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Correlative analysis and determination of the attenuation coefficients of thePhotoplethysmographic signal

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Abstract:*In this paper, a correlative method of analysis has been proposed to guide the doctor in his therapeutic approach.*
The aim of our work is based on correlation analysis of the photoplethysmographic signal PPG representative of the efficiency of pulmonary exchanger which evaluates the pulsed concentration of oxyhemoglobin HbO_2 in the blood, showing in particular the attenuation coefficients which seem to be relevant indices for pathological cases.

Keywords:PPG,autocorrelation function,envelope of the signal, attenuation coefficients, low pass filter.

I. INTRODUCTION

A physiological signalis a revealer informationofthe patient'spathophysiological state.
The extraction ofinformation describinga pathologyfrom thephysiological signalsrequesttheir analysisby experts. Physiological signal processing techniques have significantly contributed to the analysis of these signals, helping the doctor in his diagnosis. For this, we have benefitted the PPG signal with digital processing tools, through the implementation of a correlative analysis [1], by implementing an algorithm for calculating the autocorrelation function, the layout of the envelope of this function through a low pass filter and the approximation of the envelope of the autocorrelation function by determining its attenuations coefficients.

II. MATERIALS AND METHODS

II.1. COLLECTION OF PHOTOPLETHYSMOGRAPHY SIGNAL

This one usesthemolecular absorption spectrophotometryforinfraredrecordingpulsedoxyhemoglobin[2] bythelast$\mathbf{HbO_2}$contributionofinfraredemitting diodeand aphototransistoras shown infigure1 [3]. Therecordingpulseoxyhemoglobinreflects theefficiencyof pulmonaryexchanger[4] that is tosayofthe alveolar-capillary action andconsequentlya possiblehypoxemia [5].
The principle is toemitmonochromatic lightthroughelectroluminescentdiodein the infrared andto assess theabsorptionofthe latter bymeans of areceivingphotocell(phototransistor).
It was constructed around a 16F876A microcontroller [6] equipped with a 10bits ADC module and a USART module with Sampling frequency of 2,4KHz.
Local Protocol Communication (RS232): The parameters RS232 [7] which we have used are:
Transmission speed 57600 bauds
8 bits of data
A bit of parity
A bit of stop

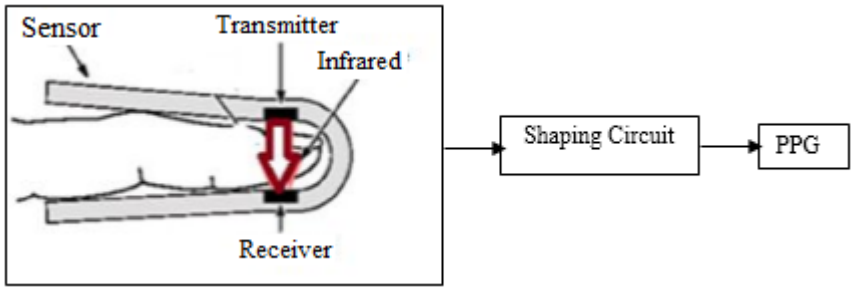

Fig.1 Schematic diagram of the collection of the PPG signal.

II.2. CORRELATIVE ANALYSIS

Correlative Analysis permits the calculation and plot of the autocorrelation function of the signals such as PPG. The calculating algorithm of the auto correlation discrete functions has been implemented in accordance with the following relation definition (i.e., (1)) [8]:

$$K_x(\tau) = \frac{1}{N}\sum_{k=\tau}^{N} x(k)*x(k-\tau), \text{avec:} N=2^q \quad (1)$$

et $\tau=0,..,N$.

We have $N=2^{12}=4096$ (Corresponding to thenumberofthe samplingsignal).

III. RESULTS

In this work,we are aimingphotoplethysmographysignalPPG processingbya correlativeanalysishighlightingin particularthe attenuation coefficients that appear to berelevant indicatorsfor pathologicalcases.

III.1. AUTOCORRELATION FUNCTION

To extract the information from different signal we have used the autocorrelation functionofPPGsignal, whichisshown in figure2.

