CardioViz: Contextual Capture and Visualization for Long-term ECG Data

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In the project CardioViz we explore a novel system for long-term Electrocardiogram (ECG) monitoring. In contrast to conventional ECG monitoring, the system additionally provides means to capture contextual information, such as activity, location and photos. We investigate how contextual information can be helpful when assessing long term ECG data and when relating anomalies to certain real-world situations. We assume that contextual information correlated over time with the ECG data allows for a better understanding. In the prototype we show the ECG signal together with photos and notes overlayed on a map. It seems that by these hints users can more easily remember where they were and hence what situation might be related to a specific period in the ECG. CardioViz consists of a mobile phone based client application and web based backend. The client application uses the sensors in the phone (e.g. camera) as well as further sensors (ECG, Accelerometer, GPS) connected via Bluetooth.

1. Introduction

Each year cardiovascular disease (CVD) causes over 4.35 million deaths in Europe accounting for nearly half of all deaths (49%) in Europe [1]. Long term monitoring of Electrocardiogram (ECG) can aid in diagnose and treatment of CVD and can provide valuable information for individuals wanting to improve their overall fitness level or improve their health through regular exercise.

The main goal of the project CardioViz, is to create a long term heart monitoring system that allows recording and review of contextual information together with the ECG data. By combining information from different sensors we aim to provide a better understanding of the user activities and their related physiological signals. In our experiments we used commercially available sensors[1] to monitor ECG and other physiological signals. The availability of several other prototypes and products where the sensors are incorporated in clothing articles, for example they have been integrated into T-shirts[2] or into sport bras[3], motivated the project further. Such

[1] http://www.alivetec.com
[2] http://www.actimon.de/eng/produkte_shirt_e.html
[3] http://www.numertex.com/

developments show that in the future the monitoring of ECG during normal daily activities will be possible without causing any interference with ongoing activities. MPTrain, a system that monitors heart rate during exercises and uses music to influence the frequency [2], shows an interesting example of the direct use of ECG data to influence a specific application. A further example of a personal coaching system that uses physiological data is described in [3]. Our work in contrast focuses on options for long term monitoring and reviewing of physiological data in combination with contextual data that is available from various sensors.

2. Contextual Monitoring of Physiological Parameters

So far many physiological parameters are only monitored in the hospital, but with advances in medical technology it becomes more and more feasible to do monitoring in real world environments. In the following we focus on ECG monitoring, as this is a standard procedure that is conducted for the diagnosis of several medical conditions and here monitoring outside the lab is established and has an important function.
Typical forms of ECG monitoring include short-term monitoring, monitoring under conditions of physical stress, and long-term monitoring. Short term monitoring is traditionally done during a visit to a doctor's practice. This form of monitoring is sometimes combined with exercises (e.g. riding a stationary training cycle) to assess the influence of such activities on the patient's ECG data. Long-term ECG is used to spot and understand anomalies in the ECG signals over a longer period of time (typically several hours or days). Here it is especially interesting when and where anomalies in the ECG occur. Our approach is designed to improve long-term ECG monitoring and the analysis of those data by incorporating contextual information.
Currently, long term ECG are applied by a cardiologist. The device obtains a continuous monitoring recording, and all of the ECG data are time stamped. In a later review by the cardiologist, the time is used to estimate the circumstances (e.g. situation, physiological stress, emotional stress) under which the data were collected. In some cases, patients are asked to keep a paper diary to record their activities for the duration of monitoring period. In an interview with a cardiologist we confirmed that missing contextual information makes it difficult to correlate certain ECG anomalies with particular situations.

