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A new algorithm applied to the analysis of the electrocardiogram of an isolated rat heart

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Abstract:

A new correlation algorithm has been developed to analyze an isolated rat heart electrocardiogram (ECG).This is done as follows: The original ECG signal is altered into a wave having three levels +1,-1 or zero depending on whether the signal is above zero, below zero or approximately zero respectively. This reduces the computation the time and storage memory considerably, by altering the multiplications into simple additions or subtractions when the signal is positive or negative and no operation when the signal is zero. The algorithm has been developed, implemented and tested using a Pentium PC.

Keywords:

Electrocardiogram (ECG), isolated rat heart, correlation analysis, algorithm

Introduction:

For the last forty years, many researches have been taking place in the isolation and preservation of animal organs, in particular hearts. This is done by isolating the heart, putting it on a Langerdorff column controlled automatically using a computer,(1) then cooling it down to subzero temperature for a pre determined time, then re warming again to normal temperature (37degrees), then analyzing the normality of the ECG. But unfortunately a difficult question arises "What is a normal ECG?" Each ECG differs from any other ECG even if they are from the same species, in many ways. One is the rate of the heart beats, where in the case of the rats, it could vary from 250 beats/minute to 400 beats/minute depending on the weight of the animal from which the organ has been obtained, perfusion pressure and strain under which the organ is sustained. The shape of the ECG also differs from one heart to another either in width or height. On top of that the P wave is so small in many ECGs that it cannot be detected.

The continuous auto correlation function of a signal X(t) is defined as:

$$Rxx(\tau) = \lim_{T\to\infty} 1/2T \int_{-T}^{T} X(t)* X(t+\tau)d\tau \quad (1a)$$

And the cross correlation function of two signals X9t) and Y(t) is defined as:

$$R_{XY}(\tau) = \lim_{T\to\infty} 1/2T \int_{-T}^{T} X(t) * Y(t+\tau)d\tau \quad (2a)$$

If the two signal are periodic with period 2T then the auto and cross correlations would be:

$$R_{xx}(\tau) = 1/2T \int_{-T}^{T} X(t) * X(t+\tau) d\tau \quad (1b)$$

$$R_{XY}(\tau)= 1/2T\int_{-T}^{T} X(t) * Y(t+\tau) d\tau \quad (2b)$$

The digital forms of the above equations are:

$$R_{xx}(n) = 1/N \Sigma_{i=0}^{N-n-1} X(i) * X(i+n) \quad (3)$$

$$R_{xy}(n) = 1/N \Sigma_{i=0}^{N-n-1} X(i) * Y(i+n) \quad (4)$$

Where N is the total sampled data points and n is the number of the delayed samples at which the correlation is evaluated.

To apply the algorithm, it could be noticed the sharpness of the waves which make the ECG. So the ECG shown in figure(1a) could be modified to the form shown into figure(1b).

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Abstract

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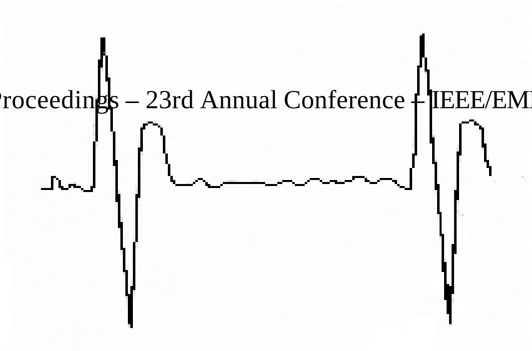
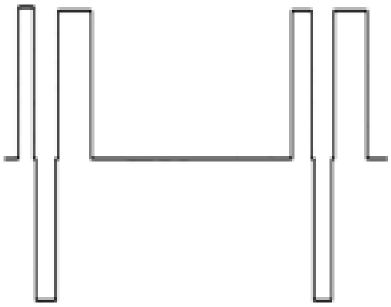
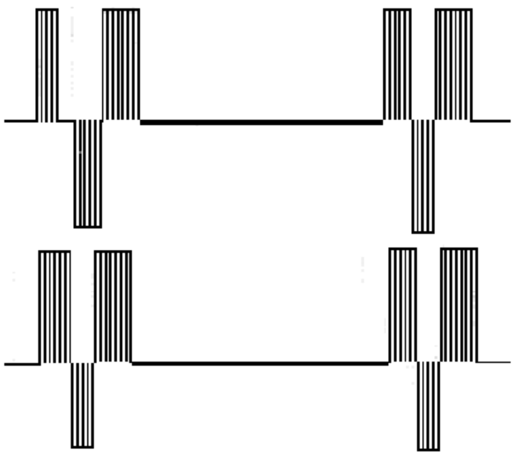


