HMD system for visual field impaired students

Hiroyuki Kawabe†
Department of Social Work, Faculty of Social Work
Kinjo University, Hakusan, Japan
Tel: (+81) 76-276-4400, Email: kawabe@kinjo.ac.jp

Yuko Shimomura
Department of Social Work, Faculty of Social Work
Kinjo University, Hakusan, Japan
Tel: (+81) 76-276-4400, Email: shimo@kinjo.ac.jp

Hidetaka Nambo
Faculty of Electrical and Computer Engineering, Institute of Science and Engineering
Kanazawa University, Kanazawa, Japan
Tel: (+81) 54-279-2371, Email: nambo@blitz.ec.t.kanazawa-u.ac.jp

Shuichi Seto
Department of Business Administration
Kinjo College, Hakusan, Japan
Tel: (+81) 76-276-4411, Email: seto@kinjo.ac.jp

Hiroshi Arai
Department of Art
Kinjo College, Hakusan, Japan
Tel: (+81) 76-276-4411, Email: arahiro@kinjo.ac.jp

Abstract. The purpose of the research project in progress including this study is to construct a system that a visual impairment student can attend the lecture of the university without any inconveniences. In this research project, we developed support glasses for them. The support glasses is consist of two cameras and a head mounted display (HMD), which gives the visual field impaired a normal person's visual field. One of cameras is for capturing normal person's visual field and another is for observing the eye movement and detecting the point of eye of wearer of HMD. In HMD, the picture captured by the former camera is displayed at a certain location depending on the situation of lack of the visual field and the point of eye. This is the moving window for reducing fatigue of the person of HMD wearing, which is caused by looking at small images with a fixed gaze without moving eyeballs. In this study, we show the system we developed.

Keywords: Visual field defect, Tunnel vision, HMD, Supporting glass

1. INTRODUCTION

The glaucoma and the age-related macular degeneration mainly bring diseases in visual field impairments. Then, visual field impaired students, especially ones by the glaucoma increases in universities (JASSO 2012). Therefore we have to prepare to accept them and have to keep information supports for them.

There are various kinds of the visual field defect, such as the tunnel vision (a lack of perspective), the scotoma (a half blind) and the hemianopsia (a central scotoma). The main stream of research on the visual field defect is the medial study. In these studies glasses with fish-eye lens or prism sheets are tried as medical supports for the visual field impaired persons. Both of them has a problem that for the former the visibility is low and for the latter view is discrete at the boarders of the prisms. There is another type of studies using information technology. A system that enhanced outer edges of view captured by camera are overlaid on a residual field of view was proposed. However, the overlaid image was too complicate to understand sights.

From 2011, we built tunnel vision support glasses to provide the normal person's view (Shimomura et al. 2011, 2012, 2012, 2013 and 2014, Kawabe et al. 2014 and 2015). Visual images are projected onto the glasses in real time. A person wears the glasses and can walk around with the glasses. For our glasses we adopt a head mounted display (HMD). Depending on the situation of lack of the visual field, the view captured by a camera is displayed at suitable location on the screen of HMD. At that time, eyestrain becomes a problem, which is caused by looking at a small image with fixed gaze without moving eyeballs. In this study, we briefly show the outline of our project and explain the solution we work out.

2. OUTLINE OF OUR PROJECT

Our project is composed of three processes, (i) an embodiment of an ultra-small camera into HMD, (ii) a detection of the ocular movement, and (iii) a migration of the window to display an image depending on the point of eyes. In this section, we show the outline of our project.

To observe the movement of eyeballs, we disassemble an USB camera and mount the parts of the camera at the inside of HMD so nicely that one can wears HMD and the camera can captures the image of eyeballs. We analyze images captured by the camera set inside of HMD to detect the movement of eyeballs. As the camera is mounted at the inside of HMD, the ocular image captured by the camera will be dark and low in contrast and it will be not so easy to detect the movement of eyeballs. Then we make the image clear and sharp by the image processing techniques, for example, an adoption of an infrared camera for capturing eyes, a removal of an infrared filter which is covering lens of the camera, and an enhancement of contrast. Then we determine the point of eyes. As the tunnel vision person cannot see the whole screen of HMD, we show a shrunken image in the point of eyes with the movement of eyeballs and aim at reducing the fatigue by HMD wearing by keeping the freedom of the eyeball movement.

