Design and Implementation of a Wireless Chest Compression Monitoring and Feedback System

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ABSTRACT
This paper introduces a chest compression monitoring and feedback system based on a wireless sensors network. This system, consisting of a pressure sensor, an accelerometer and an ECG monitoring module, can acquire and process numerous vital signals of compressing pressure, acceleration and velocity, and ECG in the real-time. With the wireless network, the improved communication protocol and the monitoring user interface, the base-station can collect and analyze the chest compression signals from the distributed monitoring and feedback nods wirelessly.

Keywords
chest compression; wireless sensors network; monitoring system; feedback.

1. INTRODUCTION
In the treatment of cardiac arrest, the high quality of cardiopulmonary resuscitation can improve the patient's survival rate and increase the likelihood of the full recovery of the nervous system. Meanwhile, the external chest compression is an essential key step for the cardiopulmonary resuscitation [1]. In accordance with the regulation of the International Cardiopulmonary Resuscitation Guidelines 2005, the external chest compression will not generate effective effect unless the correct compression frequency (100 times/min) and compression depth (4-5cm's caving of sternum) can be guaranteed.

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To evaluate the clinical emergency treatment and the first-aid personnel's external chest compression level of each Grade-one Class-three hospital of Beijing objectively, Philips Company carried out a nine-month clinic trial in Beijing aiming at the Grade-one Class-three hospitals in Beijing, dominated by the People's Liberation Army General Hospital, including Navy General Hospital, Air Force General Hospital, Beijing Military Region General Hospital, 304 Hospital, 721 Hospital, 309 Hospital, etc, in which 500 emergency treatment frontline first-aid personnel were tested and it found that the quality of the external chest compression delivered by 95% of them failed to conform to the standards of the International Cardiopulmonary Resuscitation Guidelines 2005. During the emergency treatment, lack of effective monitoring and guidance for the external chest compression, the medical personnel could not accurately judge the compressions pressure and frequency, which shall be the main reasons accounting for the too slow or too shallow external chest compression and for the failure in meeting the quantitative requirements of the International Cardiopulmonary Resuscitation Guidelines 2005.

This Paper is to introduce a kind of feedback monitoring system for the external chest compression based on the wireless sensor network. This system holds one iphone handset terminal and multiple wireless network monitoring nodes. Use one iphone handset terminal and then the compression depth, pressure, frequency of several feedback monitoring nodes of the external chess compression, the patients' electrocardiogram, as well as many other data can be monitored in real time. This system will not only guide the medical personnel to carry on the accurate and efficient external chest compression, which is of great significance to improve the cardiopulmonary resuscitation efficiency under the emergency situation and to increase the patient's survival rate, but also will play an important role in the aspect of feedback monitoring over the high-quality external chest compressions training.

2. Overall Scheme of the System

The external chest compressions feedback monitoring system is mainly composed of the wireless feedback monitoring node formed by multiple feedback monitoring devices and a wireless terminal constituted by an iphone and a built-in wireless receiver. The diagrammatic drawing for the overall scheme is as shown in Figure 1. To be more specific, the wireless terminal will take charge to conduct communication with each wireless feedback node, inquire the external chest compression feedback data of each feedback node, and record & store the related parameters. The wireless receiver of the wireless terminal will inquire and receive the external chest compression feedback data from each monitoring feedback node in real time and transmit the related data through the serial port to the iphone terminal for analyzing & recording. During the external chest compression, each monitoring feedback node will feed the following six parameters back: the compression depth, pressure & frequency, the patient's electrocardiogram, the springback degree of the chest wall, and the compression interruption time. Furthermore, when any one parameter goes beyond the designated range, the feedback node will release the alarm signal. At the meantime, the feedback node holds the functions for storage and record so that it can save the key parameters of the external chest compression for future analyzing and managing. Moreover, according to the needs of different occasions, each feedback monitoring node of the external chest compression not only can constitute an independent device to be used alone but also can conduct the wireless networking so as to carry out the wireless data transmission.

