ECG Data Compression Using an Adaptive Hermite Model *

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ABSTRACT: An orthogonal transformation based on Hermite functions is proposed for ECG data compression. We applied this method to P, QRS and T waves of ECG records from the MIT/BIH database, evaluating the percent root-mean-square difference (PRD) as a function of the number of coefficients and the width parameter (b) of the Hermite functions. We show that, for an ECG with a biphasic P wave, only 6, 6 and 2 parameters represent the P, QRS and T waves, respectively, with less than 10% PRD. If we select a 3% PRD 7, 11 and 6 parameters are necesary for each wave. An adaptive system is used for beat-to-beat parameter estimation, attenuating noise not correlated with the signal.

I. INTRODUCTION

The great amount of data obtained when recording bioelectrical signals, like the ECG, necessitates data compression techniques for storing, transmitting and analysing the data, without loss of clinical information [1]. In this work we study a method for ECG data compression that is based on a transformation using Hermite functions. This method was first used in [3] for evaluation of QRS shape features. It is based on calculating the inner product between the ECG signal and each Hermite function. These coefficients represent the QRS shape and the width parameter b defines the width of the Gaussian in Hermite functions [3]. Subsequently, we proposed in [2] an adaptive estimation system for calculating these coefficients in each beat of a real ECG sequence, attenuating noise not correlated with the signal.

In this work we study the potential of this method for ECG data compression. We have separately applied the procedure to the different waves of the ECG signals (P, QRS and T waves) from the MIT/BIH database. The representation of ECG signals by means of Hermite functions is presented as an inner product, using an adaptive estimation system.

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II. THE HERMITE MODEL

ECG signal waves can be represented by a set of orthogonal Hermite functions, with a finite number of parameters. These functions have the expression:

$$\Phi_n(t,b) = \frac{1}{\sqrt{b2^n n!\sqrt{\pi}}} e^{-\frac{t^2}{2b^2}} H_n(t/b) \qquad (1)$$

where $H_n(t/b)$ are the Hermite polynomials, and parameter b determines the temporal width of the Hermite functions. The approximated ECG waves (P, QRS, T) can be expressed as a linear combination of $\Phi_n(t,b)$:

$$\left\{ \begin{array}{c} \mathrm{P(t)} \\ \mathrm{QRS(t)} \\ \mathrm{T(t)} \end{array} \right\} \simeq \left\{ \begin{array}{c} \sum_{n=0}^{M_P} w_n^P(b_P)\Phi_n(t,b_P) \\ \sum_{n=0}^{M_{QRS}} w_n^{QRS}(b_{QRS})\Phi_n(t,b_{QRS}) \\ \sum_{n=0}^{M_T} w_n^T(b_T)\Phi_n(t,b_T) \end{array} \right\} \qquad (2)$$

where each wave i (= P, QRS, T) is characterized by M_i+1 parameters: the M_i coefficients w_n^i and the parameter b_i.

III. THE ADAPTIVE ESTIMATION SYSTEM

We proposed an adaptive system [2] for estimating the w_n^i coefficients and the b_i parameter. It is based on the multiple-input adaptive linear combiner [4]. The primary input signal d_k is synthesized as the concatenation of the P, QRS or T wave windows from consecutive beats, respectively. Thus, d_k contains the deterministic signal and the noise n_k. The reference inputs are formed by the M_i Hermite functions, considered for each wave. $\Phi_{nk}(b)$ is formed by concatenation of centred sequences of L samples of $\Phi_n(t,b)$.

In [2] it is shown that the output signal y_k in the steady state results in the deterministic component of d_k projected to the space defined by the M_i Φ_n considered at the reference input. Thus, the weights w_n are the inner product value of this deterministic component with the $\Phi_n(t,b)$ functions, which are the coefficients in our study. In this way we have a beat-to-beat estimation method to compress the ECG, attenuating the effect of uncorrelated noise by the adaptive system. The adaptation process for the w_n is done with the LMS algorthm [4]. The b parameter is also adaptively estimated [2].

IV ECG DATA COMPRESSION

In this section we study the capability of the Hermite functions for ECG data compression, testing on records of the MIT/BIH database ($f_{samp} = 360$ Hz). This method has been applied to P, QRS and T waves, respectively. The percent root-mean-squared difference (PRD) between the original and reconstructed signal has been used in evaluating ECG compression performance [1].

