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# Two-dimensional Compression Schemes for Electrocardiogram Signals

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## Introduction

In the last twenty years, there has been a continuing proliferation of computerized ECG processing systems. The volume of ECG data produced by monitoring systems can be very large, as a long period of time is required to gather enough information about the patient. For that reason, efficient methods for storing and retrieving ECG data have been proposed in the literature. By observing ECG waveforms, it can be concluded that they do not only show correlation between adjacent samples but also between adjacent heartbeats. Therefore, this paper discusses the efficiency of using a two-dimensional ECG compression scheme, combined with some preprocessing techniques. The MIT-BIH Arrhythmia database is used to evaluate the performance of the method.

## Materials and Methods

In order to construct an image from the 1-D ECG signal, we have first to identify each heartbeat by a QRS detection algorithm. Then, the signal is cut at every 130$^{th}$ sample before each QRS peak and heartbeats are aligned in a matrix. The second step is to apply some preprocessing techniques in order to make the ECG image smoother and then easier to compress by transform coding.

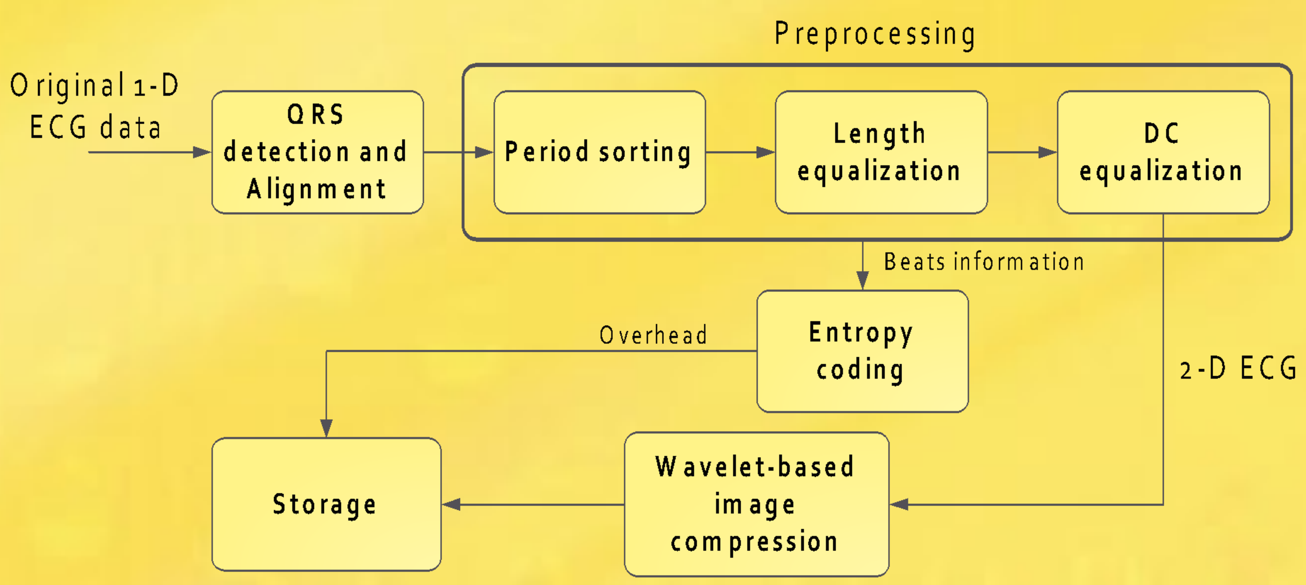


Fig.1 The 2-D compression scheme.

Figure 1 shows the 1-D to 2-D conversion process, which includes the QRS detection and alignment of the heartbeats along with a wavelet-based compression. The period sorting, proposed in [1] is done in order to improve the inter-beat correlation and is especially effective for records with irregular periods. As the different periods of the signal obviously do not show the same length, length equalization must be done in order to map the periods in a matrix. It can be made in different ways, including zero-padding, mean extension and period equalization. The period normalization consists of changing the length of all periods to a common value, using cubic splines [2]. Moreover, a DC equalization step eliminates the high frequencies along the vertical axis. The preprocessing steps bring some side information that needs to be recorded losslessly for further reconstruction. After the preprocessing, a wavelet-based image coder is applied on the matrix. The output of this block, along with the overhead information gives the final bitstream. The advantage of performing period equalization is that the normalized period size, N, can be chosen to be smaller than the mean length of the heartbeats. For example, if the mean period length is 300 and we take N equal to 100, it is just as if we have already compressed the image by a factor of 3. However, the period normalization is a lossy technique that will tend to increase significantly the distortion if N is too small. Then N should be carefully chosen. Figure 2 shows the non-compressed ECG image obtained with no preprocessing (left) and preprocessing (right) for record 119.

