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Electroretinogram (ERG) Signal Processing & Analysis in Labview

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Abstract*—Non-invasive recordings of the retinal activity have an important role to play in the diagnosis of retinal pathologies. Medical examination, based on the recordings of the electrical activity of human eye, to diagnose the state of the retina is called electroretinography. The clinical ERG is the recording of electrical potentials evoked by a flash of light and picked up at a distance i.e., at the cornea. For diagnostic purposes, an electrode is placed on the cornea and special kind of visual stimulus is presented to a patient. Depending on the stimulus parameters, different responses can be obtained. This paper aims to demonstrate the possibility of finding features reliable for more precise distinguishing between standard and abnormal Electroretinogram (ERG) recordings. Understanding the specific features (onset, time delay, amplitude, line shape) of the ERG components and their relationship represents the principal aim of past and present research in the field of ocular electrophysiology. ERG waveforms are simulated using National Instruments LabView graphical programming environment. Analysis is carried out to detect abnormalities. ERG belonging to a subject with abnormality called Achromatopsia (ACR) and ERG belonging to a subject with abnormality called Congenital Stationary Blindness (CSNB) are simulated and analyzed. The proposed system is readily usable low cost alternative to sophisticated costly equipments used in hospitals for the ERG signal analysis purpose. One of the purposes of this study was to develop a graphical interface, very easy to use by persons who are not well trained in computer use.

Keyword: sElectroretinogram (ERG); Laboratory for Virtual Instrumentation and Engineering Workbench (LabVIEW); International Society for Clinical Electrophysiology of Vision (ISCEV)

I. INTRODUCTION

Biomedical engineering is one of the fields in which virtual instrumentation has penetrated rapidly and strongly, in both research endeavors and current use equipments. An important note must be taken towards the fact that virtual instrumentation will not replace traditional instruments entirely, especially in highly specialized domains. In the case of many applications, combined solutions are preferred, based on both measuring techniques and providing the advantages stemming from these.

Virtual instruments use the open architecture of regular computers, including their processing speeds, memory and display capabilities together with inexpensive interface boards, connected to the appropriate bus, and the renown connectivity of such computers for creating equipments that are efficient, re-usable and re-configurable. The end result is a piece of virtual equipment whose performances, uses and configurations are set and defined by the user. The advantage of virtual instruments over traditional instruments will continue to rise due to fast developments in the world of PC tehnologies. The major benefit resides in the increase of performance, coupled with a sharp decrease in implementation costs. A further characteristic of virtual instruments that needs to be underlined is the possibility to use the same computer for different virtual instruments (of course, with the appropriate interface), and to transfer data acquired with one such instrument to the other, at the software level.

The emergence of this concept was chiefly determined by the intrinsic limitations of any closed type architecture, represented in the case of biomedical engineering by classical box-like instruments. The functionality of the latter is defined by the producer, limiting both the possibilities for expanding the diagnostic or intervention process, and the performance the user may desire at a certain point. The upgrading process, which in the case of computers is easy, cheap and accessible, can be difficult or even impossible for classical instruments.

When a light flash falls on the retina, a large amount of photoreceptoral cells are activaterd. This process includes changes in the interlayer currents, determining variations in the trans-retinal voltage: its temporal evolution is recorded in the electroretinogram (ERG) [1]. This signal consists of a sequence of components originated in different retinal layers and provides valuable physiological information about the photoreceptor behavior in the human eye. Understanding the specific features (onset, time delay, amplitude, line shape) of the ERG components and their relationship represents the principal aim of past and present research in the field of ocular electrophysiology.

The clinical ERG is the recording of electrical potentials evoked by a flash of light and picked up at a distance i.e., at the cornea [2]. It consists of various components (wavelets) which arise in different layers of the retina reflecting light-evoked potentials generated by different cells. Figure 1 shows the section of the retina.