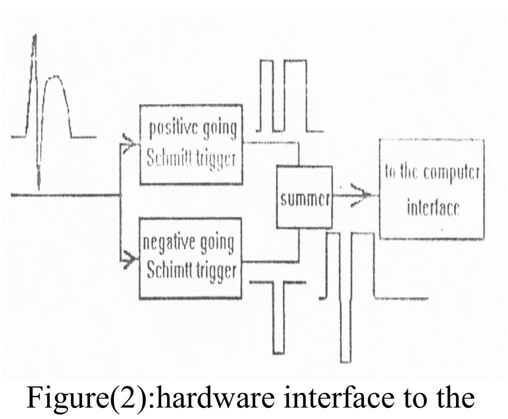
figure(1a) shows a normal ECG



figure(1b) shows the modified ECG



figure(1c) showing the sampling of the signals to be correlated.



Figure(2):hardware interface to the modified ECG to the computer

When applying the algorithm to figure(1c), only three values are possible; above zero which could be represented by +1, below zero which could be represented by –1 or on the zero line which could be represented by 0. Thus when applying the algorithm, if the signals are both positive or negative, addition takes place; if they are different but both non zero, substraction takes place and if one at least is zero, the operation is skipped all together.

<u>Signal interfacing to the computer:</u>

After putting the isolated rat heart on the perfusion apparatus(1), the ECG is picked up by two cupper leads; one soldered to the perfusion cannula which is inserted into the heart's aorta and the other is inserted in the collecting vase of the perfusion solution just underneath the touching bottom end of the organ. When the heart beats, it induces a small electrical signal between the leads. This signal is fed to the computer interface shown in figure(2).It is amplified then passed through a blocking
Capacitor to block any DC offset, then split into two components; one fed directly to a Schmitt trigger, whereas the other is inverted and applied to a second Schmitt trigger. The outputs of the triggers are added together and sampled, then stored for the algorithm to take over.

<u>Implementation of the algorithm</u>:

Once the two signals to be correlated are stored, the algorithm takes over, starting by setting the displacement n between the two signals and resets the accumulator. It reads the corresponding two points and compare them. If they are of the same polarity, the accumulator is incremented, if they are of different polarity, the accumulator is decremented. If at least one is zero, the operation is skipped. The algorithm moves to next point and the procedure repeats itself until all points are scanned. The net result stored in the accumulator represents the strength of the correlation at the delayed point n. The above procedure is repeated until all correlation points are computed. Figure(3) shows the flow chart of the algorithm.

Results and discussions:

The ECG shown in figure(4a) is modified to the form shown in figure(4b). Its auto correlation graph is shown in figure(5). It shows a sharp peak at n=0 then it decays rapidly to zero as expected. This is not surprising due to the fact that the ECG complexes (QRS,S and T) are very sharp as it is shown in figure(4).

Then the ECG shown in figure (6a and 6b) was tested. The auto correlation graph is shown in figure(7). This time the peak is also at the origin, but it decays more slowly if compared with that of figure(5). This is also not surprising because the ECG complexes are wider, so it is expected to have a wider autocorrelation peak.

Then the two signals were cross correlated, giving the graph shown in figure (8). Because the two complexes are different in width, resulting in the correlation graph to be wider. Then the signal shown in figure(9a and b) has been correlated. Here the P wave is apparent and contributes to the graph. This has introduced a negative part as shown in figure(10).

