Home Care and Health Maintenance Systems

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Abstract—**In this article there are described applications of embedded systems for the diagnostic and the maintenance planning in healthcare applications. During the recent years, there was a rapid growth in the development of maintenance telemedicine systems and monitoring devices for patients with chronic diseases and those requiring continuous telemonitoring treatments. However most of these systems only provide telemonitoring services or a basic information about the health conditions of the patients. For this reason an intelligent home health care embedded system that can provide to the patients with diagnosis their health status at home is developed. As a result different types of pluggable medical transducers for patients with different illnesses can be flexibly connected to interface of the embedded system. The home care system is possible to use as a predictive diagnostic system.**

I. Introduction

REGARDING to health care systems and devices, cost and need for more care and monitoring of the growing group of the elderly people will involve ICT technologies and especially embedded systems of different kind from soft to hard safety criticality to people. Healthcare systems can be decomposed into three broad categories. These categories are:

--Managing unwell patients (with particular emphasis on managing chronic conditions, implants, embedded medication)

--Managing the health of well patients ("wellness management").

--Clinical support (from primary service to acute one and managing the interface among other support services)

In the past the patients with chronic diseases often had to spend a precious time and had to pay inconvenient visits to had health checking at either hospitals or clinics.

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As our life quality is being improved many telemedicine systems and monitoring devices are developed. To reduce the inconvenience an intelligent home health care embedded system which can provide diagnosis about health status for patients directly at home was proposed [5].

Patients can check their health by themselves easily and advices about their health status are displayed to them immediately. According to the type of biomedical signals that needs to be obtained from the patients, different types of pluggable medical transducers will be connected to the embedded system for signal acquisition. By feeding the digitized biomedical signals to embedded medical transducer parameter detector/extractor, relevant parameters will be extracted out by using promising techniques like wavelet transforms [4].

Finally these parameters are sent to expert system with updatable knowledge base for diagnosis of the health status. Primary diagnosis results directly related to discomfort possibly occurred or disease likely to encounter are displayed as a preliminary advice to the patients. Patients have a clearer idea about their health and can pay visits to their physicians only if their problem gets necessary.

The heart that controls life of every human being is an important organ in our body. By studying the electrocardiogram (ECG) valuable information about the health status of the patient can be obtained. Therefore ECG analysis is an indispensable part in the embedded system. Although there are various types of QRS detection methods wavelet one is still adopted in our proposed system for the purpose of increasing speed and reducing size of the embedded system. In fact the wavelet manipulation can be implemented through using filters with different groups of coefficients which imply the migration from software algorithm to hardware circuits.

Home care systems are able to measure several parameters including ECG, blood pressure, oxygen saturation (SpO2), blood glucose, heart rate, temperature and respiration. The blood pressure and the blood glucose (e.g. systolic and diastolic for blood pressure, glucose level for blood glucose) which require fewer parameters can be treated similarly to the treatment on ECG signal as long as the transducers are well-designed.

