An Information Layout Method for an Optical See-through Head Mounted Display Focusing on the Viewability

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Abstract

Accessing information when we are on the move is a key feature if mobile computing environments, and using an optical see-through head mounted display (HMD) is one of the most suitable ways to do this. Although the HMD can display information without interfering with the user's view, when the sight behind the display is too complex or too bright, the information displayed can bee very difficult to see. To solve this problem, we have created a way of laying out information for the optical see-through HMD. The ideal area for displaying information is determined by evaluating the sight image behind the HMD captured by a pantoscopic camera mounted on it. Moreover, if there is no suitable area for displaying information, our method select involves using the sight image around users use to the ideal direction and instructing them to face the direction. Our method displays information to ideal areas.

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Prototyping;

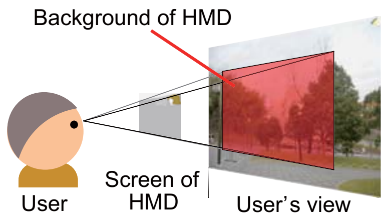

Figure 1: Optical see-through HMD

Figure 2: An example of hard recognizable information

1 Introduction

In recent years, the downsizing of portable computers has led to research into wearable computing; users wear computers and use them as part of their daily life. In wearable computing environments, computers provide information that is appropriate to the users' situation that is collected by using sensors worn on the users. Previously various wearable computing systems have been developed: an information browsing system for factory workers and a navigation system for tourists [3].

A head mounted display (HMD) is the most suitable wearable display unit. The optical see-through HMD shows information without interfering with the user's view of his/her surroundings (Figure 1). However, the HMD has a problem; information can be very difficult to see where the background of the HMD is too complex or too bright. Figure 2 shows an example of difficult to see displayed information. An example of such information is shown in Figure 2. To solve this problem, we have created an information layout method for the optical see-through HMD that takes the sight behind the display into account. Our method determines an appropriate area for displaying information by evaluating the sight image behind the HMD captured using a camera. In addition, we have also created a framework that reflects the semantic relationships and requirements of the content creators regarding the information layout. On the other hand, a user cannot read information when the whole area behind his/her HMD is too bright, for example, when he/she faces to the sun. Our method can also be used to evaluate the user's view of his/her surroundings and recommends a more suitable direction when there is no suitable area in which to display information.

2 Assumption for Environment

We refer to a piece of information displayed on the HMD as an *object*. It includes various types of information such as letter strings and images. Moreover, as shown in Figure 1, we describe the sight behind the HMD as the HMD background.

In the conditions of our environment, a user wears the HMD which is equipped with a camera. Such HMDs are popular in wearable computing environments because they capture what the user sees. For example, [4] had created a system that records what the user has seen as well as and information related to them to help them remember something important happened long time ago. Wearable cameras are also used in the method which reads information from visual markers placed in the real world [5]. Although the optical see-through HMD equipped with camera is not available in the current market, it will be popular by the downsizing of cameras and by increasingly lower prices.

The information displayed on an HMD does not need to be overlaid on real-world objects; such information includes alerts from a personal scheduler, health advice service, and a news flash. While information in these applications needs to be correctly conveyed to the user, displaying their position is not important. Our layout support this type of information, not the information that needs to

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overlaid on real objects such that in an augmented reality applications' one.

3 Related Work

The use of several conventional methods to improve the readability of objects displayed on the HMD has been proposed.

One approach is to display objects on the non see-through area of the HMD. In this approach, the use of an occlusive optical see-through HMD (ELMO) has been proposed [6]. Using ELMO allows users to configure the pixels so that the display is transparent or opaque. However, ELMO is too large and too heavy (1.5 kg) to be used in a wearable computing system. Although the displayed objects can be read using an HMD when a part or the entire of screen is not transparent, using an opaque display interrupts the users' view and carries a lot of risk.

Other approaches include the method of changing the position and color of the displayed objects when taking the background into consideration. The background image is classified into readable and unreadable parts on the basis of the displaying font in a method proposed by [7]. This method is based on the idea that opaque displays completely block their background completely. However, optical see-through displays, those assumed in our method, cannot completely block the background, and the brightness of its background affects the viewability of objects. In addition, this difference means that the studies on relations between information and the background for normal computer displays are not applied to the optical see-through display.