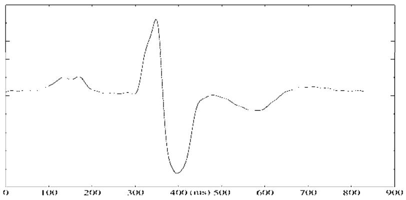

Fig. 1: Beat of the record *a118* from MIT/BIH database

The PRD is studied as a function of the parameter b, for different numbers of coefficients M. In this way, we can see the performance of data compression in a selected ECG beat (Fig. 1). In fig. 2, the improvement in PRD by increasing the number of coefficients can be analysed with the P and T wave. Note that the optimum value of PRD is obtained at different values of b, depending on M.

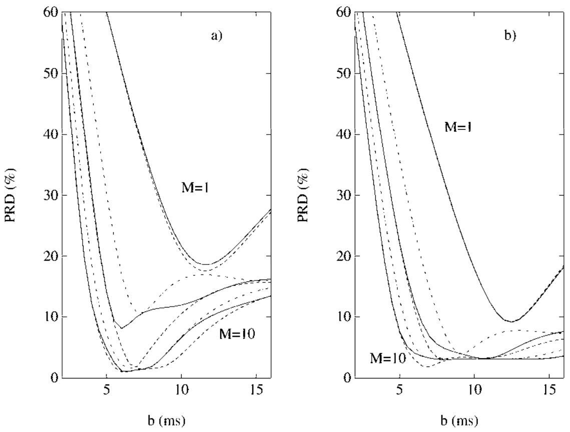

Fig. 2: PRD as a function of b parameter, for each number of coefficients ($M = 1, ..., 10$): a) P wave. b) T wave.

Table 1 shows the compression ratio (CR) [1] obtained for this ECG signal, that includes a biphasic P wave.

Table 1: ECG Data Compression

PRD	P wave (52 samples)		QRS complex (65 samples)		T wave (54 samples)	
	Param.	CR	Param.	CR	Param.	CR
10 %	6	8.7	6	10.8	2	27.0
3 %	7	7.4	11	5.9	6	9

Figure 3 shows the reconstructed P wave using different numbers of coefficients ($M = 1,...,10$) at the optimum value of b parameter for each case . We can see that for M=6 coefficients we can recover all the information necessary for clinical diagnosis.

V ADAPTIVE ECG DATA COMPRESSION

A simulation was carried out to evaluate the behaviour of the adaptive Hermite model estimation system for ECG data compression. We studied the convergence of the parameter b and the evolution of PRD for each adaptive step. In figure 4 we can see the results when the P wave

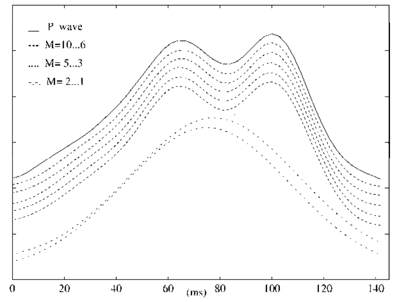

Fig. 3: Original and reconstructed P wave for different number of coefficients (M=1,...,10).

shown in the previous section was selected as an invariant deterministic signal. We can observe the convergence of the b to the optimum value, in agreement with previous studies [2]. We conclude the adaptive estimation system can be used to remove the noise and calculate the optimum coefficients corresponding to the deterministic signal, with the performance shown in the previous section.

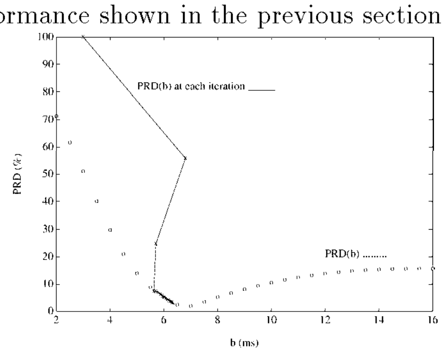

Fig. 4: Convergence of b parameter to the optimum value shown in figure 2, for M=6.

VI CONCLUSIONS

An orthogonal transformation using Hermite functions is presented as a method for ECG data compression. Applied to real ECG signals, the method is able to represent individual ECG waves with a reduced number of parameters. This includes cases where the morphology is complex, such as a biphasic P wave. Compression ratios of 8.7, 10.8 and 27.0 were obtained for P, QRS and T components, respectively. The use of an adaptive system has been shown to be a good approach to beat-to-beat estimation of the coefficients, attenuating the noise not correlated with the signal.

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