Chapter 5
Real–Time Robust Heart Rate Estimation Based on Bayesian Framework and Grid Filters

Radoslav Bortel
Czech Technical University in Prague, Czech Republic

Pavel Sovka
Czech Technical University in Prague, Czech Republic

ABSTRACT
In this chapter, the authors discuss derivation, implementation, and testing of a robust real-time algorithm for the estimation of heart rate (HR) from electrocardiograms recorded on subjects performing vigorous physical activity. They formulate the problem of HR estimation as a problem of inference in a Bayesian network, which utilizes prior information about the probability distribution of HR changes. From this formulation they derive an inference procedure, which can be implemented as a grid filter. The resulting algorithm can then follow even a rapidly changing HR, whilst withstanding a series of missed or false QRS detections. Also, the HR estimate is complete with confidence intervals to allow the identification of the moments, where the precision of HR estimation is lowered. Additionally, the computational complexity of this algorithm is acceptable for battery powered portable devices.

INTRODUCTION
In many hazardous occupations (e.g. soldiers, firefighters) the chance of a failure increases with the stress levels under which an individual performs. High stress levels can diminish person’s ability to carry out even simple tasks, which can endanger the individual or the group this individual is a part of. It is therefore desired to assess and follow the stress levels of individuals performing under harsh conditions, and to withdraw them if they become unfit for their job.

DOI: 10.4018/978-1-4666-1803-9.ch005
One way to estimate stress levels is by measuring the heart rate (HR). Once a person is highly aroused, the sympathetic branch of his/her autonomous neural system becomes active, which influences the heart, and increases HR to high levels (Andreassi, 2000).

There are several physiological measures, from which HR can be estimated. In this chapter we will describe a method based on electrocardiograms (ECG), in which we detect QRS complexes, compute the distance between two successive QRS complexes, i.e. so called R-R interval, and then estimate the HR as the inverse of this R-R interval.

The main problem of this approach is that the detection of QRS complexes can be quite unreliable if the measured subject is intensely moving. Under such circumstances the ECG record can be often heavily corrupted by various artifacts caused by electrode movement, activity of skeletal muscles or external electromagnetic interference. Additionally, HR changes can be rapid and wide, ranging from resting to the maximum HR. Under these conditions even the best of QRS complex detectors are not guaranteed to correctly identify all the heartbeats. Faulty detections can occur, and QRS complexes can be missed in time intervals stretching over several tens of seconds. It is therefore necessary to further process QRS complex detections, and devise a robust estimator that can reconstruct HR in a stable and reliable way.

In this chapter we will present an approach to a real-time HR estimation based on a Bayesian framework. This problem will be formulated as a Bayesian network, which utilizes prior information about the probability distribution of HR changes. From this formulation we will derive an inference procedure that can be implemented as a grid filter. The resulting algorithm can then follow even a rapidly changing HR, whilst withstanding a series of missed or false QRS detections. Also, we will suggest a procedure for the computation of confidence intervals to allow the identification of moments, where the precision of HR estimation is lowered. Additionally, the algorithm is designed so that its computational complexity is acceptable for battery powered portable devices.

We will also present results of real-life tests using ECG data obtained from subjects performing bouts of vigorous physical exercises. We will show that despite all the difficulties and ECG signal corruption, the algorithm is capable to estimate the HR with fair reliability.

**BACKGROUND**

The signal processing chain for the HR estimation is shown in Figure 1. First, the electric potentials created by the heart are measured, amplified and digitized. After, an algorithm commonly termed as a QRS complex detector, or simply QRS detector, searches the ECG signal, and identifies all the recognizable QRS complexes. Last, the positions of the QRS complexes are used to estimate the HR of the measured subject.

Even though in this chapter we will concentrate chiefly on the last stage - the HR estimation - it is important to understand characteristics of data we are going to process. Therefore, in this section we will provide a brief overview of all the above-mentioned signal processing stages. Namely, we will comment on heart activity, ECG signal measurement, QRS complex detection, current state of the art of a robust HR estimation, and also on the Bayesian framework that we are going to use in the design our HR estimator.

**Heart Activity**

Being controlled by both sympathetic and parasympathetic branches of the nervous system, the heart activity adjusts to meet the blood supply needs of a human body, and is affected by emotional stimuli. For the purpose of the HR estimation it is important to note that HR changes can be quite variable. Mostly, the HR is fairly stable or changing slowly (e.g. during rest, or sustained physical activity). However, sometimes a strong...
22 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the product's webpage:

www.igi-global.com/chapter/real-time-robust-heart-rate/67251?camid=4v1


www.igi-global.com/e-resources/library-recommendation/?id=1

Related Content

An Adaptive Algorithm for Detection of Exudates Based on Localized Properties of Fundus Images
Katha Chanda, Ashish Issac and Malay Kishore Dutta (2019). International Journal of E-Health and Medical Communications (pp. 18-37).
www.igi-global.com/article/an-adaptive-algorithm-for-detection-of-exudates-based-on-localized-properties-of-fundus-images/215341?camid=4v1a

Decision Support Systems in the Process of Improving Patient Safety
www.igi-global.com/chapter/decision-support-systems-process-improving/73105?camid=4v1a

Interoperability of EHR Systems Based on Semantic Representation and Transformation Models
www.igi-global.com/chapter/interoperability-of-ehr-systems-based-on-semantic-representation-and-transformation-models/106575?camid=4v1a

The Concept of Interoperability for AAL Systems
www.igi-global.com/chapter/concept-interoperability-aal-systems/47127?camid=4v1a