A clinical distortion index for ECG data compression performance evaluation

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Abstract. Most of the common distortion indexes used to evaluate lossy ECG data compression systems are based on quadratic error measurements between the original and the reconstructed signal. However they can not quantify the clinical information preserved in the reconstructed signal. In this paper we propose a clinical distortion index (*CDI*) based on clinical measurements on the original and the reconstructed ECG signals. The clinical measurements used are intervals, such as QT and PR, waveform amplitudes and morphology. The new distortion index is evaluated in the MIT-BIH Arrythmia database and compared to classical indexes, such as *PRD*, *MSE* and *RMS*. Absolute error indexes, such as *RMS*, are more correlated to *CDI* than relative indexes, such as *PRD* and *MSE*.

1. Introduction

The great amount of data obtained when recording ECG signals needs data compression techniques for storing, transmitting and analyzing the data, without loss of clinical information. During the past decades, many algorithms for ECG compression have been proposed. Lossless data compression systems can exactly reproduce the original signal, but the compression ratios obtained are very low (lower than 4:1). In many situations higher values of compression ratio are needed, and therefore lossy compression systems are used. In these cases the reconstructed signal is only an approximation to the original ECG, and the performance of data compression system must be evaluated not only with compression ratio but also with distortion.

Most of the common distortion indexes used to evaluate lossy ECG data compression systems are based on quadratic error measurements between the original and the reconstructed signal. These indexes are very easy to calculate, however they do not quantify the clinical information lost in the compression process. In this work we present a distortion index based on clinical variables that are automatically measured.

2. The Clinical Distortion Index

The Clinical Distortion Index (*CDI*) is a score based on comparing several clinical features between the original signal and the reconstructed ECG. The *CDI* in the *i*-th heartbeat is defined as

$$CDI_i = \frac{\mathbf{d}_i^T \ddot{\mathbf{E}}\, \mathbf{d}_i}{tr\{\ddot{\mathbf{E}}\}} \qquad (1)$$

where $\mathbf{d}_i$ is a feature vector of N clinical variables and $\ddot{\mathbf{E}}$ is a diagonal matrix that weights the clinical impact of every variable. Depending on the particular application (resting ECG, Holter, stress test, ST analysis) some clinical features can be emphasized. The N clinical features can be of different nature (amplitudes, interval duration, waveform morphologies), and therefore, they are normalized to a reference value V^{ref}

$$d_i[k] = \frac{\left| p_i^{orig}[k] - p_i^{rec}[k] \right|}{V^{ref}[k]} \qquad 1 \le k \le N \qquad (2)$$

being $p_i[k]$ the k-th clinical feature in the i-th beat. In our application we used N=12 clinical features: P duration (P_{dur}), PR interval (PR), QRS duration (QRS_{dur}), QT interval

(QT), RR interval (RR), P amplitude (P_A), QRS positive amplitude (QRS_+), QRS negative amplitude (QRS_-), Q amplitude (Q_A), STJ+60 (ST_J), T amplitude (T_A) and T wave morphology (T_M). These clinical features are automatically measured by means of a software developed and evaluated in our research group [1]. The reference values $V^{ref}[k]$ are related to the resolution of each clinical variable. Several authors [2] studied the appropriate resolution for automatic measurements of ECG intervals. The reference values selected are shown in table 1.

Table 1. Reference values V^{ref} for each clinical feature.

	P_{dur}	PR	QRS_{dur}	QT	RR	P_A	QRS_+	QRS_-	Q_A	ST_J	T_A	T_M
V^{ref}	22.0	11.5	12.5	20.5	12.5	20	30	30	25	30	30	1
unit	ms	ms	ms	ms	ms	μV	μV	μV	μV	μV	μV	-

3. Results

The *CDI* index was evaluated over 23 records from MIT-BIH Arrythmia database (with a total duration of 574 min). The weighting matrix $\ddot{\mathbf{E}}$ was set to identity matrix. The data compression system used was based on multilead transform coding with the KLT [3]. Mean values of distortion quantified with proposed clinical index, *CDI*, and classical indexes *RMS*, *MSE*, *PRD* are shown in Table 2 for different compression ratios (*CR*).

Table 2. *Mean distortion values (sampling rate of original ECG was 360 Hz).*

B (bits/beat)	90		110		130		150	
CR	34.5		29.0		24.3		21.2	
Channel	1	2	1	2	1	2	1	2
CDI	**1.07**	**1.15**	**0.98**	**1.04**	**0.86**	**0.98**	**0.86**	**0.98**
RMS (μV)	36.8	28.96	29.49	24.93	24.22	21.90	22.37	19.05
MSE (%)	1.19	3.15	0.87	2.29	0.69	1.85	0.61	1.21
PRD (%)	10.9	17.75	9.32	15.13	8.30	13.60	7.81	11.03

The *CDI* is an adimensional value that represents the average clinical distortion as the number of reference values. *CDI* values lower than unity indicates that mean clinical distortion is lower than reference values, and therefore with a very low clinical impact. Relative classical indexes, such as *MSE* and *PRD*, have an undesirable strong depedence on the signal energy. Absolute error indexes, such as *RMS*, have a better correlation with *CDI*. A distortion value of *RMS* 25 μV can be a good choice to avoid visual clinical distortion.

4. Conclusions

In this work a Clinical Distortion Index (*CDI*) based on clinical differences from each heartbeat of the original ECG and the reconstructed signal is presented. Twelve clinical features (5 intervals, 6 amplitudes and 1 waveform morphology) are used to represent the clinical information in each heartbeat.

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References

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