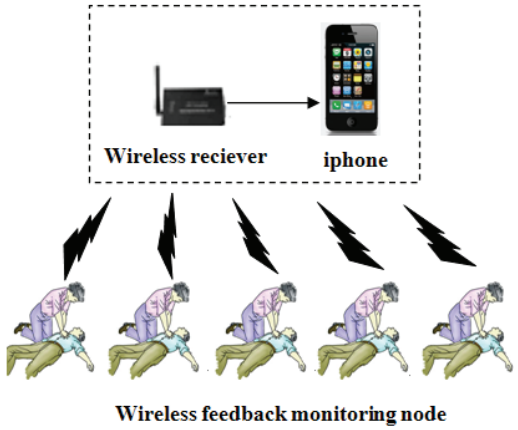

Figure 1. The external chest compressions feedback monitoring system

3. System Hardware Design

3.1 General design for the wireless monitoring and feedback node

The functional block diagram of the device hardware for the external chest compression is as shown in Figure 2. MCU is the core part of the feedback monitoring device and it takes charge to conduct the sampling analysis over the related data of the external chest compression, and to feed the analyzing & processing results back, as well as, at the meantime, to establish the wireless communication with the iphone terminal through the wireless communication module. The detection module is composed of the corresponding sensor and the appropriate regulation amplification circuit so as to detect the depth, pressure, and frequency of the external chest compression as well as the patient's electrocardiosignal respectively. Meanwhile, the peripheral LCD and buzzer will carry out the video and audio feedback respectively for the detection results.

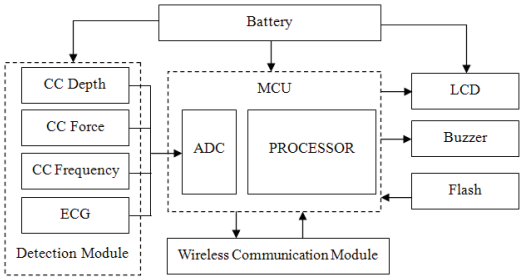

Figure 2. Functional block diagram of the device hardware for the external chest compression. CC is short for chest compression.

3.2 Node processor

The wireless feedback monitoring node will take the C8051F020 microcontroller as the control core. This microcontroller adopts the patent CIP-51 microcontroller core of Silicon Lab, which can be fully compatible with the MCS-51 instruction and the clock frequency of which can reach as high as 25 MIPS. The 2-16 MHZ Programmable oscillator integrated inside of the controller holds a 12-bit 8-channel ADC, a 64k-byte FLASH memory supporting online system programming, and a 4352-byte on-chip RAM. The I/O interfaces of the C8051F020 microcontroller are as many as 64 and it is convenient for them to connect the I/O interfaces of the sensor, as well as, at the meantime, they can simulate the SPI interface to control the RF wireless module [1].

3.3 Detection module for the compression pressure

The module is composed of pressure sensor and differential amplification circuit. The pressure sensor can catch the pressure of the external chest compression and will transform the pressure signal into the differential voltage signal. This differential voltage signal will be amplified by the differential amplification circuit and then directly delivered to the A/D conversion port of the single-chip microcomputer for analog-digital conversion.

The JQ-1 small scale weighing sensor produced by Shanghai Huicong Company has been adopted as the pressure sensor. This sensor is characterized by small external form, high precision, stable & reliable performance, strong resistance to bias & lateral pressure, and wide measuring range, which, thus, is very suitable for the measurement of the compression pressure.

3.4 Detection module for the compression depth

We will adopt the triaxial acceleration MMA7260 to detect the compression acceleration [2]. Through the quadratic integral conducted for this acceleration data, the compression depth data can be obtained. MMA7260 is a kind of low-power consumption capacitive MEMS triaxial acceleration sensor with four measuring ranges, that is, ±1.5g/2g/4g/6g, available. The encapsulation for this sensor is the smart QFN16, and it holds a wide power supply

range of 2.2V-3.6V, as well as supports the sleep mode, which actually is a kind of excellent micro low-power consumption device. The MMA7260 can stably output the acceleration value of the XYZ three mutually orthogonal coordinate axes, which, therefore, can provide reliable acceleration data for the detection of the external chest compression.

