Personal health monitoring with Android based mobile devices


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Abstract - We have developed an Android based mobile data acquisition (DAQ) solution, which collects personalized health information of the end-user, store analyze and visualize it on the smart device and optionally sends it towards to the datacenter for further processing. The smart mobile device is capable to collect information from a large set of various wireless (Bluetooth, and WiFi) and wired (USB) sensors. Embedded sensors of the mobile device provide additional useful status information (such as: user location, magnetic or noise level, acceleration, temperature, etc.). The user interface of our software solution is suitable for different skilled users, highly configurable and provides diary functionality to store information (about sleep problems, can act as a diet log, or even can be used as a pain diary). The software enables correlation analysis between the various sensor data sets. The developed system is tested successfully within our Living Lab facility. Sensor data acquisition on the personal mobile device enables both end-users and care givers to provide better and more effective health monitoring and facilitate prevention. The paper describes the internal architecture of the software solution and its main functionalities.

Keywords
Remote health monitoring, portable sensor data acquisition, mobile device

I. INTRODUCTION

The aging population of industrialized countries grows and this increases also among other things the health care costs. Transparently embedded remote health care can become a new cost effective paradigm, which can solve most of the problems primarily centralized Health Care system’s have. Currently, there is a large number of enabling technologies to measure the patient’s physiological signals remotely. With handheld and PC devices used as data acquisition (DAQ) systems we are able to collect vital information about the (elderly and demented) patients remotely. Due to the different - in most cases proprietary and incompatible- sensor technologies and solutions, it is a hard task to create generic, user friendly DAQ systems. There are already remote patient monitoring solutions available such as the Android based MyFitnessCompanion [1], which is able to support the following therapy fields: Fitness, Diabetes, Asthma, Obesity, Hypertension, CHD, or the iCare[2] which provides medical guidance, emergency alarm functionality and collects personal health information. Other example is the Microsoft HealthVault [3], which supports care of elderly persons (e.g.: neurodegenerative diseases, stroke etc.), additionally it provides online web interface to manage (process and share) health information. Biotech Lab at Obuda University is involved in AALAMSRK [4] (a national R&D project), specialized both on Android based (we call this MobileHub) portable remote monitoring applications, and normal PC based (we call this HomeHub) remote monitoring solutions (shown in Fig. 1.).

This paper shows how we have built up our remote patient monitoring environment (DAQit)[8] using a client side software and the DrHealth portal. Later on we present how this software environment has been used to do patient’s location/sudden event monitoring, remote diabetes and hypertension monitoring in our Living Lab.

Through the co-operation of commercial companies, universities and other non-profit organizations the direct goal of the AALAMSRK project was to develop an integrated, standardized dementia and health monitoring
system supported by innovative, modern measurement
and info-communication technologies. By the integration
of medical expertise and developing assisted living
patterns (ALPs), the realized system offers personalized
monitoring solution for monitoring and prevention of
elderly people, particularly who suffer from stroke,
neurological diseases such as dementia or depression. Our
two DAQ solutions (HomeHub and MobileHub) are able
to serve overlapping patient categories (shown in Table
1).

<table>
<thead>
<tr>
<th>Targeted Patients &amp; persons</th>
<th>PC based HomeHub</th>
<th>Android based MobileHub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Elderly monitoring</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Parkinson’s disease</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Alzheimer</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Stroke</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Movement problems</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Obesity</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

A. Motivation

Considering the real social and market demands and
the needs of the health care service provider segment [5],
the general project aim is to improve the quality and cost
effectiveness of health care services by developing service
models, methods, tools, products and services. We are
doing research and development of a full scale remote
telemonitoring system that monitor both activity levels
and vital signs such as blood pressure, blood sugar level
and heart rate, alerting caregivers about potential health
problems or emergency situations.

Service categories of a generic home-based care/remote
patient monitoring solution

Remote patient monitoring builds up from the following five evitable service pillars:

- Data acquisition services

DAQ services collect physiological information of a
person’s condition from deployed sensor infrastructure or
from the person directly.

- Store/forward and visualize services

Services to store, process and visualize locally the
captured physiological information of a person’s condition
at the patient’s device and to forward these information
using ICT towards the central data collector node for
further data processing, storing, visualization.

- Activity recognition services

Recognition of psychophysical performance of
patients or elderly people for effective therapy
intervention (quantitative and qualitative measurement of
body movement).