3. EYE TRACKING

For detecting the eyeballs movement or the eye tracking, the image processing is necessary mentioned in the above. In this field, there are some studies, such as the Haytham Gaze Tracker. The Haytham Gaze Tracker is one of the eye tracking systems, which is developed by a research group at the IT University of Copenhagen, Denmark (Agustin et al. 2009 and 2010; Johansen et al, 2011), and are maintained as an open source project. “Haytham is an open source video based eye tracker suited for head-mounted or remote setups. It provides real-time gaze estimation in the user’s field of view or the computer display by analyzing eye movement. Haytham offers gaze-based interaction with computer screens in fully mobile situations. The software is built by C#, using Emgu and AForge image processing libraries.” This requires a webcam or video camera with night vision and infrared illumination and a fairly decent computer. Recent portable PCs are powerful enough for executing the Haytham Gaze Tracker. However, the required cameras are difficult to get in japan.

We have another way to construct the eye tracking system, “built from scratch”. To develop the eye tracking system for our demand, we use OpenCV (Open Source Computer Vision Library), which is an open source computer vision and machine learning software library and originally developed by Intel corp. (Nakagawa 2012) OpenCV is a library for C/C++, Java, and Python. Mac OS X, UNIX, Linux, Windows, Android, and iOS, etc. are supported as platform of OpenCV. The libraries are very powerful; “OpenCV was designed for computational efficiency and with a strong focus on real-time applications. Written in optimized C/C++, the library can take advantage of multi-core processing. Enabled with OpenCL, it can take advantage of the hardware acceleration of the underlying heterogeneous compute platform. Adopted all around the world, OpenCV has more than 47 thousand people of user community and estimated number of downloads exceeding 9 million. Usage ranges from interactive art, to mines inspection, stitching maps on the web or through advanced robotics.” By using OpenCV we write our own eye tracking software from scratch or modify the Haytham Gaze Tracker for our requirements, and execute pre- and post-processing of image.

Since the eye has two parts, the white and the black of the eye, it is enough for us to treat the gray scale image. This situation is suitable in the viewpoint of the computational complexity.

With the movement of the eye, the distribution of the gray scale pixels captured changes. In the gray scale image, each pixel has a value from 0 to 255 corresponding to from black to white. When we interpret the gray scale pixel distribution as a mass distribution, the change of the gray scale pixel distribution becomes the movement of the center of weight. Therefore we can detect the movement of the eye by calculating the center of weight of the gray scale image.

4. MOVING WINDOW

Now we can detect the point of eye. The next step is to show the captured image at the well working region of eye with movement of eyeballs. Therefore we transform the movement of eye into the movement of window. For following the eye, a high sensitive or a quick following makes the window quiver, on the other hand, a low sensitive or a dull following gives a delayed movement of window. Therefore we have to introduce and adjust sensitive parameters.

When we move our eyeballs, we have will to see that direction of eyeballs. Therefore, it is natural that the image of that direction is larger than other directions. This sort of distortion of image is given by the Affine transformation of geometry.

5. NUMERICAL EXPERIMENT, RESULT AND DISCUSION

We started from a preliminary experiment, the center of weight calculations for still pictures. As the pixel values are expressed as *unsigned char* in C language and are from 0 to 255 corresponding to from black to white in the gray scale image and we want to trace the movement of the black eye, we regard the reverse of the bit pattern of the pixel as the mass, i.e. the darker is the heavier. The origin of coordinate is set at the upper left corner. The direction of the x-axis and that of the y-axis is top-to-bottom and left-to-right, respectively. The coordinate of the lower right corner is (0, 0).

