Chapter 2.4
Computer-Aided Diagnosis of Cardiac Arrhythmias

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INTRODUCTION

In this chapter, the field of computer-aided diagnosis of cardiac arrhythmias is reviewed, methodologies are presented, and current trends are discussed. Cardiac arrhythmia is one of the leading causes of death in many countries worldwide. According to the World Health Organization, cardiovascular diseases are the cause of death of millions of people around the globe each year. The large variety and multifaceted nature of cardiac arrhythmias, combined with a wide range of treatments and outcomes, and complex relationships with other diseases, have made diagnosis and optimal treatment of cardiovascular diseases difficult for all but experienced cardiologists. Computer-aided diagnosis of medical deceases is one of the most important research fields in biomedical engineering. Several computer-aided approaches have been presented for automated detection and/or classification of cardiac arrhythmias. In what follows, we present methods reported in the literature in the last two decades that address: (i) the type of the diagnosis, that is, the expected result, (ii) the medical point of view, that is, the medical information and knowledge that is employed in order to reach the diagnosis, and (iii) the computer science point of view, that is, the data analysis techniques that are employed in order to reach the diagnosis.

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BACKGROUND

Arrhythmia can be defined as either an irregular single heartbeat (arrhythmic beat), or as an irregular group of heartbeats (arrhythmic episode). Arrhythmias can affect the heart rate causing irregular rhythms, such as slow or fast heartbeat. Arrhythmias can take place in a healthy heart and be of minimal consequence (e.g., respiratory sinus arrhythmia), but they may also indicate a serious problem that may lead to stroke or sudden cardiac death (Sandoe & Sigurd, 1991). Ventricular arrhythmias may be categorized broadly as premature ventricular contractions (PVCs) and ventricular tachyarrhythmias, the latter including ventricular tachycardia (VT) and ventricular fibrillation (VF). Atrial fibrillation (AF) is the most prevalent arrhythmia in the western world, affecting 6% of the individuals over age 65 and 10% of those over age 80.

REVIEW OF THE PROPOSED METHODS

There are several aspects that can be addressed in order to review the proposed methods for computer-aided diagnosis of cardiac arrhythmias. The type of the diagnosis is the most important since cardiac arrhythmia is a very complex problem, having several different characteristics that need to be considered before reaching a safe diagnosis. Also, the electrocardiogram (ECG) analysis that is employed for this purpose is another important aspect. Finally, the data analysis and classification algorithms that are used define the accuracy and robustness of each approach.

Type of Diagnosis

Concerning the type of the diagnosis, two main approaches have been followed in the literature: (i) arrhythmic episode classification, where the techniques focus on the total episode and not on a single beat, and (ii) beat-by-beat classification, in which each beat is classified into one of several different classes related to arrhythmic behavior. Arrhythmic episode classification was performed in most of the methods proposed early in the literature, addressing mainly the discrimination of one or more of ventricular tachycardia (VT), ventricular fibrillation (VF), and atria fibrillation (AF) from normal sinus rhythm (NSR). More recent approaches mainly focus on beat-by-beat classification. In each case, a much larger number of different types of cardiac arrhythmic beats are considered. A combination of these two different approaches has been proposed by Tsipouras (Tsipouras, Fotiadis, & Sideris, 2005), where beat-by-beat classification was initially performed and the generated annotation sequence was used in order to detect and classify several types of arrhythmic episodes.

Medical Data and Knowledge

In what concerns medical information, the main examination that leads to cardiac arrhythmia diagnosis is the ECG recording; thus, the majority of the methods proposed in the literature are based on its analysis. In the early studies, the ECG waveform was directly used for the analysis from it. However, more recent approaches are based on ECG feature extraction. In this case, features are mainly on the time and frequency domains in the early studies, while more complex time-frequency (TF) and chaos analysis are employed in the more recent studies, trying to access the nonstationary dynamic nature of the signal. Related to morphological features, QRS detection is the easiest to apply and the most accurate ECG processing method and thus, the most commonly used in the literature: almost all proposed methods include QRS detection in some stage of their analysis. Several other morphological features, inspired from the physiology of the ECG signal, have been employed in the proposed studies. However, the detection and measurement of all morphological