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Automatic detection of photoplethysmogramm's parameter

Mourad Kholkhal*, Fethi Bereksi Reguig, Tahar Omari

Geni-Biomedical Laboratory, Departement of Biomedical Electronic, Faculty of Science Engineering, University Aboubekr Belkaid Tlemcen, B P 119, (TLEMCEN ALGERIA)

E-mail : kholkhalm@gmail.com

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ABSTRACT

Photoplethysmogramm signal is one of the informational signals that deliver the status of the cardiovascular system. Thus in this paper we are interested in locating the various segments and waves helping to extract this information. The work is summarized by a set of algorithms that were developed to identify the peaks and valleys and the period of the signal photoplethysmogramm to measure heart rate, the dicrotic notch locate and assess the variability of the value average of the signal. These properties are of interest diagnosis, for assessing cardiovascular disease in different cases. Thus, these algorithms were tested on a set of signals from different healthy subjects.

KEYWORDS

Photoplethysmogramm' parameter;
Dicrotic notch;
Heart rate;
Signal;
Waves;
Cardiovascular.

INTRODUCTION

Historically, the spectral analysis was applied by[1-3] in order to analyze the pulsate component.

On the other hand, the use of time technique to extract information carried by the signal Photoplethysmogramm (PPG) was addressed by[3-5].

Thus[6-8] have tried to correlate the extent PPG signal with blood pressure with the aim of automatic measurement of blood pressure by the oscillometric method.

Further work is developed to detect cardiovascular physiological data from the morphology of the PPG signal. They include those of[9], and those who used this signal for determining the heart rate[10]. The study of these parameters was made on an experimental basis, based on measurements by hand. The use of the machine is often more secure and offers greater precision in this field.

The invention of calculating machines and software developed in the field of signal processing have facilitated the search because we have a computation time too short, storage space very important, then it is possible to reliably analyze the time domain and frequency or time-frequency signal PPG.

It is in these perspectives a set of algorithms are developed to detect parameters that can describe the cardiovascular status of the topic.

The algorithms are developed based on rules changed by the programmer; it can change so as to improve their performance.

MATERIALS AND METHODS

To enable a comprehensive and effective photoplethysmogramm signal, a set of parameters describing the signal, are described below and relate mainly