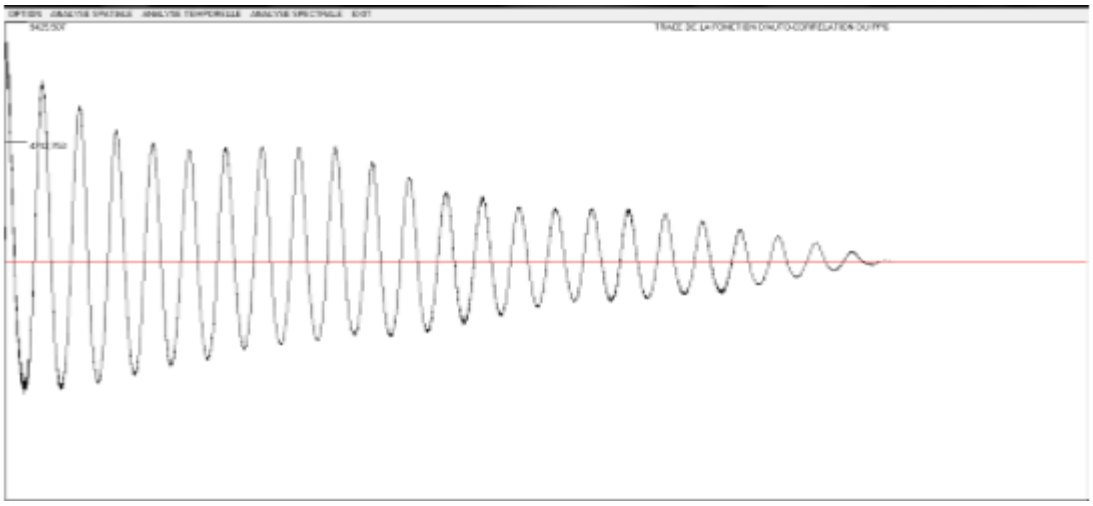

Fig. 2 Layout of the autocorrelation function of an PPG signal

III.2. LAYOUT OF THE ENVELOPE OF THE AUTOCORRELATION FUNCTIONS

Establishingrelevant indicesofinformative processessuch as physiologicalsignalsis factbymeans of theenvelopeoftheautocorrelationfunction, whichallows to deducethe attenuation coefficientsof this one.
It seems to us interesting to put at the disposal of experts of medicine these indices for the diagnostic help.
The determination of theenvelopeandthecalculationof the attenuation coefficientsisdone by usingthe low pass filter.

- The transfer function of an ideal low pass filter (i.e., (2)) is:

$$H(f) = \Pi_{2F_M}(f) \quad (2)$$

Consequently its impulse response (i.e., (3)) is:

$$h(t) = 2F_M \frac{\sin 2\Pi F_M t}{2\Pi F_M t} \quad (3)$$

The simplestfilter has thetransfer function in sight of its electronic materialization has a following equation (i.e., (4)):

$$\frac{V_S}{V_E} = \frac{1}{1+jRC\omega} \quad (4)$$

With cutoff frequency(i.e., (5)): $f_c = \frac{1}{2\Pi RC}$ (5)

This filter is use to extract the averages values or the signal envelope.
We implementedthis filterusing Matlabenvironmentand we gotthe following results:
Layoutof the envelopeofthe autocorrelation function appliedto the PPG signal (figure 4).

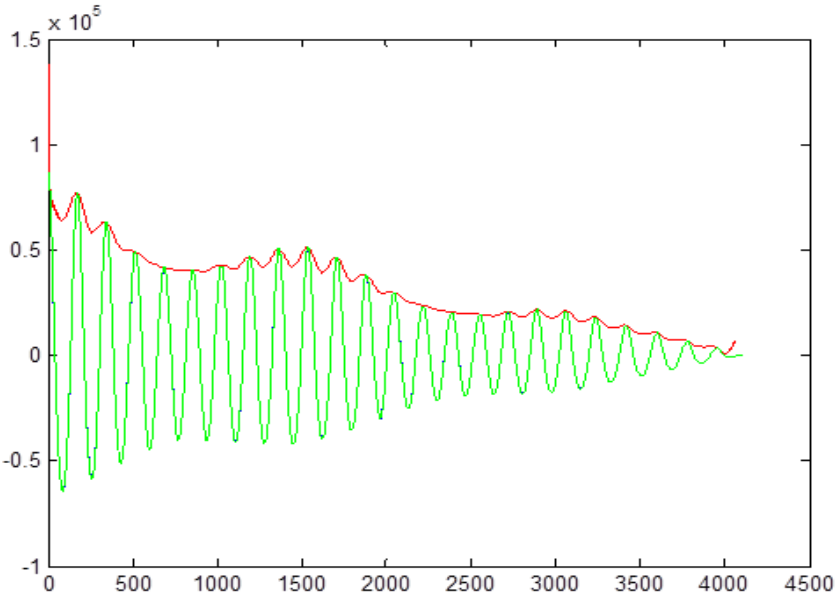

Fig.4 Plot of the envelope applied to signal PPG

- The approximationof the envelopeof the autocorrelation functions:

The approximationof the envelopeof the autocorrelationfunction wasobtained by determiningthe attenuation coefficientsusingthe algorithm thatinvolvesa decreasing exponential (figure 5) according to thefollowing definitionequation(i.e., (6)):

$$Y=Ae^{-\propto b} \qquad (6)$$

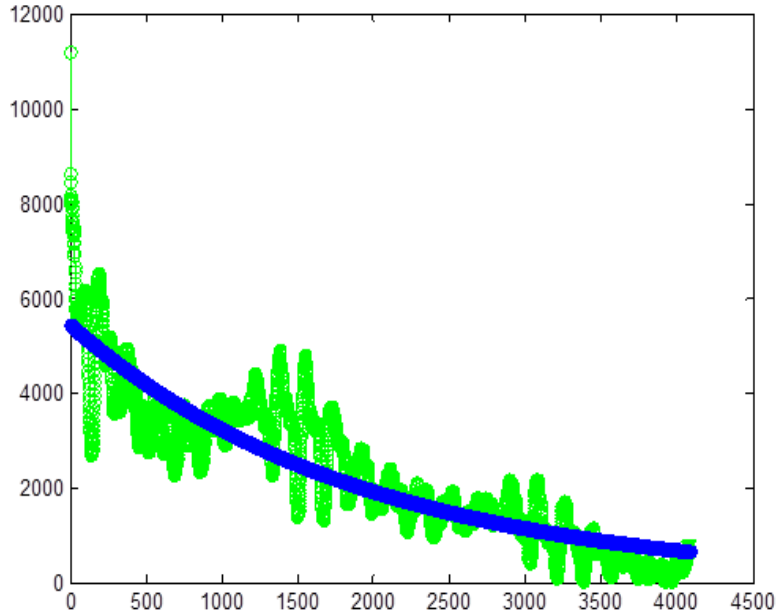

Fig.5 Plot of the envelope approximation applied to the PPG signal

•Presentationofattenuationcoefficientsαof autocorrelation functioncorresponding to thePPG signals (table 1).

From table 1, we remark that the attenuationcoefficients (α) ofPPGhave the same valueapproximatelyaround of0.46.

Table 1.Presentationof the attenuationcoefficientsα ofthe autocorrelation functionof PPG signals of ten volunteers.

SIGNAL	$C_0(1)$ (A)	$C_0(2)$ ($\propto$B)	FILTER
PPG1	$9.43*10^3$	$0.47*10^{-3}$	Lowpassilter
PPG2	$9.37*10^3$	$0.46*10^{-3}$	Lowpassfilter
PPG3	$9.45*10^3$	$0.47*10^{-3}$	Lowpassfilter
PPG4	$9.98*10^3$	$0.48*10^{-3}$	Lowpassfilter
PPG5	$6.37*10^3$	$0.46*10^{-3}$	Lowpassfilter
PPG6	$6.90*10^3$	$0.47*10^{-3}$	Lowpassfilter
PPG7	$6.38*10^3$	$0.47*10^{-3}$	Lowpassfilter
PPG8	$6.85*10^3$	$0.47*10^{-3}$	Lowpassfilter
PPG9	$6.92*10^3$	$0.47*10^{-3}$	Lowpassfilter
PPG10	$6.35*10^3$	$0.46*10^{-3}$	Lowpassfilter

IV. CONCLUSION

This work isan opportunity for usto presentthecorrelativeanalysismethod that we haveproposedthe PPGsignal,this PPG signalrepresents the estimateof pulsedconcentrationof oxyhemoglobinHbO_2, this oneis revealingof a possiblehypoxemia.
Our work consists inperform acorrelativeanalysis ofPPG signal, calculate itsautocorrelation function, trace theenvelopethrough the low pass filter and extractfromthis latterthe coefficients ofattenuation. Whichmakes available tomedicalactorsvaluableparameters (autocorrelation function andattenuationcoefficientsof this function) giving them the possibility of wellestablish theirdiagnosis.

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