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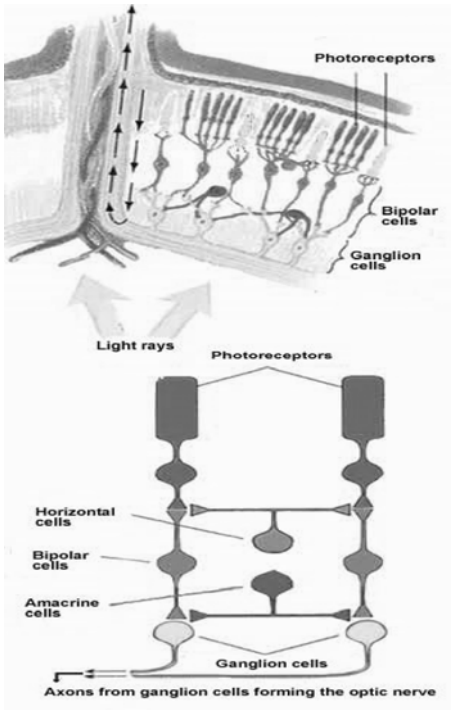

Fig. 1: Section of the Retina.

The ERG illustrated in Figure -2. Is a response recorded using a recording system with a wide frequency range, and evoked by a bright flash in order to record all components.

The ERP is a rapid discharge recorded with an extremely high intensity flash in a well dark – adapted eye using high – frequency amplifiers.

The a–wave is a negative potential generated extracellularly along the radial path from the cell body of the photoreceptors which hyperpolize in response to light, and is an important component of the clinical ERG as a measure of photoreceptor activity. The a–wave consists of two components i.e., a1 and a2, arising from the cones and rods respectively.

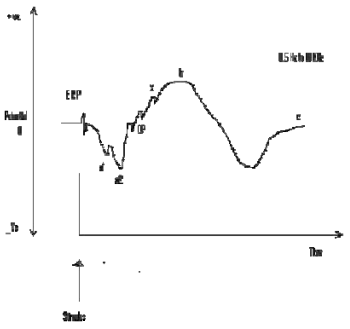

Fig. 2: The Elecroretinogram (ERG) Signal.

The b–wave is the most readily recordable major component of the clinical ERG. It reflects the postsynaptic summed neuronal activity of the inner nuclear layer and is thus an important measure. B–wave consists of two components, b1 and b2, representing the cone–mediated and rod–mediated responses respectively.

The oscillatory potential (OP) appears as a rapid oscillation on the rising phase of the b–wave of the ERG evoked by a bright flash. The last oscillation is relatively well defined, can be recorded on a open recorder and is called the x –wave or b1. The amacrine cells, the inner plexiform layer and optic nerve fibres have all been suggested as possible generators of the oscillatory potential.

The c–wave can be seen as a small, slow, positive deflection after the b – wave, although it actually starts slowly from the beginning of light stimulation. Briefly the integrity of the pigment epithelium and photoreceptors is an essential factor for the generation of the c–wave.

II. ISCEV STANDARD ERG

A. Dark-Adapted 0.01 ERG (rod Respons)

Dark-adapt the patient for a minimum of 20 min before recording the dark-adapted ERG (and longer if the patient had been exposed to unusually bright light) [3]. The Dark-adapted 0.01 ERG shown in figure 3. Is normally the first signal measured after dark adaptation, because it is the most sensitive to light adaptation. The stimulus is a dim white flash of 0.01cd_s_m-2; with a minimum interval of 2 s between flashes.

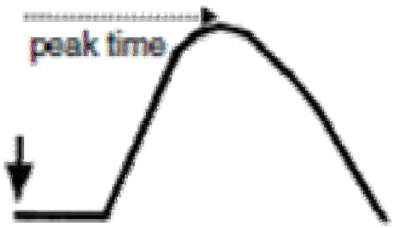

Fig. 3: Dark Adapted 0.01 ERG

B. Dark-Adapted 3.0 ERG (Combined Rod-Cone Response)

This is produced by a white 3.0 cd_s_m-2 flash in the dark-adapted eye. There should be an interval of at least 10 s between stimuli. It os as shown in figure 4.

