International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 12 (2019), pp. 2849-2851

A Study on the Visual Function Reinforcement Training Design using the Pupil Recognition Program

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Abstract

Despite the increasing interest in maintaining individuals' healthy life in the midst of a rapidly aging society, people experience greater rates of visual function impairment and various eye diseases causing such results. Thus, the ratio of the population using medical aids such as glasses and contact lenses has been continuously increasing. [1~3] The recent studies show that ocular diseases such as myopia or reflexes, which are the main causes of decreased visual function, can be treated for partially restored visual function or improved visual function through visual function training. [4~5]

This study provides a visual function reinforcement training design using the pupil recognition program that effectively prevents the prevalent refractory ophthalmologic disorders impairing visual function with customized diagnosis and prevention of refractive ocular diseases, customized treatment of visual function, and analysis and management of treatment effect data collection.

Keyword: Vision Therapy, Device, Visual Function, Calibration, Eye Disease, Reinforcement, Training

I. INTRODUCTION

While there are various medical aid devices for visual function training in the market, the currently existing medical devices are limited in terms of training and treatment effects due to its simplicity, lack of result analysis, absence of integrated specialist diagnosis, and insufficient accessibility of treatments to patients as they can receive them only by visiting hospitals. While it is necessary that patients receive regular visual diagnosis and doctors obtain patient record management for the effective prevention and treatment of ocular disease, patients experience burden in their time and budget to visit the optician for their every visual test, the only option currently available for patients. [6-7]

In order to alleviate these difficulties, VR images can be used for visual function reinforcement training by diagnosing the visual acuity with observations of the center of the retina and the condition of the eyes with the measurements of central vision. Further, by using the VR device, patients can overcome their accessibility challenges with the customized diagnosis and training program designs, which improve the overall effectiveness of the treatments. [8]

This study focuses on providing solutions to these existing challenges by implementing visual function reinforcement training designs using pupil recognition programs in a wearable device, VR, which consists the visual analysis and customized VR content-based training and eye care service features for the entire treatment periods of eye diseases.

Ⅱ. DESIGN OF EXPERIMENTAL EQUIPMENT

Ⅱ. Ⅰ Experimental Equipment

The experimental equipment used for this study consists a pupil tracking camera that collects the movement record of pupils with a series of pictures taken. Further, this device features custom patient management program that collects data, categorizes training results, and evaluations of patients' diligence in training based on images taken during the treatments. The specifications of training device are shown in Table 1. This study selected the highest performing, definition camera that is capable of tracking pupils. Fig. 1 shows the overall structure and features of the device.

Table 1. Specifications of Training Device

Device Feature	Specification
Display	WQHD OLED
Resolution	2560 x 1440
Refresh Rate	70Hz
Field of view	90 ~ 199 degrees
Tracking area	-
Built-in audio	3.5mm audio jack
Built-in mic	No
Controller	No
Sensors	120 frames per second eye- tracking system(x2), less than one degree of accuracy
Connections	HDMI 1.4, USB 3.0, USB 2.0

Fig. 1. Wearable device for visual function reinforcement

Ⅱ.Ⅱ System Development of Training Programs

In order to test the pupil recognition rate, the recognition rate is confirmed through several iris pupil sampling images, and the image correction (optimization of the numerical value of the HSV value) before the image analysis is performed. Further, this device adjusts the error range by comparing the sizes of pupils in images taken before and during the training and obtaining approximate values of collected data with the images. The training system is checked with the image, and the recognition rate is adjusted by adjusting the frame, the image transmission unit, and the brightness and contrast of the hardware. In addition, the data logs are accumulated during the right-left training and provides a graph after the training.

Ⅲ. DESIGN OF VISUAL FUNCTION REINFORCEMENT TRAINING

Ⅲ.Ⅰ Image Collection during the Control-mode Training

In this study, the pupil recognition rate tests are performed through a pupil tracking camera. The pupil sizes are measured by taking pupil images from the equipment as shown in Fig.2.

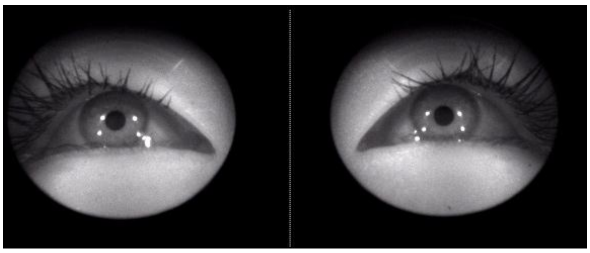

Fig. 2. Image of pupils taken by the device

The obtained image is converted into grayscale, and a single sample image, in which the value of each pixel represents the amount of light, is obtained, then only the information of luminous intensity is transmitted. These images are known as black and white or monochromatic and are made up of gray shades, so that they have various structures ranging from the most luminous black to the most intense white. The image and source code to convert from RGB model to grayscale are shown in Fig.3.