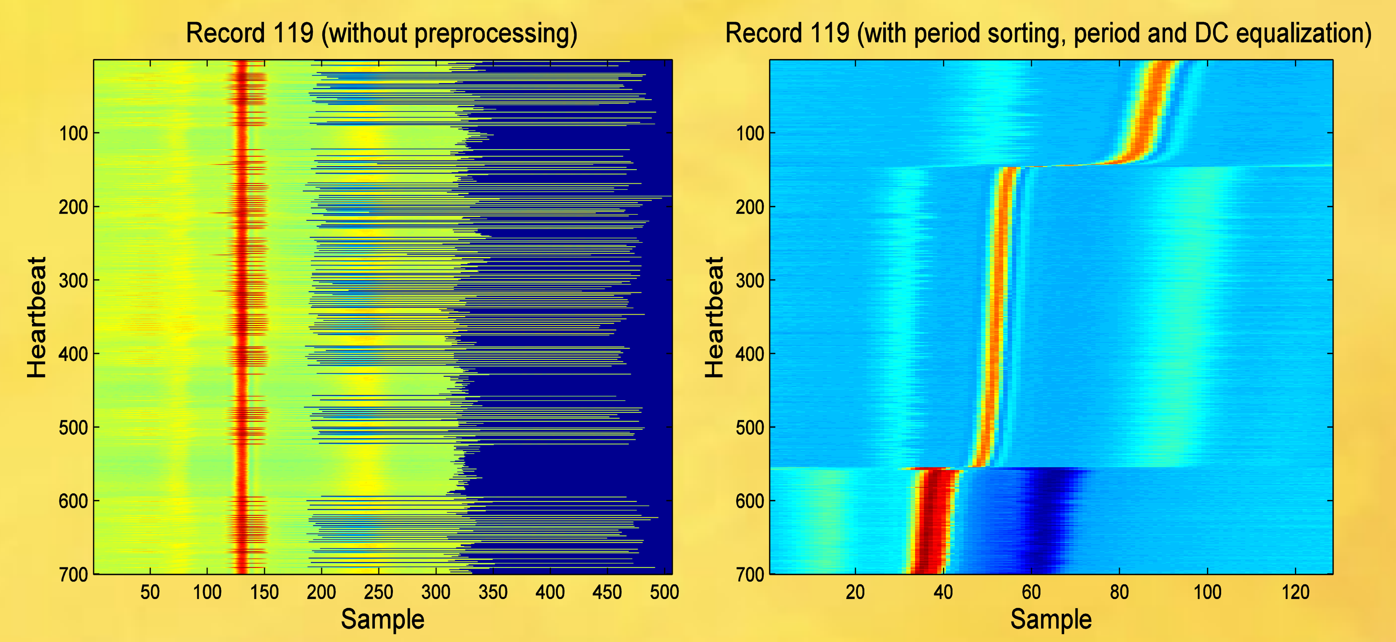


Fig.2 2-D arrays formed with 10 min of ECG from record 119.

## Simulations and Discussion

The performance indicator used in this study is the Percent Root mean square difference (PRD):

$$PRD = \sqrt{\frac{\sum_{i=1}^{M}[x_{ori}(i) - x_{rec}(i)]^2}{\sum_{i=1}^{M}[x_{ori}(i) - 1024]^2}} . 100\ [\%]$$

First, we tested the proposed compression scheme on the entire MIT-BIH Arrhythmia database (48 records), with the JPEG 2000 standard coding system. We compared the performance with different length normalization approaches, such as zero-padding, mean extension, period normalization, and the DC equalization step (figure 3, left). The period sorting block is always used (except for the no preprocessing case). The matrices include approximately 10 min of ECG data. The number of columns is equal to the maximum period length, except for the period normalization, where N is equal to 128.

