Development of the eyeglasses-based electrooculogram (EOG) for the objective measurement of the visual acuity

Hyuk-June Moon[1], Hyoun-Joong Kong[2], In Bum Lee[2], Sung Hoon Kwon[1], Hee Chan Kim[3], Jeong- Min Hwang[4], and Jong-Mo Seo[1, 4]

[1] School of Electrical Engineering, Seoul National University, Seoul, Korea
[2] Interdisciplinary Program, Bioengineering Major, Graduate School, Seoul National University, Seoul, Korea
[3] Department of Biomedical Engineering, College of Medicine, Seoul National University, Seoul, Korea
[4] Department of Ophthalmology, College of Medicine, Seoul National University, Seoul, Korea

Abstract — **The objective measurement of the visual acuity is one of the most important issues in ophthalmology clinics, and the optokinetic nystagmus (OKN) can be a good candidate for this purpose. In this paper, an eyeglasses-based electrooculogram (EOG) for the detection of the OKN is introduced. It is convenient to use and allows the refractive error correction for the visual acuity measurement.**

To evoke the OKN, moving strips with various spatial frequencies are generated on the monitor in front of the patients' view. The OKN is observed by the wearable EOG eyeglasses. Both the EOG signal acquisition circuit and chrome electrodes were integrated with the eyeglasses. The EOG signal is processed through an acquisition circuit to personal computer for the further analysis and the real-time display of the EOG signal according to the visual stimuli.

The proposed system can monitor OKN well, while making patients more comfortable by removing bulky and burdensome devices. Also it can adopt the lenses for the refractive error correction. Those advantages make visual acuity test more objective and accurate.

Keywords— **Visual acuity test, objective, EOG, wearable, OKN**

I. Introduction

A standard method for visual acuity test is necessary to make comparisons and to record people's visual acuity. There are some common methods used widely around the world, such as Snellen chart test. Nevertheless, those methods depend on verbal responses of the patient. Therefore, those cannot be used for infants, nonverbal subjects, mutes and people who have some mental disease. Furthermore, patient can tell a lie intentionally. It means the methods usually used are subjective. Hence, an objective method for assessing visual acuity is required.

Visual evoked potential(VEP)[1], optokinetic nystagmus(OKN)[2,3] and preferential looking technique[4] could have been tried for objective visual acuity test. The OKN is a specific eye reaction to the patterns that move across one's view repeatedly. It occurs involuntarily, so the measurement could be objective compared to the traditional Snellen chart test. Therefore the method using OKN to provoke patient's eye movement was chosen for an objective evaluation of visual acuity.

To track and record eye movement, a camera based tracking[5,6,9], contact lens[7] and EOG-based tracking technique[8] are used in various research area. Among these techniques, EOG is simple and non-invasive, so we suggest an objective visual acuity test system using wearable EOG eyeglasses. It can be made with relatively simple circuits and in lightweight structure. It can provide not only comfortable test environment for the examinees doing the test, but also accurate and objective results for the examiner.

II. Materials and Methods

To test the visual acuity with OKN, a test system has to observe the OKN by tracking the eye movement. The block diagram of the total system is shown in Fig.1. It is composed of stimulation system, EOG-eyeglasses, signal acquisition circuit, DAQ board and personal computer (PC).

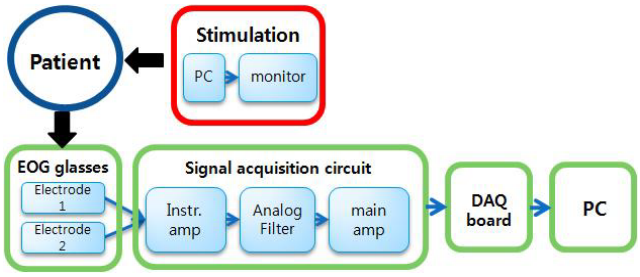

Figure 1. Block diagram of the system

1) EOG eyeglasses

In our research, the glasses type EOG system is adopted to track eye movement. When someone wears a glasses, the glasses is in contact with the face at some points like temples. Therefore, just by taking place the EOG electrodes on

O. Dössel and W.C. Schlegel (Eds.): WC 2009, IFMBE Proceedings 25/XI, pp. 271–274, 2009.
www.springerlink.com

the proper parts of the glasses, EOG signals can be acquired from the examinee wearing the special glasses, without bulky tools. The appearance when wearing the EOG-eyeglasses is shown in Fig.2. As shown, it looks like just an ordinary eyeglasses.

