High Efficiency Information Presentation Method for Head Mounted Display on Work Support

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ABSTRACT

We developed an information presentation method for head mounted displays that does not interfere with the field worker. This method achieves low power consumption by a processing method that does not require a graphic processing unit and a camera for space recognition.

1 INTRODUCTION

1.1 Background

Work support systems that exploits digital technology are expected at work sites where improvement in productivity is required [1]. In addition, the occurrence of human errors is a problem, and human errors must be reduced. There is a work support system as a technology to increase productivity and reduce human error. There are two main work support systems that we are developing. (1) Work support information presentation by augmented reality using HMD [2], (2) Work support information presentation using tablet / smartphone [3][4][5]. Among them, work support systems based on augmented reality using HMD (Head Mounted Display) are attracting attention, because it can present information without blocking the operator's hands, unlike using a tablet or smartphone [6][7].

Fig. 1 shows the overview of the work support system with HMD we are developing. The HMD worn by the field worker is connected to the network and can also be connected to an external analysis computer and sensors at the work site. The analysis computer receives information from the HMD and cameras and sensors installed at the work site and analyzes the work. The HMD receives commands from the field worker or analysis computer and changes contents on the display. At this time, the content displayed on the HMD should not interfere with the field worker. In this paper, we propose a user interface that does not interfere with the field worker. Furthermore, we aim for this user interface to eliminate human error.

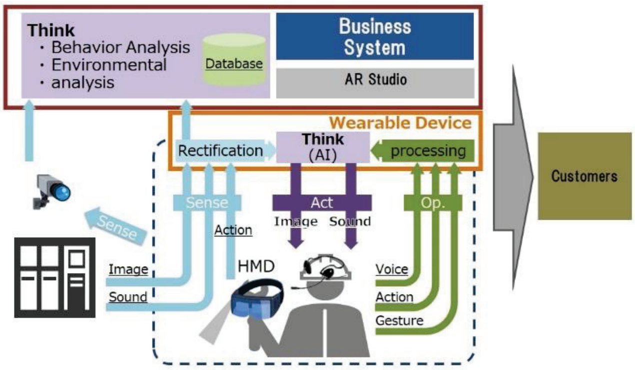

Fig. 1 Overview of work support system

Table 1 Hardware target specification

Item	Target Specification
Power consumption	< 2.5W
Battey life	> 4h
Total weight	< 200g

1.2 Target Specification

1.2.1 Hardware

We performed hardware requirement adjustments to be accepted in the working sites. The HMD worn by the filed worker must not interfere with the work. Therefore, we interviewed field workers to set hardware target specifications. Table 1 shows the hardware target specifications of HMD that were found through the interview. In order to determine the weight target of the HMD, field workers wore some commercially available HMDs and evaluated the weight. It was found that the weight that the worker does not get tired when working for a long time is 200 g.

When we conducted interviews at various work fields, many opinions were expressed that they wanted to use them all day. Therefore, replacing the battery at lunch time, we estimated that the battery duration was required more than 4 hours. Furthermore, from the results of the interviews, it was found that the weight of the battery could be up to 50 g. Therefore, we assume that a battery with a weight of 50 g (10 Wh) is mounted, and the power consumption target for the entire system is set to 2.5 W or less.

1.2.2 User interface

For compatibility of usability and safety, the HMD needs to present information without interfering with the user's work. To meet it, the HMD should not place contents in interfering places in real space.

We thought that content should not be placed in the

Fig. 2 Gaze plot of field worker

space often seen by field workers. Therefore, we investigated where the field workers looked closely during the work. We asked the field workers to wear wearable glasses “SMI Eye Tracking Glasses [8]”, and analyzed the gaze of the field workers.

Fig. 2 shows the result of line-of-sight analysis of one of field workers. The horizontal angle in the figure is FOV (Field of View) 60 degrees. It was found that the field workers often looked at about 30 degrees centering on the lower part in the head direction. So we decided to place the display content at the top of the screen. This result is limited to this work site, and readjustment is required at other sites.

We took a video of field workers doing the work and analyzed their behavior. We classified the behavior of the workers from the images taken by the video camera and calculated each behavior time. We classified the behavior into the following three categories.

(1) Executing and confirming the operation
(2) Confirming the work procedure manual and drawing held in hand
(3) Searching for the operation position.

Other behaviors such as moving, wiping sweat, and talking are excluded from the analysis of this survey. As a result of the analysis, the “(2) Confirming the work procedure manual and drawing held in hand” had the largest percentage of time in the overall work, and the average was about 45%.Therefore, our research starts by presenting work procedures and drawings to the field workers.

2 DEVELOPMENT

2.1 Information Presentation

Fig. 3 shows an overview of the user interface that we have developed. A virtual screen is displayed in a cylindrical shape around the user's head. On the virtual screen, a work procedure manual and drawings related to the current work are placed. The reference position of the virtual screen can be changed by operating the HMD. Therefore, it is possible to present information that does not interfere with the user's work by displaying the content above the work target.

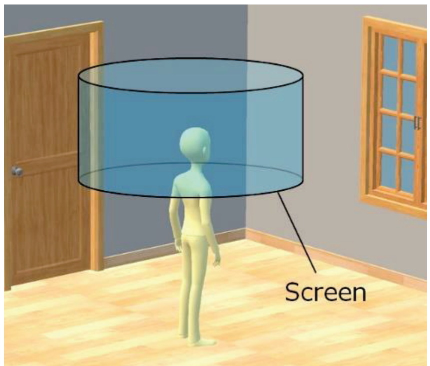

Fig. 3 Overview of user interface

In general, the HMD draws the screen using a GPU (Graphics Processing Unit). However, in order to realize a virtual screen, the GPU consumes a large amount of power. Therefore, we realize a virtual screen with low power consumption by FPGA(Field Programmable Gate Array). We must implement virtual displays with simple processing, because low power consumption FPGAs have low processing power.