There are some studies intended for optical see-through HMD. Gabbard[2] evaluated the text legibility on the HMD in various environments. He evaluated only space formed using posters showing various textures, such as red brick and sky, as the HMD background, and his approach is quite similar to that of our research. This study might use the assumption that a direct ray of light does not enter the background of the HMD. Although this study is quite applicable to such environments, our assumption is that the objects are displayed not only on a poster but also on the real sky.

On the other hand, there is some research into managing annotations displayed on HMD. Bell[1] developed a component that is suitable for managing the view for virtual and augmented reality. This component is used to place annotations while avoiding other objects. This can be done without needing to consider the affect of the background of the annotations and targeted displayed information that is related to the real-world.

4 Information Layout Method

Our method can be used to determine a suitable region in which to display information by evaluate the HMD background and determining the layout while taking restrictions for displaying the position of objects into account. Because the relations among objects may be disrupted when determining which region is suitable, we constructed a framework for considering the layout restrictions for each object.

A region of the HMD background is a part of a sight image captured on camera. It is divided into 16 areas and the other region around the HMD background is divided into 4 areas (upper, lower, left, and right) as shown in Figure 3. We call each divided area a *slot*.

As shown in Figure 4, to get the user's left and right sight image, we use mirrors. Omni-directional cameras and a fisheye lens that are often used to acquire large-range images can also be used in our method and we employ mirrors because it is easy to use.

Our method determines the layout of objects as follows:

1. Calculate the image feature quantities

2. Calculate the viewability

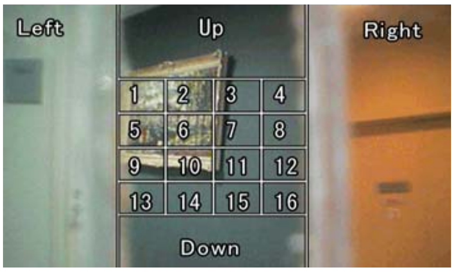
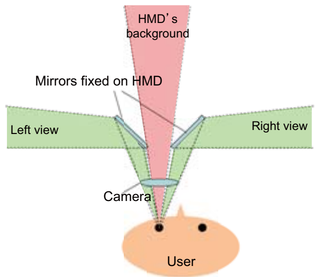


Figure 3: Division images


(a) User wearing the HMD


(b) HMD appearance



(c) User's view

Figure 4: HMD equipped with camera attached to mirrors.

3. Determine the most suitable object layout given any restrictions on object layout

Note that users must calibrate their region of the background HMD on the captured image before using this method.

4.1 Calculate image feature quantities

The viewability of objects is determined by using the image feature quantities in each slot. Some users who are used to wearing the HMD said that reading objects is difficult when the background is too bright or too complex. In addition, wearable computers do not have high-performance resources. For these reasons, we use the averages of RGB and HSV color spaces and the variances in RGB, YCbCr, and HSV color spaces as image feature quantities. We do not use the average values of the YCbCr color space because they can be linearly converted from an RGB color one.

4.2 Calculate of viewability

The viewability depends on the image feature quantities. We define *degrees of influence on the viewability* by using the following equation.

$$S_i = \sum_X a^X A_i^X + \sum_Y v^Y V_i^Y \qquad (i = 1, 2, 3, \cdots, 16) \tag{1}$$

We define A_i^X as the average of image feature quantity X in slot i, V_i^Y as the variance in image feature quantity Y in slot i, S_i as the degrees of influence on the viewability in slot i, and a^X and v^Y as the coefficients of image feature quantity X and Y.

Table 1: PCGA-VC2 Specification

CCD	1/6 inch. 350k-pixel CCD
Minimum object illumination	20 lux
White balance	Auto
Shutter speed	Auto
Focus	f = 2.8mm
Image size	320 × 240

We determined a^X and v^Y by evaluating the viewability of objects placed various backgrounds. The details of the evaluation is described in the following sections. We used the result to modify the previous equation.

$$S_i = 0.6A_i^R + 0.9A_i^G + 4A_i^B + 40V_i^Y + 200V_i^S \quad (i = 1, 2 \cdots 16) \tag{2}$$

The average of RGB, the variance of S in HSV, and Y in YCbCr affect to the readability.

