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Concept and modular telemedicine platform for measuring of vital signs, ADL and behavioral patterns of elderly in home settings

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Abstract—**In this contribution a new centralized platform for telemedicine is presented. It combines functions for measuring of vital signs, ADL and behavioral patterns and is especially designed for home care scenarios and the use by elderly people who are not familiar with the use of a PC. Unlike many other approaches we did not use a modified standard PC but developed a new dedicated hardware platform. It comes with various interfaces to communicate with different medical home care systems. We implemented a modular software architecture, which allows managing multiple user accounts with different personal settings. Every account can be adapted individually to the user. Every medical device that can be connected to the platform has its own software module, in which data is analyzed, displayed, stored to an internal database or transmitted to a server. Though the user is not bothered with technical issues such as setting up a connection to the internet, he keeps control on his data because he decides if and when data is transferred to a web server. The device was developed in an iterative process and evaluated in focus groups by n = 31 subjects (average age: 67 years) under the supervision of a psychogerontologist. All findings obtained from those sessions were directly incorporated in the presented work.**

I. Introduction

TELEMEDICINE as such is not a new concept. In fact, it has been known for a long period of time [1]. However, as the handling of huge amounts of data requests reasonable computing power, the growth of telemedicine systems is strongly connected to the developments in computer technologies and systems in general. This explains why interest in the field has increased dramatically in the 1990s [2]. The spectrum of applications is very broad and includes medical data analysis and transfer, remote diagnosis and care, electronic health records, ambient assisted applications, wearable devices and clothing as well as implantable sensors and robotics for healthcare [3].

Chronic conditions are more prevalent in older populations. In the USA eighty-five percent of people aged 65 years and older have one or more chronic conditions. As the number of seniors is growing increasingly, the number of people with chronic conditions is projected to increase steadily for the next 30 years [4]. Quality medical care for people with chronic conditions requires a new orientation toward prevention of chronic disease and provision of ongoing care and care management to maintain their health status and functioning. Telemedicine and new system architectures as for example presented in [5] and [6] can not only help to support people with chronic diseases but also be of great value in the early detection or prevention of health decline. In order to obtain the highest benefit from telecare systems as many kinds of health information as possible should be observed. Telemedicine platforms as presented in [7], [8] and [9] are suited for processing one or more of the classical vital signs (ECG, blood pressure, pulse, oxygen saturation, blood glucose, temperature, weight). Some platforms only transmit video information such as medical images or pictures of the patient [10]. Other systems focus on the detection and processing of ADL (Activities of Daily Living) or physical activity as “new vital signs” [11], [12]. In geriatric assessment it is common to use not only vital signs that can be obtained through direct measurements, but also to evaluate the health status through functional assessment. As a consequence telemedicine platforms for elderly care going beyond the state of the art should provide the possibility to gather and process vital signs and behavioural information in a combination. For that purpose the presented platform has been developed.

II. System Design

A. Task and Approach

The presented Central Telemonitoring Platform CTP was designed to truss several peripheral systems and to offer a central user interface. In order to achieve benefits from the combination of different data sources the intention was to gather information about both classical vital signs and behavioral patterns of a user. Vital signs can be obtained from the following sources:

- *Integrated Sensors:* As a telemedicine platform is designed to work absolutely reliable and to have sufficient computing power, it offers the possibility, to use the given resources and integrate sensors to measure vital signs directly within the device.
- *Standard home care devices:* There already is a wide selection of medical home care devices available on the market. A central platform should offer the interfaces to read out such devices.
- *Mobile approaches and BANs (Body Area Networks):* In current research more and more projects aim to offer continuous monitoring of vital signs by

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integrating sensors in every day life objects such as textiles or cars. For a close documentation of the health status it should be possible to transfer the data to the central platform.

The measurement and analysis of vital signs is a standard procedure. Hence numerous sensors and devices exist and the choice is only about which ones to use. Less knowledge exists about the measuring of human behavior. However, we propose that the following information offer additional value when analyzed in combination with vital signs and hence should also be regarded in a telemedicine platform:

- *Physical Activity:* There are many approaches to detect a person's physical activity. Most of them are based on the analysis of accelerations by a user worn device. Such devices appear most applicable for constant monitoring of physical activity. Hence a central telemedicine platform should be able to read out information from such devices.
- *Activities of Daily Living (ADL):* Changes of the health status usually affect a person's daily routine. Thus the long term monitoring of ADL can help to detect trends and to investigate the reasons for changes at an early time. In current research there are many systems that aim to detect ADL. A central telemedicine platform should be capable of processing the information provided by such systems.
- *Additional information:* Some symptoms cannot be measured with medical devices (e.g. emotional state, pain etc.). However, their documentation might be of medical interest. Thus a telemedicine platform should offer the possibility to enter extra information that can not be obtained from a technical device.

