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Evidence-based multi-sensor information fusion for remote health care systems

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ABSTRACT

This study designs a remote Android platform IOT home community health care wireless network. This is an interdisciplinary study of Android platform IOT home community health care system implementation. This system maintains patient identity, signal processing and results collection and analysis via cloud computing. Results are transmitted to the medical host for diagnosis. The target patient population is family geriatric psychiatric patient communities and remote monitoring healthcare situation. Physiological signal processing fusion algorithms and the theory of evidence are used in this study to improve fusion result accuracy and reduce the measurement time due to different classification error signals. In addition to emphasizing cloud computing, Android and wireless sensor network technology is used to achieve a variety of physiological signals correctly classified by Instant Screenshot Collection. The physiological signal measured results reflect the patient physiological behavior for medical personnel assisted diagnosis.

1. Introduction

The rapid development in computer and communication technologies has brought new opportunities in health care system development. Applying information technology to health care has been a key objective for each developed country. Many countries in Europe are actively promoting healthcare information infrastructure (Health Care Information Infrastructure, HCII). China has also promoted remote healthcare networks and other projects aimed at integrating information science, computer technology and communication technology applications in the high-tech health care field to optimize health care services, accelerate hospital management and medical and health modernization processes. As health care awareness has gradually risen, home medical equipment is increasingly used. With the Internet and a variety of biomedical sensing technology, physical health measurement technology will be the future focus of health care development. If electronic extensions allow the medical health care system gradually become more complete, the elderly population problem can be managed. This study developed a simple physiological signal detection system combined with the cloud. Basic physiological measurements, such as blood pressure, oxygen intake, ECG and body temperature are available with current products. The majority of these products are unable to determine more than the standard values, so a combination of biomedical research through portable mobile device modules (such as tablets, smart phones) are used to develop the principal measurement functions. We measured the physiological data using Bluetooth portable mobile devices to make a preliminary diagnosis with hazard warnings published through cloud technology. The data will be uploaded to the cloud for storage archival to facilitate medical personnel data tracking for diagnosing various medical conditions [1].

According to CEPD 2012 the elderly population growth trends and age structure, the number of people aged over 65 will increase significantly. The senior share of the population over 80 years old was 25.1% in 2011. By 2060 the senior population will increase by 41%. Taiwan's aging population has become the world's fastest growing. Since the advent of an aging society, the elderly in Taiwan have found medical resources in short supply. The use of personal home style care system has allowed office workers to keep abreast of the situation for their elderly at home. These home healthcare devices make it convenient for the elderly to understand their own health, also providing an alarm if there is an emergency situation [2] (refer to Fig. 1).

The global aging trend is dominated by chronic illness. Aging in place is currently the world's primary care services concept and therefore community-based care centers and home care service model will become subject to caregivers meeting elderly needs in an important way. Home care in the past was mostly in the form of

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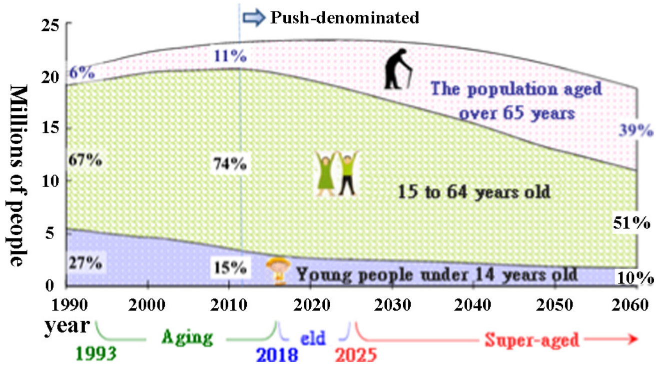

Fig. 1. Population structure trends change.

