COMPARISON OF THE KARHUNEN-LOEVE TRANSFORMATION RESULTS WITH THE RESULTS OF THE MODIFIED SPECTRAL METHOD FOR TWA DETECTION IN TIME DOMAIN

Milan Rychtárik
Doctoral Degree Programme (1), FEEC BUT
E-mail: rychtarik@phd.feec.vutbr.cz

Supervised by: Ivo Provazník
E-mail: provazni@feec.vutbr.cz

ABSTRACT

The modified spectral method was developed as a tool for the T-wave alternans progress detecting (TWA) in time domain. This method was compared with method based on Karhunen-Loeve transformation. The results show that both these methods are able to catch the changes of TWA in time domain.

1. INTRODUCTION

Microvolt-level T-wave alternans (TWA) present in ECG signals are defined as a consistent 2:1 variation in T-wave morphology. It means that T-wave is changed in its shape every second or it has different amplitude at least. The presence of microvolt-level T-wave alternans in surface electrocardiograms is recognized as a marker of electrical instability, and is related with patients at increased risk of suffering malignant ventricular arrhytmias and sudden cardiac death [1].

However, visually apparent microvolt T-Wave alternans is a rare electrocardiographic finding and lacks value as a clinical tool. For these reasons many methods for μ-TWA detection were developed. One of them – spectral method was modified for running reading values in time ("sliding windows") and compared with method based on Karhunen-Loeve transformation. Methods were tested on the real signals with stimulated alternans, with aim to verify their ability to catch change of the alternans in signal.

2. EXPERIMANTAL DATA

In this study, the experimental data measured at the Department of Internal Medicine and Cardiology, University Hospital Brno was used. The ECG signals were recorded at the heart rate 90-105 beats per minute with sampling frequency 3000 Hz. The resolution was 2.29 μV/LSB [2].

Typically, 128 beats were analyzed in each recording. This number provides a reasonable compromise between the ability to reduce noise and ability to track variations in the TWA

level over time. The T wave alternans were simulated by addition Gaussian-window to every second ST-T complex.

The signals were processed using a FIR-filter based QRS detector followed by consecutive ST-T complexes selection and ordering to a matrix. Whole process is described in [2].

3. METHODS

3.1. MODIFIED SPECTRAL METHOD

The modified spectral method (MSM) was derived from classical spectral method (SM), which is considered as a standard for microvolt TWA detection. In the classical spectral method, beat-to-beat fluctuations in the electrocardiographic amplitudes are represented as power spectra by calculating the squared magnitude of the fast Fourier transformation of beat-to-beat fluctuations in the each sample point amplitude of the 128 time-aligned heart cycles. Power spectra calculated for each point within and then T wave are summed and the final results are represented by aggregate spectrum corresponding to the sums over each of these intervals.

Electrical alternans V_{alt} which represent the TWA value is expressed as follows:

$$V_{alt} = \sqrt{S_{alt}} \quad [\mu V] \tag{1}$$

where S_{alt} is evaluated as alternans peak minus mean of noise on relative frequency 0.5.

The main disadvantage of classic spectral method is inability to detect sudden changes of TWA in signal. For these reasons, a modified spectral method was developed as a complement to a classical spectral method.

The method is realized by using a sliding window. This window is moved in the same matrix of ST-T segments needed for SM with one cycle step. The aggregate power spectrum is computed the same way as in classical method for each window at the same time. The V_{alt} value is also calculated from this spectrum, so that for 128 windows position we gain 128 V_{alt} values, which represents the progress of TWA in time domain. The number of window positions is the same as number of ST-T complexes (T-waves) because the cycles, missing at the end of matrix, are inserted from the beginning of the matrix. The more about SM and MSM is described in [2][3].

3.2. METHOD BASED ON KARHUNEN-LOEVE TRANSFORMATION

Karhunen-Loeve transformation (KLT) is well-known statistical method which is very similar to Principal Component analysis (PCA). We can assume that the KLT and PCA methods are the same when the data vectors have a zero mean.

These methods are orthogonal transform techniques that minimize the error between a signal and reduced linear combination of the basis functions. Outputs of these methods are vectors called the principal components, which represents linear combination of the origin vectors. These methods have been widely used for data compression in signal and image processing applications [4]. Further, the KLT will be discussed.

In KLT method the covariance matrix is computed from the original data set. The original data set represents the same matrix of separated ST-T segments needed for MSM. In this matrix each column represents an input variable and each row represents single observation. Further, the eigenvectors respective eigenvalues are computed from the covariance matrix.

After that, each principal component is obtained by multiplying of the original data matrix by each eigenvectors. The order of principal component is given by the appropriate eingenvalues size of the eigenvectors. Hence, the first component is computed by the eigenvector with the biggest eigenvalue, whereas the last component is computed using the eigenvector with the smallest eigenvalue.

Before using KLT, the original data set (matrix of ST-T segments) is filtered using SM. That means that all relative frequencies above the relative frequency of 0.4 are deleted. Then the KLT itself serves as a filter which is able to catch the T waves changes in time domain.

The important information is which percentage of the origin variables variations is spent by the appropriate component. It was verified that the first component spends 50-80% of the origin variables variations. The rest of variation is spread to other components. For this reason, TWA is demonstrably presented only in the first component.