4.2.1 Derivation of coefficients of image feature quantities

To determine modules in Equation (1), we examined which image feature quantities influence the viewability of objects. We used a DataGlass2/A (Shimadzu) HMD and PCGA-VC2 (Sony) camera. The specifications of the camera are shown in Table 1.

4.2.2 Evaluate of the object's viewability

The same 16 objects were shown in each of 16 slots on the HMD and the color of the objects were changed at given intervals. Participants marked the viewability of the each object in three levels: readable (◯), unreadable (×), and noncommittal (no mark). On one trial, participants kept their view still, and the background image and the marked results were recorded. The participants were three people who were habituated to the HMD. They evaluated them in various environments such as indoor, outdoor, day, and nigh, and obtained 47 sets of results.

4.2.3 Determine image properties

We determined the modulus used in Equation (1), which fits the result of the users' evaluation, by calculating all the patterns of possible values for each modulus. We changed the value of a^X from 0 to $2^j (j = 1, 2, 3, 4)$, and v^X from 0 to $2^j \times 10 (j = 1, 2, 3, 4)$ discretely, then we finely adjusted the determined value by changing the value with smaller steps. The result of this procedure is shown in Equation (2).

We used the similarity D to evaluate whether a modulus set fits the result of the users' evaluation. We calculated D as the difference between the average degree of influence on the viewability of readable areas and that of unreadable areas, as follows:

$$D = U - R \tag{3}$$

Note that U denotes the average of S_i in unreadable slots and R denotes the average of S_i in readable slots.

