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A Mobile-Phone-Based
Health Management System

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1. Introduction

"Prevention is better than cure." The system proposed in this chapter aims to achieve this. According to the bulletin report of Taiwan Ministry of Interior, the elder population in Taiwan at the end of 2008 was 2.4 million, about 10.4% of the total Taiwan population. This percentage has already exceeded the standard for aging society set by the World Health Organization (WHO). Furthermore, it is estimated that in 2025 the elder population in Taiwan will reach more than 20% of the total population; therefore, the "long-distance home health care service" has become one of the key emerging businesses in Taiwan. It was estimated that the market revenue of home health care for these elders reached 300 million dollars in 2010.

In recent years, several studies integrating communication and sensor technologies for home health monitoring system have been discussed (Chang, 2004; Chen, 2008; Lee, 2006a, 2006b, 2007a, 2007b; J.L. Lin, 2005; T.H. Lin, 2004, Shu, 2005; Wu, 2004; Ye, 2006; Yu et al., 2005), such as monitoring long-term health data to find out the abnormal signs and monitoring the medical record regularly for chronic patients to cut down their treatment frequency, to save doctor's treatment time, and to reduce medical expenses. Based on the sensor and communication technologies used, these systems can be categorized into two systems: immobile and mobile long-distance health monitoring systems. Our previous works all focused on mobile long-distance physiological signal measuring based on either a single-chip-microprocessor or a smart phone. The physiological sensor used was a RFID ring-type pulse/temperature sensor. The measured data can be transmitted via different communication protocols, such as Bluetooth, ZigBee, HSDPA, GPRS, and TCP/IP. In order to meet the requirement for mobile health monitoring system (MHMS), the system design needs to adopt light modular sensors for data collection and wireless communication technology for mobility. The popular smart phones used in people's daily life are the best devices for MHMS.

In this chapter, a different mobile e-health-management system based on mobile physiological signal monitoring is presented to practice the idea of "Prevention is better than cure." This system integrates a wearable ring-type pulse monitoring sensor and a portable biosignal

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recorder with a smart phone. The ring-type pulse monitoring sensor can measure pulse and temperature, while the biosignal recorder can record electroencephalogram (EEG), electrocardiogram (ECG), and body 3-axis acceleration during daily lives. The smart phone provides mobile "exercise-333" health management mechanisms. The user can monitor his/her own pulse and temperature from the smart phone where the "exercise-333" health management mechanism can help him/her to develop a healthy life style: taking exercise 3 or more times a week, at least 30 minutes per time, raising heart rate to 130 per minute. With the popularity and mobility of smart phones, this system effectively provides the needs for mobile health management.

2. System architecture, hardware, and software

2.1 System architecture

The proposed monitoring system architecture is shown as Fig. 1 where the ring-type sensor measures pulse/temperature and transmits the physiological data to the reader using wireless RF, the biosignal recorder collects EEG/ECG/body-acceleration data and sends data to the
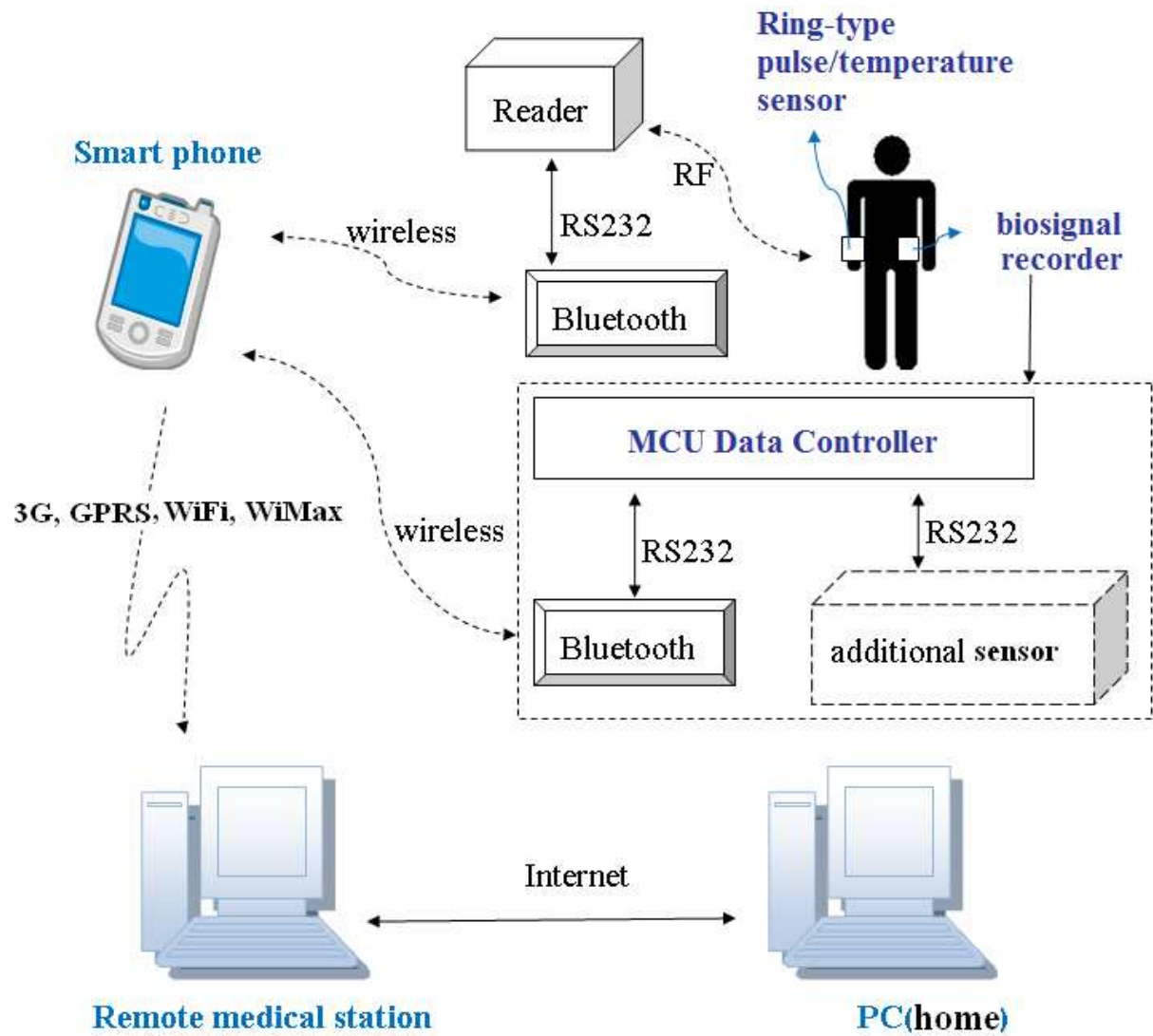

Fig. 1. MHMS Architecture

MCU data controller, the Bluetooth adaptors connected to the reader and the MCU data controller pass the data to the smart phone, and the smart phone records/displays the physiological data and also transmits data to the remote medical station using GPRS, HSDPA (3.5G), WiFi, or WiMax. The GPS built in the smart phone can provide the position information of the monitored person so that the medical personnel can be dispatched to the right location more promptly in an emergency situation. The proposed system architecture is capable of integrating additional physiological sensors via the MCU data controller. Therefore, it can be used as an e-coach to keep the user having healthy life style. It also can be applied to the baby-caring by detecting baby's pulse and/or ECG to identify whether the baby is being suffocated by pillow or blanket.

2.2 Hardware

The hardware used in MHMS includes RFID pulse/temperature sensor tag (Ring) and RFID reader, Bluetooth RS232 adaptor, biosignal recorder, and smart phone.

2.2.1 RFID pulse/temperature sensor

Although there is a ring-type pulse monitoring sensor in the market, shown as Fig. 2, the measured data are displayed in the LCD and cannot be transmitted out of the ring. In this paper, a RFID wearable ring-type sensor designed by Sinopulsar Technology Inc., Taiwan was adopted, instead. Fig. 3 shows this RFID ring (tag). This ring sensor is non-invasive, portable, and mobile. It can measure pulse and temperature signals which are processed by a built-in microcontroller. It uses optical sensors to detect heart rate and has anti data collision mechanism. Physiological data are then transmitted by RF wireless transmission with FSK modulation using UHF ISM band (up to 50 meters) to a RFID reader shown as Fig. 4. Fig. 5 illustrates the integration of Bluetooth adaptor, RFID ring (tag), and RFID reader.