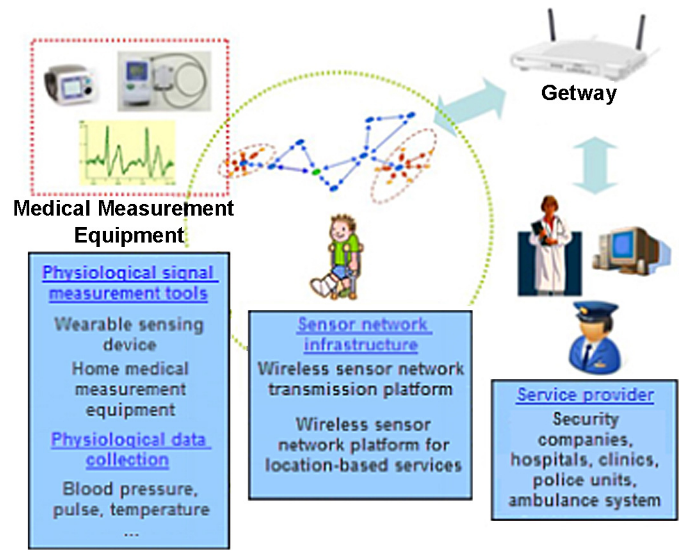

Fig. 2. Combined with wireless sensor network platform for home care.

non-professional care services. This situation causes misallocation of human resources by the caregiver who may not be able to provide real good care assistance. Personal home care systems allow the chronically ill to enjoy life in their own homes with immediate physiological detection and professional two-way interaction. This greatly reduces the strain on patients and professionals, increases patient freedom of movement and allows self-management of their disease. Over the long-term this approach reduces medical costs and improves patient quality of life. In the telecare system wireless transmission technology is the most important bridge. Wi-Fi breaks the limitations of time and space and also reduces the cost. It is easy to use and does not require the installation of cables and other hardware. Today the network has penetrated into each person's life. Biomedical technology combined with wireless transmission technology is currently the main trend in the health care market. The next decade will see the development of portable medical electronic products with simplified user interfaces so that the elderly can clear their own physical condition. Physiological data sent over the network to the cloud server will be easily downloaded to PCs. This advantage lies in the family being able to keep up with the doctor with various health information issues. Eliminating the commute to and from the hospital can save time and money and medical institutions can reduce health care costs.

The cloud has changed the way we link to information. The first generation of cloud mobile applications is still limited because of the notebook and keyboard type, so the application effect is not very good. Enterprise applications are also subject to the same restrictions. Mobile devices (e.g. iPad) have ubiquitous native applications, enhancing the efficiency of action. A proportion of enterprise applications for mobile devices have grown significantly. Almost everyone is carrying an iPad. People began to work in different places, whether it is in the coffee shop or at home. The mobile cloud allows people to be increasingly able to manage their own lives. Billions of tablet PCs, automotive and medical devices can be used to connect networks and the cloud will change the business, health of the infrastructure, bringing new storage and cloud computing model. The future can also provide network virtualization. At present, more hospitals are using iPad action rounds, round actions to develop Web edition systems that allow the attending physician to participate in inpatient visits. Heavy medical records no longer need to be carried around. Medical records can be accessed over the wireless network to spread information to an iPhone or iPad. The latest inspection report can be immediately received [3–5].

2. Literature review

With the gradual increase in the elderly population a variety of high qualification diseases such as hypertension, stroke and other diseases, subject to long-term care are also getting attention. In hypertension, for example, long-term tracking method in the past the doctor asked the patient self-measured blood pressure regularly, and then recorded on paper cards on their own, such as return visit to the doctor when it is judged paper card. However, this approach has a drawback in that it is easy to fake, mainly because patients do not fit, the amount is usually the patient forget easily fill a number up, and cause doctors misjudgment and delay treatment. While another relatively new approach is to measure the patient is complete, the blood pressure values are temporarily stored in blood pressure, and the patient will then own sphygmomanometer connected to the computer to send data on the line, but the disadvantage is that the elderly are not familiar with computer operation. Others can be asked to assist but this is not convenient. The use of wireless sensor network technology can improve this situation. At present, medical equipment manufacturers are developing a ZigBee wireless communication technology sphygmomanometer, blood glucose, combined with provisioning in wireless sensor networks. The user measured value is automatically transmitted through a wireless sensor network. As shown in Fig. 2, the entire wireless sensor network platform for home care, users are not required to carry out the measurement point of the action, as long as anyone else in the house can measure, equivalent test is completed, the value through wireless sensor network gateway, sent to the backend via the Internet service provider industry or the police ambulance system, anytime, anywhere immediate situation and respond appropriately [6–8].

