AMON: A Wearable Medical Computer for High Risk Patients

Paul Lukowicz, Urs Anliker, Jamie Ward and Gerhard Tröster
Wearable Computing Lab, IfE,
ETH Zurich, Switzerland
uanliker, lukowicz, ward, troester @ife.ee.ethz.ch

Etienne Hirt, Christopher Neufelt
Art of Technology
Zurich, Switzerland
hirt, neufelt@art-of-technology.ch

Abstract

We present a wrist worn medical monitoring computer designed to free high risk patient from the constraints of stationary monitoring equipment. The system combines complex medical monitoring, data analysis and communication capabilities in a truly wearable watch-like form. The paper summarizes the functionality, architecture and implementation of the system.

1 Introduction

Health monitoring is among the most attractive application fields for wearable electronics and has been studied by many research groups [1, 3]. A variety of wearable devices for monitoring physiological parameters are commercially available today (e.g POLAR www.polar-usa.com/) with many others in research and development stage. However the majority of such devices are aimed at the recreational market (e.g joggers) and are not suitable for medical monitoring of high risk patients. Those devices that have been qualified for medical use are usually fairly simple measuring just one or two parameters and providing little or no online analysis. Many are also quite bulky (e.g. [2]). The AMON (**A**dvanced **M**edical M**oni**tor) system is a next generation wearable medical monitoring computer that has been developed by a European Union IST sponsored consortium consisting of 5 industrial partners (Art-of-Technology, Aurelia, Hôpitaux de Paris, Tadiran Spectralink), and one academic (wearable Computing Lab ETH Zurich.) It provides complex monitoring, data analysis and communication capabilities in a single wristworn unit. AMON has been conceived as a clinical device for high risk patients requiring constant monitoring, logging and analysis of their vital signs. Today such patients are severely restricted in their mobility since the required monitoring equipment is either stationary or bulky. With the help of AMON those restrictions will be largely removed.

2 AMON Functionality

The main innovative features of the AMON system are:
Multi-parameter monitoring and logging The system continuously monitors and logs, pulse, blood oxygen saturation and temperature of a patient. It also has an acceleration sensor to indicate the level of physical activity. In addition blood pressure and one lead ECG can be taken whenever necessary.

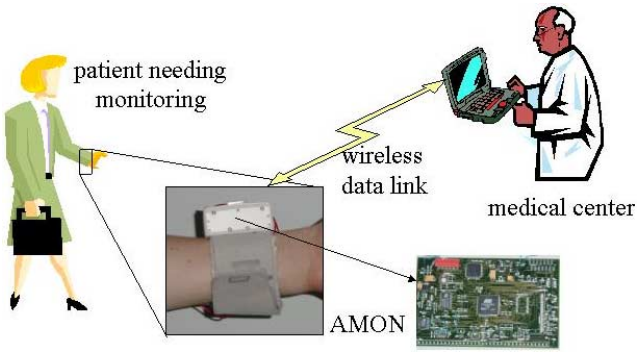

Figure 1: Prototype of the AMON wearable medical computer (box) and its role in the monitoring system.

Online health state analysis Using the continuously monitored parameters and user activity information the system performs an online analysis of the user's health status. Should the system decide that the users state deviates from a predefined user specific range, additional measurements including ECG and blood pressure are performed.
Automatic and manual alerts Should analysis of the additional measurements confirm such deviations, the system can automatically alert a doctor at a remote Medical Center using a built-in mobile phone link. A key advantage of AMON lies in the complexity of the analysis which minimizes the number of false alarms. Of course the system also has a manual alert function that can be user triggered whenever he or she feels that they need help. In whatever case an alert is triggered, all data logged during the previous hours is sent to the medical center providing doctors with a basis for more accurate diagnosis.
Interactive communication The system allows medical center personnel to communicate with the patient using simple on-screen text messages. In addition the medical center personnel can control the AMON device and instruct it to make new measurements.
Watch-like form AMON with all its electronics, sensors and a battery sufficient for 24h is contained in a watch-like housing mounted on a wrist worn blood pres-

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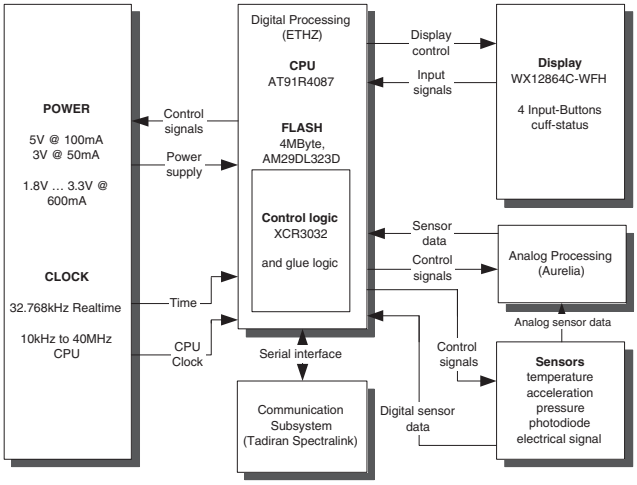

Figure 2: Block diagram of the AMON wearable health monitoring computer.

sure cuff. (see figure 1).

3 AMON Architecture

As shown in figure 2 the main system components are: a sensor/analog subsystem, a user interface subsystem, a communication subsystem, a digital data processing unit and a power supply and management subsystem.

Sensors/Analog Subsystem The most important AMON sensor is a blood oxygen level and pulse sensor custom made by SPO Inc for our project. It is based on the difference in the infrared to red light absorption ratio of oxygen saturated and oxygen poor blood. The skin temperature is measured using a thermopile temperature sensor with a built in PTC as an external reference. In the first system prototype a commercial wrist based blood pressure meter has been adapted and integrated into the system. For the single lead ECG silver electrodes, one mounted under the housing the other on top (for contact with patient's other hand during readings) are used together with a specially designed amplification and filter circuit. The analog sensors are connected to a custom analog processing circuit with an 11 bit analog to digital converter (ADC) and appropriate amplifiers for each channel.

User Interface The main criterion in the design of the user interface was simplicity. The system has to be operated by ill and elderly people who may not feel immediately comfortable with technology; any complicated interface would simply prove counterproductive - especially in an emergency situation. An appropriate interface has been realized using a 128x64 grey scale LCD screen and four large buttons.

Communication Subsystem A Siemens TC 35 GSM module together with some control electronics is used for communication with the medical center. It features a small size (36x55x7mm) and low operating current (35mA at 3.3V).

Digital Processing The main tasks of the digital data processing subsystem are: control of the sensors and ADC, handling the user interface, running medical analysis algorithms, and taking care of messages to and from the medical center. The different activities are coordinated by a modified AMX embedded multitasking operating system. The above tasks can be performed with mostly low computation intensity, with bursts of computing power required only for the infrequent ECG and blood pressure readings. To provide this functionality with minimal power consumption the system is build around an ARM7 processor with 136 KB on chip RAM that can be operated at between 1MHz (1.8V) and 40MHz (3.3V). For data logging and patient parameters there is a 4MB off chip low power FLASH.

Power Management Power consumption was among the main concern of the AMON design. The system must be operational for at least 24 hour without recharging, with a battery small enough to fit the wrist mounted housing. The power supply consists of a Toshiba LGR 18500P 1000mAh battery and three DC-DC converters providing the voltages needed by the different system components (5V, 3V, and variable 1.8-3V). To conserve power, aggressive power management strategy with extremely short duty cycles for all components, and voltage and frequency scheduling for the CPU has been adopted.

At the time of writing AMON is entering first clinical trials.

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