SIMULTANEOUS ECG, FINGER AND RETINAL PHOTOPLETHYSMOGRAPHY MEASUREMENT

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Abstract: This article is focused on simultaneous ECG, finger and retinal plethysmography method development. Document describes certain parts of measurement hardware and also subsequent data processing. There is also described retinal plethysmography extraction from video records and its data processing. The result of proposed methodology is providing simultaneous signals of ECG, finger and retinal plethysmography and their comparison.

Keywords: video-ophthalmoscope, retinal plethysmography, ECG, PPG

1 INTRODUCTION

Ophthalmoscopy is the most frequent medical diagnostic method for diseases such as macular degeneration, diabetic rethinopathy, glaucoma, etc. [1] For the most of these diseases especially for glaucoma is very important early diagnosis that current ophthalmoscopy does not include. The early diagnostics of glaucomatic diseases could be settled by exploring hemodynamical changes and its dynamic parameters in ocular fundus [2].

For measuring retinal temporal changes, there was developed new type of ophtalmoscopic instrument non-mydriatic video-ophthalmoscope (VO, described in [3]) that provides long term video records of ocular fundus, its hemodynamical changes and retinal blood supply as well. All these changes are depending on cardiac cycle [4] as the heart beat induces changing in blood volume. Then the blood volume changes in retina – retinal plethysmography (R-PG), can be seen as the reflectance change of retinal cells. This can provide important information about microcirculation physical condition of glaucomatic or diabetic patients.

The blood supply is usually measured by the finger or other photoplethysmography method (PPG). To compare the R-PG and finger PPG is also used ECG measurement as the reference and control of cardiac cycle. There are many works comparing the ECG and PPG signals for classifying PPG parameters such as pulse transit time (PTT) or pulse arrival time (PAT) or others [5] or also for heart rate variability parameters [6]. Considering PPG parameters there are both shape and time differences between various distal and proximal PPG measurements mainly in PAT.

Considering these facts, there is an assumption retinal plethysmography (R-PG) as measurement of microcirculation blood supply will be also shifted in way that PAT of R-PG will be smaller than the other PPG measurement. This methodology could detect pathology in ophthalmoscopic records.

2 MEASUREMENT METHODOLOGY

Whole methodology for simultaneous measurement of ECG, PPG and the R-PG was realized by connected system of components including video-ophthalmoscope with CMOS camera, signal generator, set of Biopac system with its components (ECG electrodes, finger PPG) and computer with appropriate software. Schema of the whole system is in the Figure 1.

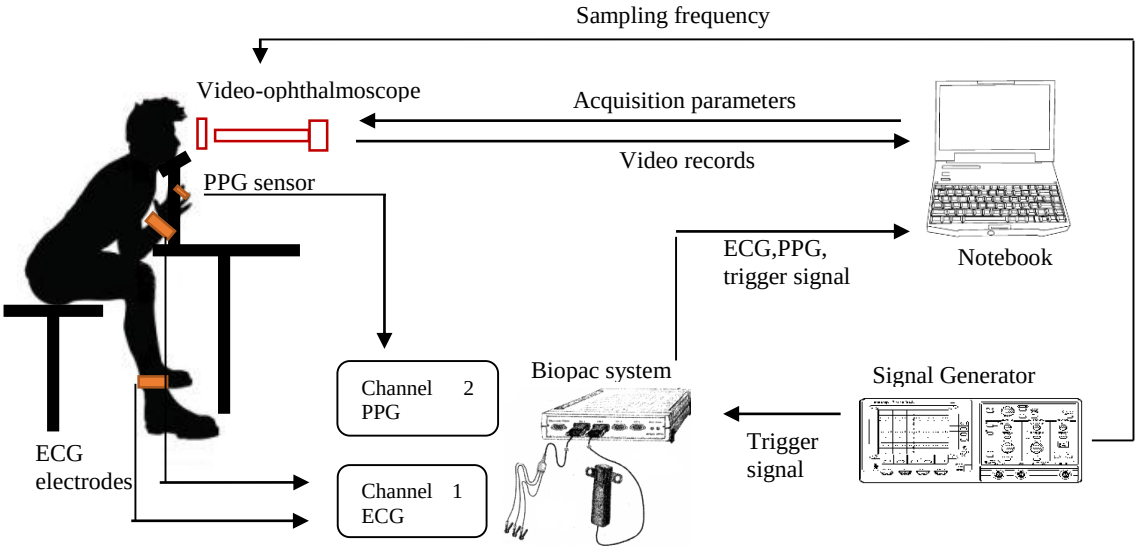


Figure 1: Schema of the simultaneous ECG, PPG and R-PG measurement

Video-ophthalmoscope – VO (Figure 2, described in [3]) is optical system including ophthalmic (40 D) as an objective lens, LED source of low illumination level and wavelength 550 nm. It uses CMOS camera (UI-3060CP-M-GL, iDS-imaging, Germany). Video records were acquired with spatial resolution of 1024x1280 px and framerate both 25 and 50 fps.