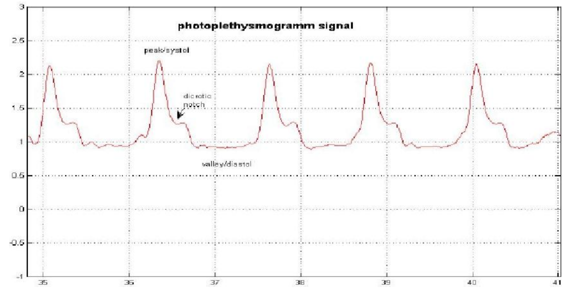

Figure 1 : Photoplethysmogramm signal

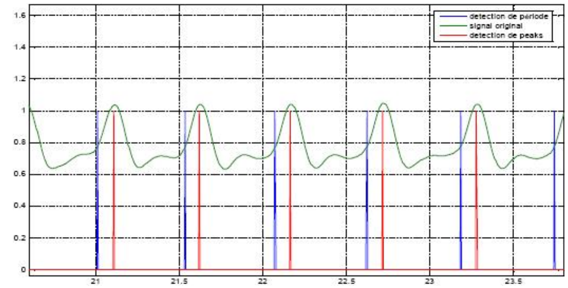

Figure 2 : The peak detector and the period detector

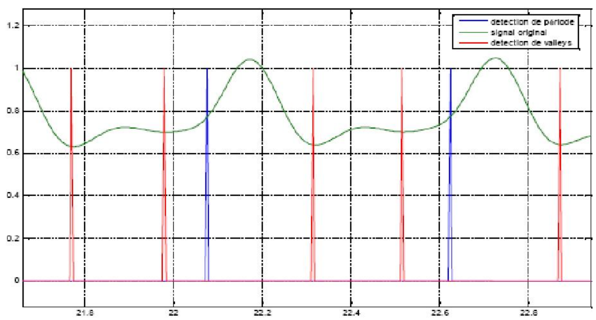

Figure 3 : The valleys and period detectors

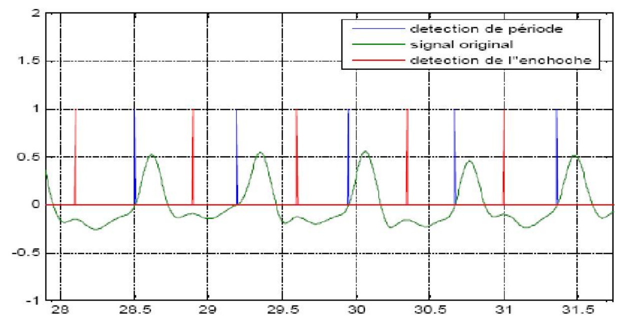

Figure 4 : Dicrotic notch detector and period detector

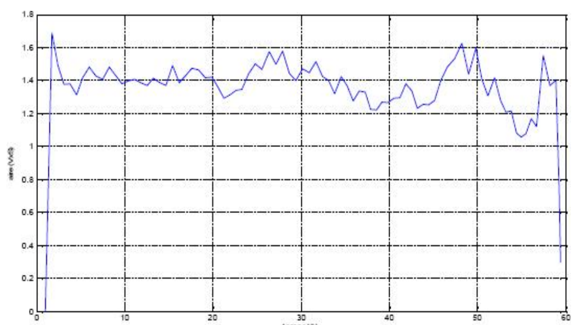

Figure 5 : Evolution of the area of the PPG signal as a function of time

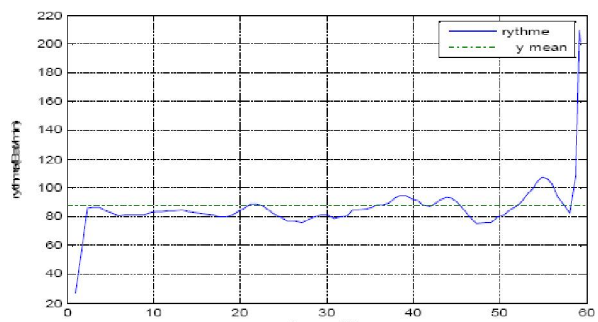

Figure 6 : Instaneous cardiac rhythm values as a function of time

to the wave reflecting the systolic arterial pulse, the local maxima and valleys defining the morphology of the signal and the identification of the dicrotic notch reflecting the reverse flow in the arteries.

A set of algorithms are developed and implemented to detect the systolic wave, local maxima and valleys, dicrotic notch and detection of these parameters led to the ability to Heart rate and the area bounded by the photoplethysmogramm signal curve (Figure 1).

Early detection of systolic wave

This algorithm allows the detection of zero crossing photoplethysmogramm signal.

It will be subsequently used for determining the value of instantaneous heart rate and the area bounded by the curve signal PPG. After loading of the signal, the signal is filtered through a high pass filter that can be used to restore the DC component of PPG signal. After filtering photoplethysmogramm signal by a high pass filter 0.05Hz the signal is carried by the zero (removing the DC component).

This operation is required for the early detection of systolic wave, for against the average signal without high pass filtering is useful as a reference to the detection of local maxima, valleys and the dicrotic notch.

Each zero crossing will be indicated by making a pulse.

Recovering the indices of these pulses, we will find the start of each systolic wave.

The same algorithm, with changes to the original terms, is used to detect the peaks, valleys and the dicrotic notch.

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Detection of local maxima

This algorithm describes how the detection of local maxima, by setting the following conditions:

a. The signal must be higher than zero
b. The first derivative of the signal must be equal to zero

The counter 2 puts a one in each column that checks these conditions, which will give the vector detector peaks.