Figure 2. Eyeglasses-based EOG proposed in this paper

On measuring EOG, Ag-AgCl electrodes with sticky electrolyte gel are usually used to lower impedance and to help adhesion to skin. However, this makes the examinees uncomfortable, so we used non-adhesive chrome electrodes without gel instead of the Ag-AgCl electrodes, even though signal-to-noise ratio(SNR) of system might be decreased. Thus the customized signal acquisition circuit amplifying EOG signals and filtering off noise is added.

2) Signal acquisition circuit

The EOG signal acquisition circuit is designed to amplify EOG-signals while filters off noises. It uses 5V-VCC and power supplied from the PC by universal serial bus (USB) data cable instead of external power sources. The circuit has an instrumentation amplifier that changes differential-input to single ended-output and amplifies the signal. Also, it has high-pass-filter (bandwidth: 0.01Hz) removing direct current offset noise, low-pass–filter (bandwidth: 170Hz) filtering out high frequency noises. The circuit is designed by using OrCAD pspice (Cadence Design Systems, CA, U.S.A.) and implemented on Universal printed circuit board(PCB).

3) DAQ and Signal Processing

The DAQ board part of system is NI USB-6008 (National Instrument Inc., U.S.A.). The EOG signals amplified and filtered by the analogue circuit must be transmitted to the PC. The DAQ board converts this analog signal to digital signal and send to the PC by USB cable. The USB cable also supplies power to the circuit.

The signal transmitted to PC is processed on the LabView program (National Instrument Inc.) by assembling several data processing blocks on it. Its data processing block diagram and user interface is shown in Fig.3. The data sampling rate of the signal is 500Hz.

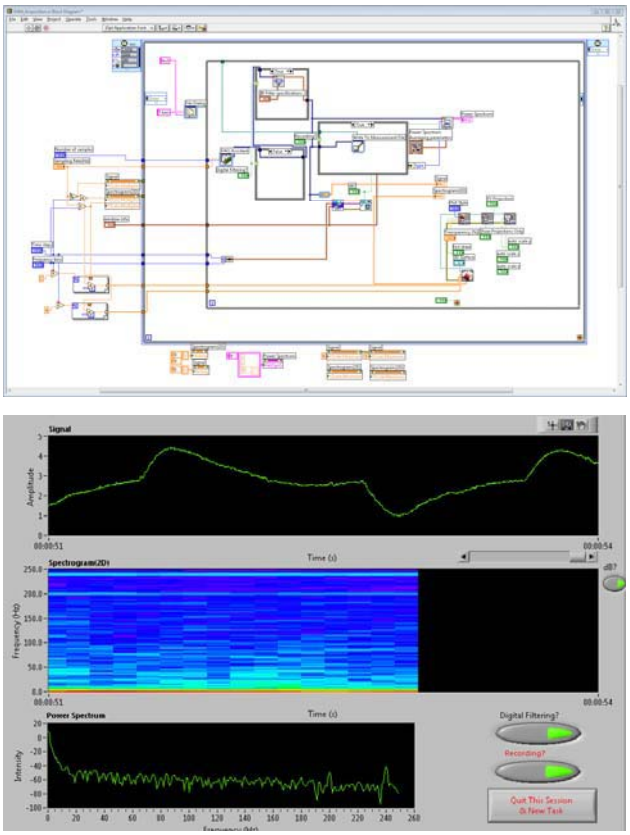

Figure 3. Block diagram of the data process (top) and the user interface of the test, showing EOG waveform and its power spectrum (bottom).

To remove power interference, 60 Hz and its harmonic frequency, 120 Hz, notch filters are added to the system. As both the analogue circuit and DAQ hardware use USB power supplied by PC, AC power interference noise is dominant as shown in Fig.4. By adding two notch filters, we can acquire even more clearer waveform and make SNR higher.