- Behavior monitoring services

Recognition of psychophysical performance of
patients or elderly people for effective therapy
intervention (quantitative and qualitative measurement of
high level living patterns).

- Lifestyle guidance services (knowledge transfer)

Feedback from medical experts/physicians based on
the acquired real-time or historical data enables lifestyle
guidance, therapy adjustment, early warning/prevention,
personalized health care & rehabilitation.

II. LIVING LAB INFRASTRUCTURE

Main novelties of the AALAMSRK project are that it
brings into the patient’s home medical assistance and
lifestyle guidance services and also it supports new
potential opportunities to capture insight medical
knowledge with its effective non-stop health monitoring
methods. The monitoring is done by our clinical trial-
ready, standardized distributed monitoring and testing
environments (so called Living Labs). Our Living Labs
are supporting all the R&D tasks of the medical,
engineering and business (marketing) work packages and
also provides evaluation and test environment for new
hypotheses and results.

The established Living Lab environments are located
in three different regions within Hungary (capital city,
middle size city and rural area), thus the type of patient
environments (living space size, accessibility, communication infrastructure, etc.) are totally
inhomogeneous [9]. During the test periods -thanks to the Living Lab studies-, we have learned a lot about the
different environment requirements, and revealed many
aspects of various problems concerning sustainability,
usability of our health monitoring and emergency
management solution.

III. FIXED (HOMEHUB) VS. PORTABLE
(MOBILEHUB) MONITORING DEVICES

During the AALAMSRK project the PC based
HomeHub was firstly developed. The HomeHub
framework supports Linux and able to run both on
proprietary solutions (like Intel HealthGuide) and on out-
of-the-box commodity PCs optionally equipped with
touch screen. Beside the HomeHub solution, later on we
have developed an Android based MobileHub (shown in
Fig. 2.) solution as well, which enables additional usage
scenarios due to its different (mobile) characteristics.

![Figure 2. HomeHub (on left) with connected sensors and GUI of the Android based MobileHub (right)](image)

The MobileHub has many attractive features (cheaper
price, portable, location awareness, inbuilt touch screen,
etc.), however on the other side it has also significant limitations compared to a full PC hardware (limited CPU power, memory, storage size and external interface connection support, etc.). The MobileHub is targeting different functionalities compared to the HomeHub solution (due to the smaller screen size and fewer hardware interfaces), and it can extend the usability with additional special features, such as mobility, location awareness and small size. Comparison with example hardware configurations is shown in Table 2.

### Table 2. Basic parameters of the two DAQ solutions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PC based HomeHub</th>
<th>Android based MobileHub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform/Os</td>
<td>Intel Health Guide (Linux)</td>
<td>Samsung Galaxy W7 Android</td>
</tr>
<tr>
<td>Size (WxHxD)</td>
<td>260 mm x 90 mm x 2.0 mm</td>
<td>64.2mm x 122.4mm x 9.9 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>2820 g</td>
<td>116 g</td>
</tr>
<tr>
<td>GUI</td>
<td>10 cm, color touch screen, LCD</td>
<td>5 cm, color touch screen, AMOLED</td>
</tr>
<tr>
<td>System help, comm. support</td>
<td>Yes, secure</td>
<td>Yes, but with limited security</td>
</tr>
</tbody>
</table>

We need to note here, that both HomeHub and MobileHub are capable to run on various other hardware configurations. The HomeHub was tested on a large set of (Linux installed and touch screen equipped) PCs with success. According to our tests the MobileHub software is capable to run almost all Bluetooth enabled and Android 1.2+ based Smartphone. We should also note here that even if both solutions working non-stop 7/24, the PC based HomeHub consumes far more power, than the Android based MobileHub. According to our tests the usage of the PC based HomeHub solution requires significant amount of electricity, and the increased electricity costs can become a limiting factor at the number of potential users.

### A. Actual sensor set of our health monitoring system

Sensors can provide digital fingerprint of the patient’s/person’s psychophysical status and performance. We categorize sensors according to their data collection methods: active or passive type sensors. In our solution we are using a wide range of sensors (both passive and active, shown in Table III.) to collect detailed and accurate information about the patient remotely about:

- patient’s blood glucose/sugar level
- patient’s actual pulse, and oxygenization level
- patient’s ECG signals
- patient’s blood pressure
- patient movement within the house, with the usage of wall mounted sensors
- patient medication, with sensors of the medicament dispenser
- patient’s eating habit, with sensors placed on the refrigerator
- patient activity with so called “Actigraph”, which is a watch like sensor on the patient’s wrist. Actimetry sensor can measure non-invasively rest/activity cycles, gross motor activity.
- patient’s weight
- environmental information, about room temperature, humidity etc.

