On the use of ECG waveforms for Health Status Estimation

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Abstract:

We present a system that uses ECG time series for reaching decisions regarding the user's health status. ECG waveforms can provide us with certain features that have diagnostic value for several cases. The system consists of two modules. The first performs the analysis of the ECG data so as to extract the aforementioned features, and the second is a hybrid intelligence system combining neural and neurofuzzy networks that uses these features to reach decisions according to certain rules provided by medical experts. The output of the system is a classification of the user's health state to certain alert levels. The system presented here can be integrated in an artificial agent monitoring a user and deciding for his health state.

Keywords: ECG analysis, wavelets, hybrid intelligence system, classifier, health status estimation.

Introduction

In the era of Pervasive Computing 1 artificial agents, hidden in information appliances [1], will be continuously running, in an invisible manner [2, 3], aiming at the best fulfillment of human users needs. In many circumstances agents would have to monitor their users and decide on behalf of them for their welfare. Such is the case of users who belong to a special population group, that of chronic patients, who need to regularly monitor their health condition. A sensor attached to the user collects his/her Electrocardiograph (ECG) and drives it to an artificial agent, residing in the user's PDA, that processes the data, makes decisions regarding the user's health state and informs the user. The PDA acts as the user interface and can also have the ability to call the health monitoring service provider in case of an emergency (serving as *actuator*). In the following we present a system architecture that employs ECG data for intelligent decision-making in such cases.

System Architecture

The proposed system comprises of two modules. The *ECG Analysis Module* collects ECG data from the sensors and employs signal processing techniques to extract certain features of interest which will be in turn forwarded to the *Hybrid Intelligence Module* that uses a combination of neural and neurofuzzy networks to classify the user's health state to certain alert levels.

ECG Analysis Module

ECG is a complex signal and there are several time-templates for which medical experts are searching for in order to provide their diagnosis. Figure 1 shows a typical ECG waveform. The basic characteristics of the ECG that medical experts examine are related with the form of the various ECG segments, their duration, relative amplitude, covered area and variance over time. The starting point for the extraction of such features is the detection of the R-peaks in the ECG time series. We have implemented a wavelet-based pulse (R-peak) detector that operates robustly even for hard-to-interpret ECGs. The motivation behind using multiresolution wavelet analysis is that the ECG signals exhibit non-stationarities and slow global variations that make the wavelet tools attractive for efficient analysis [4, 5]. The kernel of the algorithm is a multiresolution discrete wavelet decomposition scheme using a biorthogonal basis. The soft thresholding involved in the analysis procedure is based on two critical assumptions: the existence of a minimum allowable heart rate, and of a minimum allowable R-S distance (contiguous maxima and minima of QRS). For the detection of the other features of interest we have followed the approach of Sivannarayana *et al.*, [4].

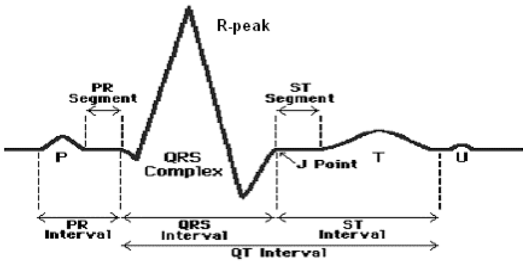

Figure 1: A typical ECG waveform

Hybrid Intelligence Module

The Hybrid Intelligence Module uses the features coming from the ECG analysis to provide us with a classification of the user's health state to *Alert Levels*. It combines neural and neurofuzzy networks; the former provides the means for learning from numerical data and can be adapted to the peculiarities of a particular user while the latter provides the means for including a priori knowledge, in the form of rules. It has been implemented using the CAM/SPM model presented in [6]. The CAM module partitions the ECG features space so as to produce linguistic terms. Linguistic terms are then used in the SPM module to activate the rules that have been modelled. Only rules corresponding to *Dangerous* and *Attention Seeking* states are included in SPM. This conforms to the medicine practice where *healthy* means *not ill*.

Experimental Results

We have provided the system with data from a variety of cases, from normal to simulated heart attacks so as to check and evaluate its operation. We have found that in the majority of the cases the system responds rapidly and reaches accurate decisions regarding the user's health status. More specifically, the R-peak detector works very efficiently for both simulated and real data. The extraction of the other features is far easier for synthetic data, while a denoising process has to be applied to real data. The hybrid intelligence part incorporates knowledge from medical experts and is able to handle the various cases with very satisfactory results concerning its ability to classify the user's health status. So far the overall system has been tested with synthetic data.

Conclusions and Discussion

The architecture presented here is part of the overall architecture of the ORESTEIA project (M**o**dular Hyb**r**id Art**e**fact**s** wi**t**h Adaptiv**e** Funct**i**on**a**lity, IST-2000-26091) [7], where artificial agents monitor their users and facilitate intelligent decision making on their behalf for their welfare in a variety of cases. Future work includes the employment of real data both for on- and off-line operation, as well as its integration to the overall ORESTEIA system.

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