Figure 3 has shown the working principle of MMA7260 sensor. To filter out the noise interference and guarantee the accuracy of the output acceleration analog signal, the output port is added with the RC low-pass filter circuit. The g-Select port is used to select the sensitivity for the measurement range of the acceleration; the SleepMode port is used to set the sleep mode of the sensor: when this port is set to low level, the working current of the sensor will be reduced to about 3uA, which has provided substantial convenience for the design of the low-power consumption product [3].

3.5 ECG detection module [4]

The core of the ECG detection processing module is the microcontroller and the front-end amplifier will adopt AD620 to carry out the pre- amplification and post- amplification for the ECG signal. The filter circuit is composed of the ultra-low power operational amplifier TLC2254 manufactured by TI Company; the ECG signal will be delivered to LCD for displaying after it has been converted and processed by the ADC integrated by the microprocessor.

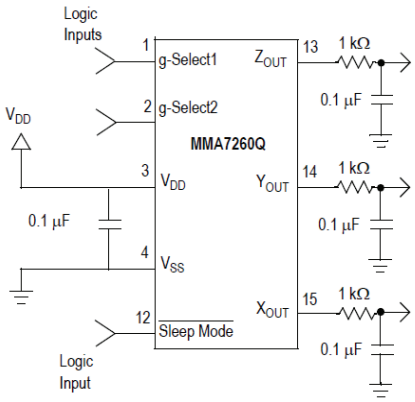

Figure 3. The working principle of MMA7260 sensor

3.6 Wireless communication and wireless networking module

The radio frequency is featured by low price, long transmission distance, & other characteristics and, particularly, the constant presence of the high cost-effective radio frequency chip has made it more and more popular. This system will adopt the nRF905 radio frequency chip manufactured by Norway Nordic Company to realize the wireless transmission of the data [5]. The nRF905 not only can meet the requirements of the detection device over the low power consumption, but also can guarantee the transmission rate and transmission distance at the same time. Upon the actual measurement, under the condition that there is wall separation in the room, the transmission distance can reach more than 25m and the wireless transmission packet loss rate is within 1/10000 so that it can guarantee that the transmitted data will not be lost. The maximum transmission rate can reach 100kbs. During the design, through the SPI interface, the processor will carry out different configurations for several nRF905 register addresses. In the actual work, the nRF905 can automatically filter out the data with different address and only the data with matched address & correct validation will be accepted and stored in the receive data register. Through the configuration for different addresses over the wireless radio frequency module, the wireless networking between one host computer and several slave computers can be realized. Due to the fact that there is one iphone terminal and several monitoring feedback nodes, we have adopted the one-to-many star network topological structure for networking.

3.7 Iphone wireless receiving terminal design

This system will adopt iphone terminal as the feedback monitoring terminal for the whole system so as to, through the external nRF905 module, conduct real-time sampling over the external chest compression data sampled and processed by several external chest compression monitoring feedback nodes.

4. System software design

4.1 Communication design and optimization for the wireless networking

Before the wireless communication has been carried out, it is necessary to conduct the initialized configuration for the RF905 first, including working frequency, output power, node model, address width, length of valid data, receiving address, CRC and external clock enablement configuration, etc. To send the data, the nRF905 can pack the data automatically, as well as can load the synchronization code, the destination address, and the CRC check code automatically; to receive the data, the nRF905 will remove the front-end synchronization code automatically, as well as will detect whether the address can be matched or not first and then carry out the CRC check automatically, and if there is no error found in the check, it will generate the interrupt signal to inform the single chip microcomputer to read the data.

In the system, the wireless network node constitutes a single-hop star topology network with the wireless terminal. Each network node of the wireless sensor holds one unique node number, which is assigned and addressed by the wireless terminal.

Under the premise that the reliability of the wireless data transmission can be guaranteed, to obtain higher transmission efficiency, we have carried out optimization over the communication protocol. We have adopted the nRF905 wireless communication module to carry on the data transmission: generally, to ensure the reliability of the data transmission, for every single time of data sending, it is required to wait for the receiver to return the confirmation information within the stipulated time. If the time is out, it will be necessary to resend the lost data; however, this mode will greatly reduce the transmission efficiency of the communication.

