ECG DISTORTION CAUSED BY WAVELET-BASED LOSS COMPRESSION

Jan Hrubeš
Doctoral Degree Programme (3), FEEC BUT
E-mail: jan.hrubes@phd.feec.vutbr.cz

Supervised by: Jiří Kozumplík
E-mail: kozumpli@feec.vutbr.cz

ABSTRACT

This paper is concerned with distortion of ECG signals caused by wavelet-based loss compression method. The aim is a comparison of the specific distortion types and their eventual influence on a diagnosis. We have tested three wavelets of biorthogonal family. For better recognizable distortion we have used low *avL* (average length of sample in bits). The outcome resulting from our tests is that the reconstruction wavelet should be smooth.

1. INTRODUCTION

Compression method SPIHT (Set Partitioning in Hierarchical Trees) is widely used for still image compression. In this paper is used a modification of SPIHT algorithm for the compression of ECG signals. This algorithm is very efficient, either loss or lossless coder, with progressive binary output. Input of coder and output of decoder are coefficients of wavelet transform (WT). We focused on influence of three different wavelets from biorthogonal family to the reconstructed signal and its distortion.

2. METHODS

The compression algorithm SPIHT was introduced in [2] and its modification for 1D signals (especially ECG signals) was presented in [1]. The process of compression and reconstruction of ECG signal is shown in Fig 1.

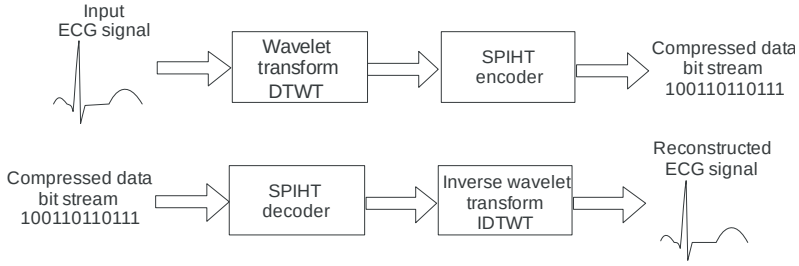

Fig. 1: Compression and reconstruction of the ECG signal based on SPIHT coding algorithm.

Compression using SPIHT is progressive with a binary stream output. It can be stopped at any bit depth, but it also can be used as a lossless compression. The compressed bit stream can be truncated to obtain more compressed version of original signal.

The algorithm is based on a wavelet transform, temporal orientation trees and set partitioning. For the signal compression is used strictly the fast discrete time wavelet transform in the dyadic form. The wavelets in DTWT are presented as a bank of filters. The realization of fast dyadic DTWT (discrete time wavelet transform) with decomposition level three is shown on Fig 2.

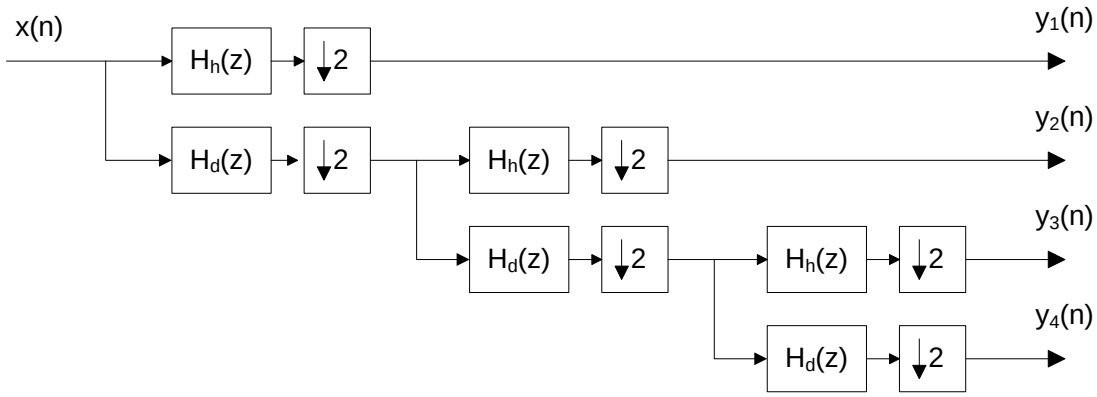

Fig. 2: Fast dyadic DTWT with decomposition level three.

For our tests were chosen three different wavelets from biorthogonal family: bior1.5 (CDF 10/2), bior3.3 (CDF 8/4) and bior4.4 (CDF 9/7), prototype wavelets are shown on Fig 3.