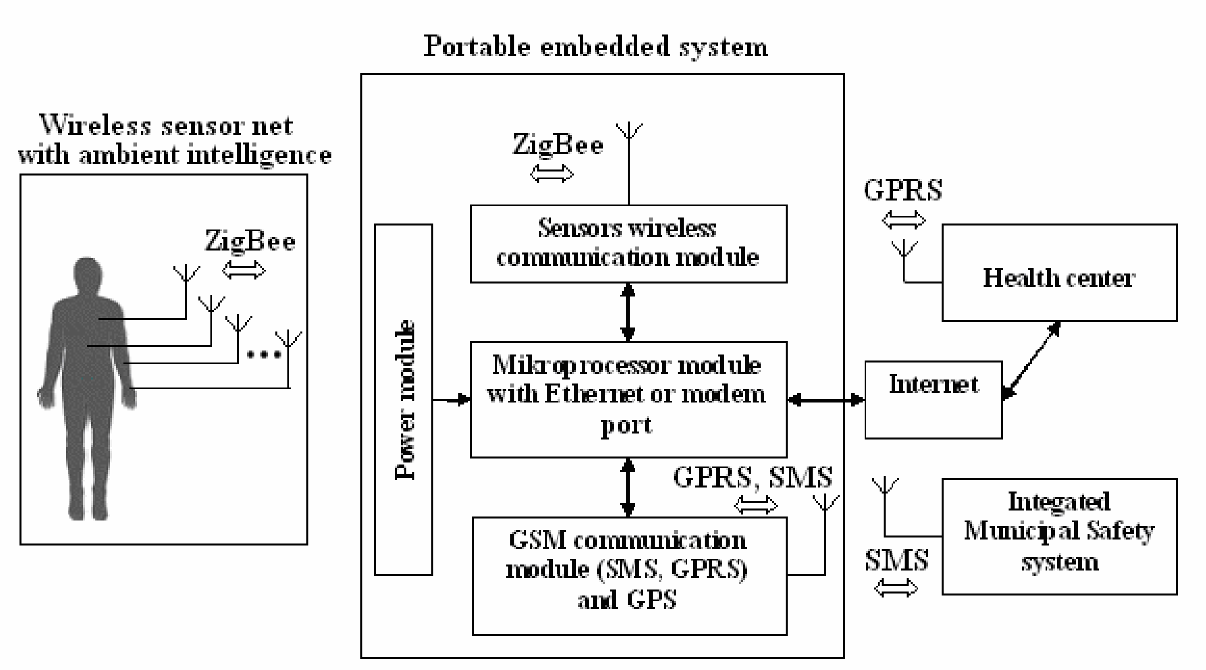

Fig. 1. Block diagram of home-care embedded system

In fact all these transducers can be added to or removed from embedded system according to the need of patient. The next parameter of home care systems are falls.

Falls are common injuries by elderly people and constitute the most health burdens. It is well known that the incidence of falls rises with increasing age. While it is clear that falls are an important cause of serious injuries in the elderly it is important to remember that falls also a result in a fear of falling, loss of confidence, and restriction of mobility and independence which may be either self-imposed or imposed by care-givers.

The ability to monitor a person's posture and movement may help either to identify people at risk of falls or to guide interventions to reduce the risk of falls for individuals who have been identified at the risk. In addition the ability to detect a fall by an older man who is alone with the resultant activation of a response/help system is an immense benefit as this leads to a shortened interval before the arrival of assistance and reduce both the physical as well as the psychological trauma of the event.

I. DESCRIPTION OF THE EMBEDDED HOME CARE SYSTEM STRUCTURE

The embedded system needs to be not only portable and non-intrusive, the weight needs to be low; but also it needs to be low-cost. The important task at design of the sensor net on the human body is to be non-intrusive.

By using ambient intelligence technologies transform the detailed interaction between healthcare processes and the home-care systems and the deep embedding of wireless sensor and actuator technologies into the environment. This is one of the particular importance for embedded systems because these systems provides technological infrastructure for the implementation of ambient intelligence.

Wireless communication tends to be one of the major trends in medical applications to increase usability and comfort in the long time patient monitoring. Nevertheless systems currently available on the market concentrate mostly on home-care or generally on scenarios that do not existentially depend on the permanent transmission of continuous data streams. Anyhow there exists a couple of short-range wireless transmission standards that allow appropriate data rates suitable to continuously transmit a sufficient set of patient vital status information.

The preliminary work on the analysis of available wireless communication standards focuses on the most common technologies with publicly available specifications which are namely Bluetooth (IEEE 802.15.1.) [1], WLAN (IEEE 802.11), WPAN (IEEE 802.15.4 / ZigBee) [2], [3], DECT and IrDA. Except the IrDA technology which uses infrared light for transmitting data, these technologies are radio based using different frequency bands.

While comparing all wireless technologies we had to choose relevant criteria for an evaluation. The main criteria used in our project were bandwidth, range, energy consumption, robustness, availability, usability and security. Depending on particular demands there may exist other criteria and/or a special weighting of the single criteria. After defining these criteria different technologies discussed for usage in medical environments were identified and compared against each other.

We have had some experience with embedded systems using Bluetooth technology [6] for transmission of individual parameters. For building of sensor nets we have decided to use an ambient intelligence sensor technology together with ZigBee technology.

The global design of home-care embedded system is demonstrated on the Figure 1. Individual parts are described below.

A. *Wireless sensors net*

The ZigBee standard IEEE 802.15.4 (band at 2.4 GHz, 250 kbps - High Data Rate Radio) covering lower layers of the protocol stack is relatively new comparing to other technologies. Hence only a few devices are available to the market implementing the entire standard, their using is very interesting for implementation of ambient sensors.