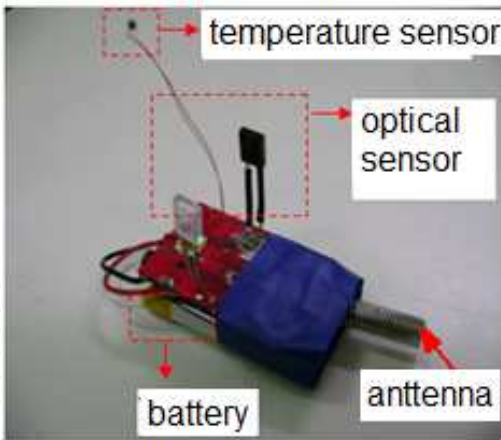Fig. 2. A commercial ring-type pulse sensor
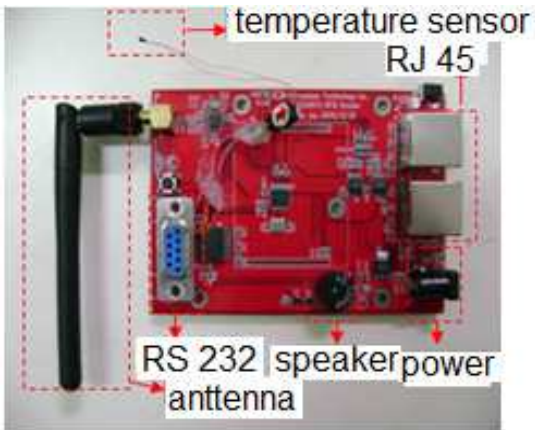
Fig. 3. RFID ring (tag)

Fig. 4. RFID reader

2.2.2 Bluetooth RS232 adaptor

The data communication between RFID reader and the smart phone is through Bluetooth. HL-MD08A (Bluetooth RS232 Adaptor manufactured by Hotlife Technology) is used in the presented system. It supports a wide range of Baud rates from 1.2K to 921.6K bps. Fig. 5 shows the picture of HL-MD08A, and Fig. 6 shows the picture of the RFID ring (tag) and the connection of HL-MD08A to the RFID reader.
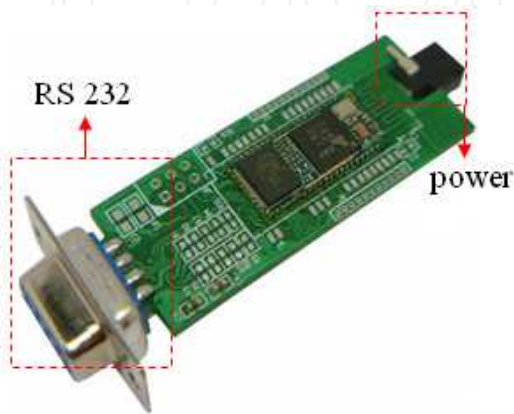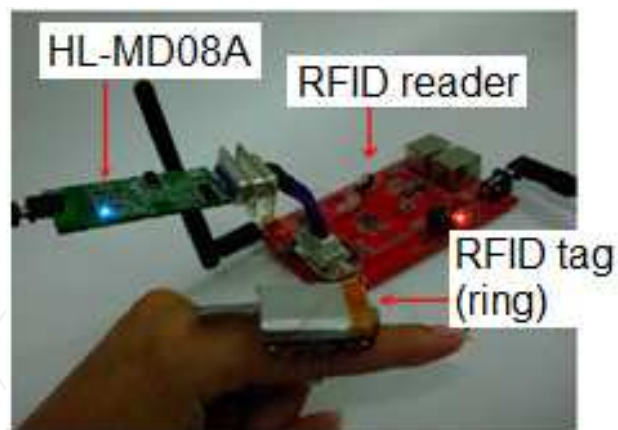

Fig. 5. Bluetooth RS232 Adaptor

Fig. 6. Bluetooth adaptor, RFID ring (tag) & RFID reader

2.2.3 Biosignal recorder

The biosignal recorder, developed in this system for assessment of sleep depth and physical activities during daily lives, can measure electroencephalogram (EEG), electrocardiogram (ECG) and body acceleration signals. The size of this developed device (45mm × 25mm × 65mm, 62.5g) is more appropriate for ambulatory recoding than that of the well-known devices such as LifeGuard (Mundt et al., 2005) (129mm × 100mm × 20mm, 166g), AMON (Anliker et al., 2004) (286g) and Smart Vest (Pandian et al., 2008) (460g). Fig. 7 shows photographs of the developed device. The device consists of an analog part, a digital part and a power supply, as in Fig. 8.

The analog part has five electrodes. Two of them are placed on the forehead and ear lobe for EEG acquisition. Another two electrodes are patched on upper-right and lower-left breast for ECG acquisition. The last electrode is put on back neck for right-leg-driving. The acquired signals are amplified by instrumentation amplifiers (Analog Devices AD627) and operational amplifiers (Texas Instruments TLV2254). The amplification factors are 60dB for EEG and 46dB for ECG. These amplification circuits also have bandpass characteristics with the passband from 0.5Hz to 100Hz. Then the conditioned signals are sent to the digital part. The digital part consists of a mixed-signal microcontroller, an accelerometer and a memory card. The mixed-signal microcontroller (Texas Instruments MSP430F4270) converts the conditioned signals (EEG and ECG) to digital signals with 16-bit resolution at the sampling rate of 256Hz. This microcontroller also collects three-axis acceleration values from the accelerometer (Freescale MMA7456L). This accelerometer provides 10-bit digital values whose range and sampling frequency are ± 8g and 8Hz, respectively. The microcontroller records these digital data into the memory card. The memory card can store digital data up to 2GBytes, large enough for 2-week recordings. The power supply provides regulated voltage to other parts. The power source is one-cell lithiumion polymer battery (3.7V, 900mAh) and connected to a voltage regulator (Texas Instruments TPS73130) through a diode-OR circuit. This diode-OR circuit enables us to hotswap batteries. The principal parts of the developed device is enclosed in an ABS plastic case (Takachi SW-65S) whose size is 45mm × 25mm × 65mm. The overall weight of the device is 62.5g. Since the current consumption is 29mA in the steady state, the device can record EEG, ECG and three-axis accelerogram for up to 31 hours with the fully-charged battery. Furthermore, the measurement duration can be prolonged up to 2-weeks when two or more batteries are used, swapped and charged alternately once a day.