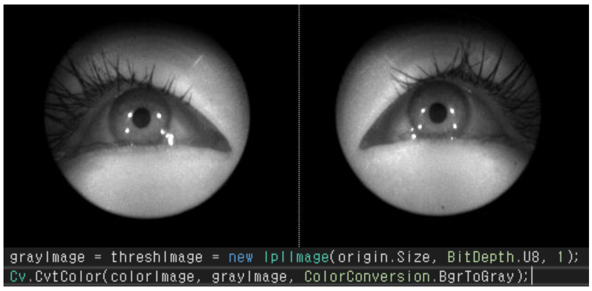

Fig. 3. Source code for converting the collected image to the grayscale

In order to classify the image into black and white, the pixels that are lighter than the given threshold are all treated as white, otherwise the process is switched to black. The image and source code are shown in Fig.4. The noise reduction method used in this device is as follows: after removing the eyelashes from the image, divide the entire image into small regions of a certain size, sort all the pixels of the divided region in order of magnitude, and find the corresponding value in the middle.

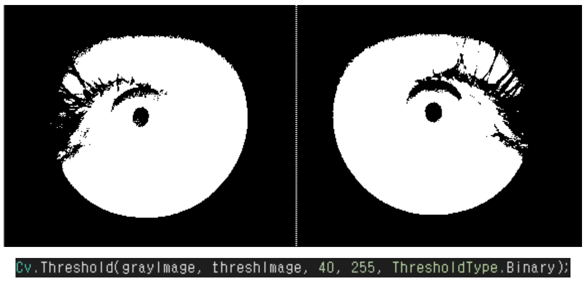

Fig. 4. Source code for converting the image to black and white

Ⅲ.Ⅱ Camera Image Processing

Pupil search is performed on the similarity with the boundary line of the pupil photographed through the pupil tracking camera, and image information necessary for the image sending control unit is transmitted. In Fig. 5, the boundary lines are shown based on the images of the pupil tracking camera and the pupil region. The bounding box surrounding the boundary is drawn and the small boundary (noise) and the large boundary (large noise in the eyebrow portion) are removed through the bounding box, and the similarity of the circle is obtained through the length of the boundary line.

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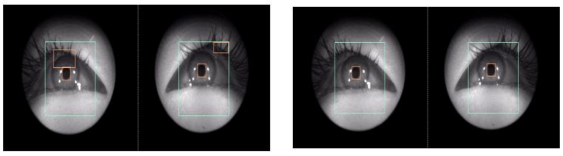

[Left] Before applying similarity algorithm

[Right] After applying similarity algorithm

Fig. 5. Image comparison of the before and after applying circle similarity algorithm

Ⅲ.Ⅲ System Analysis

Using this platform, the device collects images showing the position of the pupil when applying the training contents, selects appropriate training contents, and applies the training time and necessary filter to the left and right eyes then performs the diagnosis. The user draws a circle with a radius of boundingbox.Width divided by 2 based on the center point and displays it as shown in Fig.6. Through the client management program, the device selects the diagnosed training method and evaluates the patient's training performance by pupil recognitions. When the training is over, the pupil image and the images of distracted patients during training are transmitted to the platform. This device is capable of developing models based on the platform database structure. Fig. 7 shows the final image after processing. In addition, the results and training details will be stored. After the training is completed, this device allows the primary care physician to review the patient's training history and results that are stored in the device.

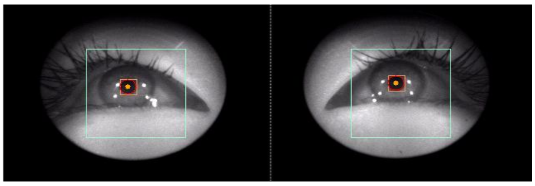

Fig. 6. Representation of the pupil

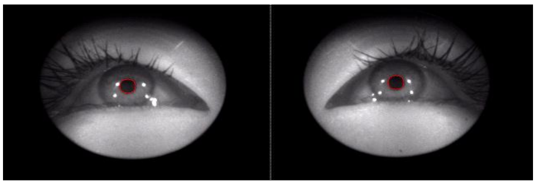

Fig. 7. Final image for the platform database

Ⅳ. CONCLUSION

This study analyzes the efficiency of the image analysis system of visual reinforcement training using pupil recognition programs and the results are as follows:

1. It is effective to improve product performance and usability level of the device by developing a business model that is used for ophthalmology.
2. Unlike surgeries, the pupil recognition program developed based on the database platform structure can be applied for providing diagnosis and treatments that adjust the structures of eyes and surrounding muscles with visual function reinforcement training.
3. It is possible to provide products and services that enable visual enhancement training by applying programs for strengthening amblyopia and presbyopia.
4. This study verifies the validity of the implementation of algorithms for movement and motion control of objects in virtual space according to user visual characteristics based on their recognition of the focus confirmation situations presented in training program.
5. Although the distance of focus may be different for each patient, it is possible to repeat the training results by implementing the recording function for the distance between the user's eyes and the object during the training.

ACKNOWLEDGEMENT

This research was supported by a grant from University Research Park Project of Busan National University funded by Busan Innovation Institute of Industry, Science & Technology Planning

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