# PURSUIT OF THE ECG INFORMATION DENSITY BY DATA CANCELLING IN TIME-FREQUENCY DOMAIN

P. Augustyniak

University of Mining and Metallurgy/ Institute of Automatics, Kraków, Poland

august@biocyb.ia.agh.edu.pl

**Abstract: This work presents new method of local information density estimation in the ECG. Its principle is the controlled elimination of the data by cancelling the time-frequency plane coefficients of an electrocardiogram with simultaneous analysis of resulted inaccuracy of basic diagnostic parameters. In some regions of the standard ECG recording cutting out a given amount of data influences more the diagnostic parameters distortion than in the others. These regions are well related to the waves start- and endpoints. Furthermore, we computed the time function representing the typical diagnostic data stream density in an electrocardiogram. This function is the background of the ECG compression with use of adaptively modified characteristics, and is useful for comparing of distortion and assessment of differences in the ECG signals.**

Keywords: electrocardigraphy, data compression, time-frequency analysis

## Introduction

The electrocardiogram is the most frequently performed electrophysiological test, due to the high mortality risk of cardiovascular diseases that are induced by the style of life in developed countries. For the low cost and high accessibility of the ECG, the compression of electrocardiogram signal is of great practical significance and is widely used in clinical practice. Various ECG applications usually need the compression, among of them three should be considered as the most important: management of databases for reference purpose, transmission of the ECG over telecommunication networks and ambulatory long term recording (Holter systems).

An interesting compromise between the compression efficiency and the signal quality is the ECG recorder sampling at the variable rate [1]. Its principle breaks the general assumption that any probable signal component may occur at any time. That traditional approach, widely used for its generality and careless use of technical resources, is far from being efficient, because the full data bandwidth has to be allotted continuously [2]. The alternative solution developed currently in our laboratory makes use of variable density of diagnostic information in the cardiac signal that is obvious to the expert however difficult to express.

Since adapting the sampling frequency rejects some information, it is necessary to determine whether the local data modification suppresses only the noise or influences the diagnostic features of the ECG. This paper describes our pursuit of the time-domain function representing the vulnerability of diagnostic information to the local high frequency data loss. This aim has been achieved in two steps: first the appropriate subset of diagnostic parameters was chosen and next the changes were assessed for parameters computed from the signal modified in the time-frequency domain. The amount of cancelled data was always the same, but changes of its position with respect to the signal contents resulted in different reliability of diagnostic parameters.

## Materials and Methods

As the reference signal set the CSE Multilead database was used. It consists of 125 simultaneous 12-lead ECG recordings and the P-QRS-T segmentation points. The amplitude resolution is 12 bits (2.44 μV/LSB) and sampling frequency is 500 Hz [3]. Two recordings (67 and 70) contained pacemaker evoked beats were not considered for the experiment.

We used the reversible wavelet transform (5-th order Daubechies [4]) to prepare the modified test records in the time-frequency domain. The signal repreesntation was modified by suppressing 6 randomly choosen t-f coefficients of 14 in the window spanning three upper octaves (32-250 Hz) and 16 ms (fig. 1). Five trials were performed for each window, and 27 window positions

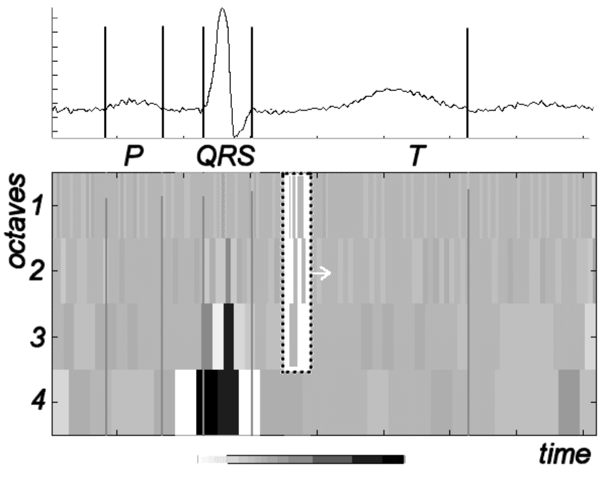


Figure 1. Suppressing the time-frequency domain ECG data in the sliding window (marked by the dotted line)

were applied to each signal. Since each lead (I, II, V1 to V6) was considered as independant recordings, the total amount of 132840 modified records were processed during the experiment.