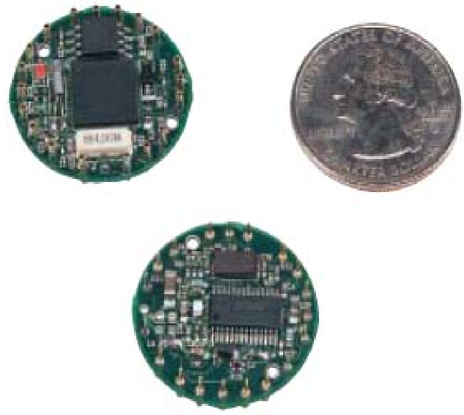

Fig. 2. Crossbow module MPR500CA

We have chosen wireless modules from six producer Crossbow technologies, Flexipanel, Cirronet, Freescale, Jennic and Panasonic. Basic parameters are in Table 1. Three modules are very interesting for our application. The first one is the Crossbow module MPR500CA which work on 868/916 MHz frequency (no ZigBee) but it is a circle module with low power consumption and with battery on the module (Fig. 2).

TABLE 1
WIRELESS SENSOR MODULES

Producer		**Crossbow Technology**	**Crossbow Technology**	**Flexipanel**	**Cirronet**	**Freescale**	**Jennic**	**Panasonic**
Type		MPR2600C	MPR500CA	PICZee	ZMN2400	13192DSK	JS24Z121	PAN4551
Dimensions [mm]		24,13 x 24,13	circle module 25 x 6		30 x 21	75 x 50	25 x 18	26,5 x 20
Power consumption	*Rx [mA]*	19,7+ 8	10	20	35/3.3V		<50	38
	Tx [mA]	17,4 + 8	27 (868/916 MHz)	18	30/3.3V		<40	31
	Idle [uA]	20	-		-		-	500
	Sleep [uA]	1+ 15	<1		25		<5	<2
External power	*[V]*	2,1- 3,6	2,7 - 3,3	2,1-3,6	2,7-5,5	9	2,2-3,6	2,1 - 3,4
Battery on module		No	3V Coin	No	No	Position for 9V battery	Development Kit FFD - 2x AAA, RFD button cell	No

The coin dimension is suitable for the fixation on the human body. Sensor boards with the temperature sensor or free boards (OEM) without sensor are available. Microcontroller is ATmega128L with 18 pin I/O connector - 6x AI (10bit), DI/DO - 9x, UART.

The second one is the Crossbow module MPR2600C which works on 2.4 MHz frequency - ZigBee (Fig. 3). Microcontroller has digital I/O, I2C, SPI, 10bit ADC and ports MIB510, Ethernet MIB600, Linux STARGATE. Both Crossbow modules run on real-time TinyOS.

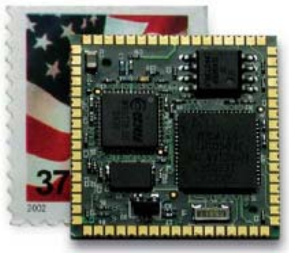

Fig. 3. Crossbow module MPR2600C

The third one is low-cost (35 EUR) Panasonic module PAN4551 with integrated antenna that works on 2.4 MHz frequency - ZigBee (Fig. 4). Microcontroller is MC9S08GT60 with 5 x 10bit ADC, 29 GPIO and ports MIB510, Ethernet MIB600, Linux STARGATE.

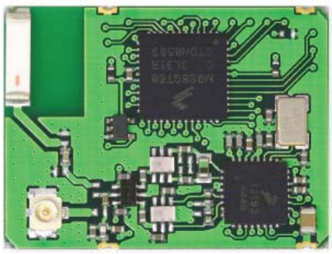

Fig. 4. Panasonic module PAN4551

The Zigbee module 13192DSK has integrated accelerometer -x, y, z and antenna, acceptable as fall sensor. The microcontroller is MC9S08GT60.

Based on the positive aspects of the Zig-Bee radio technology, a first demonstration prototype has been built to validate the usability in home-care applications. Therefore only approved sets of OEM-modules for the vital parameter monitoring have been taken into account.

Optimization of sensor systems for the wireless use would be another interesting topic but is not the main focus until general applicability of the wireless monitoring is proven for life-critical scenarios.

Two sets of sensor systems had been compared for their suitability for the first prototype evaluation. The first one was a set of five single modules providing raw data stream without any high level functionality. These modules provide:

--NIBP- non-invasive blood pressure

--SpO2 - non-invasive blood-oxygen saturation, pletysmogram

--PF - pulse frequency

--TEMP - body temperature

--FS - fall sensor - accelerometer

The second one was a set of six or seven single modules, with ECG – electrocardiogram or BGL – blood glucose level.