The calculated coordinate of the center of mass of the right directed eye and that of the centered one is (0.480, 0,510) and (0.519, 0.517), respectively. The x coordinate for the right directed eye is smaller than that for the centered eye. This means that the center of mass moves on our left and the eye moves to the right. Therefore we confirm the calculation of the center of weight of the gray scale image of eye gives the movement of eye.

As a movie is made from continuous still images, the movement of eye will be obtained by performing the above-mentioned process on each still images of the captured movie.

According to the result for the gray scale still image, we treated gray scale movies. Though we can extract the movement of eye by the movement of the center of mass, amplitudes of the movement of the weight center are smaller than those of eye, and the difficulty of determination of the direction of eye is expected. Therefore we abandon the scheme using the gray scale movie.

The reason of the heavy or insensitive motion of the center of mass is originated from the small contrast of the gray scale image. So we enhance the contrast by transforming gray scale images into monochrome ones. In this process, we introduce a threshold value bordering white and black. By suitable choice of the threshold value, we can make the amplitude of the movement larger than the case of the gray scale image and can determine the direction of eye. Then we display images captured by camera in the window that moves by the coordinate of center of mass.

Now we show our HMD system in Figs. 1 and 2, which are the whole view and the inside view. As mentioned above, our HMD is composed from three parts, HMD, the out-viewing camera and the eyeball observation camera. In these figures, a black camera on HMD is the former and a white one between a frame and a head pad is the latter. The specification of the system is given in the tables 1 and 2.

Figure 1: HMD system

Figure 2: Inside view

Table 1: Specification of HMD

Maker and model	Sony HMZ-T3
Resolution	1280 x 720
Virtual screen size	750 inch apart from 20m
Weight	320g

Table 2: Specification of cameras

Specification	Outer camera	Inner camera
Maker and model	BUFFALO BSW32KM03BK	ELECOM UCAM-DLD200BAWH
Pixels	3,200,000 pixel	2,000,000 pixel
Imaging device	CMOS	1/4.5 inch CMOS
Resolution	2016 x 1512	1920 x 1080
Focus	Fix	Auto

The last stage is to give images on the moving window. We defined and introduced a transformation matrix connecting the point of eye to the location of the window showing images, and adjusted the location of the window by modifying elements of the matrix. Controlling the moving speed of the window, we introduce the response parameters that describe the sensitivity of the movement of window following that of eye. The parameters depend on performance of camera and speed of image processing. By tuning and adjusting the parameters, the window could smoothly follow eye. To reflect user’s will of seeing the specific direction, by introducing the Affine transformation we modified the shape of a projected image so that the region along eye direction is larger another region.

6. CONCLUDING REMARKS

The purpose of the research project in progress is to construct the system that visual impairment students can attend the lecture of the university without any inconveniences. In this study, we show the outline of our project and discuss about the eye tracking technique by OpenCV and the moving window system. Our system gives the visual field impaired student a normal person's visual field with HMD. In HMD the picture from the camera is displayed in the residual part of the visual field with following the eyeball motion in the window moving with the point of eye. In our system, it is characteristic that the system keeps the freedom of motion of eyes by the eye tracking in HMD.

In this study, we resolve some problems. First, we determined the direction of eye and the position of the moving window by the coordinate of center of mass. This was a problem of a transformation matrix from the coordinate of the weight center to that of the moving window. The second was the smoothness of movement of window in HMD. Third was a camera in HMD, which captured the movement of eye. Recent USB cameras have efficiency enough for capturing images under daylight. However, inside of HMD it is dark and it is difficult to capture images clearly by the camera mounted there. We can imagine that the region around eyes is dark and the intensity of light is very weak as the eyes are covered by HMD. Then we made the image clear and sharp by the image processing and distinguish between the iris of the eye and the white of the eye. Moreover, we introduced a camera removed an infrared filter covering lens.

If our studies are developed, it becomes easy for higher educational organizations to introduce the support systems for the visual field impaired students in classroom and the barrier of entering the organizations becomes lower. Moreover, we can show the usage models of HMD with external camera such as Google glass and the power of supporting the visual impaired persons.

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