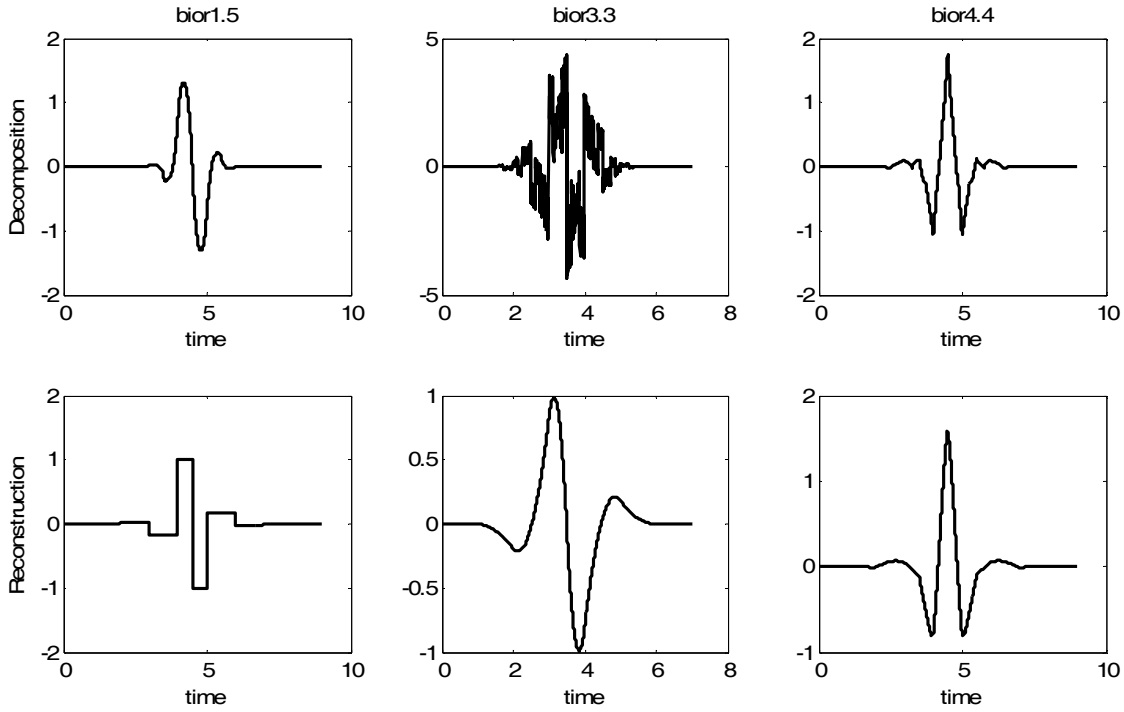

Fig. 3: Prototypes of tested decomposition and reconstruction biorthogonal wavelets (bior1.5, bior3.3, bior4.4)

The wavelet bior1.5 was chosen for continuous, smooth and odd decomposition wavelet and step, odd reconstruction wavelet. Curve of decomposition wavelet bior3.3 is quite complicated and reconstruction wavelet is smooth and odd. Bior4.4 is a favourite one for compression. Curves of reconstruction and decomposition wavelets are even and smooth. Lengths of decomposition filters (10, 8 and 9) in the filter banks for DTWT are comparable. Against that lengths of reconstruction filters are different (2, 4 and 7).

We can obtain a reconstruction wavelet from a filter bank as an impulse response. The scale of this wavelet depends on the band, which contains the impulse. This implies that the specific distortion type of the reconstructed signal depends especially on the reconstruction wavelet (filters).

The distortion of reconstructed ECG signal is frequently evaluated in percent root mean square difference (PRD).

$$\mathrm{PRD} = \sqrt{\frac{\sum_{i=1}^{n}\left[x_o(i) - x_r(i)\right]^2}{\sum_{i=1}^{n}\left[x_o(i) - \bar{x}_o\right]^2}} \cdot 100 \ [\%] \qquad (1)$$

However one number (PRD) can not describe the signal distortion and its effects on a diagnosis so a subjective classification is convenient. There are only two noticeable methods of automatic validation of decompressed signal. In [4] is used weighted diagnostic distortion (WDD) coefficient and in [3] is used an artificial neural network.

3. RESULTS

The compression algorithm was tested on signal no. 117 from MIT-BIH arrhythmia database. The original signal has *avL* = 11 bps. The ECG signal was decomposed and reconstructed using selected filter banks (wavelets). Decomposition of ECG signal in time-scale domain was compressed with three different *avL*. Values of *PRD* of reconstructed signals are summarized in Tab. 1 (*CR* means compression ratio). The *PRD* values are mentioned for a comparison to ECG compression related sources.

		bior1.5	bior3.3	bior4.4
avL [bps]	*CR*	*PRD* [%]	*PRD* [%]	*PRD* [%]
0.4	27.4	23.2	15.9	16.4
0.8	13.7	12.9	8.1	7.3
1.6	6.6	5.5	4.1	3.2

Tab. 1: *PRD* of reconstructed signals after compression with three selected wavelets

As mentioned above the values of *PRD* do not describe the distortion. We have focused on one period of the ECG signal no. 117 to investigate the specific distortion type for each wavelet.

