CODING THE VECTOCARDIOGRAM AS A SEQUENCE OF 3D OBJECTS

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Abstract: **The paper addresses the use of sequence coding algorithm to the compression of vectocardiograms. The loops representing P, QRS and T waves are considered as three sequences of three-dimensional objects. Thanks to the similarity of neighbouring loops, encoding the values of prediction error reduces the data set volume. The similarity is enhanced with spatial transforms eliminating the extracardiac variations. The residual values are de-correlated with DCT and truncated at not relevant values. The performance of the proposed algorithm is confirmed by results of numerical experiment carried out for a wide range of parameters. The data reduction ratio reaches a value of 8.15 while the PRD distortions for the most important sections of signal does not exceed 1.1 %.**
Keywords: **vectocardiography, data reduction techniques, ECG signal compression**

Introduction

The three-dimensional VCG imaging of a cardiac cycle focuses doctor's attention on loops representing P, QRS and T wave [1]. The baseline is not investigated for electrodiagnostic data. Following this approach, the signal consists of a continuous low-bandwidth component and three sequences of 3D objects (one for each wave type). Thanks to the temporal prevalence of the sinoatrial rhythm, the correlation of consecutive heartbeats is very high. In the VCG, when 3D loops are considered, a high compression ratio may be achieved with use of sequence coding methods originally developed by MPEG for video storage and transmission [2].

The software for VCG coding as a sequence of 3D objects was developed in our laboratory and is the main issue of this paper. Our previous algorithm [3] that used only prediction-based encoding of the VCG loops has been improved with use of new research results and now yields significantly higher compression ratio without exceeding the acceptable level of signal distortion.

Materials and Methods

The coding algorithm begins with calculating the P, QRS and T segment borders. The baseline component is extracted by orthogonal split of the signal spectrum at 2 Hz. Three object sequences P, QRS and T (fig. 1) are processed simultaneously. The remaining low frequency signal part is stored in the output data stream.

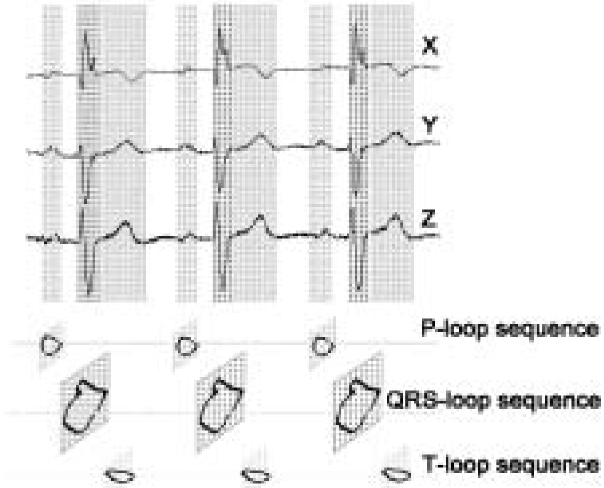

Fig. 1 Considering the VCG as three sequences of P, QRS and T loops

The spatial synchronisation [4] uses basic geometrical transforms: translation, rotation and homothety to minimise the global dissimilarity between two adjacent loops. This ameliorates the statistic distribution of local errors during the forecasting of neighbouring loops.

The loop duration is normalised with use of the cubic spline interpolation to 64 samples. In case of T-wave, being in average twice as long as P or QRS, the normalisation means also decimation and provides significant reduction of the data volume. The local signal bandwidth for T-wave is below that new frequency and therefore no significant alteration of the signal occurs.

The signal is represented by the magnitude A and two angular variables ϕ and λ. The angular data is rounded to 8-bit precision values [5] and stored at a half of their original sampling rate.

All internal loops of a sequence containing at most 15 items bordered by the "intra-coded" or I-loops are fed into two prediction-correction stages. The values of first level prediction loops, "coarse" or C-loops are predicted on the basis of I-loops values. True values of C-loops are in turn starting points for the forecast of second level prediction loops, the "fine" or F-loops, which lay in between of them. In consequence, all internal loops are represented by appropriate prediction error coefficients of very narrow distribution. The processing ends with encoding the fixed-point DCT representation of loops prediction errors with use of the Huffman Coder [7]. Both angular variables have similar statistic properties and share the same symbol dictionary.

Results

The coding algorithm was tested with use of the CSE Multilead Database (2.44 µV, 500 Hz) [8] that also provides reference segmentation points. The resulting compression ratio (CR) and distortion parameters (PRD) are summarised in the table 1.

Table 1: Compression performance and distortion level of the VCG coding as a sequence of 3D objects.

	HR	CR	distortions (PRD %)			
			total	P	QRS	T
average	95	8.15	6.22	0.94	0.16	1.09

The distortion level was computed for the whole heartbeat and separately in the range of each wave type in order to estimate how far the diagnostic data are influenced by signal alterations. The temporal distribution of distortions in the reconstructed VCG signal is also displayed in the figure 2.

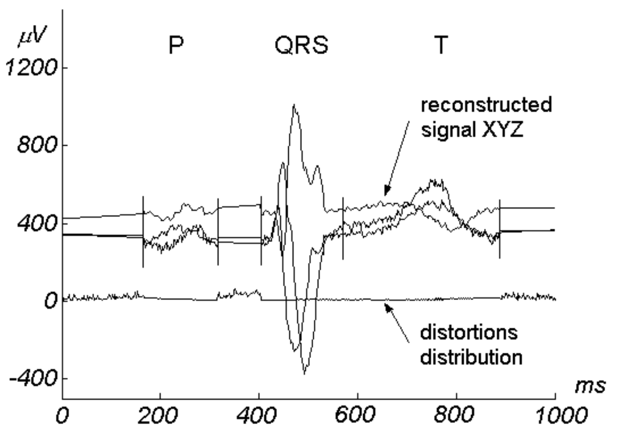

Fig. 2 Distribution of distortions in the reconstructed VCG signal

Discussion

The concept of video frame sequence coding technique was successfully adapted to three-dimensional VCG loops. The algorithm features high compression ratio and low level of distortion. The reconstruction error appears only in the signal sections of low diagnostic importance, since in these parts the data reduction is achieved by significant limitation of bandwidth. From the cardiologist's viewpoint focussed on the P, QRS and T-wave loops our method guarantees a reliable signal reconstruction (error below 10 µV).

Main drawback of the sequence coding scheme applied to the vectocardiogram is the high computation complexity. Therefore the end-user implementation is rather demanding on resources. The compression ratio depends on the heart rate and on the stability of cardiac rhythm – in subjects with high degree of irregularity the compression ratio is remarkably lower. This relationship may also be seen as a disadvantage of our method.

Extending this algorithm to the domain of conventional 12-lead ECG involves the use of one of the body mapping-derived transforms (i.e. Levkov). Despite its complexity, the algorithm of coding the VCG as a sequence of 3D objects is currently considered for implementation in a commercial ECG data retrieval system.

Conclusions

The technology originally developed for coding of the picture sequences is very efficient in an application to the vectocardiogram coding. Our method bases on irregular temporal distribution of medical data in the signal and uses variable sampling frequency for automatically detected sections of the ECG. The main novelty and advantage is the temporal management of signal distortion distribution controlled by the signal contents and by the general knowledge about the local signal importance.

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