WIRELESS SENSOR NETWORKS FOR HEALTH MONITORING

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ABSTRACT

We propose a platform for health monitoring using wireless sensor networks. Our platform is a new architecture called CustoMed that will reduce the customization and reconfiguration time for medical systems that use reconfigurable embedded systems. This architecture is a network enabled system that supports various wearable sensors and contains on-board general computing capabilities for executing individually tailored event detection, alerts, and network communication with various medical informatics services. The customization of such system with a large number of "med nodes" is extremely fast even by non-engineering staff. In this paper, we present the architecture of such device along with experimental analysis that evaluates the performance of such system.

1. INTRODUCTION

Our proposed CustoMed is a fascinating and critical class of distributed embedded systems. The main attribute of CustoMed is its fast and easy customizability capability based on patients' needs. Firstly, the customization may be at the device level. The choice of the device, the placement of the device on the body, and the interaction level of the device with the environment will be tailored to the individual and his/her needs. Secondly, the software downloaded onto the devices can be customizable. Depending on the gender, age, medical condition, and other variables, the software downloaded onto the devices differs. The idea of customization has not been emphasized before, but is an important concern, if the system is made to be robust enough to handle many different needs, as well as unexpected needs that may arise.

CustoMed can be easily custom-built for patients by non-engineering staff. The system will be quickly assembled from basic parts and configured for use. The vision is that in the doctor's office in about five minutes, the appropriate devices and the correct number of them will be assembled and affixed to the patient. Other systems take months or even years to be built, and hence lack the adaptability of the system we propose. The physician will also pick from a wide range of code to download onto the devices. We developed such a tool which enables physicians to pick a specific variation of code for a particular application and download it to the system components of CustoMed. Furthermore, it works with the environment made available to the patient. For example, in case of an emergency, the sensors can alert the security system in the house. In less urgent cases, an email can be sent across the Internet or a home appliance can be turned off or on.

2. RELATED WORK

Several "wearable" technologies exist to continually monitor patient's vital signs, utilizing low cost, well-established disposable sensors such as blood oxygen finger clips and electrocardiogram electrodes.

The Smart Shirt from Sensatex [3] is a wearable health monitoring device that integrates a number of sensory devices onto the Wearable Motherboard from Georgia Tech [8]. Several other technologies have been introduced by MIT called MIThril [7], e-Textile from Carnegie Mellon University [4] and Wearable e-Textile from Virginia Tech [9]. Furthermore, the Lifeguard project being conducted at Stanford University is a physiological monitoring system comprised of physiological sensors (ECG/Respiration electrodes, Pulse Oximeter, Blood Pressure Monitor, Temperature probe), a wearable device with built-in accelerometers (CPOD), and a base station (Pocket PC). The CPOD acquires and logs the physiological parameters measured by the sensors [2]. The Assisted Cognition Project conducted at the University of Washingtons Department of Computer Science is exploring the use of AI systems to support and enhance the independence and quality of life of Alzheimers patients. Assisted cognition systems use ubiquitous computing and artificial intelligence technology to replace some of the memory and problem-solving abilities that have been lost by an Alzheimers patient [5]. Nevertheless, none of the above projects/systems support the concept of being custom-built in minutes and reconfiguration in the extent that CustoMed does.

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3. SYSTEM COMPONENTS

3.1. Sensors

We employ various types of sensors for continual physiological measurements as well as environmental measurements to identify a wearer's physiological conditions and disorders and the case where people operating in hazardous environments. We have available to us pressure sensors, galvanic skin response sensors, flex sensors, piezo-electric film sensors and temperature sensors.

3.2. Med Nodes

The most important component of our system is the med nodes. Med nodes are stand-alone components equipped with processing units and batteries. They support various types of sensors for physiological reading from the human body. These blocks enable the system to be flexible, however their basic structure remains fixed almost all the time and thus the reconfiguration time is no longer a severe limitation. Furthermore, customization of such system with a large number of med nodes is extremely fast. The med nodes can possess several parameters such that they can be complex enough to suit a range of applications. They can as well be more basic that can perform multiple operations. Furthermore, they support a variety of analog and digital sensors such as flex sensors, piezo-electric sensors, pressure sensors, etc. Also, the block is left software programmable which can be customized for various applications and sensors. On-chip memory blocks are also available for data storage. The processors of med nodes are dot-motes developed at University of California, Berkeley and manufactured by Crossbow [1]. A med node along with sensors is shown in Figure 1.

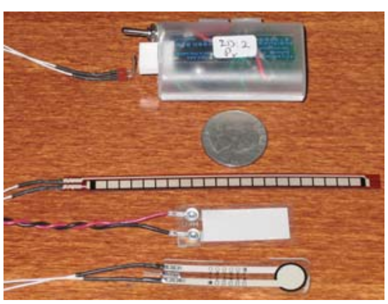

Fig. 1. A Med Node along with Sensors

3.3. Pocket PC

A Pocket PC is responsible for collecting data from med nodes and classifying them. It dispatches the critical events detected by med nodes or the Pocket PC, itself, to the Internet. Moreover, it coordinates and controls the overall functionality of the system.