The indices which contain one column used for other applications (calculation of the velocity of blood, or the PTT: time for the propagation of arterial pulse).

Detection of the valleys

The following algorithm describes the steps to determine the valleys of the PPG signal. The conditions are:

The signal must be below zero and a sample of the signal must be less than the sample that follows, which precedes it.

A counter 3 stores one in each cell that verifies these conditions.

The indices of these addresses represent one valleys contained within the peak-peak.

Detection of the dicrotic notch

For the detection of the dicrotic notch, two counters are used in our program: one for the detection of the peak and the second peak successor to detect.

The determination of these peaks is necessary to limit the range of detection.

The dicrotic notch is the inflection point just before the peak in the lower part of the curve (below average).

The proposal was made empirically, based on study qualitative Photoplethysmogramm signal.

The algorithm first determining the peak is based on the following conditions: The signal must be below the zero of the signal and the first derivative of the signal must be equal to zero.

A counter3 stores 1 in each cell that verifies these conditions.

The indices of these cells containing 1 represent addresses of peak include in the interval peak to peak.

The second detector is based on the first and setting the conditions below:

a. The index of the loop i, must be located in the interval[indices (counter2) indices (compteur4)] by incrementing the indices of the vector indices (counter2);
b. The signal must be below zero.
c. The zero crossing of second derivative signal indicates the inflection point of the curve.

It part of the curve should be increasing.

Calculating the area of the curve bounded by the signal PPG

It is mainly used to determine the stroke volume through the curve of the arterial blood pressure which has the same profile as the Photoplethysmogramm signal. The area bounded by the curve PPG is determined by the trapezoidal integration method. It can be summarized by:

Calculation of the surface between two successive values (samples of the signal), linking these two values and constitutes a segment a trapeze.

Value of this area is the instantaneous value.

Area (i) = (sum (signal) - (signal (i) + signal (i-1)) / 2) * h;

As h is the step.

The area of each signal is the sum of these values between the two defining a period obtained from the detector period.

Calculating heart rate

The rate is calculated by the same method that the area, thus:

(1) Fixed-interval calculation using the detector period.
(2) We apply the equation of heart rate

Rhythm (i) = round (60 / (t (indices (1 w) - t (indices (w)))

As evidence **indices**, is the vector containing the values of the indices indicating the start of each period of the signal.

t: time, w, i: loop index calculation. (i = 1 .. length (signal)) and (w = 1 .. length (indices)).

RESULTS

Figures shows the results obtained with those algorithms, note that the area is calculated over a limited period on a signal.

Separately we obtain the results below in figure 2-7, detection of peaks, valleys, dicrotic notch, area bounded by photoplethysmogramm curve and Instaneous cardiac rhythm.

DISCUSSION

The simplicity of instructions used to develop algorithms, result very small execution time (total 50 ms) compared with other methods.

Pulse transit time can be easily calculated, after early systolic wave detection.

The advantage of this work is in the multiparameter identification, which guide to evaluate some cardio vascular pathology. These parameters can be used in several instrument based on photoplethysmogramm signal identification, also in software we can implement an algorithm which help us to photoplethysmogramm classification.

The presented dicrotic notch detector have been tested over 732 beat , the delineator performed well with the error rate 5.43 %, sensitivity 95.31% positive predictivity 99.45%.

This result well in comparison of other derivative method by[11] use inflection and zero-crossing points, and the derivative of the signal to locate the dicrotic notch with the error rate 6.83%, sensitivity 96.53% and positive predictivity 96.64%.

CONCLUSION

A set of algorithms is implemented and tested on different samples of photoplethysmogramm signals of different subjects.

The evaluation of the detector is made of digitally comparing the number of pulses of detector's counter (peak, dichrotic notch) to that given by the counter of the period.

These algorithms have facilitated the task for determining the values of the instaneous heart rate value and the area which is proportional to the volume ejected during each period.

The total time for the execution of programs developed in MATLAB and based on these algorithms, did not exceed fifty seconds for about fifteen thousand samples.

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