When the ECG shown in figure (4) was cross correlated with of figure (9), the correlation obtained is shown in figure (11). It could be noticed that the graph is wider which is expected as well as the negative part due to the negative P wave.

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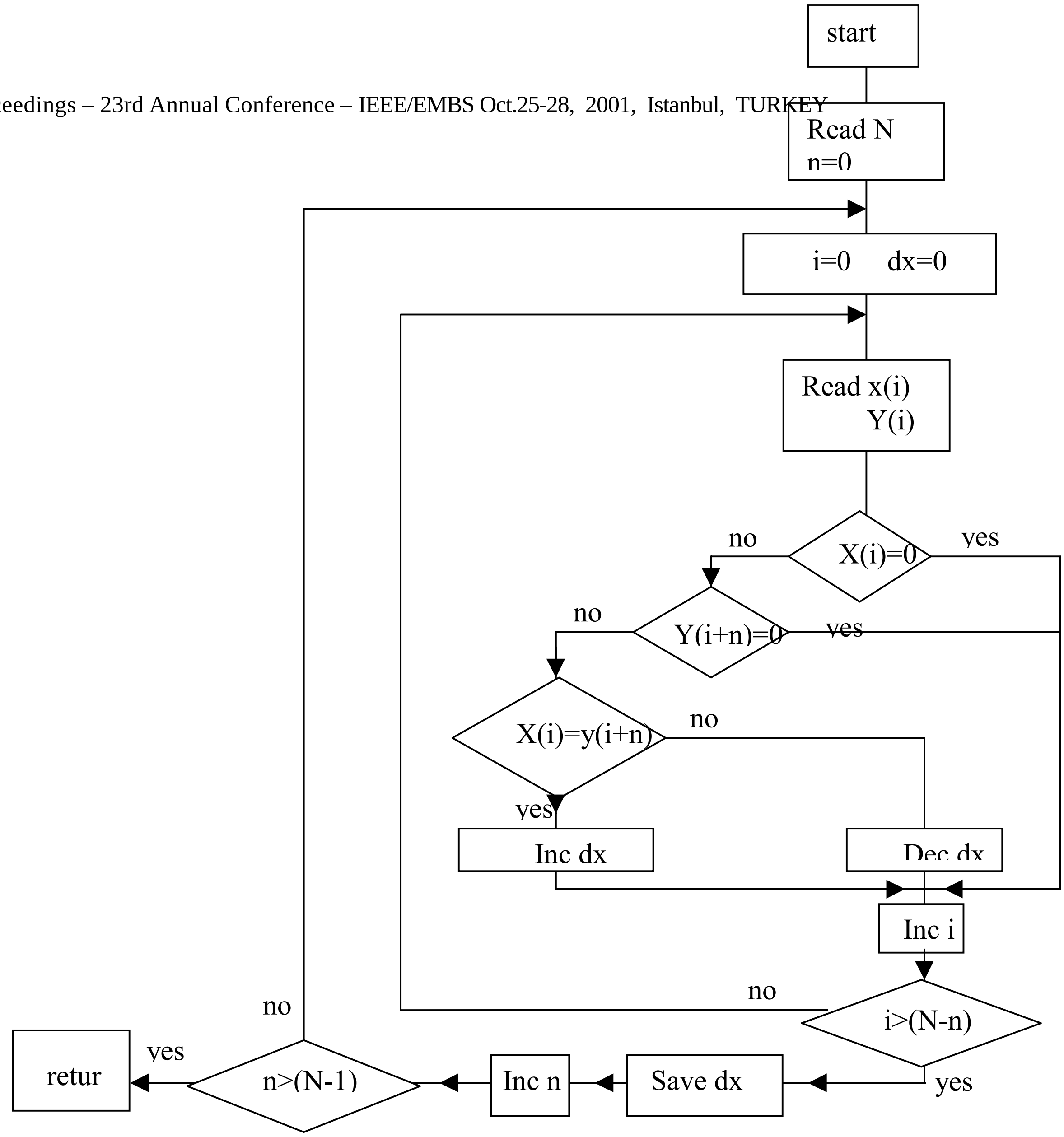
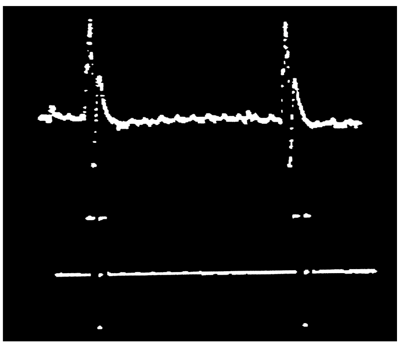
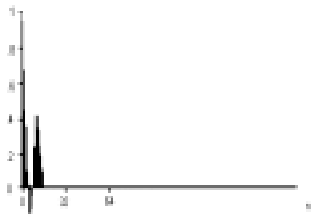