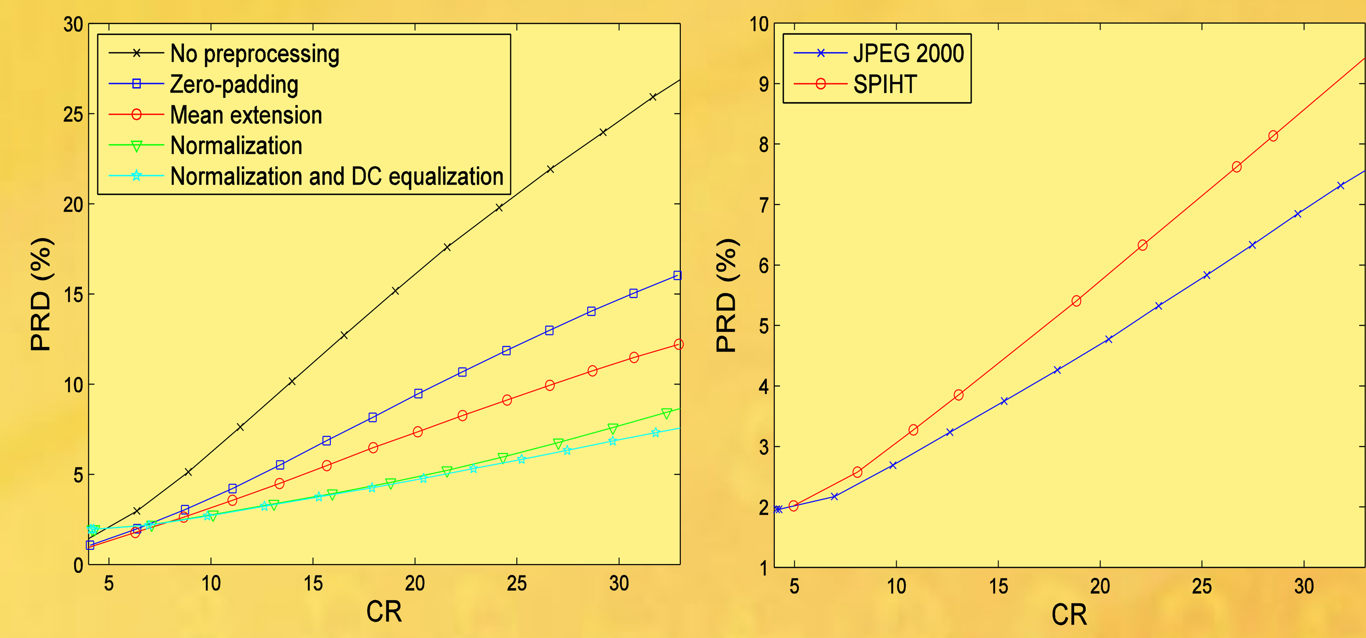


Fig.3 PRD comparasion between different preprocessing techniques (left) and between JPEG 2000 and SPIHT (right)

As we can see, the best performance is obtained with the period normalization and DC equalization. Then we compare the performance of JPEG 2000 with another powerful coding system, namely SPIHT. The number of wavelet level is 5 and we used the biorthogonal 9/7 tap filters. On figure 3 (right), we see that JPEG 2000 slightly outperforms SPIHT.

## Conclusion and Future work

In this paper, we showed the improvement added by some simple preprocessing techniques on the compression performance of 2-D compression algorithms. The next step of this work consists of implementing a modified SPIHT algorithm that would reduce the redundancy that exists among medium- and high frequency subbands, between insignificant wavelet coefficients that correspond to the same spatial location.

## References

[1] H.-H. Chou, Y.-J. Chen, Y.-C. Shiau, and T.-S. Kuo, “An effective and efficient compression algorithm for ECG signals with irregular periods,” *IEEE Transactions on Biomedical Engineering*, vol. 53, pp. 1198–1205, 2006.

[2] A. Bilgin, M. W. Marcellin, and M. I. Altbach, “Compression of electrocardiogram signals using JPEG2000,” *IEEE Transactions on Consumer Electronics*, vol. 49, pp.833–840, Nov. 2003.