(a)   (b)
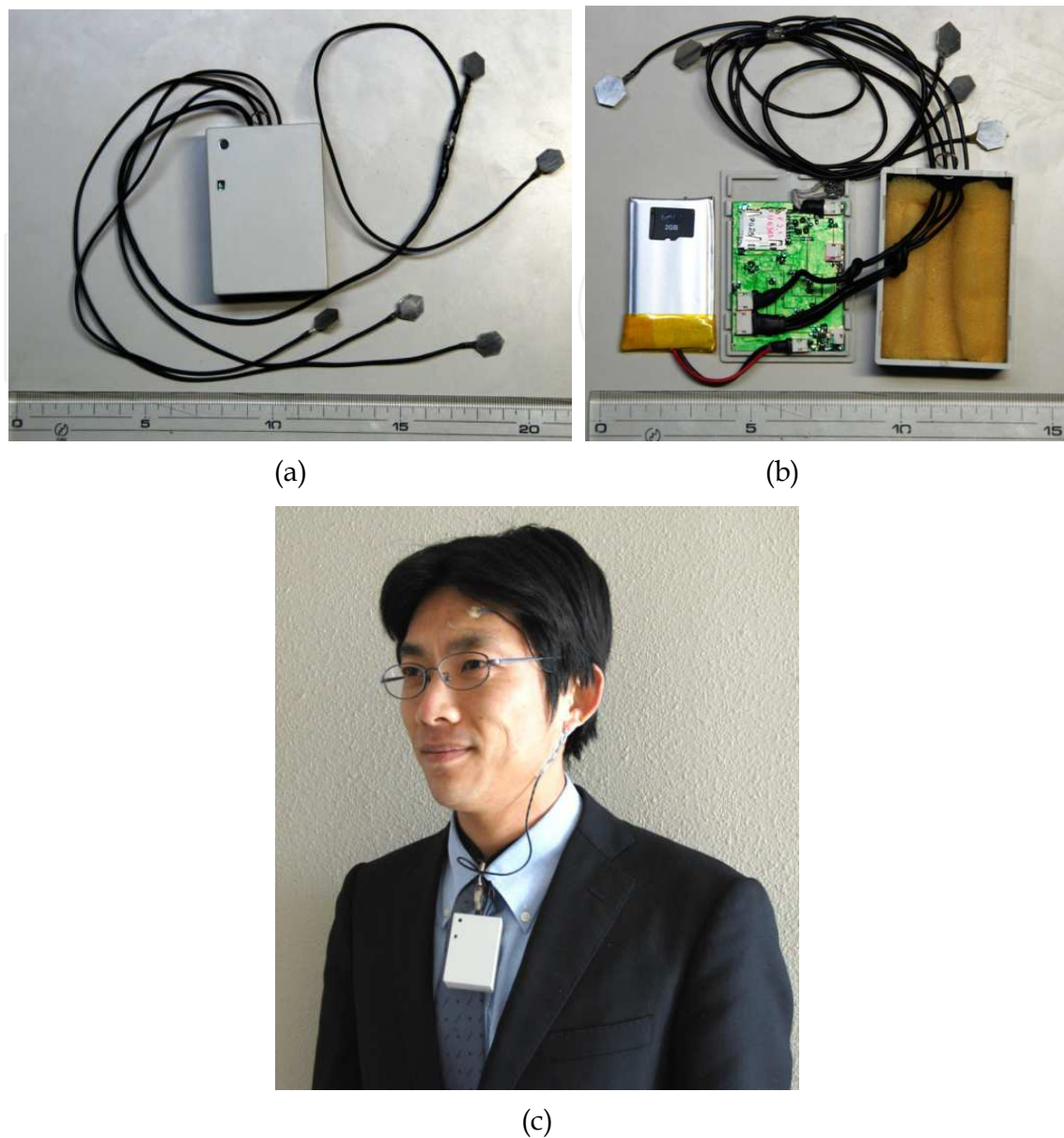

(c)

Fig. 7. Biosignal recorder (a) recorder with case closed, (b) recorder with case opened, (c) portable recorder with wires attached to user's body

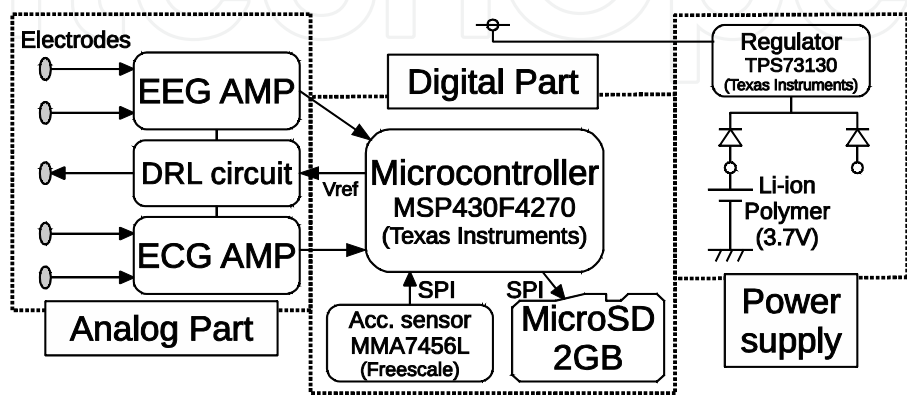
Fig. 8. Block diagram of developed biosignal recorder

2.2.4 MCU data controller

The data controller consists of a MCU (Philips P89C51RD2HBP microcontroller), a multiplexer (Hitachi HD74LS153P, Dual 4-line to one-line Data Selectors), a demultiplexer (SN74LS156N, Dual one-line to 4-line Data Decoder), and a RS232-TTL voltage conversion IC (Intersil HIN232CP). Fig. 9 shows the developed data controller circuit on a breadboard. The function of this data controller is like a data switch to bridge the biosignal recorder and additional sensor to the Bluetooth adaptor. It alternately transmits the data from these two different sensors to the smart phone via Bluetooth.
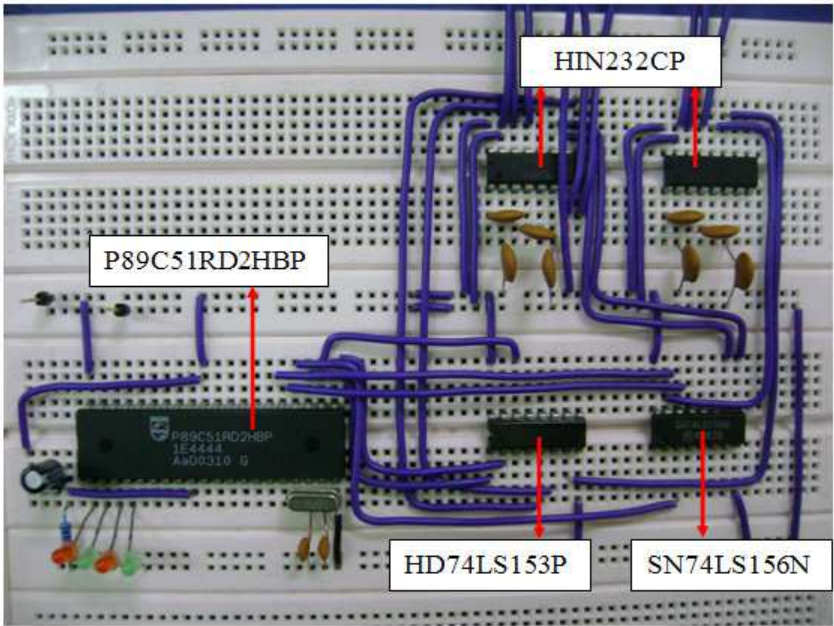

Fig. 9. MCU Data Controller

2.2.5 Smart phone

Any smart phone which operating system is Windows Mobile 6.1 is suitable for the presented system. The smart phone used in this system is ASUS P552W with built-in GPS. It supports HSDPA 3.6Mbps/EDGE/GPRS/GSM 900/1800/1900. Fig. 10 shows the picture of this smart phone.

Fig. 10. ASUS P552W smart phone

2.3 Software

The GUI programs developed on the smart phone and on the remote medical station were coded in Visual C#. Microsoft .Net compact framework 3.5 was installed on the smart phone for running the client APs, and Windows Mobile 6 SDK, smart phone emulator, and Cellular Emulator were installed on the PC for developing the client APs.

Several GUIs were developed to communicate with the RFID reader/tag and then were packaged into a DLL file for ARM-based embedded systems (smart phones). The reason of using DLL file is for the security reason so that the physical data format can be hidden in the DLL file. Table 1 shows the commands developed for the APs. The shaded area in Fig. 11 illustrates the flow chart of the AP on the smart phone. After the hardware devices are set up properly, the user is ready to run the developed AP by starting the setup procedures: 1. Open Bluetooth ComPort, 2. Execute ReaderReset command to initialize the RFID reader, 3. Execute ReaderQuery command to search for available RFID Reader, 4. Execute AllReset command, 5. Execute SearchTag command to search for available ring tag. Then, the user can start receiving data from the ring tag to the smart phone by executing the Access command. The GPS data can also be received to the smart phone by executing the "Open" command. These collected data on the smart phone can be transmitted to the remote server through 3.5G Internet communication by performing the following procedures: 1. Check connection manager, 2. Check available network , 3. Establish Internet connection, and 4. Send out data using Socket class.

| Command (for Reader)	Descriptor
ReaderReset	Reset RFID Reader
ReaderQuery	Search for all available RFID Readers
Command (for Tag)	**Descriptor**
SearchTag	Search for all available ring Tags。
Access	Read back data from ring Tag
StopAccess	Stop reading back data from ring Tag
Command (for Reader and Tag)	**Descriptor**
AllReset	Reset both RFID Reader and ring Tag
Command (for GPS)	**Descriptor**
Open	Open GPS receiver
Command (for SMS)	**Descriptor**
SendSMS	Send SMS text message