4.3 Restrict object layout

Generally, applications have the restrictions related to how they lay out objects. For example, in an application that in which animation characters navigate the user, the characters' serif should be displayed next to them. In addition, an object representing a cloud should be allocated in the upper part of HMD. To meet these semantic requirements, we have created a framework that describes the layout restrictions on objects.

```
<?xml version="1.0"?><object ID="B" importance="3">
<content type="balloon">You've got a Mail. </content>
<relation type="follow" objID="A"/></object>
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Figure 5: Description of a restriction

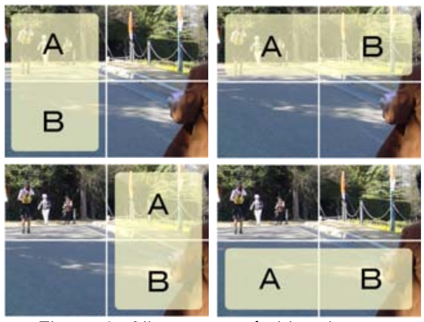

Figure 6: All patterns of object layouts

4.3.1 Restrictions factor

Objects should be laid out considering the requirements of the contents creator and the semantic relation among objects. First, we implemented the fundamental restrictions regarding the relation of objects, the position where the creator wants to display them, and their importance.

4.3.2 Layout determination

The restrictions are described in extensible markup language, as shown in Figure 5, in which the an object's ID is B, its importance is 3, and it should be placed to the right of or below object A.

When our method is used to determine the layout of objects, all restriction descriptions on the displayed object are read as well as the entire degrees of influence on the viewability E in all possible layout patterns. For example, when the background is divided into 4 areas and objects A and B that have the restrictions shown in Figure 5, there are four possible patterns as shown in Figure 6.

The entire degrees of influence on the viewability E is calculated by using the following equation for all possible layout patterns.

$$E = \sum_{id} I_{id} \times S_i \times P_{id} \tag{4}$$

The importance of an object is I. An object that is highly important should be displayed in a slot that is easier to view. The degree of influence on the viewability in slot i is S_i and is calculated using Equation (2). In addition, the evaluation multiplies S_i by movement cost P since the object can be difficult to see when it changes frequency. The value of P becomes smaller when the object does not move for a while. The layout pattern has the smallest E.

5 Recommendation of Direction

In the case where the whole area of an HMD has a strong influence on the viewability, we cannot read objects wherever they are laid out. For example, when a user is outside and faces the evening sun, the whole of the background of the HMD is too bright and there is no appropriate area to display the object. However, if user changes his/her view to the ground, they can easily read the object. Thus, our method selects an appropriate area from the image around the user's view and recommends turning to a more readable direction if there is no appropriate area for displaying objects in the user's current view.

Our proposed method calculates the viewability of a determined layout in each frame captured by camera. When the viewability becomes lower than a threshold, our method is used to compare the viewability to that of areas around the HMD's background. If the viewability of surrounding areas is higher, it recommends the user to change their direction in order to read objects easier.

5.1 Detect readability

When there is an area that has the larger degrees of influence on the viewability than threshold T, our method calculates the degrees of influence on the viewabilities of up of, below, right of, and left of the HMD background. If there is a direction has a lesser effect, our proposing method recommends the user to change his/her direction so that recognizing objects is easier. We defined that T is 4.0977. The value was conducted to be higher than a degree of influence of 95% of the readable areas evaluated in Section 4.2.2.

5.2 Compare of readability

If the following three conditions are met, the user will be advised to change their direction. The degree of influence on the viewability of a slot where an object is displayed is Si and S_d is the smallest degree of influence on the viewability from the above, the lower, the right, and the left areas around the HMD background.

Condition 1 $S_d + C < Min(S_i)$

Condition 2 $Min(S_i) < S_d + C < \sum_i S_i/n$

Condition 3 $\sum_i S_i/n < S_d + C < Max(S_i)$

One of the slot ID is taken by i. Since frequently being advised to change inconveniences users, the direction-change cost C is added to S_d. We experimentally determined C as 2.

When Condition 1 is met, the surrounding area of the HMD background is more readable than the most readable slot of the object displayed slots. On the other hand, Condition 3 means the surrounding area is more readable than the least readable slot of object displayed slots. When Condition 2 is met, the surrounding area is more readable than the average level of readability.

The system changes the strength of direction change recommendation on the basis of the condition. For example, if a system recommends the change by voice: "You should turn to the right," the loudness of the voice depends on how strongly visibility is being affected by the prevailing conditions.

6 Pilot Study

We subjectively evaluated our method by conducting an experiment using a news flash application that showed short news messages on an HMD. When the test subjects were able to read a news message, they clicked a button attached to their waists. We measured how many messages they read, we found how easy they were to see.

The test subjects were 9 people who had not worn an HMD. Each of them wore the experiment system for about 2 hours.

We instructed the subjects to go about their daily routine as normal. The system showed a news object at long intervals (a 10-minute Poisson-Distribution average) so that the subjects would have a chance to focus on other thing. The news objects were shown for one minute in a slot which is decided by a method randomly selected from the two methods. One is our method and the other is a method that is used to randomly decide the position. In addition, we explained only the process of the experiment to the test subjects, and we do not explain the purpose of the experiment nor the mechanism for displaying.

6.1 Result

The number of times the test subjects could read a news message is shown in Table 2. The test subjects, except for D and H, who used our method responded more frequently than when a random method was used. There was a significant difference in the reaction ratio average ($\alpha = 0.05$).

Table 2: Number of messages and reactions

Test subject	Our method	Random method
A	1/2	1/3
B	3/3	3/4
C	4/8	2/9
D	3/4	4/4
E	3/3	1/4
F	6/7	2/4
G	8/8	5/6
H	7/8	8/8
I	7/7	8/8

Values stand for reactions / messages.

On the other hand, we did not include the function that is recommendation of direction in this experiment. The number of correct reactions where using our method led to a displayed objects being judged as unreadable (readability S is over the threshold T) were few both in our method (5/10) and in the comparative one (3/10). This result suggests that our way of making recommendations will work well. A detailed evaluation is our future work.

7 Conclusion

We have created a way of laying out information for a see-through HMD equipped with a pantoscope camera. This method can be used to determine the ideal layout of information by taking the HMD background image into consideration. If there is no appropriate area for displaying objects in the user's view, our method indicates the appropriate direction from the image around the user. Moreover, to test the effectiveness of our method, we implemented a prototype system that provides the user with a news-flash application.

Our future work is to evaluate the effectiveness of our method in various wearable systems and to expand our method to use other presentation devices such as headphones and vibrating devices.

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