The modified records were processed with use of the subroutine marketed as a firmware for a family of stand-alone automatic 12-lead recorders by Aspel S.A. company. Since three years it received wide recognition in the medical world. It was also tested for accuracy against the CSE 12-leads Database [5] and achieved on average the 6-th position in the ranking of 20 ECG reference results.

The global estimator of diagnostic parameter's divergence was computed as weighted sum of segmentation points inaccuracy values. This choice was justified by nearly linear drop of segmentation accuracy with diminution of the signal bandwidth. Other parameters can be recovered from the band-limited signal (e. g. R-peak position), cannot be computed at all (e. g. LP-presence) or are not influenced by high frequency data loss (e. g. ST-T segment parameters). The weighting coefficients were calculated from the values of segmentation tolerance recommended by CSE accordingly to the table 1.

Table 1 Segmentation accuracy contribution to the global estimator of diagnostic parameter's divergence.

| segmentation point | P | | QRS | | T |
|---|---|---|---|---|---|
| | **onset** | **end** | **onset** | **end** | **end** |
| tolerance [ms] | 8.0 | 7.8 | 4.4 | 5.8 | 15.6 |
| weighting value | 0.174 | 0.179 | 0.317 | 0.240 | 0.090 |

**Results**

Averaging the values of diagnostic parameter's divergence estimator separately for each position of modification window led to the relationship of time and the data vulnerability (fig. 2). This function represents a quantitative measure of local signal importance in diagnostic aspect. It is suitable to control the adaptive sampling rate algorithm that preserves the signal quality in most important parts and allows some extent of distortion in the remaining zones.

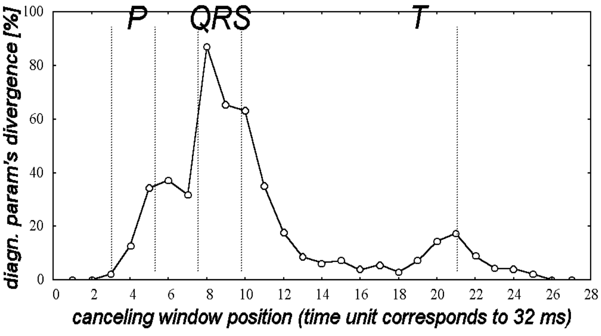


Figure 2. Relationship of the temporal position of canceling window and the ECG data vulnerability

**Discussion**

The function estimating global diagnosis quality loss resulting from the local data canceling in time-frequency domain meets all our expectations on the local information density estimator. It reliably describes the instantaneous importance of electrocardiogram and may be easily transformed to the desired signal bandwidth in an acquisition system using variable sampling rate. The investigations were performed on locally bandwidth-reduced signals modified exactly as it would be in the target application.

Relatively large sampling interval is not a drawback of the importance function. Higher sampling frequency cannot increase the bandwidth adaptation performance because its slope is limited by the uncertainty (Heisenberg) rule. On the other hand, the sampling interval is short enough to represent the particular ECG waves.

The importance function was calculated with respect to the ECG wave's positions, what reflects the physiological approach to the information contained in the signal. Therefore, the general importance function must be adapted individually for each segmented heart evolution. This involves the segmentation procedure for every consecutive heart beat in the recording. Fortunately, the segmentation points do not have to be calculated very precisely, because of the limitation of sampling rate adaptation slope mentioned above.

The pursuit of the local information density by controlled data elimination in the time-frequency domain is expected to work fine for other signals as well. It opens new applications area for variable sampling rate systems that are more adequate to the signals of irregular information density. The point to consider in each case individually is the right choice of data quality estimator. Its value should be linearly correlated with the signal bandwidth.


**Acknowledgment**

This work was supported by Polish State Committee for Scientific Research grant no: 8 T11E 007 17


**REFERENCES**


[1] AUGUSTYNIAK P. WRZEŚNIOWSKI A. (2001) 'ECG Recorder Sampling at the Variable Rate', Proc. VI-th Int'l Conf. SYMBIOSIS, Szczyrk, Poland pp. 11-13

[2] PROAKIS J. (1989) 'Digital communications' 2-nd ed. New York McGraw-Hill 1989

[3] WILLEMS J. L. (1988) 'CSE Multilead Atlas – Data Set 3' Commission of the European Communities – Medical and Public Health Research, Leuven 1988

[4] DAUBECHIES I. (1992) 'Ten lectures on wavelets' SIAM, Philadelphia 1992

[5] WILLEMS J. L., ARNAUD P., VAN BEMMEL J. H. (1985) 'Assessment of the performance of electrocardiographic computer programs with the use of a reference data base' Circulation, 1985, Vol. 71 No. 3, p 523-534.