Table 1. Commands for APs
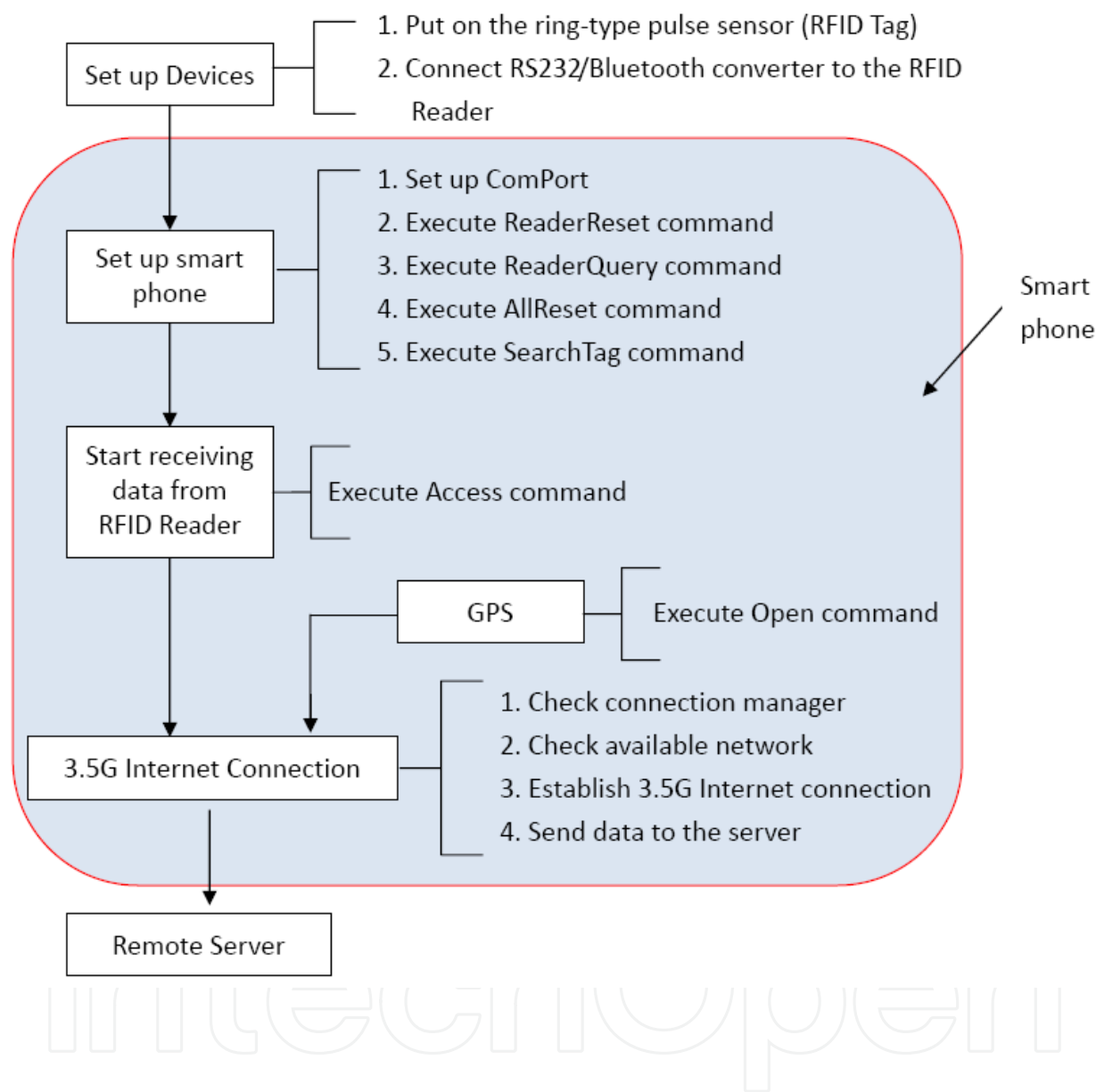
Fig. 11. Flowchart of MHMS under normal situation

Fig. 12 shows the interactions among the smart phone, RFID reader, and ring Tag for those commands used on smart phone. For instance, the SearchTag command instructs the RFID reader (action 1) to search for available ring Tag (action 2), and the available ring Tag responds Tag ID back to the reader (action 3) and the reader sends the received Tag ID to the smart phone(action 4). Fig. 13 depicts the flow chart of sending SMS text message to the emergency contact's phone under emergency situation when the SOS button on the Tag is pressed.
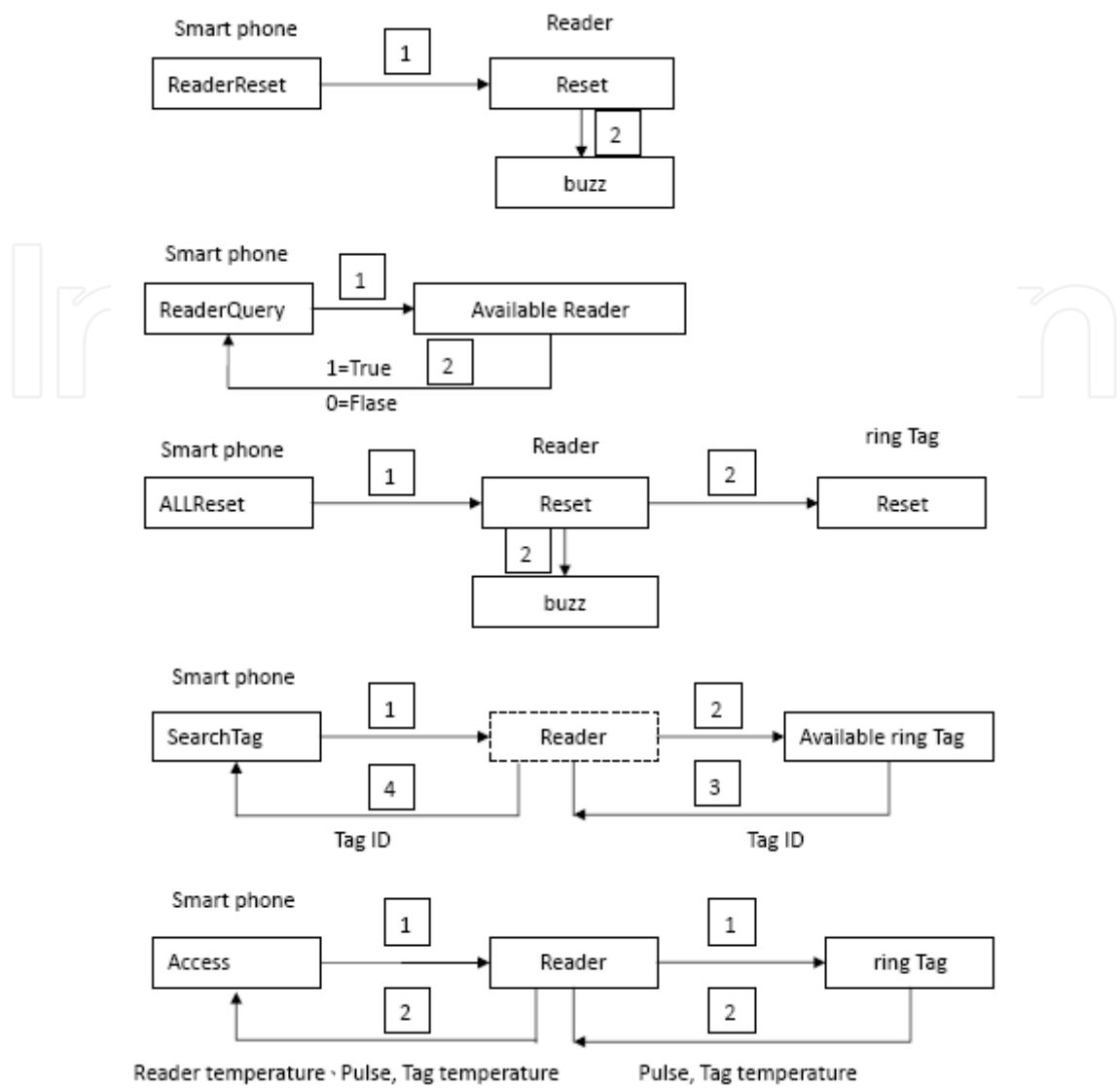
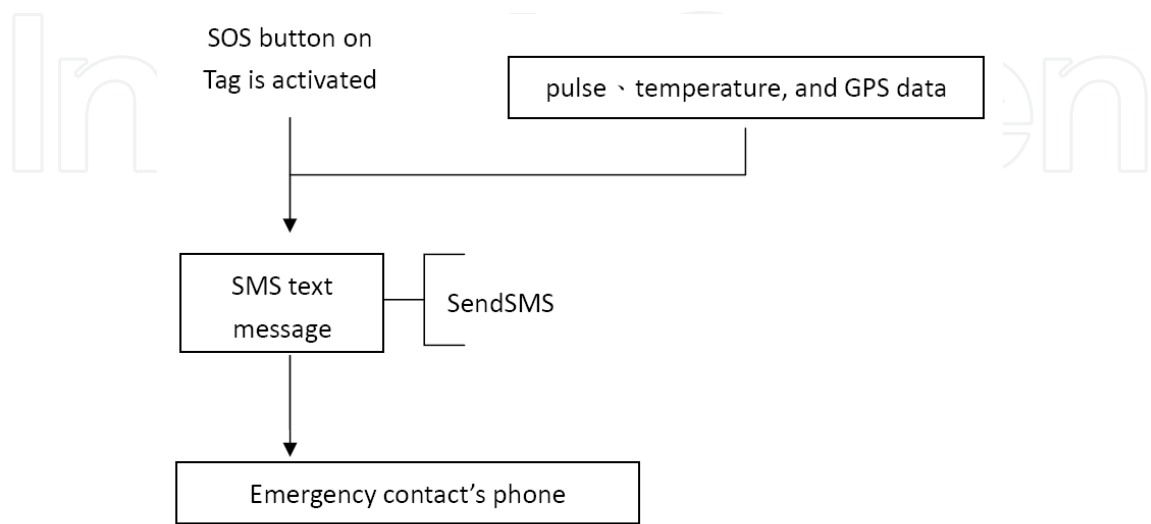Fig. 12. Interactions among smart phone, Reader, and Tag