The most common wireless technologies had been compared for their usability in medical real-time monitoring: regarding bandwidth, communication range, energy consumption, robustness of communication and general usability. Zig-Bee stated out as the currently most suitable technology for home-care real-time communication. Based on this analysis a first demonstration prototype has been built.

B. *Portable embedded system*

On the one side the portable embedded system communicates remotely with a sensor network (see Fig. 1). On the other side the portable embedded system is able to make the decision based on the data recorded and to transmit results to the remote system via GSM or wire connection (Ethernet or modem).

GSM and GPS communications are useful on the street at the falling accident. At home is possible to use both communications, wire communications for sending medical data to the health center is often cheaper. The parameters related to the decision-making process are able to be modified remotely.

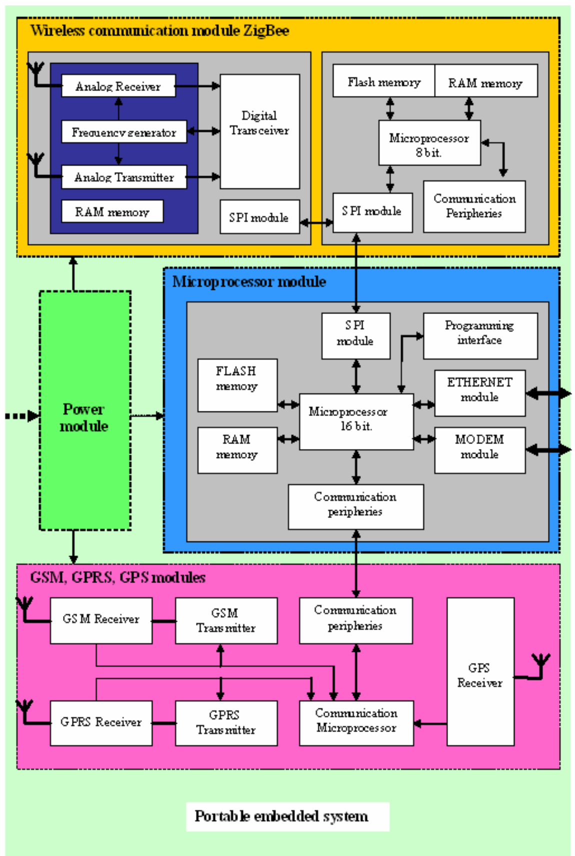

Fig. 5 Block diagram of portable embedded system

When the patient goes out of the house, the portable embedded system is possible to bring with on the street. When he comes back connects it to the socket for the outside battery-charging.

The local installation part of the system had been tested successfully in a laboratory setting for internet, GSM and GSP communication. The next step evaluates telecommunications particularly the update facility, after which a field trial of remote assessment in elderly subjects begins. The block diagram of the portable embedded system is demonstrated on the Figure 5. Types of processors are depended on the configuration of the sensor network. On the Figure 5 is configuration for basic sensor network without processing of the ECG signal.

II. HELTH MAITENANCE SYSTEM AND PREDICTIVE DIAGNOSTIC

Health maintenance system represents an opportunity to follow in real-time, at distance, subject conditions through the use of medical knowledge and telecommunication devices support. Home monitoring is assuming more and more importance to perform patient diagnosis and therapy and reduces hospitalization costs. Telemedicine technologies allow unifying different clinical objectives: prevention, diagnosis, therapy, admission and home assistance.

This out-of-hospital system makes closer patient-physician relationship because of patient active participation to patient own treatment process. In this way it is possible not only to check patient's health condition but also to study care efficacy as to eventually modify pharmacological treatments.

A. *Falling accident*

The function of possibility of falling accident integrates three processes that survey the arrival of the data. The first detects the arrival of the data from the sensor network, and integrates the data preprocessing functions. The second evaluates data of the falling accident.

If it occurred process sending the SMS to the local support network which includes family or friends or neighbors and emergency services (e.g. Integrated Municipal Emergency System, socio-medical network, etc.), and sending the data via internet for storage. SMS includes also data from GPS. The third process sends data to the medical support network (doctors, nurses, etc) to receive more detailed information by internet.