All of the information mentioned above should be stored and administrated locally on a central data base integrated in the platform. This offers the opportunity to display and automatically analyze data without the need of any data transfer. As the gathered information is very private the user should have the possibility to decide which data can be accessed remotely by a third person. For that reason it should be up to the user to decide which data is uploaded to a web server. The proposed architecture is displayed in fig. 1.

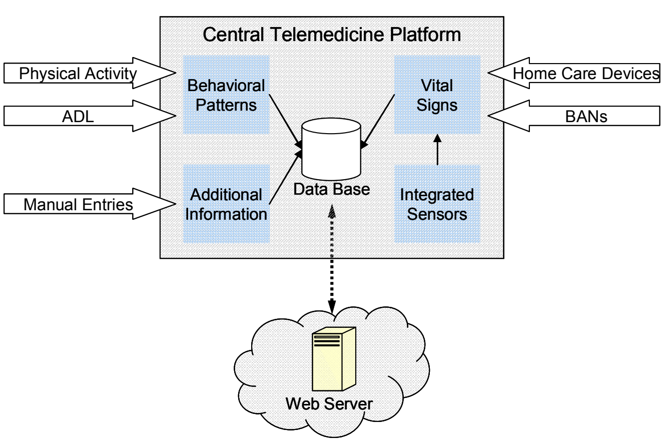

Fig. 1 Architecture of the Central Telemedicine Platform

B. Hardware Architecture

Tasks of the CTP are storing and administrating of user data as well as analyzing and displaying information. Finally it must be able to transmit data to a web server. The hardware structure derives from these tasks and the proposed system structure.

The platform needs a central processing unit (CPU) for data processing. This is the basis of the system and will provide all functions implemented through the software. To keep the dimensions of the device small the CPU is provided by a picoITX embedded single board computer. To read out information from peripheral systems and devices the CTP needs the corresponding interfaces. They provide a peripheral communication and include hard-wired and wireless interfaces. Thus the CTP comes with USB, UART, Bluetooth and a NanoLOC 2.4 GHz radio module. To enable the measurement of certain vital signs, internal sensors are integrated in the hardware architecture as well. We chose a reflective SPO2 sensor that is capable to measure pulse and blood oxygen saturation when touching it with a finger. To archive the collected data a central data memory is needed, which can be accessed from the CPU. This component is a Solid-State-Disk (SSD). The hardware needed to transmit information to a web server is included in the data communication part. To offer the user different possibilities to connect to the internet this part also includes hard-wired and wireless technologies. They are a 56k modem, a LAN-card, a WLAN-card and a UMTS modem (3G) integrated in the device. Finally, the central telemedicine platform needs a human-machine-interface to display information and enable the user to enter commands. For that purpose the platform is equipped with a 7'' touch screen, speakers and a microphone. Of course, all components must be supplied with power. The hardware architecture is displayed in fig. 2

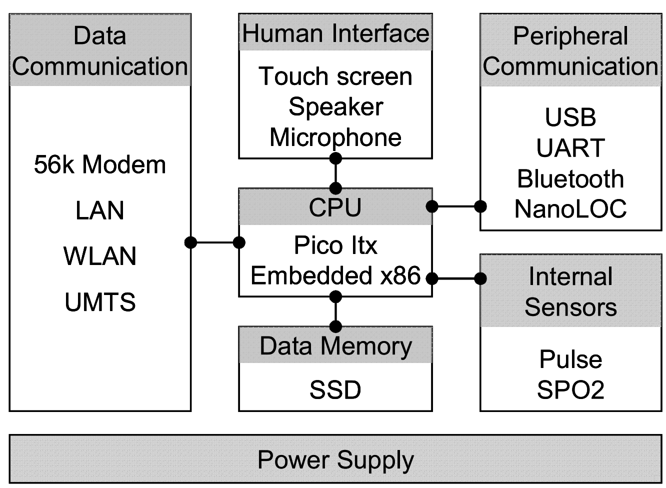

Fig. 2..Hardware Architecture of the Central Telemedicine Platform

C. Software Architecture

The Software of the Central Telemedicine Platform has to meet the following demands:

- Provision of a simple user interface, which is suited to be used by elderly people without PC knowledge.
- Possibility to create several user accounts.
- Expandable menu structure that can be extended or reduced according to the desired functionality.
- Local data management.
- Clear and easy display of information.
- Automatic setup of communication technologies (phone, connection to the internet).
- Data transfer on demand.
- Automatic recognition and reading out of peripheral devices.

The core of the implemented software architecture consists of three main modules called Visual, Back-End and Plug-In. All three of them can access interfaces to the modules data communication, data management, peripheral communication, the internal sensors and finally the human machine interface. The software architecture is shown in fig. 3. The main functions of the modules are described in the following.

1) Visual

The task of the module *Visual* is to display information to the user. To do so it provides design templates that can be used by the other software modules. This assures a consistent design of screens and a logical menu structure.

