smart window application. The other specification is shown in table 1. That was made by LTPS-TFT process, and its resolution is around 47 ppi.

Figure 6: 17 inch highly transparent AMOLED

Table 1: The Specification of 17 inch transparent AMOLED

Item	Content	Unit
Panel size	17	inch
Physical dimension	4:3, landscape	
Resolution	47	ppi
TFT type	LTPS-TFT	
Transmittance of panel	70	%
Brightness	~465	nits

4. Summary

In this research, we have developed dynamic information fusion interactive system on direct-view transparent display in the mobile field. We simulated the situation for outside scene which can be seen by passenger, and we showed the fusion information on transparent display which corresponding background objects that passenger can see through the transparent display. We also applied the visual field tracking adaptive information generation method to get better fusion results for the system which accuracy of information fusion is greater than 80%. The transparency of the transparent AMOLED display is greater than 70% so that we can see the clear outside view in vehicles. We deeply believe that there will have a lot of smart windows in vehicles in the near future. And this kind of application will be widely used on smart window in vehicles, especially for sightseeing.

5. References

[1] Y. H. Lin, P. Y. Chen, K. K. Chen, K. Jen, H. H. Lu, C. H. Liu, and H. J. Hong, “Highly Transparent AMOLED for Augmented Reality Applications”, SID Digest, 49, 621-623, 2018.

[2] Y. H. Tsai, L. H. Wang, W. L. Hsu, and K. T. Chen, “Dynamic Information fusion system on Transparent Display”, in Proceedings of the *International Conference on Flexible and Printed Electronics*, 2019.

[3] Y.H. Tsai, Y.T. Liou, W.C. Chen, K.T. Chen, G.C. and J.C. Ho, "Dynamic Information Fusion System with Anti-diffraction Backplane Design for Mobile Application", SID Digest, 52, 1166-1169, 2021.