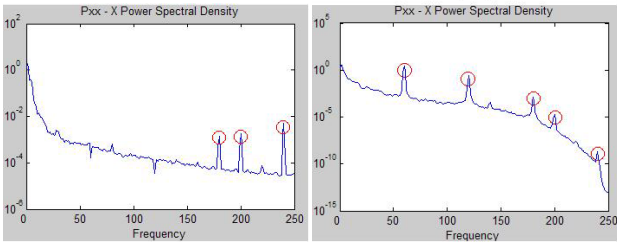

Figure 4. Power spectrum with two notch filters (60,120 Hz) (left) and without notch filter (right)

4) Stimulation

Our system adopted stimulation program and method from the research of Shin et al.[9] as shown Fig. 5. Among induction method and depression method, the induction method is adopted. Black and white stripes presented on a monitor located in front of the patient, which move right direction continuously to evoke the OKN responses of the examinee. If the width of stripes be too narrow to be discriminated, the OKN is not observed. By changing the width of the stripes, the visual acuity is assessed.

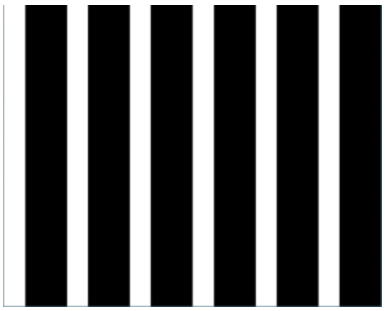

Figure 5. OKN Stimulus pattern

III. Results

The EOG acquisition system proposed in this paper works well. The system is designed to swing 0V to 5V and use 2.5V as a virtual ground. If the signal is higher than 2.5V, it is regarded as a positive signal and it means that the examinee looks right side. In contrast, if the signal is lower than 2.5V, it is regarded as a negative signal, even it is higher than 0V and the negative means left gaze.

At first, we have test the system's eye tracking ability by inducing intentional eye movement. It tracks eye movement well and signal waveform is very clear and obvious owing to notch filters. However, if examinee keeps on looking one point, EOG become have dc component only, so EOG signal is attenuated to 0(2.5V) independent of eye gaze. If we implemented Human computer interface (HCI) system, it might be serious problem. In visual acuity test, however, it is not important because we want to track the eye gaze changed continuously.

After verifying eye tracking ability, we assess the visual acuity of the patients as the method mentioned previously. The result EOG signal waveform is shown in Fig.6 (b). The signal is smaller than the signal of voluntary movements, nevertheless it clearly shows slow phase and fast phase of the OKN. So, we could approximate examinee's visual acuity successfully by using proposed system.

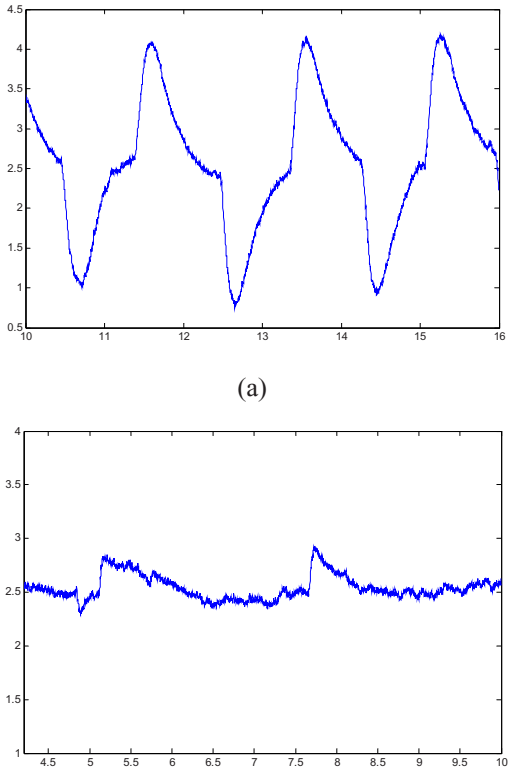

Figure 6. (a) EOG signal waveform reaction to intentional eye movements (b) EOG signal waveform reaction to OKN stimulation patterns

