Comparative analysis of algorithms for detection of myocardial ischemia in electrocardiograms

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Abstract

This work presents a study in which three algorithms for detection of ischemic episodes in electrocardiograms were implemented and evaluated. The algorithms were first implemented in MATLAB source code, then individually tested for their capability in detecting actual ischemic patterns, and, finally, compared to each other in terms of how well they perform in a simulated cardiac monitoring setting. The purpose of this work is, therefore, to select the best method that can be used in a real cardiac monitoring system with support for medical decision-making.

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Introduction

Cardiovascular diseases are the main cause of death worldwide. According to the World Health Organization [5], they represented about 30% of all global deaths in 2004. Ischemic heart disease – also called coronary artery disease – was responsible for 12% of the deaths (7.2 million). That makes it the leading cause of death, and, thus, the focus of international research effort.

This cardiac condition is originated by atherosclerosis, the thickening of artery walls by accumulation of fatty substances. It reduces the blood flow to the heart, and originates a disorder called myocardial ischemia – *ischemia* comes from Greek and signifies "lack of blood in the heart muscle". Myocardial ischemia may induce chest pain, known as *angina pectoris*, or may have no symptoms at all. Since blood is responsible for carrying oxygen and removing metabolic waste, a prolonged deprivation of blood supply to the heart can lead to cellular necrosis – premature death of cells in living tissue –, which in turn causes myocardial infarction.

Ischemic episodes can be detected in an electrocardiogram (ECG) by analyzing its characteristic waves, namely the QRS complex, ST segment and T wave (section 1 introduces briefly these concepts). Distinguishable artifacts, such as ST depression and T wave inversion, are the main criteria on which specialists base their diagnosis for ischemia. Thus, many methodologies for automatically detecting ischemic episodes in ECGs have been proposed that take into account these and other criteria.

The research effort seeks to aid the medical community in diagnosing myocardial ischemia at early stages. With computer-assisted detection of ischemic episodes, physicians are able to identify the disease more quickly and make adequate decisions (e.g. reestablishing blood supply to the heart by means of surgery). That is why, in this work, we attempt to assess a few existing techniques and learn what advantages they have with respect to one another, and, especially, if they can be deployed in a real cardiac monitoring system with support for medical decision-making.

The choice of algorithms to be discussed here is the result of a previous study realized by Guilherme Lima [1]. In the aforementioned study, several methods proposed by various authors in scientific articles were investigated and compared, based primarily on positive predictivity and sensibility, but also accuracy when this information was available or computable[1]. Lima selected five algorithms as candidates for deeper investigation, three of which were chosen to be implemented in the present work.

The arrangement of this paper is as follows: the first chapter gives a short description of how the heart works, as well as an overview of ECG signal acquisition; the second, third and fourth chapters address the implementation of the algorithms proposed by Rocha et al. [4], Mohebbi et al. [3] and Gopalakrishnan et al. [2], respectively; the final chapter compares the three methods and gives conclusion.

[1]Sensibility, specificity, positive and negative predictivity, and accuracy, are concepts used to determine the degree to which a diagnostic test (that needs to be assessed) can yield true or false results, with respect to a well-known reference method (usually performed by specialists).

1 Basic understanding

This section tries to give the reader a basic understanding of cardiac physiology, the procedures involved in acquiring electrical activity from the heart, as well as the irregularities produced in the ECG by ischemic heart disease.

1.1 How the heart works

1.2 Electrocardiogram signals

1.3 Ischemic effects on the ECG

In the remaining part of this paper, we shall discuss the three algorithms implemented.

2 Method of Rocha et al.

The method proposed by Rocha et al. is divided into three stages: preprocessing, feature extraction and classification/detection. The key points of the methodology are (i) a measure of ST deviation based on time-frequency analysis of the ECG signal and (ii) expansion of the QRS complex and T wave morphologies onto Hermite basis functions. Figure 1 shows a high-level block diagram of the strategy adopted.