We describe how to implement a virtual screen. The HMD tracks the user's head with the acceleration sensor and gyroscope in the HMD, and changes the displayed image. In order to perform head tracking, it is necessary to estimate an angle indicating where the head is facing. In generally, Euler angles, DCM (Direction Cosine Matrix), and quaternions are used as angle expressions. In this study, we use a quaternion with a small amount of computation .

Next, we describe the angle estimation method. The angle can be easily estimated by integrating the output value of the gyroscope attached to the head. However, a phenomenon called drift occurs due to the accumulation of the measurement error, because the value output from the sensor includes a measurement error. If drift occurs, the angle will shift even though the sensor is not moving. Therefore, several methods have been proposed to improve estimation accuracy using sensors that can acquire head movements other than angular velocity [9][10][11]. In this study, we use the Madgwich filter [11], which has the least amount of computation and relatively high accuracy. The Madgwich filter can determine the angle using gyroscope / accelerometer / magnetometer or gyroscope / accelerometer. We assume that the HMD developed in this study will be used for industrial purposes, and it is expected that there will be many devices that generate electromagnetic waves in the field. For this reason, we use a Madgwich filter that does not use magnetometer in this study. However, angles cannot be easily reflected in quaternions, because quaternions are expressed by vectors and rotations,. Therefore, the HMD converts from the quaternion expression to the Euler angle expression (Roll, Pitch, Yaw) for calculation.

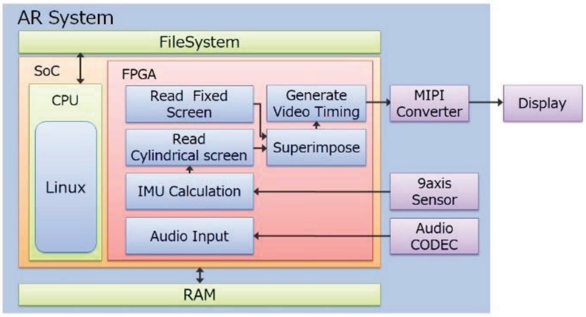

Fig. 4 Block diagram of the system

The virtual screen is stored in two dimensions on DDR memory. Here, we assume that the virtual screen is expanded to the address *ADDR* of the DDR memory. The virtual screen is assumed to be *VDW* [pixel] in the horizontal direction, *VDH* [pixel] in the vertical direction, and 4 [bytes] per pixel. Then, the address A (*px*, *py*) of the desired pixel (*px*, *py*) can be obtained by the following equation.

$$A(px, py) = ADDR + (VDW * py + px) * 4$$

The display area is an area obtained by extracting *DAW* [pixel] in the horizontal direction and *DAH* [pixel] in the vertical direction from the pixel (*px0*, *py0*) with the upper left pixel of the virtual screen as the origin (0, 0). Pixels (*px0*, *py0*) are calculated using the following equations.

$$px0 = \left(\frac{VDW - DAW}{2}\right) - \frac{Yaw}{FOVW} * DAW$$

$$py0 = \left(\frac{VDH - DAH}{2}\right) - \frac{Pitch}{FOVH} * DAH$$

Here, *FOVW* [pixel] indicates the horizontal direction FOV (Field of view) of the HMD, and *FOVH* [pixel] indicates the vertical direction FOV of the HMD. Since the pixels are continuous in the memory space in the horizontal direction, the HMD can perform burst reading at high speed. By this method, we realized the virtual screen with the simple processing of reading data from memory.

2.2 Implement

Fig. 4 shows a block diagram of the system. We developed a board on which Zynq [12], an SoC (System on a Chip) with an integrated FPGA and CPU, is mounted. By implementing these processes in a FPGA, the latency from head movement to display was 1 frame (about 16.6 ms), and the power consumption of the entire system was 2.0 W. The power consumption excluding optical parts is 1.5W. The weight of the board is 7.5g.

3 EXPERIMENT

We experimented with our HMD. Fig. 5 shows the confirmation time of the work procedure with and without the HMD in six subjects. If the subject does not wear the HMD, he/she performed work with reference to the procedure manual printed on paper. In addition, we eliminated the influence on the procedure confirmation

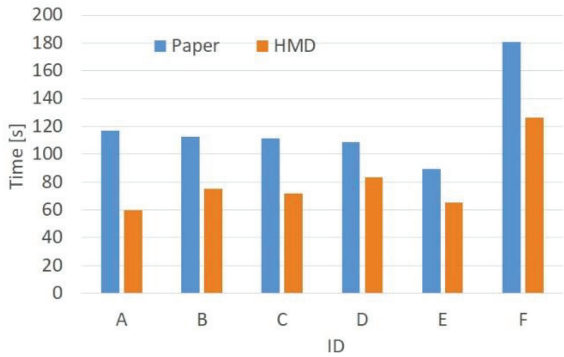

Fig. 5 Confirmation time of procedure manual

time due to learning the work procedure by changing the work procedure between the work with the HMD and the work using the procedure manual printed on paper.

Procedure confirmation time decreased by an average of 33% by wearing our HMD. In addition, in the work without HMD, a work error occurred due to misrecognition in total of three times during the experiment, but it did not occur in the work with HMD attached.

4 CONCLUSION

We have developed a low power HMD that implements a user interface that does not interfere with the user's work. The developed board operates at 1.5W and weighs 7.5 g. We shortened the working time by using the developed HMD and eliminated human error

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