Fig. 13. Flow chart of sending SMS text message under emergency situation

3. Physiological data presentation

The hardware is implemented as Fig. 6. The Bluetooth adaptor is connected to the RFID reader and the ring Tag is worn on the user's finger. The setup steps for communication between the smart phone and the RFID reader/Tag can be executed either on the smart phone emulator (on PC) or on the smart phone using the Cellular Emulator. Fig. 14 illustrates these steps on the smart phone emulator.
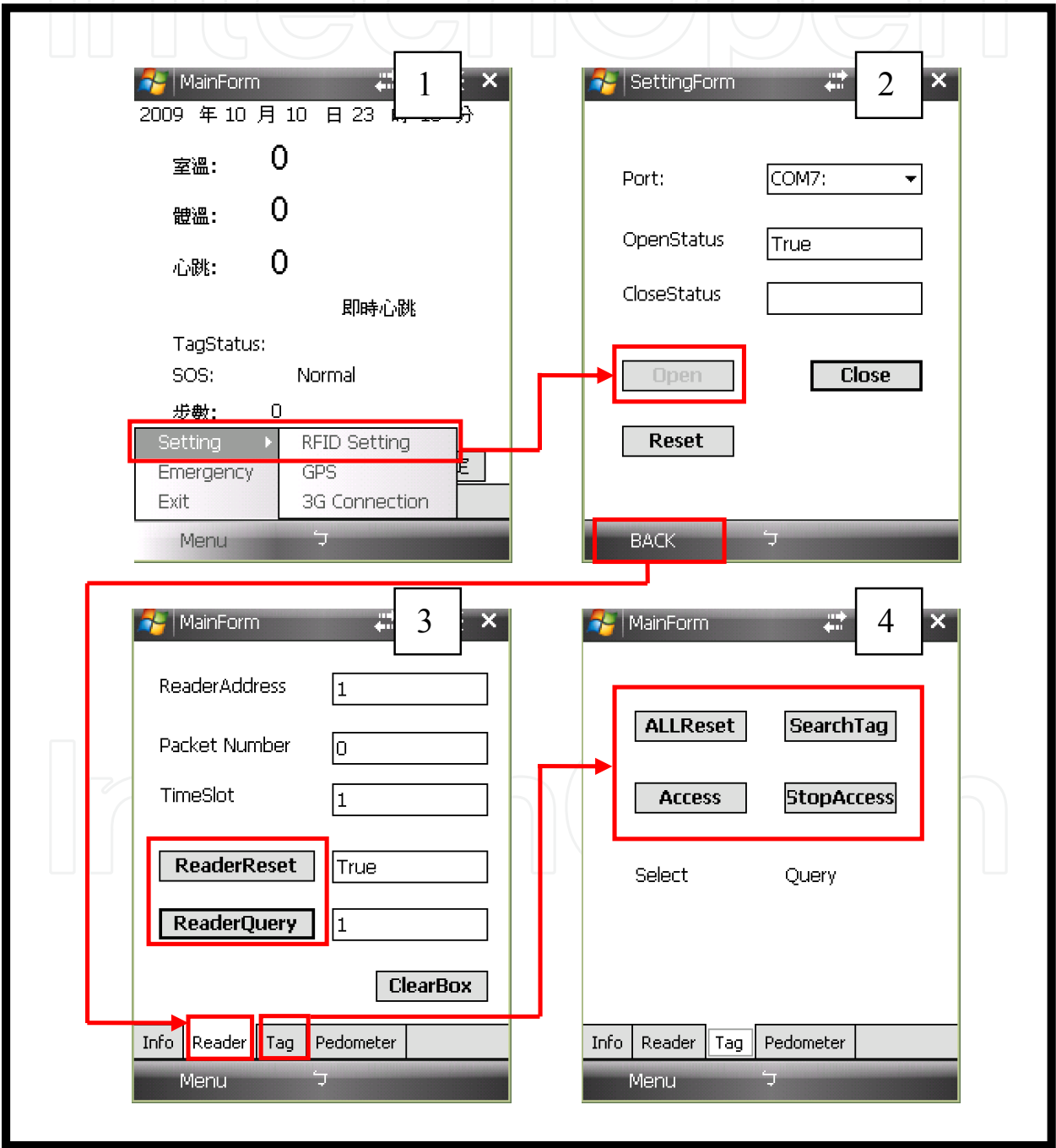

Fig. 14. Setup steps for communication between the smart phone and RFID reader/tag

Step 1. On the main page, click the "Menu," go to "Setting," and then choose "RFID setting." RS232 COM port setup page will pop up.

Step 2. Choose the correct COM port and click "OPEN." Then, click "BACK" to return to the main page.

Step 3. Click "Reader" and "Reader setup" page will pop up. Click "ReaderReset" to reset the RFID reader, and the RFID reader beeps and "True" is shown on the message box. Then click "ReaderQuery" to search for the Reader's address. The message box of ReaderQuery shows the address number.

Step 4. Click Tag and the "Tag setup" page will pop up. First click "ALLReset" and turn on the power of the ring Tag. Then click "SearchTag" to search for the ring Tag around the RFID reader. Once the ring Tag is detected, the Tag ID number will be shown on the page and finally click "Access" to go to the physiological data monitoring GUI.

Fig. 15 depicts the physiological data monitoring GUI on the smart phone emulator. The same GUI on the smart phone is shown in Fig. 10. On this page, two temperature values measured by RFID reader and Tag and pulse data are shown. The SOS message box indicates the status of the SOS button on the ring Tag. If this button is pressed, the smart phone will dial the pre-set emergency phone number(s) to send out SMS with the GPS position information to other people for help. Fig. 16 shows the GUI for setting up pre-set emergency phone number(s). Fig. 17 shows the GPS information.

Fig. 15. Physiological data monitoring GUI

Fig. 16. GUI for emergency numbers

Fig. 17. GPS information

Fig. 18 presents the 3G communication of smart phone and the webpage of remote medical station. The 3G connection setup page of the smart phone is shown on the left side and the webpage of the server is on the right side where temperature values, pulse, and Google map are displayed. Based on the GPS position information sent from the smart phone, the Google map helps the medical staff to locate promptly the monitored user who needs further assistance.

Fig. 18. 3G communication setup and the webpage of remote medical station

For evaluation of the developed biosignal recorder, a 4-day measurement was performed. Figures 19–21 show typical waveforms of EEG, ECG and accelerogram during the 4-day measurement. Fig. 19 represents waveforms during deep sleep. In the EEG waveform, sleep spindles appeared frequently. The heart rate was very slow (42 bpm) as seen in ECG waveform. The accelerogram did not change during this period. Fig. 20 was acquired during shallow sleep. The ECG and accelerogram are almost same to these in Fig. 19. On the other hand, sleep spindles are not seen in EEG waveform. In Fig. 21, waveforms during deskwork are shown. The heart rate (50 bpm) was faster than that during sleep. The accelerogram denotes that subject's body is upstand. In EEG waveform, large artifacts generated by eye blinks appear. Fig. 22 shows waveforms during walk movements. Up and down movements of the walking cycle are observed in the accelerogram. The heart rate was moderately fast (about 90 bpm) due to the walking movements. In Fig. 23, waveforms during meal are indicated. The EEG waveform was disturbed by chewing movements. This phenomenon was not desirable for true EEG recording, however, this characteristic waveform is useful for activity estimation The characteristics of these waveforms suggest some indices for

estimation of sleep depth and physical activities. In Fig. 24, four indices listed below are shown for the waveforms during the 4-day measurement:

1. Median value of heart rate derived from 3-minute ECG waveform,
2. Standard deviation for 3-minute absolute values of accelerogram,
3. EEG power ratio of gamma band (30~128 Hz) to delta band (below 4 Hz) derived from 128-second EEG waveform,
4. EEG power ratio of alpha band (8~13 Hz) to beta band (13~30 Hz) derived from 128-second EEG waveform.

These indices are calculated for every 3-minute periods, and time courses of them are shown. Note that the index value for a particular 3-minute period disappears if more than 5% of the raw waveform exceeds the A/D conversion range during the period, for example in the EEG ratios at the first day's night (from about 20 to midnight).

