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# Development of a wrist-worn integrated health monitoring system

J. M. Kang[1], J. W. Choi[2], and H. C. Kim[3]
[1]Interdisciplinary Program, Biomedical Engineering Major, Graduate School and
[2,3]Department of Biomedical Engineering, College of Medicine and Institute of Medical & Biological Engineering, Medical Research Center, Seoul National University, Seoul, Korea

*Abstract*—**In this paper, we report upon the prototype development of a wrist-worn integrated health monitoring device(WIHMD) with a tele-reporting function. The functional objective of the WIHMD is to provide information concerning clinical state, such as vital biosignals and locational information, to experts at a distance. Thereby, the unit provides the facility for rapid and appropriate directions to be given by experts in emergency situations, and enables the user or the supervisor to manage changes in health condition with helpful treatment.**

*Keywords*— **health monitoring device, telecommunication , telemedicine**

## I. Introduction

We developed a wrist-worn integrated health monitoring device (WIHMD) with a tele-reporting function. Our strategy is that every possible vital biosignal instruments is built into a wrist-worn unit and a central processor supervises the operation of each component, analyzes the measured data and then rapidly communicates with patient's caregivers such as doctors or relatives through a connected telecommunication device. Thus, it is possible to get rapid and appropriate directions made to handle emergency situations and to enable the user or the caregiver to detect and manage changes in the user's health. The technical challenge in the development of such device is to make the system easy to operate and manage, reliable under various operating conditions, and affordable for most possible users.

## II. Methodology

The WIHMD consists of five vital biosignal measuring modules, which include a fall detector, a single channel electrocardiogram (ECG), and noninvasive blood pressure (NIBP), pulse oxymetry ($SpO_2$) and body surface temperature measuring units.

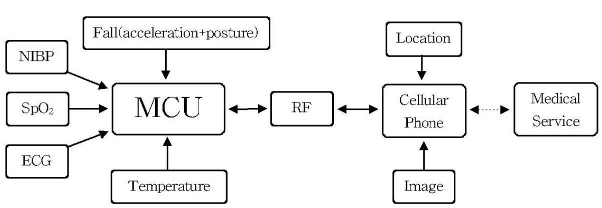


Fig. 1. Functional block diagram of the WIHMD system

As shown in Fig. 1, the central unit of a micro-controller (ATmega103L, Atmel, USA) manages the operation of each measurement module. The hardware of the actual device is composed of a wrist cuff for the NIBP measurement and a main unit mounted on the cuff. Two textile electrodes for ECG and a semiconductor temperature sensor are attached to the surfaces of the cuff and a finger clip type $SpO_2$ sensor is connected to the main unit.

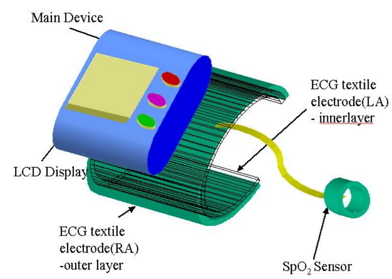


Fig. 2. Schematic drawing of the prototype WIHMD

Fig. 2 shows a schematic drawing of the proposed system to be developed. It also contains two printed circuit boards, which include analog and digital circuitry and other onboard sensors. The size of the WIHMD is 60x50x20mm excepting the wrist cuff and the total system weighs 200g including two 1.5V AAA-sized batteries.

The software of WIHMD was developed for operational simplicity and efficiency. Considering the fact that possible users are relatively old and infirm, any complicated user interface would be counterproductive in daily life or in emergency situations. The WIHMD provides relatively large graphic icons on a 128x64 pixel graphic LCD and three input buttons as user interface, and connects with public telecommunication devices, like cellular phones, in a wireless manner. The WIHMD performs all measurements and sends the measured data to preassigned caregivers using cellular phone as quickly as possible .

In the case of tele-reporting function, The tele-reporting device is an essential part of telemedicine or telehealthcare systems like WIHMD. Nowadays, many kinds of wireless communication devices are available, e.g. Bluetooth$^{TM}$, wireless LAN, radio frequency (RF) transceiver and a cellular phone. In our previous research, we compared the telecommunication methods to be used with a chest strap type of patient monitoring device for emergency telemedicine system(ETS) [1]. Based on the results of the previous study and considering the system complexity, power consumption, and reliability, we chose an RF transceiver and a cellular phone for short and long range telecommunications, respectively.

## III. Results

Fig. 3 shows the photograph of the developed system worn on the wirst. The detail results of each measurement modules and tele-reporting device are as follow

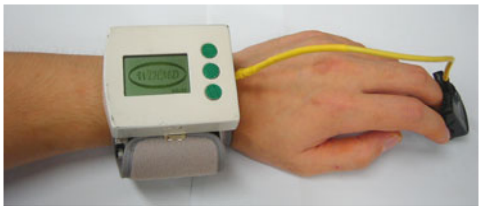

Fig. 3. Photograph of the developed system worn on the wrist

### A. Fall Detector

We developed a simple fall detector using a 2-axis accelerometer (MMA3201, Motorola, USA) and an in-house made posture sensor, which is basically composed of a photo-interrupter with a pendulum. As a result of a pendulum swing, a photo-interrupter acts as an on-off switch to indicate the wearer's wrist orientation with respect to gravity. Once the acceleration sensor output exceeds the empirically determined threshold, then the posture sensor output determines whether the WIHMD wearer has fallen or not.