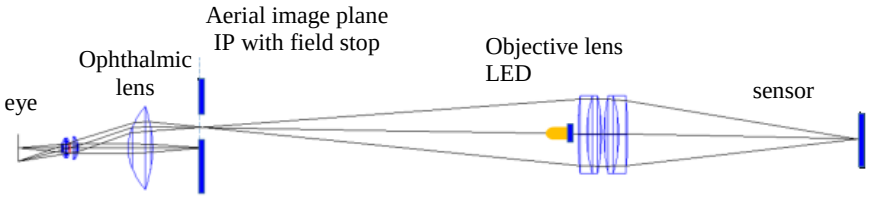


Figure 2: Video-ophthalmoscope used for retinal video sequences acquisition

Biopac system – Biopac system MP35 is used for PPG and ECG measurement with sample frequency (F_s) 50 kHz.

Signal generator – Agilent 33220A is used for rectangular trigger signal generation (F_s 50 kHz) that provides whole system synchronization for subsequent data processing and it is also used for CMOS camera settings (acquisition frequency) and acquisition start.

PPG, ECG and trigger signal is acquired into Biopac software. Due to dependency CMOS recording on trigger signal generation, the video record starts with rectangular triggered signal.

Human stability and head fixation is needed for the measurement, that is why the next important part of the system is also chin rest.

3 DATA PROCESSING

3.1 PREPROCESSING

There are four types of measured data – PPG, ECG and triggered signal (recording by Biopac SW) and video records (CMOS camera). The triggered signal is a help signal where the first and last rising edge is marking the start and end of CMOS camera record and simultaneously the first and last PPG and ECG valid sample also. Exact rising edge detection is possible thanks to high F_s=50 kHz. Data need to be preprocessed as selection of valid samples only.

Due to different F_s of data, the next preprocessing step is to unify them. The Biopac signals of F_s 50 kHz need to be decimated 200 times. On the other hand, video record interpolation needs to be done after video processing steps (described below).

3.2 PPG SIGNAL

Besides pulsatile component in the vessels depending on cardiac cycle, the PPG signal is also influenced by artifacts due to the motion or breathing. There are many methods to eliminate the mentioned artifacts e.g. moving average filter, wavelet transform or others. In this case, simple high pass filtering with cut off frequency of 0.5 Hz to eliminate DC component (representing motion artifacts) is fully sufficient.

3.3 ECG SIGNAL

The ECG signal measurement is affected by various types of influences – breathing (DC component), muscle activities (high-frequency electromyographic noise) and others. Therefore there are also many methods for ECG filtering based on e.g. adaptive filtering etc. In this case the bandpass filter is used with limit frequencies 0.5 Hz and 45 Hz.

3.4 RETINAL VIDEO RECORDS

Schema of the video record processing is in the Figure 3.

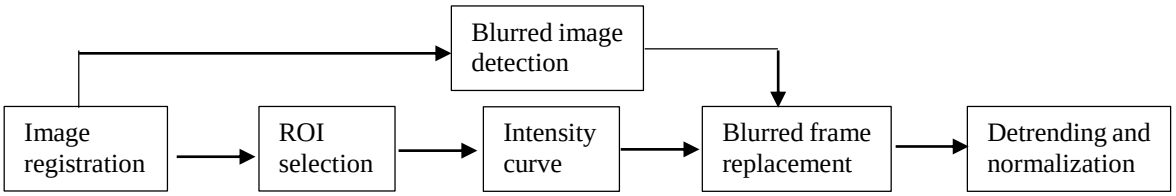
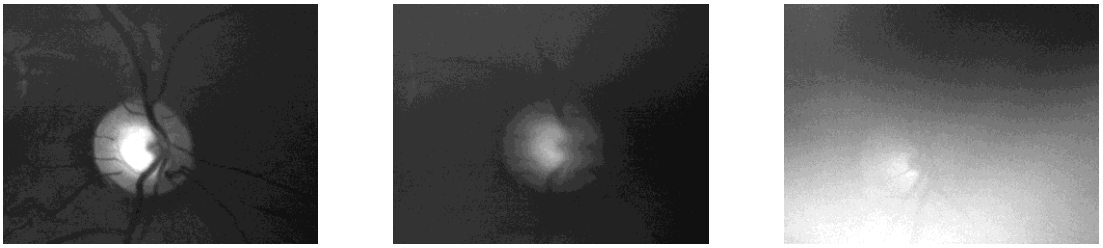


Figure 3: Video record processing schema

Due to eye movements, during the fixation on target, the first step in retinal video records processing is image registration to have stable record for subsequent processing. Method described in [7] are used for image registration. The method covers spatial transformation – shift, rotation and scaling. This method is based on phase correlation using the selected video record frame as the reference. Alignment of the frames is based on anatomical tracking points selection and Lucas-Kanade tracking.

Video records include (except sharp frames) also blurred and empty images due to eye saccadic movements and blinking (see in Figure 4), that are unsuitable for the analysis. Therefore the detection of these distorted images is needed as the next step. For distorted frames detection, the reference image method using phase correlation is used as described in [8], where the reference image is the best video record frame enhanced on entropy base.