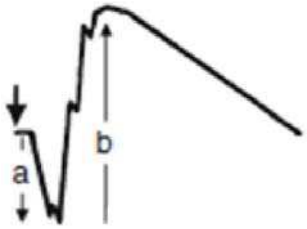

Fig. 4: Dark Adapted 3.0 ERG

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C. *Light-Adapted 3.0 ERG (Single Flash Cone Respose)*

A 3.0-cd_s_m-2 stimulus should be used, with at least 0.5 s between flashes. Figure -5 shows the light adapted 3.0 ERG. To achieve stable and reproducible cone ERGs, a minimum of 10 min light adaptation is required, because the cone ERG may increase during this period. The background luminance should be 30 cd_m-2 measured at the surface of the full-field stimulus bowl.

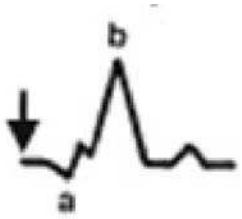

Fig. 5: Light Adapted 3.0 ERG.

D. *Electronic Recording Equipment*

1. *Amplification*

The bandpass of the amplifier and preamplifiers should include at least the range from 0.3 to 300 Hz and be adjustable for oscillatory potential recordings and special requirements [4]. The input impedance of the preamplifiers should be at least 10 MX. Amplifiers should generally be AC (alternating current) coupled (i.e., capacitatively coupled) and capable of handling offset potentials that may be produced by the electrodes.

2. *Patient isolation*

The patient should be electrically isolated according to current standards for safety of clinical biologic recording systems in the user's country.

3. *Display of data*

The final record should represent, without attenuation, the full amplifier bandpass. Good resolution can be achieved with computer-aided (digital) systems or oscilloscopes but not with direct pen recorders. To avoid a loss of information, digitizers should sample ERGs at a rate of 1kHz or higher in each channel. With computer-aided systems, it is important that ERG waveforms be displayed promptly so that the operator can continuously monitor stability and make adjustments during the test procedure. Recording units that digitize ERG signals can usually average them as well. All single flash responses should be presented with at least 20 ms of baseline preceding the flash, to allow judgment of baseline stability. It is recommended that each type of stimulus be replicated at least once and that both responses be displayed to show consistency.

E. *ERG Analysis and Reporting Standards*

1. *Single Flash ERGS*

In general, b-wave amplitude and time-to-peak (implicit time) is measured for all ERGs (except oscillatory potentials), and the a-wave should also be measured when recognizable as a distinct component. According to current convention, the a-wave amplitude is measured from baseline to a-wave trough, the b-wave amplitude is measured from a-wave trough to b-wave peak; the a-wave and b-wave implicit times are measured from the time of the flash to the peak of the wave.

2. *Normal values*

To describe the limits of normal, the median value (not the mean) should be used, and the actual values on either side of the median that bracket 95% of the normal range of ERGs (in other words, the 95% percentile determined by direct tabulation of ERGs). ERG parameters increase rapidly during infancy and decrease modestly with age thereafter. At elderly ages, the fall in amplitude can be substantial. Thus, normative values should be adjusted for age.Although circadian variations of the ERG are small under ordinary recording conditions, It is recommend that the time of ERG recording be noted on all records because it could become relevant for certain diseases or for repeat measurements.

3. *Reporting the ERG*

ERG reports should include representative waveforms of each of the standard ERGs displayed with amplitude and time calibrations and labeled with stimulus variables and the state of light or dark adaptation. These should include at least 20 ms of baseline prior to the stimulus for single-flash responses and, where feasible, should indicate the stimulus time for each flash with a marker or line (for flicker as well as single-flash). Two responses from each stimulus condition should be displayed to demonstrate the degree of consistency or variability. The time integrated luminance of the stimulus flashes (cd_s_m-2) and the background luminance (cd_m-2) should be given in absolute values. All reports should give patient results listed along with normal values and ranges. Finally, reports should note the time of testing, pupil diameters, and any conditions that are not specified by the standard, including type and position of electrode, sedation or anesthesia, and the level of compliance.