From examination of Fig. 24 and subject's handwritten note, the availability of these indices for activity and sleep depth estimation can be pointed out. Both the median of heart rate and the standard deviation of accelerogram are low during sleep. Therefore these indices are useful for estimation of sleep/wake state. More complicated algorithm may enable us to estimate physical activities from these biosignals. The EEG power ratio of gamma band to delta band shows sharp peaks. The peak times coincide with mealtimes of subject's record. This EEG ratio surges when chewing EMG appears and is useful for estimation of mealtime. The EEG power ratio of alpha band to beta band changes periodically during sleep periods. This phenomenon suggests that this index may reflect changes in sleep depth. However, further investigation is required for more rigorous conclusions.
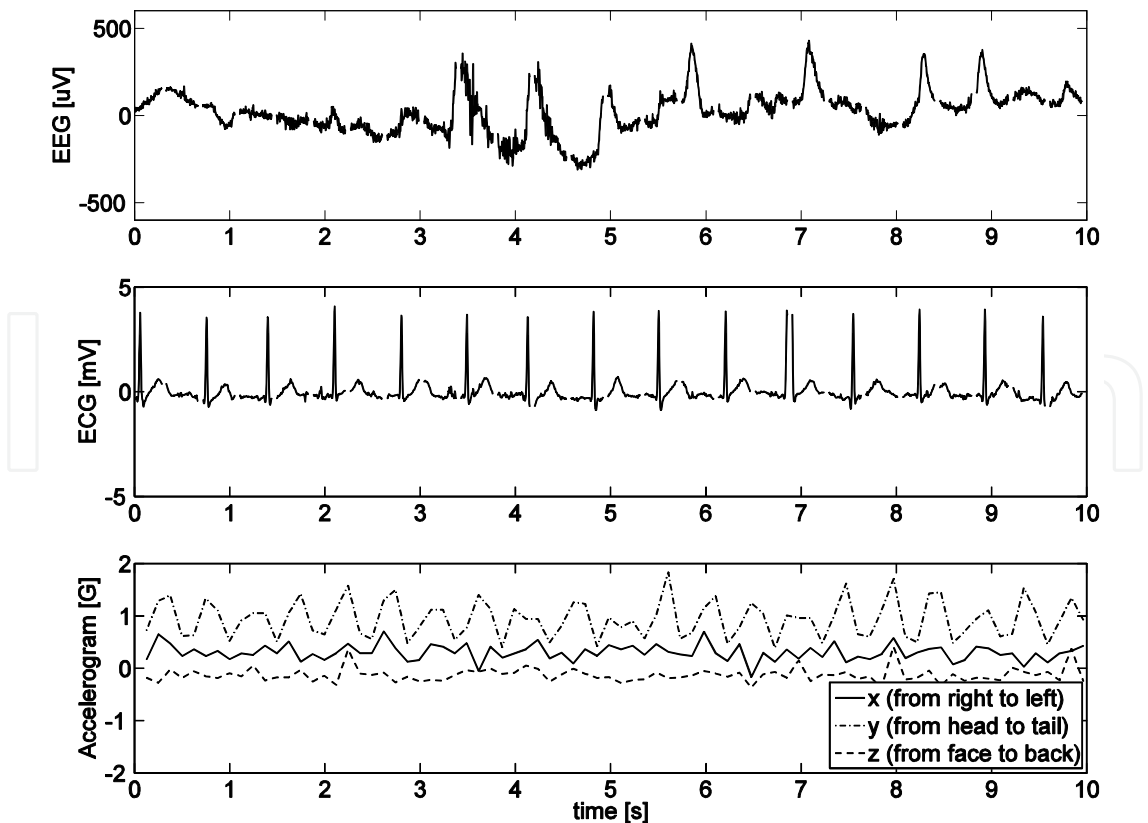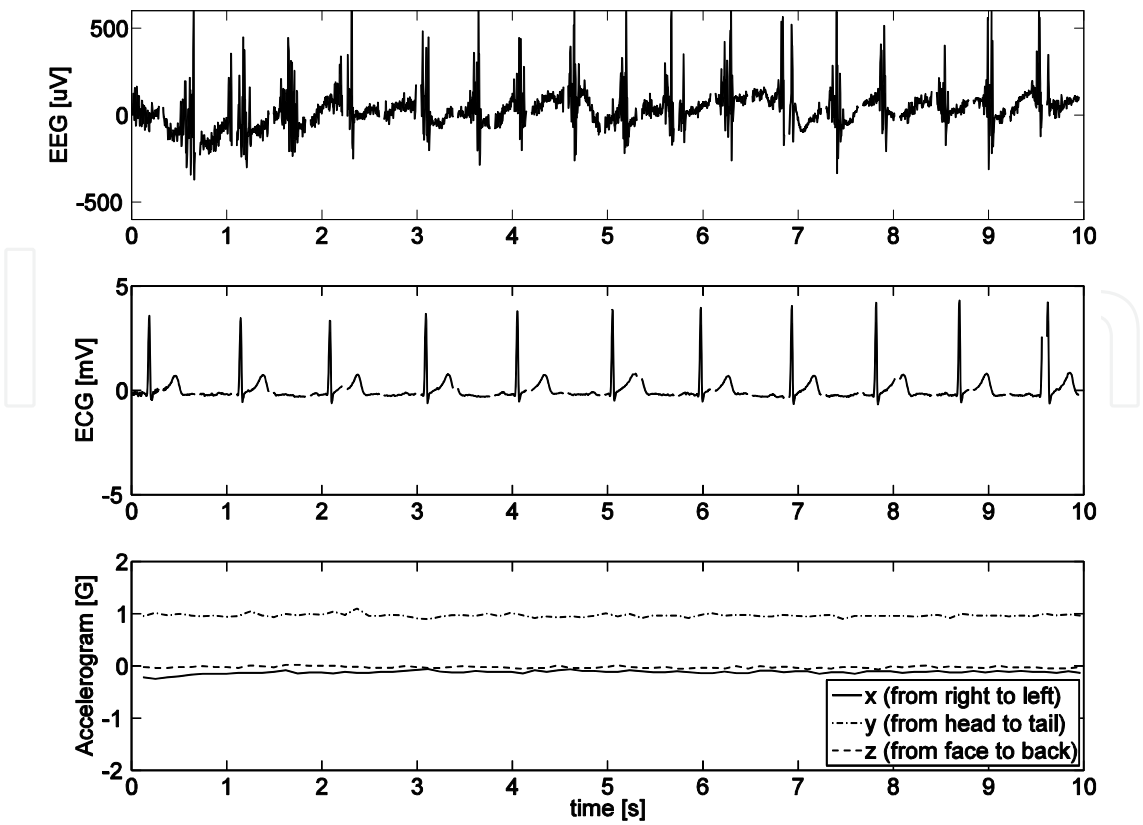