4. RESULTS

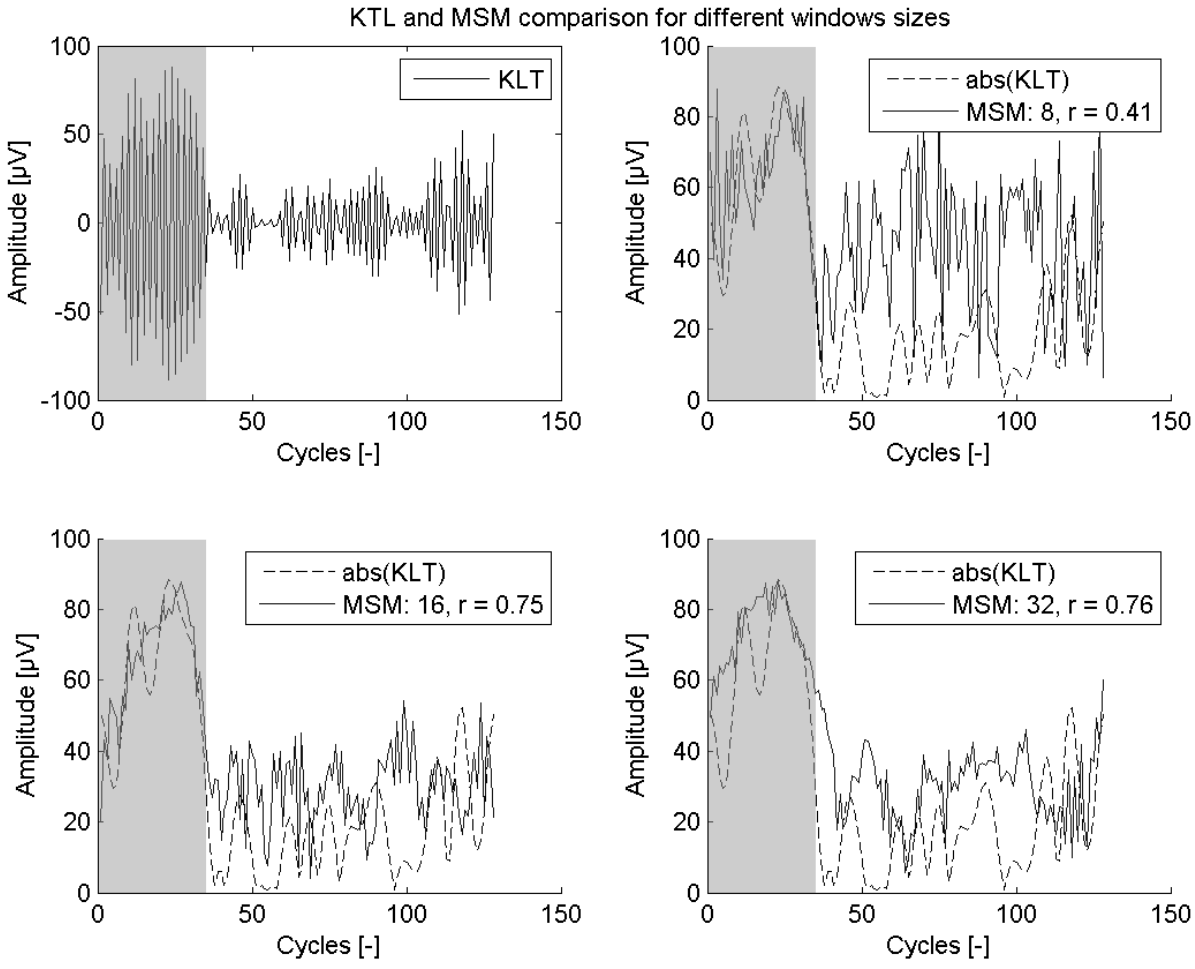

Fig 1 Results of two methods for TWA detection in time domain – method based on Karhunen-Loeve transformation (sign as KLT) and modified spectral method (sign as MSM). The modified spectral method is realized with different windows size on the same signal. The *r* represents the value of Pearson's correlation. The grey areas signify the parts with inserted temporary alternance. The maximum amplitudes of the both methods were scaled on the same value.

Both methods were tested on real signals with stimulated alternans and compared with Pearson's correlation coefficient. The Pearson's correlation coefficient was computed from MSM results and absolute value of KLT results. Althought the results of the both methods are presented in microvolts, the meaning of course is slightly different. The amplitude of the MSM represents the value of TWA voltage in time, whereas the amplitude of the KLT represents linear combination of the input signals. The maximum amplitudes of the both methods were scaled on the same value.

5. CONCLUSION

The modified spectral method was developed as a tool for detecting the T-wave alternans (TWA) progress in time domain. This method was compared with method based on Karhunen-Loeve transformation. The results show that both of these methods are able to catch the sudden changes of TWA in time domain and also proves very good correlation computed by Pearson's correlation coefficient. The coefficient value was ranging from 0.4 to 0.85 depending on TWA level and the speed and the size of the changes. The higher the TWA level, the higher the correlation value, whereas the correlation value nearly decreased down to zero with incresing noise level. Because there is no standard for TWA detection in time domain, we can assume that both of these methods could to give us the good information about TWA progress.

ACKNOWLEGMENTS

The research was supported by the grants 102/07/P521 and 102/07/1473 from GACR, and by Research Programme of Brno University of Technology MSM 0021630513.

REFERENCES

[1] HUNT, Anthony C.: *T Wave Alternans in hight arrhythmic risk patients: Anylysis in time and frequency domains*: A pilot study, c2002, poslední revize 12.3.2002 [cit.2005-5-8]. Available on: <http://www.biomedcentral.com/1471-2261/2/6>

[2] RYCHTÁRIK, M.: *Analýza signálu EKG, metody detekce variability vlny T*. Brno, 2006. Thesis, FEEC BUT, Department of Control and Instrumentation

[3] RYCHTÁRIK, M.: Monitoring of progress of T-wave alternans in time domain using modified spectral method, Student EEICT 2007, vol. 4, pp.271-275

[4] TANNENBERG, M.: *Using the Principal Component Analysis as the T wave alternans detector*, Student EEICT 2005, vol. 3, pp.462-466