The medical service is able to verify if there is a real risk of falling, in order to modify the detection parameters in case of a false alarm. When the server receives a demand for an update from the medical service a connection is established via GSM and the parameters are updated.

B. *Remote diagnostic system*

Next application of the health maintenance system is remote diagnosis. An adaptable software agent combined with an adaptable embedded system together comprises what we call adaptable remote diagnostic system.

One of the easiest ways to accomplish remote diagnosis of embedded systems is to have a web-based access to field equipments (Fig. 6). This will let technical people use easy to available browsers to maintain the remote systems and learning curve on tools is considerably reduced.

Fig. 6 General Configuration of remote diagnose

The expert diagnoser is the person who will run a series of tests on the embedded system. The expert diagnoser will be accessing the central server over the internet. The central server houses the software agents that run various diagnostic tests on the embedded system. The embedded system is connected to the central server over a LAN (it could be internet as well since the embedded system has an assigned IP address).

C. *Predictive diagnostic*

In the case of predictive diagnostic in maintenance health systems there are many types of diseases but only percentage of them we can predict by technique. For the most part we measure actual accident, which is not predictable or with a little timing advance like falling or apoplectic stroke.

But with the help of embedded system capabilities we can calculate and predict some life endangering situation like allergic reaction, coronary thrombosis, hypoglycaemic shock and sudden death syndrome etc. From this point of view we can assume and predict health hazard from set of information collected and reviewed by the embedded system. In these cases this system early and reliably recognizes a dangerous patient hood change. For example the sudden death syndrome is predicted from ECG signal (Fig. 7. and 8.), temperature, breath frequency and blood oxygen saturation. Also prediction of blood pressure and blood glucose (which require fewer parameters e.g. systolic and diastolic for blood pressure, glucose level for blood glucose), can prevent from hypertension shock and hyper or hypoglycaemic shock.

With the view of plotting record's has been also designed and realized testing program in MATLAB environment, which makes it possible well-arranged orientation in the designed method detection and analyses single ECG recording [7]. These way get results are use for depiction waveform heart tachogram, which sequentially transforms into frequency areas with the view of analyses spectral coulisses. Final exit processing is classification physiological or morbid changes heart rate measured patients. The results of that work may be contribution for on - line recognition causes complex sudden death of humans.

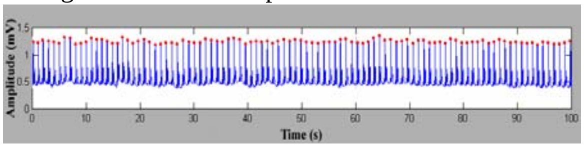

Fig. 7 The graph from MATLAB where ECG curve is filtered and highlight point, where was detected R-peaks

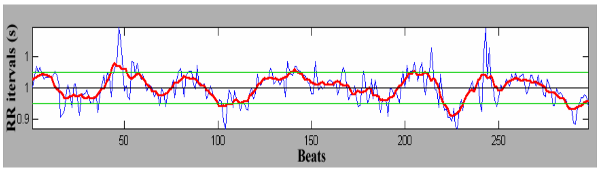

Fig. 8 Hearth tachogram display heart rate variability in time. The thinner curve with pikes is showing immediate heart rate and the thicker curve is showing average heart rate.

D. *Biomedical feedback control systems*

However it is well known that there are other indirect physiological parameters that can be measured which provides an indirect indication of the key parameters that require close monitoring or regulation. Examples of such indirect parameters include *end tidal carbon dioxide tension, oxygen saturation in blood, glucose concentration in interstitial fluid* etc. Methods of soft computing can be applied to combine continuous measurement of indirect parameters to produce sensors that can provide continuous estimation of the key physiological parameters:

--Closed loop control of blood carbon dioxide and oxygen tension

--Blood glucose regulation in diabetics

--Pain management of postoperative patients - patient controlled analgesia

III. CONCLUSION

In the present time the embedded systems forge an integral part of our everyday lives. Comparatively in the near future embedded systems will ward over our lives and health. It enables both reductions of costs for patient in the hospital and increasing the level of the health care in such a way that the critical states of patients just for hospitalization will be found out more quickly.

The future of embedded health maintenance systems fully depend on development of specific sensors, data transmission, also on embedded systems improvements that take up modern role of our personal guards. Presently is an effort to decrease the days' number of the patient's stay in hospital. In such a way that a part of the patient's care is transferred into his home environment - home care.

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