Fig. 19. Waveforms during deep sleep

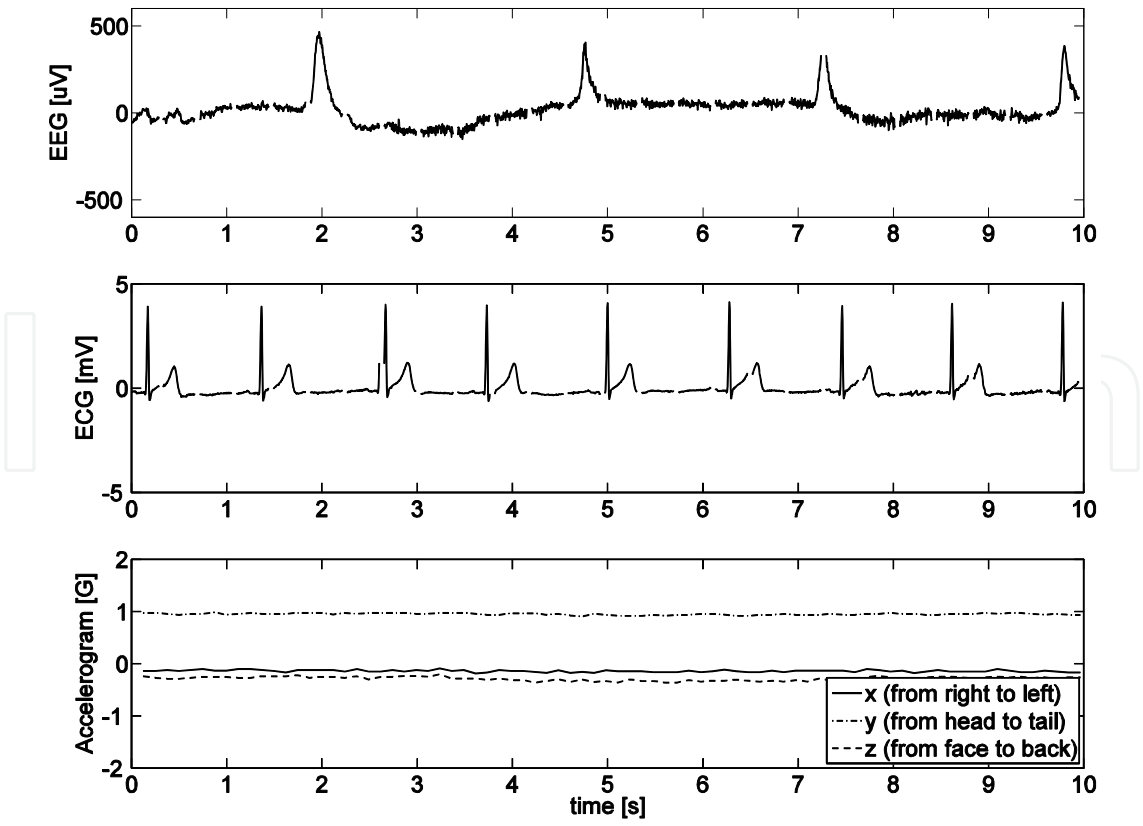Fig. 20. Waveforms during shallow sleep
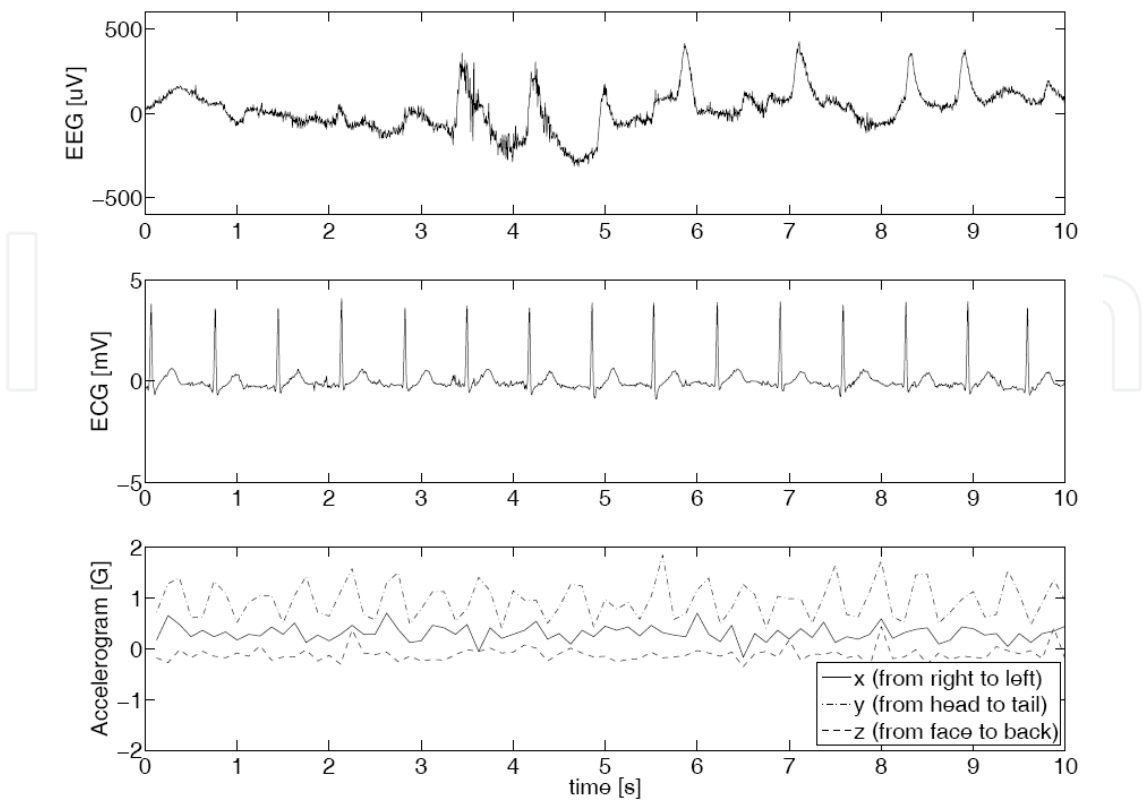

