Real-Time Discrimination of Multiple Cardiac Arrhythmias for Wearable Systems based on Neural Network

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➢Overview

The goal of this work is to implement a wearable system able to recognize the most significant cardiac arrhythmias through an efficient algorithm, in terms of low computational cost and memory usage, implementable in a portable, real-time hardware.

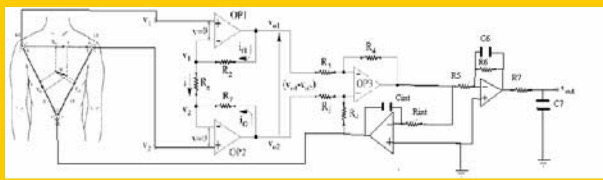
➢Wearable Systems

In the last few years wearable systems have been achieved a large diffusion in research and business. They show many advantages in terms of portability and longevity for long-term monitoring. The most common applied fields concern biomechanical analysis, rehabilitation and portable non-invasive acquisitions of physiological parameters [1]. Nevertheless, wearable systems require small-sized hardware and low power consumption and this can limit a high level of local post-processing especially when real-time is required.

Sensorised shirt developed by Smartex within the European integrated project WEALTHY

➢Methods (embedded into PSoC Microcontroller)

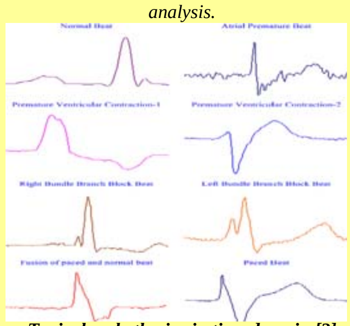
1: *ECG is acquired by means of surface electrodes and conditioned through circuit showed in Figure below. The circuit consists of a differential amplifier in 3 op-amp configuration (for a good rejection of common mode) with an integrator in feed-back chain in order for the baseline to be stationary. Two low-pass filters (active and passive) are located at the end of this block, in order to minimize the high frequency noise. The output signal is digitalized through an incremental ADC with sampling rate of 360 Hz, according with MIT-BIH Arrhythmias Database records sampling rate, and 12 bit resolution.*



2: *The extraction of QRS complex through detecting of the R-wave and gathers the signal within a time window of about 280ms centred in the R-peak previously found. If the stationary condition is respected, then the R-wave can be detected through a simple threshold technique, allowing the real-time requirement and memory saving*

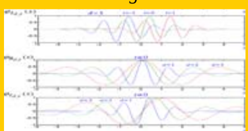
➢Innovations in ECG arrhythmias

Advances in cardiology allowed to identify different cardiac arrhythmias in clinical scenario, see Figure below, which can produce critical damage to cardiovascular system. The innovation here introduced consists of a wearable systems for non-invasive and long-term monitoring of ECG signals with a local processing in order to classify pathological QRS complexes. This system can also record and transmit the signal to a remote workstation for a high post-processing analysis.



Typical arrhythmias in time domain [2]

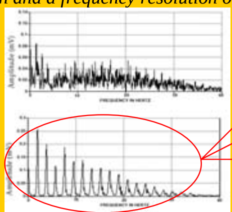
3: *In order to enhance spectral discrimination the use of wavelet spatial filter as Morlet wavelet (from [14]) was investigated.*



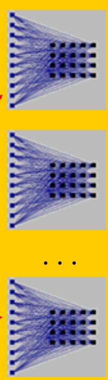
$$\varphi(k) = \cos\left[\frac{5(x(k)-t(k))}{d}\right] e^{-\frac{(x(k)-t(k))^2}{2d^2}}$$

For k=0…Ns-1.
Where d is the dilatation parameter, x is a sequence of samples obtained from the QRS complex; t is a sequence of samples obtained from the QRS complex of normal beat.

4: *In order to minimize memory usage and enhance feature discrimination a Discrete Fourier Transform (FFT algorithm) was applied in the time domain , obtaining a reduced number of samples in the frequency domain and a frequency resolution of 3.6 Hz.*



The input vector for the classifiers is composed by the first 10 samples of QRS complex spectrum[30 Hz].



Seven KSOM (2x2)

5: *Pattern recognition was implemented by using one minimal Kohonen Self-Organizing Map (2x2 neurons for two input classes) for each cardiac arrhythmia. This choice of neural network is justified because KSOM requires only the storage of weight and label array and the output is performed with a simple sum of products. Nevertheless, KSOM requires a long training phase with many examples. Training phase was performed in offline mode [3]. In this work the integrate-and-fire neuron model was used, the winner-takes-it-all training strategy was adopted using a distance-based learning method. A decay factor over epoch time was used for both the learning rate and the learning radius. All the elements of the input vector are connected to all the artificial neurons of the KSOM. After training process, a supervised labelling step is performed. Cluster labels are assigned to the individual artificial neurons. In order to check the generalization capability of the neural network, a cross-validation process is carried out.*

➢Results and Discussion

A simple algorithm able to discriminate in real-time normal and pathologic QRS complex was rightly implemented into a portable hardware by means of small memory usage and lower complexity. The QRS complexes were effectively extracted through a threshold method to find the R-peaks. FFT algorithm was applied in order to extract and decimate sample features and minimal KSOMs were used to pattern recognition.
Wavelet spatial filter tested showed lower frequency discrimination. Therefore for this wearable system wavelet filter method is not acceptable.
Results showed both accurate discriminations (see Table on the right) and faster processing time during pathological QRS classification, when used FFT and KSOM.
Considering the wavelet filter application, results showed good specificity, but in some cases lower sensitivity. The hardware here realized showed high portability with low power consumption, suitable for wearable system applications.

	FFT – KOH		WAV – FFT – KOH	
Heartbeat	Specificity	Sensitivity	Specificity	Sensitivity
Paced	99.99%	99.94%	99.97%	99.50%
Left Bundle Branch block	99.62%	97.34%	99.28%	93.59%
Fusion of Paced and Normal	99.85%	92.30%	94.23%	98.46%
Right Bundle Branch block	99.91%	98.49%	99.23%	83.59%
Premature Ventricular Contraction	98.50%	90.07%	96.74%	90.49%
Atrial Premature Contraction	99.61%	99.88%	n.c.	n.c.

➢ References

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