Reconstructed signals are shown on Fig 4. Each picture consists of two graphs. In the upper one are an original (light gray) and a reconstructed (black) signal, in the lower one is an error signal – the scale of the error signal is the same in all pictures. In the firs row are

signals compressed with *avL* = 0.4 bps. The distortion is very strong. The most noticeable is a step distortion made by bior1.5. Bior 3.3 and bor4.4 produced a smooth curve, but all ECG waves are damaged, especially by bior 4.4. In the second row are signals compressed with *avL* = 0.8 bps. Bior 3.3 and bior4.4 produced acceptable outcome. The ECG waves are retained and in addition a noise is filtered. In the last row are signals compressed with *avL* = 1.6 bps. All signals are almost perfect reconstructed, but using bior1.5 still leads to the step distortion of the noise.

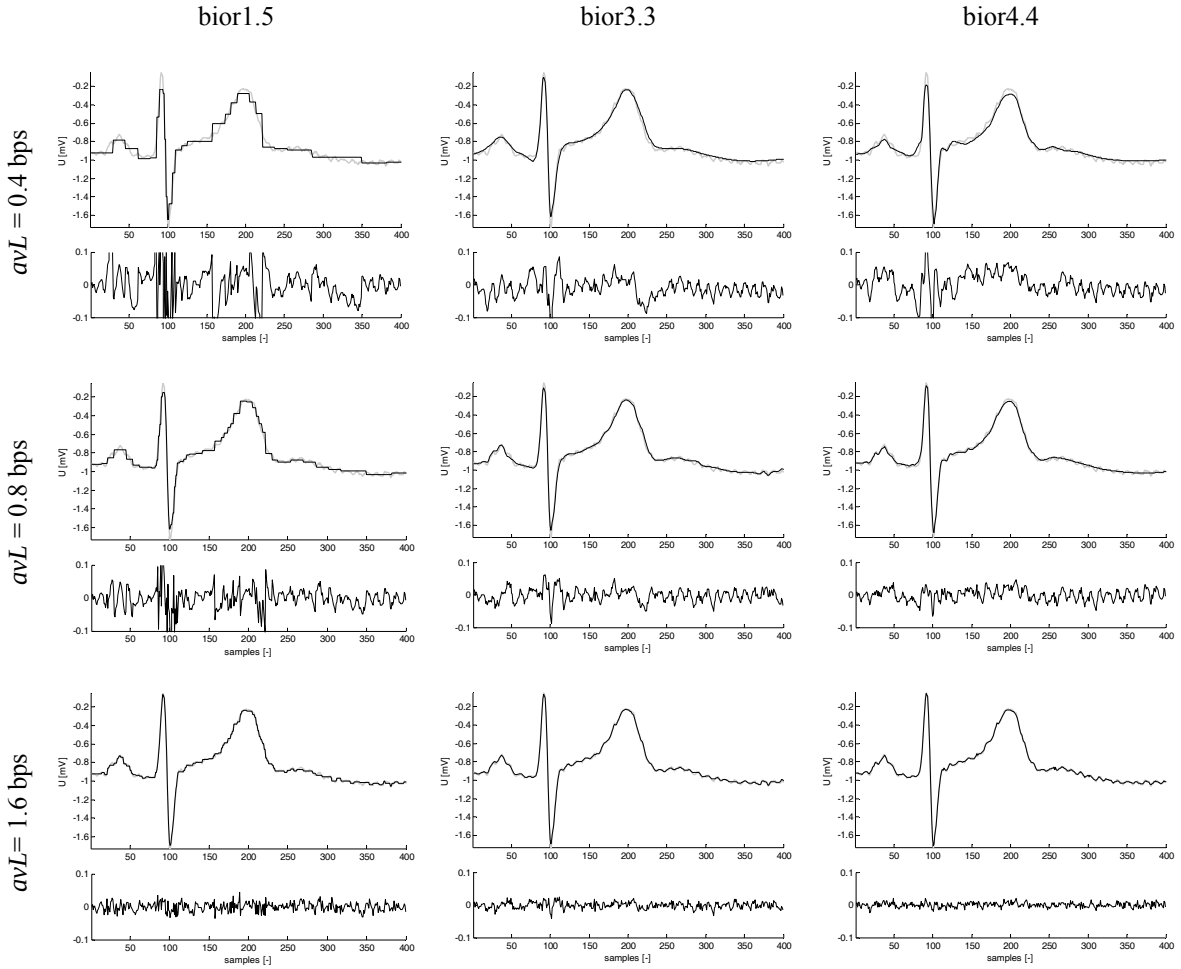

Fig. 4: One period of ECG signal no. 117, reconstructed signals, error – black, original signal – light gray

4. CONCLUSIONS

The pictures of reconstructed signals confirm influence of reconstructing wavelet to the reconstructed signal. The most noticeable is step distortion of reconstruction wavelet bior1.5. It is irrelevant if the reconstruction wavelet is odd or even. Also direct influence of decomposition wavelets is insignificant. The wavelet bior4.4 gives reason for its popularity and confirms its qualities for compression.

5. ACKNOWLEDGEMENT

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