III. SYSTEM DESIGN

The ERG analysis system is developed in Labview platform. labview is a graphical user interface based virtual instrument environment which has lot of features

for signal processing applications [5,6]. One of the purposes of this study was to develop a graphical interface, very easy to use by persons who are not well trained in computer use.

The biomedical signals acquired from the human body are frequently very small, often in the millivolt range, and each has its own processing needs. For instance, electroencephalography signals are in the microvolt range and have many frequency components. Obviously these biomedical signals require processing before they can be analyzed. LabVIEW contains the tools, from fast Fouriertransforms (FFTs) to digital filters, to do the job. In order to do frequency analysis, a complex signal must first be broken down into its frequency components. One of the most common ways to do this is with an FFT. In order to facilitate this type of analysis, LabVIEW comes with built in FFTs that make the process of component separation quick and easy. In addition, biomedical signals, being extremely small in amplitude, are prone to being overwhelmed by noise. To combat this, it is necessary to run the acquired signal through a set of filters. This can be done external to the computer using standard hardware filtering devices. However, after the signal reaches the computer, it can still contain noise. Another way to solve the noise problem is to use the digital filters provided with LabVIEW. LabVIEW offers the choice of Butterworth, Bessel, Chebyshev, and Chebyshev II digital filters. With a few adjustments, these filters can be configured for almost any design that is needed.

ERG signal is simulated by reading the data from a file. Data is manually extracted from the ERG recordings obtained from the hospital. Figure 6. Shows the block diagram of the proposed system. Signal peak values are measured using labVIEWs waveform measurement features and peak values are displayed.

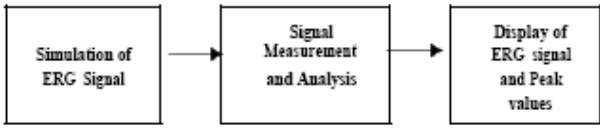

Fig. 6: Block Diagram of the System.

IV. RESULTS

ERGs belonging to three groups of subjects; they were recorded in the same experimental conditions.

A. *ERG Belonging to Healthy Person*

- ERG belonging to a subject with abnormality called Achromatopsia (ACR). ACR is a hereditary disease due to lack of cone vision. Their eye do not adapt normally to high levels of illumination and they experience pain under strong light exposure.
- ERG belonging to a subject with abnormality called Congenital Stationary Blindness (CSNB). CSNB is a rare inherited non-progressive disorder of the retina involving the rods. CSNB patients have reduced sharpness of vision.

B. *Normal ERG Signal*

For normal subjects, the a-wave is a negative potential marked by two dips. Denoted as a1 and a2. The a-wave is followed by the positive b-wave. In the figure- 7, The front panel Shows the positive and negative peak values in the numeric indicator.

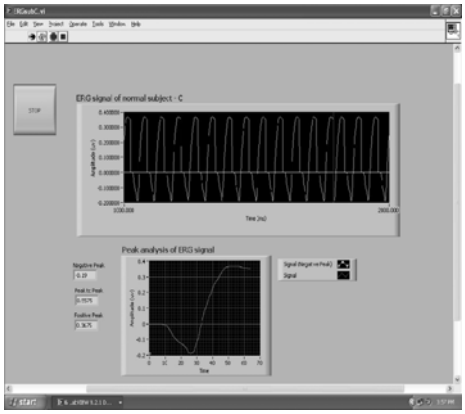

Fig. 7: Front Panel Showing Normal ERG Signal

The main difference between the normal ERG and ERG of abnormal subject is, the two dips present in normal ERG is replaced by only one minimum, that occurs later than the first minimum of normal subjects. The absence of a second dip and the temporal delay of the only one are indicative of a slower respose caused by the functioning failure of one retinal population.

C. *Abnormal ERG Belonging to Achromatopsia (ACR) Subject*

The ERG belonging to ACR patients shown in figure-8, has a reduced b-wave. The front panel Shows the positive and negative peak values in the numeric indicator.

