

# Automatic ischemia episodes detection on ECG recordings

José García and Pablo Laguna

Communications Technologies Group, University of Zaragoza, Spain

E-mail: [jogarmo@posta.unizar.es](mailto:jogarmo@posta.unizar.es)

**Abstract.** In this paper we describe the design and validation of a ST-T complex changes detector based on the measure of morphological ECG variations (including ST segment, T wave and entire ST-T complex intervals) in the Karhunen-Loève transform domain. The detector has been validated in the European ST-T database with results of sensitivity and positive predictivity of 80% and 77%, respectively, for ST-T complex changes. It is also described, by means of a correlation analysis in the transform domain, a repetitive ischemic pattern found in around 20% of the recordings that may be related to Prinzmetal's angina.

## 1. Introduction

There is no doubt about the importance of early myocardial ischemia detection. However, most of the developed systems use a similar detection scheme, based on the measure of amplitude variations in one specific ECG point (usually STJ60 or STJ80). In this work we propose the use of the information extracted from the entire ST-T complex to provide a wider characterization of the ischemic events.

## 2. Detector design

The system presented here is based on the detection of variations in the Karhunen-Loève transform (KLT) domain. The KLT technique applied to different waves of the ECG signal provides a useful tool to estimate morphological changes. The beat-to-beat dynamic evolution can be characterized by the study of the KLT coefficients time series evolution [1]. The detector measures changes in a distance function,  $d(t)$ , from the first four KLT coefficients adapting its detection threshold for the noise in the series (by using a sigmoid function) and slow drift changes (by exponential averaging). An example of ST-T complex changes detection (including ST segment and T wave ischemic episodes) is shown in Fig. 1.

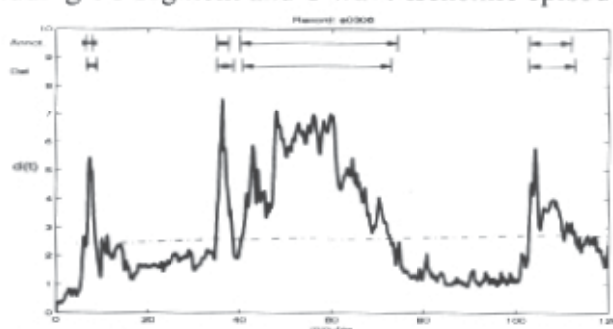


Figure 1. ST-T complex changes detection example on the distance function  $d(t)$ .

## 3. Detector validation

The detector was validated using all the recordings from the European ST-T database [2] in terms of sensitivity (S) and positive predictivity (+P), reaching high levels of performance as it is shown in Tab. 1 (original set of ischemic episodes).

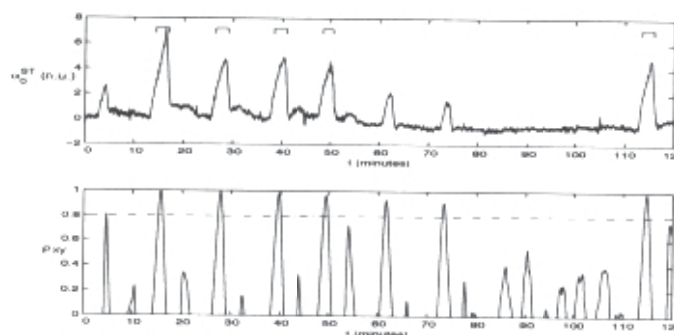
**Table 1.** Performance statistics of the KLT-based detector on the original set of episodes and

on the new set that includes episodes added after the correlation study.

Interval	Original set		After correlation	
	S	+P	S	+P
ST-T complex	80.24	76.95	80.14	69.91
ST segment	81.11	80.23	82.44	72.79
T wave	71.85	54.48	72.10	51.03

#### 4. Correlation analysis

A repetitive ischemic pattern was found in several patients. Although small repetitions were not annotated by the cardiologist, they may have clinical importance. This behavior was analyzed by studying the episodes correlation in the KLT domain. In every recording the largest annotated ischemic episode was selected and its corresponding excerpt in the first order KLT time series was taken as template in the KLT domain. Then, the normalized correlation coefficient,  $\rho$ , between the ischemic template and the corresponding KLT time series was estimated, and new episodes were selected applying a threshold on it ( $\rho > 0.8$ ). An example of this analysis is shown in Fig. 2 and the total new episodes after applying the analysis to the database are presented in Tab. 2. This analysis recommended the use of lower threshold values to detect these small repetitions in spite of the decrease of +P (see Tab.1).



**Figure 2.** Correlation analysis in the KLT domain. Top: first order KLT series for the ST segment, together with the annotated intervals at the database. Bottom: estimated  $\rho$  and the three new episodes.

**Table 2.** New episodes added following correlation criterion.

	ST segm.	T wave	ST-T comp.
Episodes added	35	17	38
Records with new eps	18	6	22

#### 5. Discussion and Conclusions

A system has been presented showing a high performance in detecting changes in the entire ST-T complex. A correlation analysis in the KLT domain has permitted to detect ischemic episodes repetitions found in around 20% of the recordings that may be related to Prinzmetal's angina.

##### Acknowledgements

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##### References

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- [2] A. Taddei, G. Distanto, M. Emdin, P. Pisani, G.B. Moody, C. Zeelenberg and C. Marchesi. The European ST-T database: standards for evaluating systems for the analysis of ST-T changes in ambulatory electrocardiography. *European Heart Journal*. 13 (1992) 1164-1172.