Since almost all emergency situations are accompanied by a fall, the fall detector remains active all the time and is crucially used to detect emergency onset. When the WIHMD detects a fall event, it confirms whether the wearer is conscious or not by raising a sound alarm. Then if there is no response from the wearer in a given time (ten seconds), the WIHMD starts the vital biosignal measurements and provides the emergency occurrence to preassigned caregivers with the appropriate information.

### B. Single channel ECG

For ECG measurement on the wrist, we used only 2 textile electrodes for a single channel (Lead I), which record between each arm. The textile electrodes are made of a conductive sheet, which has a surface resistance of $0.05\sim0.1\Omega$ /$cm^2$. One textile ECG electrode for the left arm is attached to the inner surface of the wrist cuff and the right hand must touch the other electrode at the outer layer of the cuff. The analog circuitry of the ECG module consists of an instrumentation amplifier, a notch filter and a non-inverting amplifier with a total gain and bandwidth of 80dB and 40Hz, respectively. The ECG signal is converted to a digital signal with sampling rate of 100Hz for heart rate (HR) estimations.

Performance evaluation of the developed ECG module was accomplished using a commercial ECG simulator (Patient-Simulator 214B, DNI Nevada Inc. USA). For various simulated ECG outputs with range of 40~240(BPM), the developed ECG module produced HR outputs within an error range of ±1%.

### C. NIBP

A conventional digital wrist sphygmomanometer was developed. The NIBP module was constructed using, a motor, pump, solenoid valve, and wrist cuff from a commercialized product (SE-309, Sein Inc., Korea) and a small semiconductor pressure sensor (MPXM2053, Motorola, USA). All electronic circuitry and the program for the oscillometric pressure measurement were developed in this laboratory [2].

The performance of the developed NIBP module was verified using a commercial simulator (BPPump2M, BIO_TEK, USA). For all simulator outputs, the developed NIBP module provided outputs within an error range of ±5%.

### D. $SpO_2$

A $SpO_2$ module was developed using a commercial finger clip sensor (8000H, NONIN, USA) connected to the main unit, which includes the required electronic circuitry and program. The performance of the developed $SpO_2$ module was verified using a commercial $SpO_2$ simulator (Oxitest plus7, DNI Nevada Inc, USA). Over various range of $SpO_2$ levels, the output showed an accuracy within an error range of ±3%.

### E. Body surface temperature

the body surface temperature module was fabricated using an IC type temperature sensor (TC1047, Microchips, USA). It is small in size, cheap, consumes little power and is highly accurate. The sensor is attached to the inner surface of the wrist cuff with its sensing surface contacting the skin. To evaluate its performance, the developed module was tested inside a heated chamber at temperatures which were incremented over the range 25~40($^{o}$C) in one degree steps. The results obtained showed good linearity and an accuracy within an error range of ±1%.

### F. Tele-reporting device

In the developed system, tele-reporting was accomplished in two separate ways. The first involved an RF link between the WIHMD and a cellular phone for short-range transmission. The second involved the transmission of information to remote caregivers and/or a server computer through the commercial cellular phone network. We used TXM-LC and RXM-LC (433MHz, 10mW, FM, LINX tech, USA) as RF transmission and reception modules, respectively, the latter is connected to a cellular phone (IM-3000, SK Teletech, Korea) via an RS-232 connection. Recently, the PDA (personal digital assistant) equipped with a code division multiple access (CDMA) module has become available and provides more processing power as well as a telecommunication function. This is especially helpful when a larger amount of data is collected and analyzed. Fig.4 shows the Photograph of the cellular phone connected to the developed WIHMD and SMS display format for tele-reporting application.

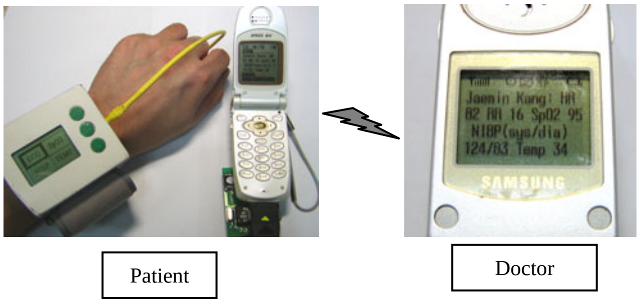


Fig. 4. Photograph of the cellular phone connected to the developed WIHMD and SMS display format for tele-reporting application

## IV. CONCLUSION

We have developed a wrist-worn integrated health monitoring device (WIHMD). The unit was designed to provide tele-healthcare services for high risk patients and the solitary elderly on an ‘any time/any place’ in an unconstrained fashion. The transmitted vital information comprises five physiological parameters and variables, namely, fall detection, single channel ECG, arterial blood pressures, $SpO_2$ and body surface temperature. The tele-reporting function of the WIHMD was realized by wireless connection to a cellular phone.

A shortcoming of the WIHMD is the limited fidelity of the measured biosignals due to its limited body contact with an area of the wrist. If we could measure biosignals at other sites, such as the chest, waist, and ankle, and connect such distributed measurement modules using a so-called personal area network (PAN), then more and higher fidelity biosignals would be acquired. Bluetooth$^{TM}$ will be a more promising and stable solution in this case because it has encryption, security, low power consumption, ad-hoc networking, and works at short-range [1]. Furthermore, a Bluetooth$^{TM}$-enabled mobile phone, which will be available soon, (in fact, a Bluetooth$^{TM}$-enabled PDA is available now) is expected to provide a practical solution for the central unit of a personal area network.

In this preliminary study, we demonstrate that the developed WIHMD provides convenient and comfortable multi-parameter health monitoring for a period of weeks or months, or even continuous monitoring in a very cost effective manner with acceptable reliability.

## ACKNOWLEDGMENT

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