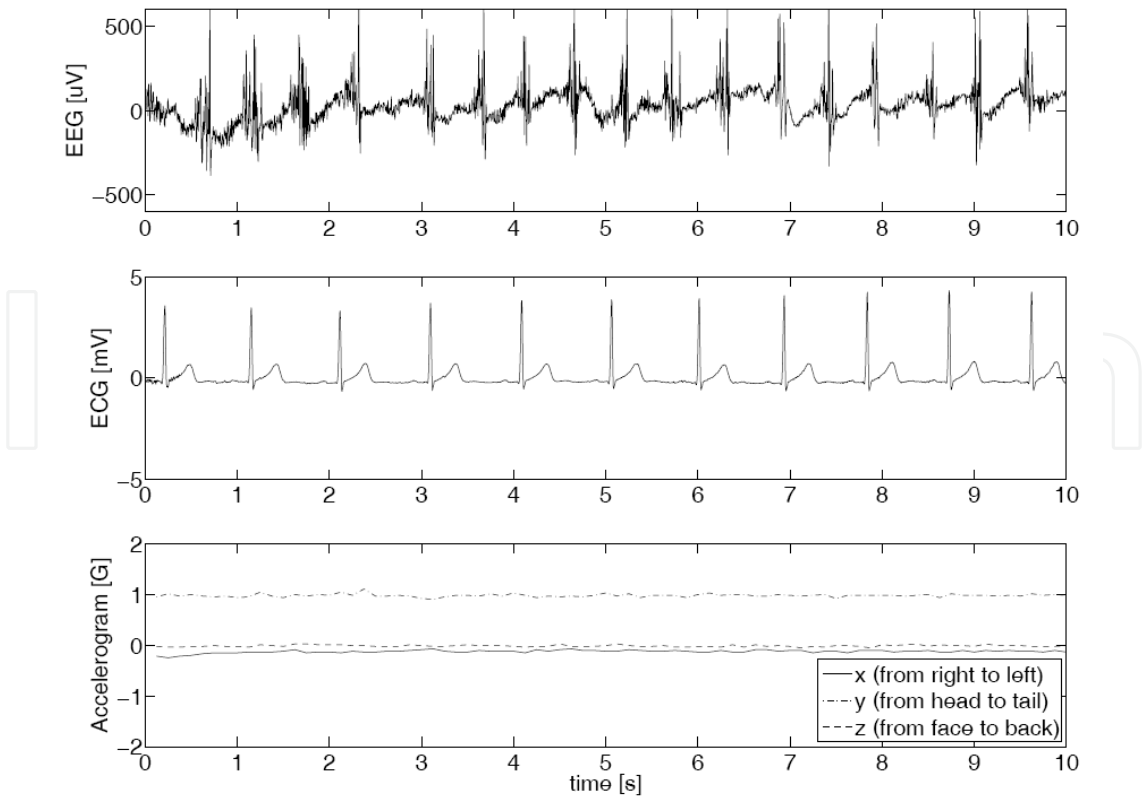Fig. 21. Waveforms during deskwork

Fig. 22. Waveforms during walk
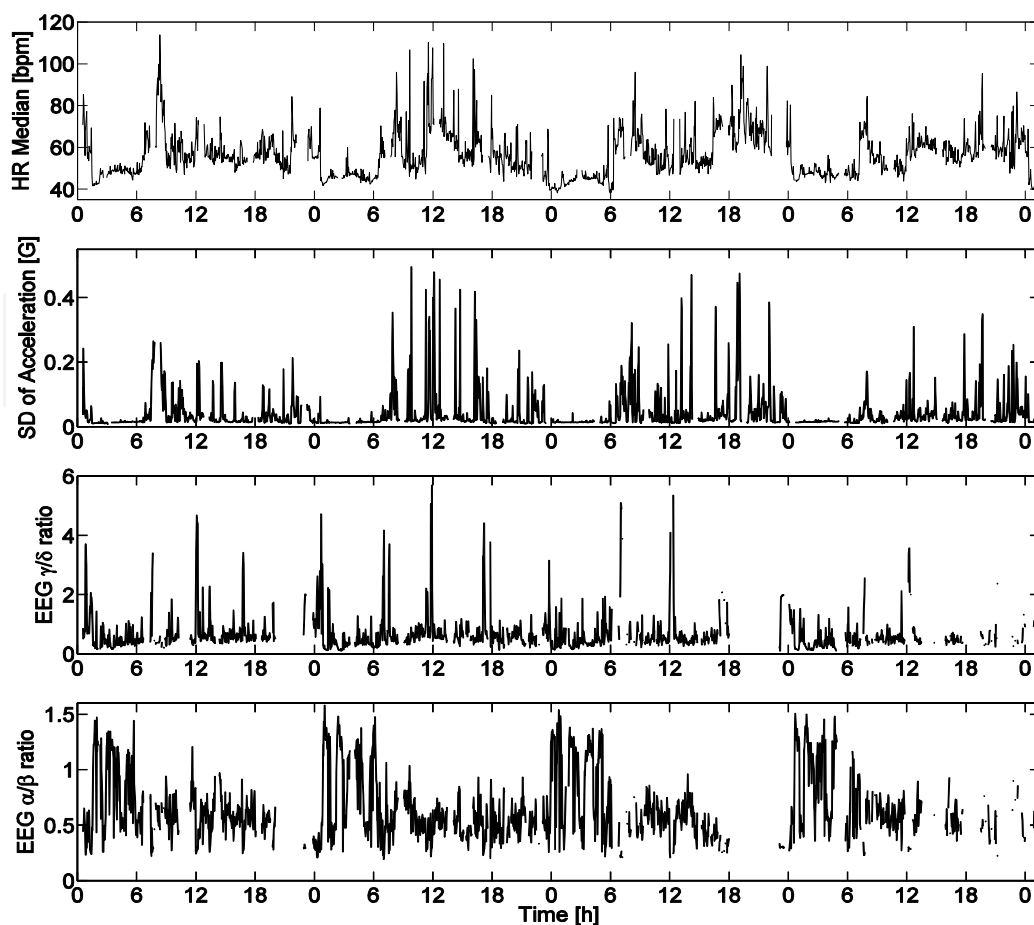

Fig. 23. Waveforms during meal

Fig. 24. Indices for activity estimation

4. "Exercise 333" health management mechanism

Compared to the traditional medical care that people receive medical treatment after they feel ill, an effective health management program can provide prevention of illness in a more aggressive manner — prevention is better than cure. Especially for people working in present modern high-tech society under lots of pressures and lacking exercise, such a preventive health management becomes essential. According to the report conducted by a hospital in Taiwan (Cheng-Ching Hospital Medical Center, 2010), exercise-333 can effectively prevent cardiovascular diseases. The concept of "exercise-333" is quite simple; i.e., taking exercise 3 or more times a week, at least 30 minutes per time, raising heart rate to 130 per minute. The health management mechanism presented here, based on "exercise 333", can help to remind the user to develop such a healthy life style.

Fig. 25 depicts the exercise-333 health management GUIs on the smart phone. In the first GUI, the user can set up 3 weekdays as checking points and at each checking point it will show the progress status to remind the user. In the second GUI, at the end of each day it will show the user whether his/her heart rate has ever been over 130 for more than 30 minutes. And at the end of each week, this GUI also shows the condition whether the user has accomplished exercise-333. With these two smart-phone GUIs, the user can constantly receive reminders and check his/her exercise status.

Based on the fact that in Taiwan every 100 people have 108 cellular phone numbers (Y.S. Lin, 2008), the high popularity of smart phone makes the presented health

management system effective and convenient to help people on developing a healthy life style.
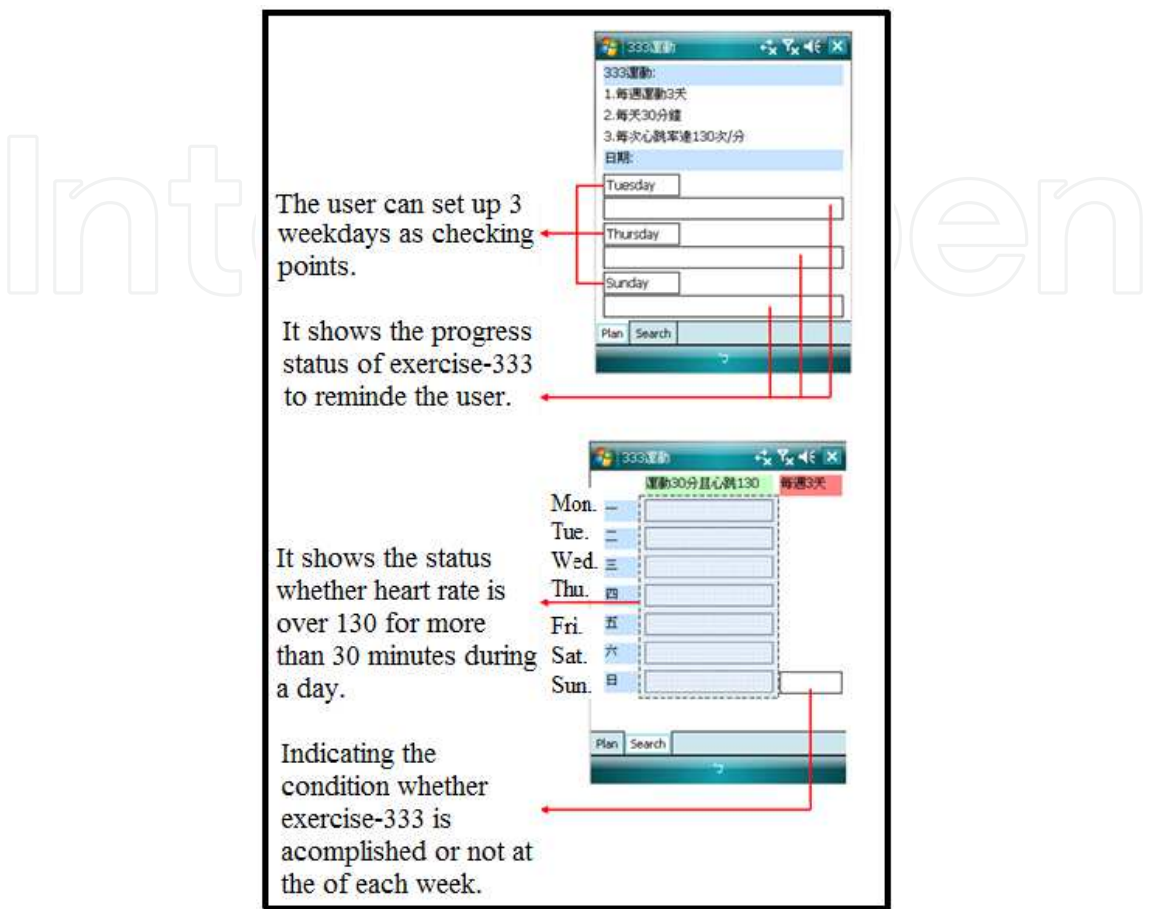

Fig. 25. Exercise-333 health management GUIs

5. Conclusions

In this chapter, a mobile e-health-management system has been presented. This system integrates a wearable ring-type pulse monitoring sensor and a portable biosignal recorder with a smart phone. The ring-type pulse monitoring sensor can measure pulse and temperature, while the biosignal recorder can record electroencephalogram (EEG), electrocardiogram (ECG), and body 3-axis acceleration during daily lives. Based on these EEG, ECG, and acceleration data, several indices can be evaluated to estimate the user's physical activities. With the help of the mobile "exercise-333" health management mechanism developed on the smart phone, the user can monitor his/her own physiological data to practice the idea of "Prevention is better than cure," developing a healthier life style. The presented system, with the popularity and mobility of smart phones, effectively provides the needs for mobile health management.

6. Acknowledgement

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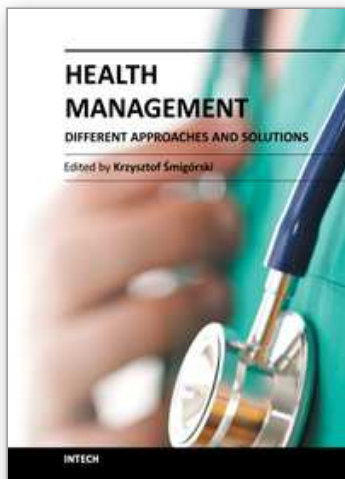
Health Management - Different Approaches and Solutions

Edited by Dr. Krzysztof Smigorski

The development in our understanding of health management ensures unprecedented possibilities in terms of explaining the causes of diseases and effective treatment. However, increased capabilities create new issues. Both, researchers and clinicians, as well as managers of healthcare units face new challenges: increasing validity and reliability of clinical trials, effectively distributing medical products, managing hospitals and clinics flexibly, and managing treatment processes efficiently. The aim of this book is to present issues relating to health management in a way that would be satisfying for academicians and practitioners. It is designed to be a forum for the experts in the thematic area to exchange viewpoints, and to present health management's state-of-art as a scientific and professional domain.

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