In light of the fact that the maximum byte number sent by the nRF905 for every single time is 32, the node will take 32 bytes as the basic unit of sending and the data sending format is as shown in Table 1. The 1st byte is the serial number of the sending node; the 2nd byte refers to the serial number of the data packet sent at the moment; and the 3rd to the 32nd bytes are the measurement data.

When the 1st group of data has been delivered, the receiver will return the confirmation information according to the received data, the format of which is as shown in Table 2. The 1st byte refers to the series number of the receiving node; the 2nd refers to the total number of errors of the received packets; The 3rd and 4th bytes are corresponding to the confirmation information of the 16 packets for each group: if any one of them is zero, it will be necessary to resend the packets corresponding to the byte and repeat the above-mentioned operation till all data of the group have been completely received. In addition, if, within the prescribed time, no any information is received, it will be necessary to resend the data till the confirmation information is received.

Table 1. The data sending format

Byte	1	2	3-32
Format	the serial number of the sending node	the serial number of the data packet	measurement data

Table 2. The data receiving format

Byte	1	2	3-4
Format	the serial number of the sending node	the total number of error received packets	the serial number of error received packets

4.2 Program design for the wireless monitoring feedback node

The system program of the wireless monitoring feedback node is composed of the main program, the data acquisition subprogram, the subprogram to communicate with the wireless terminal, etc. To be more specific, the main program is the core of the monitoring feedback node system and it will mainly complete the call over each subprogram so as to realize the acquisition, processing, and storage for the data of the external chest compression, as well as to communicate with the wireless base station.

5. Wireless iphone terminal interface design

The main functions of the wireless iphone terminal are to detect the related data relating the external chest compression collected by the multiple monitoring feedback nodes in real time, as well as to store and record the related data. The operation interface of terminal shall be simple, practical and beautiful. According to the functional requirements of the wireless terminal, we have taken advantage of the Sweb Apps programming tool to design and realize the monitoring interface. The monitoring interface of the base station is as shown in Figure 4.

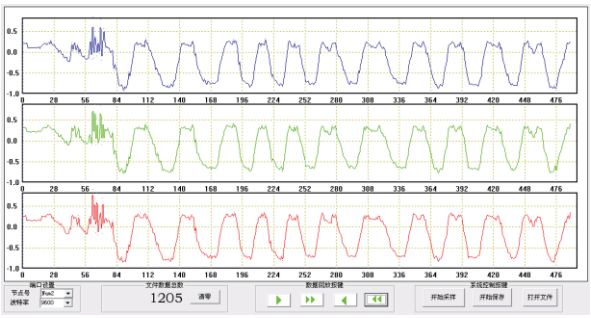

Figure 4. Wireless iphone terminal interface

6. Conclusion

This design is integrated with the compression pressure detection module, the compression depth detection module, and the ECG monitoring module, which can carry out a comprehensive and accurate feedback monitoring over each index of the external chest compression, as well as can provide quantitative basis and correct guidance for the accurate operation of the external chest compression. At the same time, applying the network technology of the wireless sensor, this design has constituted a wireless monitoring feedback system, which, through an iphone handset terminal, can carry out real-time and accurate monitoring over the feedback data collected by the multiple nodes of the external chest compression. This system will substantially reduce the work intensity of the emergency medical personnel and improve the success rate of the cardiopulmonary resuscitation, which, thus, has a broad application prospect in the monitoring & training guidance of the cardiopulmonary resuscitation, and other aspects.

7. References

[1] R.Koster, C.Deakin, B.Böttiger, D Zideman, Chest-compression-only or full cardiopulmonary resuscitation?[J],The Lancet , 2007 Jun 9, 369(9577).

[2] [Freescale Semiconductor. ±1.5g-6g Three axis low-g micromachined accelerometer. 2006,2.

[3] Wang Xi, Li Weiwei. Design of Electronic Brush Based on ARM and Acceleration Sensor. [J]. Application of Electronic Technique, 2007, (3): 69-71.

[4] Zhu Qiang, Wang Xuemin, Hu Bin, Etc. ECG Wireless Remote Transmission System Based on Embedded System [J]. Journal of Tianjin University, 2005, (1) : 34 to 39.

[5] RF905datasheet, 2004.