### B. MobileHub basic software features

- Multi-language support (English, German, Italian, and Hungarian).
- Silent sensor DAQ mode (automatic data collection) via Bluetooth.
- Health status visualization (with statistics and data mining facility) at the data center.
- Manual DAQ mode (optionally GUI initiated sensor data collection) only via Bluetooth.
- Limited data compression and encryption during data transmission towards the data center.
- Automatic sensor data pre-evaluation at the MobileHub.
- Full featured location aware mobile emergency alarm.
- Real-time sensor data forwarding to the central data collector server
- Store and forward mode to enable offline data collection

In Table 3, round brackets contain the sensor vendor’s name and the connection interface type of the sensors is shown in between slashes (e.g.: BT=Bluetooth).

### Table 3. Sensor compatibility of the developed health monitoring infrastructure

<table>
<thead>
<tr>
<th>Sensors and parameters</th>
<th>PC based HomeHub</th>
<th>Android based MobileHub</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse oximeter</td>
<td>No</td>
<td>Yes (NONIN) BT</td>
</tr>
<tr>
<td>Blood pressure monitor</td>
<td>Yes (AND) USB + BT</td>
<td>Yes (AND) BT</td>
</tr>
<tr>
<td>Weight</td>
<td>Yes (AND)</td>
<td>Yes (MEDITECH) BT</td>
</tr>
<tr>
<td>Pulse meter</td>
<td>Yes (AND)</td>
<td>Yes (AND) BT</td>
</tr>
<tr>
<td>Activity Sensor-Actigraph</td>
<td>Yes (MEDITech) BT</td>
<td>Yes, built-in sensor, used with external software module</td>
</tr>
</tbody>
</table>

The MobileHub and HomeHub software are designed to be suitable for different skilled users. Both user interfaces are highly configurable to support elderly persons (high contrast, huge characters, simple UI). For the HomeHub a large GUI was designed with huge buttons and characters to make touch screen usage easy (shown in Fig. 3.).

### Figure 3. User interface of the HomeHub
Based on the test results received from the Living Lab experiments—due to the small touch screen—on the MobileHub multiple separated GUI have been developed for the differently skilled elderly persons. To overcome all the usage limitation problems, we have identified two user skill sets, which can categorize the hardware/software utilization ability level of the patient:

- GUI for elderly persons without any IT knowledge (oversimplified single button type GUI)
- GUI for normal and expert end-users the panic button is just an icon and all the in-build additional software/hardware functionalities of a normal Android mobile phone are available (menu sets, SMS, dialing, applications, etc.). Patient can manually initiate sensor management and can manually provide measurement inputs on the GUI (shown in Fig. 5. and Fig.6.).

C. MobileHub additional software functionalities

1) Location and sudden event monitoring service

In a sudden panic situation an alarm can be activated manually (by the patient) or automatically (by e.g. the accelerometer) with the mobile device. When an alarm signal initiated the central dispatcher is able to acquire location information (based on GPS and GSM/GPRS cell information) immediately. The automatically established two way voice communication can help to understand the context of the sudden event. The MobileHub can work as a location independent, always-on personal emergency notification device.

2) Diary / reminder services

Besides pure data collection our MobileHub enables to do correlation analysis of stored data series. Reminders are intended to notify user in pre-defined appointments about data collection needs. This feature enables to track data in certain periods like measuring patient’s blood glucose level on a regular basis.

IV. CONCLUSIONS

During our almost 4 years long development period both the fixed and portable solutions have been rigorously tested in the LivingLab environment. Beside patient monitoring we had to monitor remotely not only the patient’s status, but also some mobile hardware and software specific parameters (such as: battery level of sensors), and we had also to redesigned the whole user interface of the handheld device to support elderly persons with low IT skills. According to the received result both our PC and Android based DAQ solutions are capable to provide seamless remote monitoring of elderly persons not only at home, but with MobileHub also abroad. The developed solutions provide important feedbacks about health status to the patient and to the medical experts.

V. ACKNOWLEDGMENTS

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