Fig. 2. Client Program on Pocket PC

4. DRIVER APPLICATION

The design and development of the system framework is meant to be versatile enough to be applied to many different medical applications. The requirements of the system, specifically with the ability to quickly and easily make a custom-made system per patient, were deeply affected by this vision. The following is a sample application that has inspired the overall system requirements and the initial idea. Post-knee surgery tracking of patients:
Structuring of imaging data from the musculoskeletal system will be accomplished utilizing novel MR pulse sequences to support canonical imaging values from tissue independent of acquisition techniques. Two med nodes are placed on knees and two on the ankles. The med nodes on the knees are equipped with flex sensors while med nodes on the ankles utilize pressure sensors. Med nodes on the knees are responsible for tracking the angular motion of the knees and transmitting the collected data to the pocket PC. Med nodes on the ankles, however, measure the forces and pressures under the foot as well as the load distribution. In addition, we place another med node on the neck to measure the angular motion of the back/neck.

5. EXPERIMENTAL ANALYSIS

In this section, we illustrate system specifications of CustoMed along with the experimental analysis that we performed to evaluate the performance of the system.
The code on mica2dots is implemented with NesC under TinyOS [6]. The software on Pocket PC is written with Embedded Visual C++. A summary on the system speci-

Max Sampling Rate	200Hz
Bits per Sample	10bits
Max Number of Sensors per Med Node	5
Power Consumption of each Med Node (Wireless ON, CPU active)	54 mW
Battery Lifetime of each Med Node	9 hours

Table 1. CustoMed System Specification

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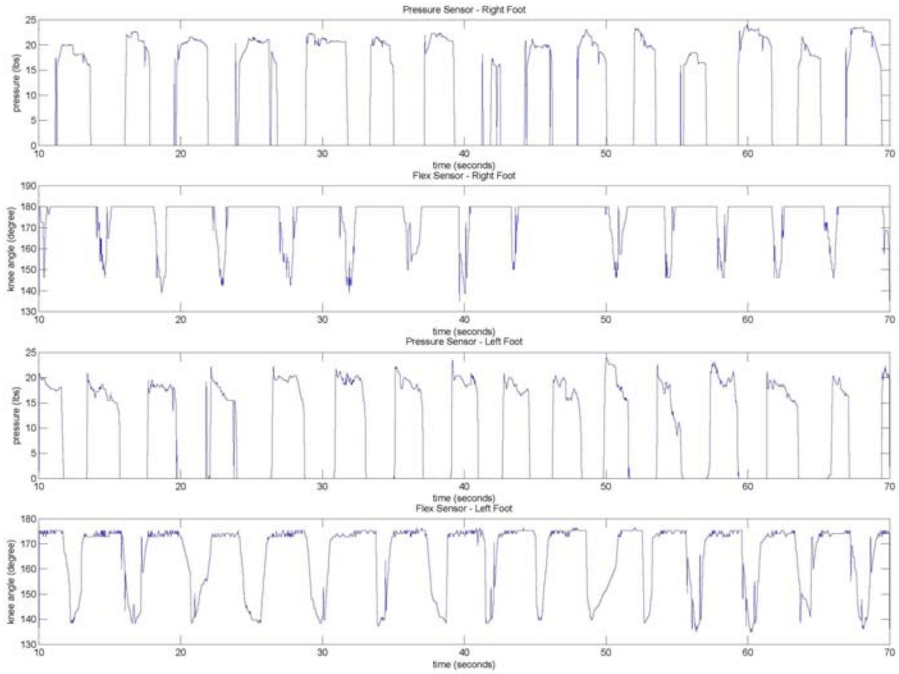

Fig. 3. Sensor Readings

fication of CustoMed is presented in Table 1. All the experiments were carried with med nodes transceivers operating at $433MHz$. All med nodes were equipped with one $3V$ Duracell DL2450 batteries except the med node placed on the waist (with three batteries) since it is connected to the Pocket PC and must remain on continuously. As for the medical application, we considered the application for post-knee surgery tracking of patients. We placed med nodes equipped with flex sensors on the knees and two with pressure sensors under the heels in the shoe bed. The med node placed on the waist was responsible for collecting data from other med nodes and transmit it to the Pocket PC through UART (Universal Asynchronous Receiver/Transmitter). In this scenario, all the med nodes continuously transmitted their sensor readings to the med node on the waist. CustoMed worn by a person was tested under various conditions (in indoor/outdoor environments and with slow/normal walking speeds). The data shown in Figure 3 represents the case where the person was slowly walking indoors. The sensor readings from both left and right legs are depicted. The active sensing area of pressure sensors is a 0.375” diameter circle placed under the heels. The results show that our system is capable of continuously monitoring/logging patients’ daily activities.

6. CONCLUSIONS

In this paper, we presented CustoMed, a medical monitoring system which can be easily custom-built for various medical applications by physicians or non-technical staff. We tested our proposed architecture with one medical application and laid out its performance metrics.

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