2) Back-End

The *Back-End's* main purpose is the automatic handling of certain processes to make the use of the CTP as easy as possible. The different modules of the Back-End are described in the following:

- *The Peripheral Communication* provides functions to communicate with peripheral devices and to control the corresponding hardware modules in CTP. For example, it questions all available Com ports sequentially. If a device is detected this Back-End module will start the corresponding action. Hence the communication with peripheral devices gets completely automated by this process.
- Via the *Data Communication module* connection to the internet is set up. To do so it checks whether the CTP is connected to a LAN or a WLAN. If not, the 56k Modem is checked for a connection to the analog phone line. If none of the above mentioned possibilities is available the UMTS modem is used for data transmitting. This module is also used to setup a phone connection (using GSM).
- *The Internal Sensors module* is used to detect the usage of the SpO2 Sensor and to read out its values.
- *The Data Memory* provides several functions for the use of a SQL data base. Thus it manages the local storing of data. But it is also used for data transfer between the local data base and the web server.
- *The Human Interface* is used to give acoustic and visual feedback to the user. This is realized by displaying information on the touch display, by signal sounds and by voice output (if activated).

3) Plug-In

This component is the basis for the modular extension or reduction of the platform's functionality. Every new function is implemented as Plug-In. For example, there is a Plug-In for the internal SpO2 Sensor, a Plug-In for the telephone function. The big advantage of this structure is that Plug-Ins can be implemented for arbitrary devices. As soon as a new Plug-In is integrated in the structure the CTP can interoperate with the corresponding device. As all available Plug-Ins are listed in the main menu of a user account, the Plug-In architecture makes the modularity of the software visible for the user.

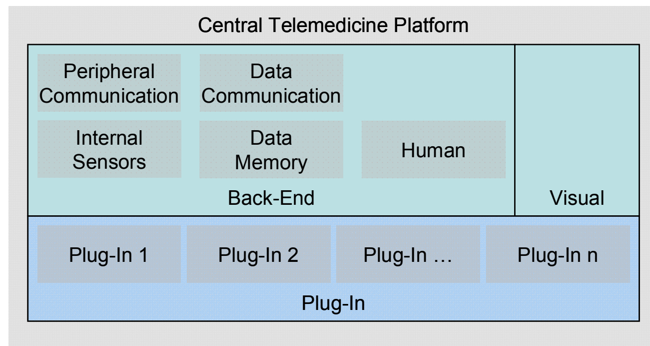

Fig. 3 Software Architecture of the Central Telemedicine Platform

D. Development Process

The development of the Central Telemedicine Platform took place in two steps. A first hardware prototype and three different software user interfaces were evaluated in three focus groups led by a psychogerontologist from the Institute of Psychogerontology of the Friedrich-Alexander-University Erlangen-Nuremberg. A session lasted about two hours and the size of each group was 9 – 11 subjects. The 31 subjects were between 59 and 78 years old (average: 67 years; SD = 3.98). The valuable feedback from the focus groups was implemented in the second prototype, which is presented in this paper. Some of the main suggestions were:

- Tiltable display
- Bigger font sizes and symbols
- Higher contrasts
- Visual and acoustical feedback when touching buttons on the touch screen
- Unified color scheme for every Plug-In

III. Results

The presented Central Telemedicine Platform implements all suggestions that were worked out in the focus groups. The final design of the CTP is shown in fig. 4.

Fig. 4 The Central Telemedicine Platform. Left picture: The main menu with icons of the implemented Plug-Ins. Right picture: Pulse measurement with the integrated sensor.

Furthermore the CTP fulfills all requirements defined at the beginning of the paper as follows:

- *Integrated Sensors:* A reflective SpO2 is integrated.
- *Interfaces for Standard Home Care Devices:* The most important interfaces exist (USB and Bluetooth). Plug-Ins for a blood pressure measurement device (using USB) and for an ECG device (using Bluetooth) were implemented.
- *Integration of mobile approaches and BANs:* The Central Telemedicine Platform is able to read out data from the system presented in [13].
- *Integration of physical activity:* A Plug-In for the accelerometer based activity recognition device presented in [14] was implemented.
- *Integration of ADL:* A Plug-In for the system presented in [12] was implemented.
- *Additional information:* We implemented a Plug-In and an additional PC software with which questions can be asked to the user of a Central Telemedicine Platform. The PC software drops the questions in the web server where they can be picked up by the CTP.

IV. Conclusion

In this article a new Central Telemedicine Platform CTP was presented. It was the aim of the work to develop a central telecare unit for home settings, which gathers information about vital signs and the user's behavior. To do so, the CTP can interact not only with medical home care devices that are available on the market but also with systems from current research. All information is stored in a local data base on the CTP. The user has the option to upload data to a web server. This allows medical staff to check the data remotely. It is also possible to question the user of the CTP remotely. The proposed Plug-In software architecture offers high modularity. Hence the CTP can individually be adapted to the user's needs.

In future work the CTP is to be evaluated in real life settings.

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The scope of the research consortium is to develop technology based solutions which will help elderly people in their future living environment comprising home and workplace as well as in communication and transportation.

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