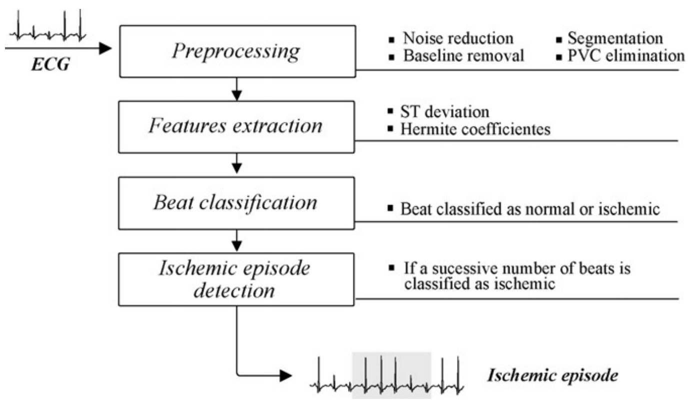

Figure 1: High-level block diagram of the strategy used in Rocha

2.1 Preprocessing

In this stage, a discrete input signal containing the normalized amplitudes[2] of an ECG lead is processed for (i) noise suppression, (ii) segmentation into characteristic waves, (iii) elimination of premature ventricular contractions and (iv) baseline removal. Implementation of these procedures is detailed below.

2.1.1 Noise suppression

2.1.2 Segmentation

2.1.3 PVC elimination

2.1.4 Baseline removal

2.2 Feature extraction

In this stage, two groups of features are drawn from the ECG signal, namely the ST segment shift estimation and the Hermite expansion of QRS complex and T waves. In the first group, changes in ST segment shift measured from the baseline are used to discriminate ischemic from non-ischemic beats. In the second group, changes in QRS complex and in T wave morphologies are also indicators of ischemic or normal beats.

2.2.1 ST segment deviation based on R peak location

2.2.2 ST segment deviation based on time-frequency analysis

2.2.3 QRS complex and T wave characterization

2.2.4 Expansion in Hermite functions

2.3 Classification and detection

In this stage…

[2] here, normalized means $(SignalAmplitude - VerticalOffset)/VoltageGain$

2.3.1 Ischemic ST elevation

2.3.2 Ischemic ST depression

2.3.3 Ischemic episode detection

2.4 Results

To assess the performance of the algorithm, we use the concepts of sensibility and positive predictivity, which are calculated based on the number of true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN) given by a diagnostic test. Here, sensibility is the ratio of cardiac beats correctly identified as ischemic to the number of truly ischemic beats ($TP/(TP + FN)$), whereas positive predictivity is the ratio of cardiac beats correctly identified as ischemic to the number of beats diagnosed as ischemic ($TP/(FP + TP)$).

With this definition, one can say that sensibility is a measure of how rarely the test misses actual ischemic beats, whereas positive predictivity is a measure of how optimistic – in the ironic sense of diagnosing ischemic beats – the test is with respect to the set of samples. We shall use the same concepts in the forthcoming sections.

3 Method of Mohebbi et al.

4 Method of Gopalakrishnan et al.

5 Comparison and results

References

[1] G. L. de Lima. Detecção automática de isquemias cardíacas, 2012.

[2] R. Gopalakrishnan, S. Acharya, and D. H. Mugler. Real time monitoring of ischemic changes in electrocardiograms using discrete hermite functions. In *Proceedings of the IEEE Engineering in Medicine and Biology Society. 26th Annual International Conference*, volume 1, pages 438–441, San Francisco, USA, 2004.

[3] M. Mohebbi and H. A. Moghadam. Real-time ischemic beat classification using backpropagation neural network. *Signal Processing and Communications Applications*, pages 1–4, 2007.

[4] T. Rocha, S. Paredes, P. Carvalho, J. Henriques, M. Harris, J. Morais, and M. Antumes. A lead dependent ischemic episodes detection strategy using hermite functions. *Biomedical Signal Processing and Control*, 5(4):271–281, 2010.

[5] *The global burden of disease: 2004 update*. World Health Organization, 2004.