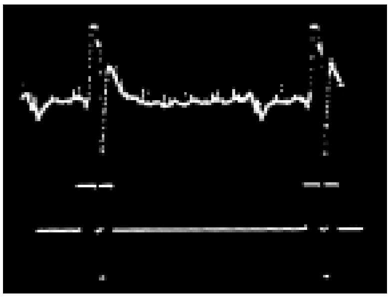
Figure(3) showing the flow chart of the algorithm



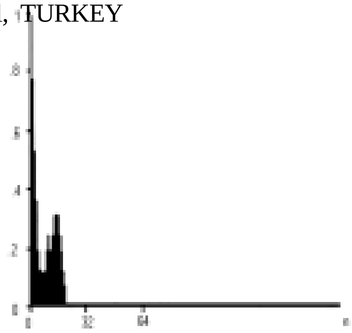
Figure(4) a- normal ECG of an isolated rat heart
b- modified version of the ECG



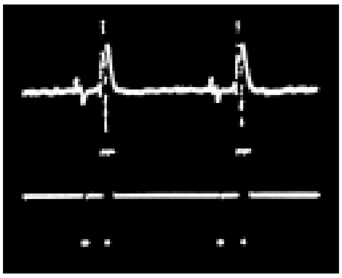
Figure(5) auto correlation of the modified ECG of figure(4b)



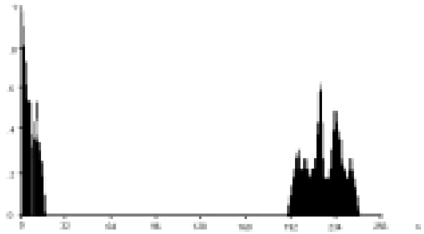
Figure(6) a-normal isolated rat heart ECG
b-its modified version



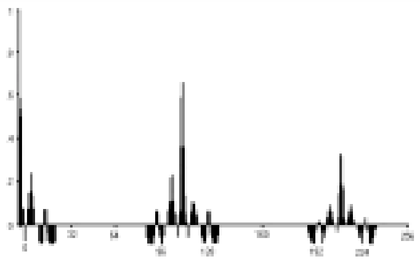
Figure(7) auto correlation of the modified ECG a shown in figure(6b)



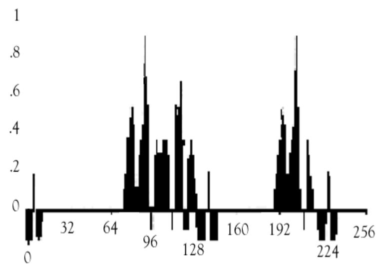
Figure(8)cross correlation between ECG shown in figure(4b) and ECG shown in figure(6b)



Figure(9) ECG with P wave and normally placed with respect to QRS



Figure(10)auto correlation showing the negative part due to the P wave



Figure(11) cross correlation between ECG shown in figure(4b) and ECG shown in figure(8b)
It the two negative parts due to the P wave