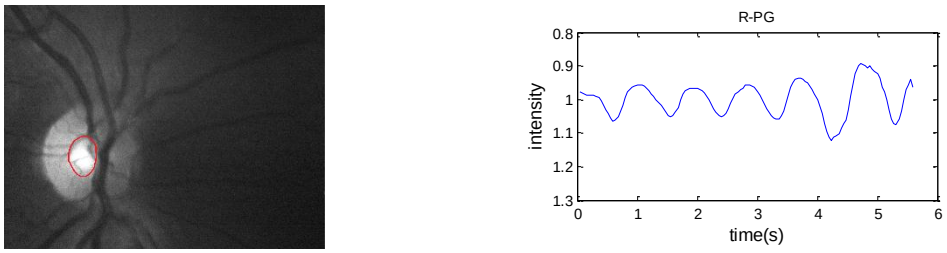
a b c

Figure 4: Example of frames in video-records: a, sharp frame b, blurred frame (eye movement) c, empty frame (blinking)

As the distorted frames are marked, the intensity curve in time can be extracted as the mean value of the selected region of interest (ROI) in frames. The ROI in this case represent the cup in optic disc (OD, see in Figure 5), where the biggest changes in blood supply can be observed. These changes modulate the reflected intensity in VO records. The reason of reverse intensity axis in intensity curve graph, representing retinal plethysmography, is that the increase of OD blood supply decreases OD reflectance therefore the intensity either.

The intensity curve R-PG still includes damaged frames (blinking, eye saccadic movements). These frames marked before are replaced by spline interpolated value.

The last step of video record processing is to eliminate trend line caused by human subject movements. The trend filtered and normalized R-PG is computed as intensity curve divided by trend enhanced by Savitzky-Golay algorithm, with window length of three cardiac cycles computed on base of R-PG spectrum. The resulted normalized curve of specific ROI is in the Figure 5.



a b

Figure 5: R-PG of certain retinal video-record: a, selected ROI in retinal frame b, R-PG

4 RESULTS AND DISCUSSION

Results of simultaneous PPG, ECG and R-PG measurements are in the Figure 6, where are simultaneously visualized plethysmography curves representing blood supply of retina and finger due to cardiac cycles substituted by ECG signal.

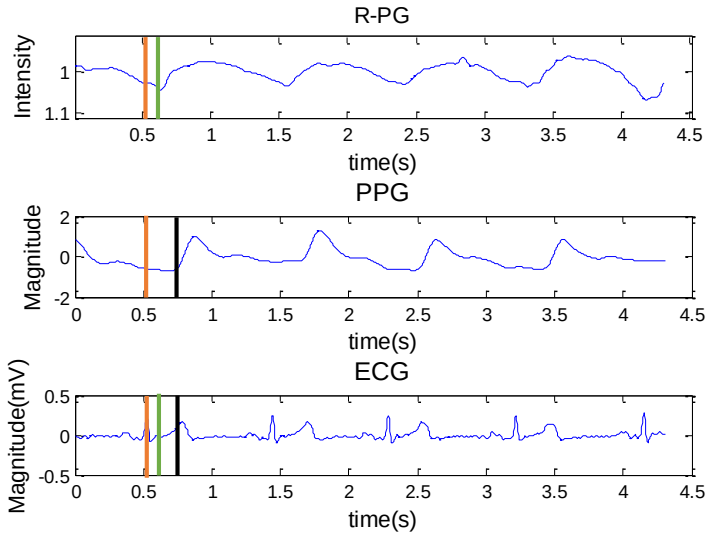


Figure 6: Resulted graphs of PPG, ECG and R-PG simultaneous measurement (red line – R wave as cardiac cycle start, green line – first R-PG rising edge sample, black line – first PPG rising edge sample)

This measurement allows data comparison and measuring plethysmography parameters as PAT or PTT, due to cardiac cycle. Considering PAT time, the R-PG PAT was smaller in comparison to finger PPG PAT in measured dataset, see Figure 6, where the red line marks the start of cardiac cycle and also the start of PAT interval, the green line marks R-PG rising edge sample and the end of R-PG PAT interval, the black line marks PPG rising edge sample and end of PPG PAT interval. Studying of these parameters and their changes can be promising in retinal diseases diagnostics.

The R-PG signal is very sensitive to ambient lighting, subject movements, eye saccadic movement and other influences. Moreover, there are other artifacts caused by intraocular fluid or certain proteins in retina, that usually damage R-PG signal.

5 CONCLUSION

The methodology of simultaneous PPG, ECG and retinal pletysmography measurement was introduced. There were used different approaches to process retinal video records to extract intensity curve representing blood supply of ocular fundus, in other words retinal plethysmography. The R-PG is very sensitive to various influences and the method could be improved in measurement hardware as well as in data processing to eliminate retinal artifacts. The resulted R-PG is corresponding to cardiac cycle and can provide useful information about microcirculation physical condition.

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