IV. Discussion

This paper proposes objective visual acuity test system using wearable EOG eyeglasses and its application. There are several visual acuity test method, such as visual evoked potential(VEP), optokinetic nystagmus(OKN), preferential looking technique. But VEP makes much discomfort to the examinees, because it needs many electrodes that adhere to the scalp. In addition, analysis of VEP signal is not easy to be quantified. Preferential looking technique is usually used for infants, and somewhat subjective above those methods. Therefore, the method using OKN is chosen in this paper. The OKN can be observed only when patients sense the moving pattern and it occur involuntarily, so it is suitable for objective measurement of the visual acuity, and it is also verified in several papers. [5,6,9]

Another important point of the system is EOG-based eye tracking technique. There are several methods more accu-

rate than EOG, but most of them are inconvenient to use and make patients somewhat uncomfortable. On the contrary, our system based on eyeglasses-EOG is lightweight and looks simple. By using the glasses with chrome electrodes, the system does not need sticky electrodes and also it does not interfere examinee's view at all. In addition, EOG is easy to analyze because measured voltage itself indicates eye movement directly. It makes total system simple and fast.

The system does not need an external power source which might make the system heavy and bulky. Instead, the system uses USB power supplied by PC. That's enough to operate the system, because the system consumes very low power. That is another advantage of the system.

In visual acuity test, making patient his or her best condition is very important issue to get one's visual ability more accurately and objectively. In point of that view, we believe that proposed system is suitable for the visual acuity test.

However, for the better visual acuity measurement, more clinical tests are required to verify its usefulness. Also wireless glasses-computer interface technique, such as Bluetooth, should be considered to offer more comfortable test environment. The signal processing part should also be improved, because there might be some noises caused by eyeblink or other EMG components such as from the temporalis muscle. Those noises have to be detected and removed from the signal waveform by using software algorithms.

V. Conclusion

In our research, we successfully implemented the proposed objective visual acuity test system using EOG eyeglasses. The system can detect eye movement accurately and effectively. Also, it provides patients more comfortable and convenient test environment.

Acknowledgement

This study was supported by a grant of the Korea Health 21 R&D Project, Ministry of Health, Welfare and Family Affairs, Republic of Korea, A080299

References

1. E Marg, DN Freeman et al. (1976) Visual acuity development in human infants: evoked potential measurements Invest Ophthalmol Vis Sci.
2. Schmid KL, Wildsoet CF (1998) Assessment of visual acuity and contrast sensitivity in the chick using an optokinetic nystagmus paradigm. Vision Res 1998;38:2629-2634
3. Kim MS, Choi YS, Lu WN, et al. The development of an objective test for visual acuity assessment using optokinetic nystagmus stimuli presented head-mounted display:Seohan Objective Visual Acuity Test. J Korean Ophthalmol Soc2001;41:863-871
4. S Sokol, VC Hansen et al. (1983) Evoked potential and preferential looking estimates of visual acuity in pediatric patients, Ophthalmology
5. A.Tomono et al. (1989) A tv camera system which extracts feature points for non-contact eye movement detection, in: Proc. Of the SPIE Optics, Illumination, and Image Sensing for Machine Vision IV, vol.1194, pp.2-12
6. Y. Ebisawa et al. (1993) Effectiveness of pupil area detection technique using two light sources and image difference method, in: A. Szeto, R. Rangayan(Eds.), Proc. Of the 15th Annual Internat. Conf. of the IEEE Eng. In Medicine and Biology Society, pp.1268-1269
7. D.A. Robinson, (1963) A method of measuring eye movements using a sclera search coil in a magnetic field, IEE Trans. Biomed. Eng. 10 137-145
8. A. Kaufman et al. (1993) An eye tracking computer user interface,in:Proc. Of the Research Frontier in Virtual Reality Workshop, IEEE Computer Society Press, pp.78-84.
9. Shin YJ, Park KH, Hwang JM et al. (2006) Objective Measurement of Visual Acuity by Optokinetic Response Determination in Patients With Ocular Diseases, Am J Ophthalmol, 141:327-332.