2.1 Capture ECG data with Context

The basic idea is to use the phone to collect implicit and explicit contextual information that can later be correlated with the ECG. Any pictures that are taken, any memos that are recorded, any messages that are sent, and the particular locations that are visited can each provide contextual information that is relevant for the interpretation of the ECG. Pictures that are taken explicitly can be helpful to remember a situation for the analysis of the ECG. Additionally, further sensor information such as the location and step-counter, can be related to the ECG. Such rich contextual information can be used to relate the recorded ECG data to real-life

situations and daily activities. Location and context may reveal much more than what is usually captured in a hand-written diary. Diary studies in general are often incomplete; this was also confirmed in an interview with a cardiologist for the notes people take while a long term ECG is recorded.
It has been reported in the literature [4] that pictures are particularly valuable for remembering situations; similarly, we expect that with a picture and the position the user could more easily remember what he was doing at a given point in time.

2.2 Access to ECG aided by Context

Our enquiries showed that the requirements for the presentation and access to contextual ECG data may vary a lot. Hence, one of the design goals was to keep the capture and access well separated. The various data sources are linked based on their time stamp. Having the data available with meta-information allows the traditional plotting of the ECG signal over time with the option to zoom in.
A correlated visualisation of pulse, ECG and contextual information is hereby a novel form of information presentation that can be of great value to doctors and patients. The recorded data from all sensors as well as from the media are displayed in a way that their temporal relationship are preserved, aided by a synchronized navigation. The user can choose a picture and the visualization of the ECG is moved to that particular moment in time; going to a specific point in the ECG signals shows the relating position in the map and the media captured around that time.
The user interface for reviewing the data is designed to allow a simple transition between monitoring the precise ECG-curves of a signal and assessing a whole day. If the whole day is viewed the pulse rate is visualized. When the user zooms within the interface, the interface is switched to a visualization of the ECG-curves. This allows a quick assessment of the overall data and provides an easy mean of highlighting details following the basic principles of visualisation for large data sets.

3. Implementation

To explore the concept of contextual ECG monitoring further and to have means to allow users explore its potential, we implemented a system that permits the correlation of sensor information with ECG data.
The CardioViz system architecture consists of 2 parts (Figure 1 & 2): The client side which runs on a mobile phone and collects data from the sensors via Bluetooth connections, and the server side which receives the data. The mobile phone acts as a gateway between the sensors and the server. In the current implementation, 3 sensors from 2 devices are used: The Alivetec Alive heart monitor which has a single channel electrocardiogram (ECG, 300 samples/second) and includes a 3-axis accelerometer (75 samples/second), and the LD1W Nokia GPS sensor. Both devices are connected to the mobile phone via Bluetooth. The client side is implemented in Java ME.
The server side includes a database that stores the data received from the mobile phone. The client and server side are connected via a HTTP connection over GPRS.

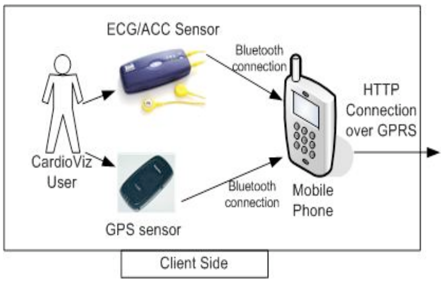

Fig. 1. The mobile client has a minimal interface for contextual capture and connects to an ECG and GPS sensor.

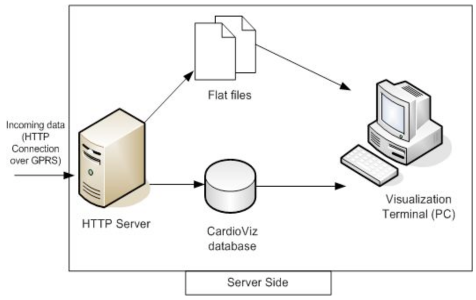

Fig. 2. On the server side the ECG data is received over HTTP and stored in a database. Contextual visualization uses a web interface.

4. Conclusions

The CardioViz project shows an approach to use captured contextual information to overcome the disadvantage of traditional long-term ECG monitoring systems where the user has to write a diary to enhance ECG data with contextual information. With CardioViz, this information is recorded implicitly by sensors which are wirelessly connected to a mobile phone or explicitly by the user by taking a picture or making a recording. One lesson we learned form this project is that implementing the user interface on the phone lowers the hurdle for using novel applications.

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