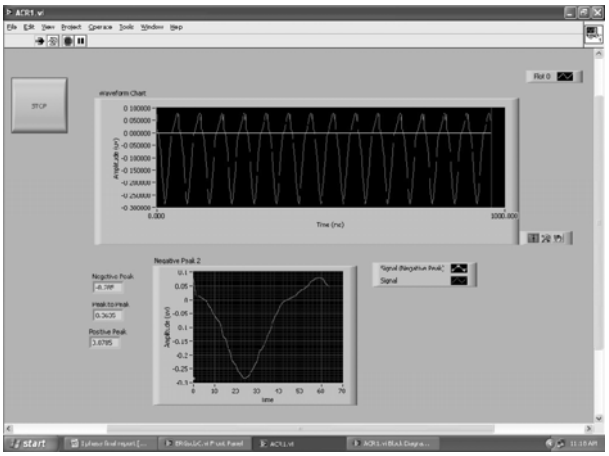

Fig. 8: Front Panel Showing ERG Signal of ACR Subject

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D. Abnormal ERG Belonging to Congenital Stationary Blindness (CSNB) subject

The ERG belonging to CSNB subject figure-9, shows that b-wave is absent it is because of the non-physiological behavior of the rods, that does not alow the transmission of the signal to the retinal layers. The front panel Shows negative peak value in the numeric indicator.

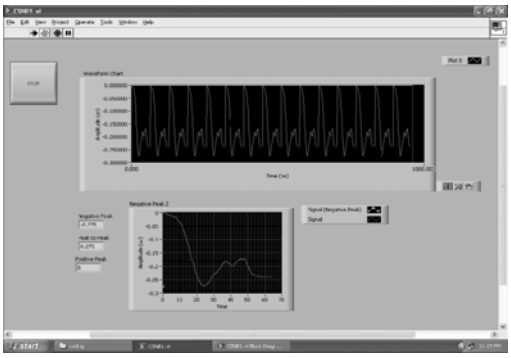

Fig. 9: Front Panel Showing ERG Signal of CSNB Subject.

V. CONCLUSION AND FUTURE WORK

The project is designed to detect the abnormalities, ERG's corresponding to subjects with abnormalities is simulated and analyzed. The proposed system is low cost alternative to sophisticated costly equipment used in hospitals for the ERG signal analysis purpose.

In the future work many more abnormalities of retina will be analyzed by simulating corresponding ERGs. It may require some DSP processing features for the analysis of some kind of abnormalities.

PERG (Pattern electroretinogram) is evaluated by using Discrete Wavelet processing (DWT) which is more accurate than time-domain data [7,8]. Both time-domain and wavelet features of these waveforms will be visualized using principal components analysis. Processing and analysis of PERG- work is in progress.

The developed LabVIEW code can be readily used in hospitals to classify the disorders, provided the acquired signal made available in a standard format.

REFERENCES

[1] R Barraco, D Persano Adorno, L.Bellomonte and M Brai, "A study of the human rod and cone electroretinogram a-wave component", Journal of Statistical Mechanics: Theory and Experiment. 4th March 2009, doi: 1742-5468/09/P03007.

[2] A.M. Halliday-"Evoked Potentials in clinical testing." 2nd edition, U.K. Churchill Livingstone, 1992.

[3] Marmor MF, Zrenner E (for the International Society for Clinical Electrophysiology of Vision). Standard for full-field Clinical electroretinography (2008 update). Doc Ophthalmol 2008; vol 118 pp 69-77.

[4] Brigell M, Bach M, Barber C, Kawasaki K, Kooijman A, "Guidelines for calibration of Stimulus and recording parameters used in clinical electrophysiology of vision." Doc Ophthalmol 1998; vol 95: pp 1-14.

[5] Li Chengwei, Zhang Limei, Hu Xiaoming,"The study on Virtual Medical Instrument based on LabVIEW." IEEE Engineering in Medicine and Biology 27th Annual Conference Shanghai, China, September 1-4, 2005, pp 4072-4075

[6] www.ni.com/academic/students/

[7] Akay M (1997) Time frequency and wavelets in biomedical signal processing. Wiley-IEEE Press, New York

[8] Duda R, Hart P, Stork D (2000) Pattern classification. Wiley-Interscience, New York