When there is an emergency situation, emergency messages will be passed out through a device worn on the patient's body. Because this system provides data transmission capabilities and also has an indoor patient positioning function, arriving rescue workers can quickly find the patient. These applications are convenient auxiliary systems for care centers and nursing homes. This model has been applied in a number of nursing homes and villages for testing. The test results will be used to expand the service to more people in need. The country has combined with other cable operators for information integration, transmitting all messages through digital TV set-top boxes. There are a lot of elderly people who live alone. Many young people cannot accompany their elderly parents due to work commitments. Through this system young people can monitor their parents at home and respond to an immediate situation. The parental home situation is learned through television screen messages and also in combination with other back-end service mechanisms to further establish a comprehensive home health care network [9,10].

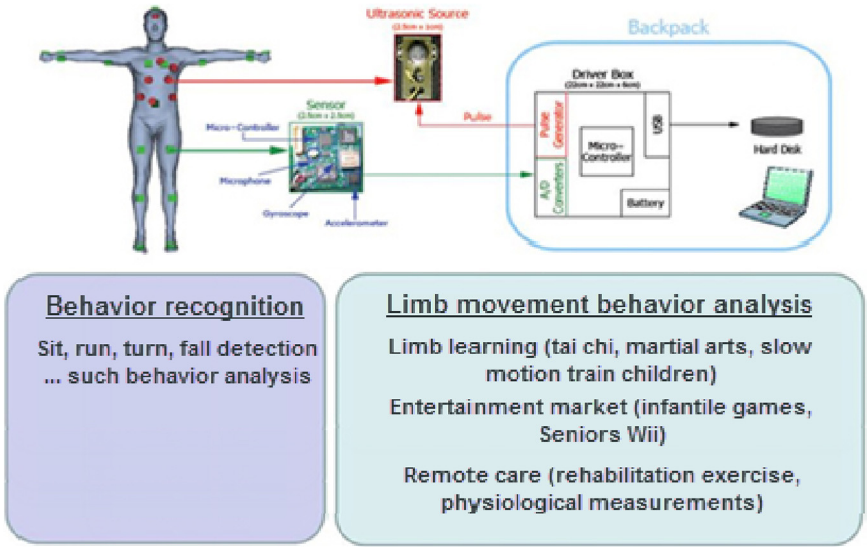

Fig. 3. Use of wireless sensor network behavior analysis technology.

In addition to illness care, the health of people in fact will have such needs, as some rehabilitation patients. Past rehabilitation hospitals require time-consuming labor and doctors cannot pay attention to multiple patients simultaneously. New technology can help doctors help patients become more self-sufficient. The Institute for Innovation Foresight Program "for rehabilitation exercise physiological information tracking and physically interactive system" has set up a development plan for such technology. The development of a physical rehabilitation tracking system with an actual medical needs interactive platform is underway. Fig. 3 shows a research and development direction for this project. Through behavior identification and behavior analysis technology, applied physical learning and entertainment markets and remote nursing and other fields, this project has the following four content items:

- developed hardware platform features: it contains actions, physiological signal sensing, and simultaneous collection, noise filtering pre-processing, and storage and so on.
- quantitative analysis: the selected action recognition algorithms, and patient rehabilitation demonstration system presents information on personal actions, with the traditional optical gait analysis to compare and analyze the performance and results to prove its usefulness.
- combined with professional knowledge of experts: academics, such as human factors engineering and rehabilitation division, with the patient's rehabilitation program as well as age, so that a limb rehabilitation interactive games.
- entertaining limb interactive interface: for the user population, customized set of actual game situations, and with the rehabilitation of medical experts recommended processes have developed a progressive rehabilitation program with an interactive entertainment system, because consider the traditional rehabilitation are carried out in a hospital, so the system is also considering whether the system can be home rehabilitation of, and through this interactive systems embedded systems technology and hardware miniaturization, making rehabilitation meet individuals carrying medical products.

Fig. 4 is a physically interactive system application scenario, in addition to the primary purpose of the behavior of rehabilitation through Internet links, so that doctors can learn about rehabilitation of persons affected by the current situation at home. The entertainment system and rehabilitation system improve patient

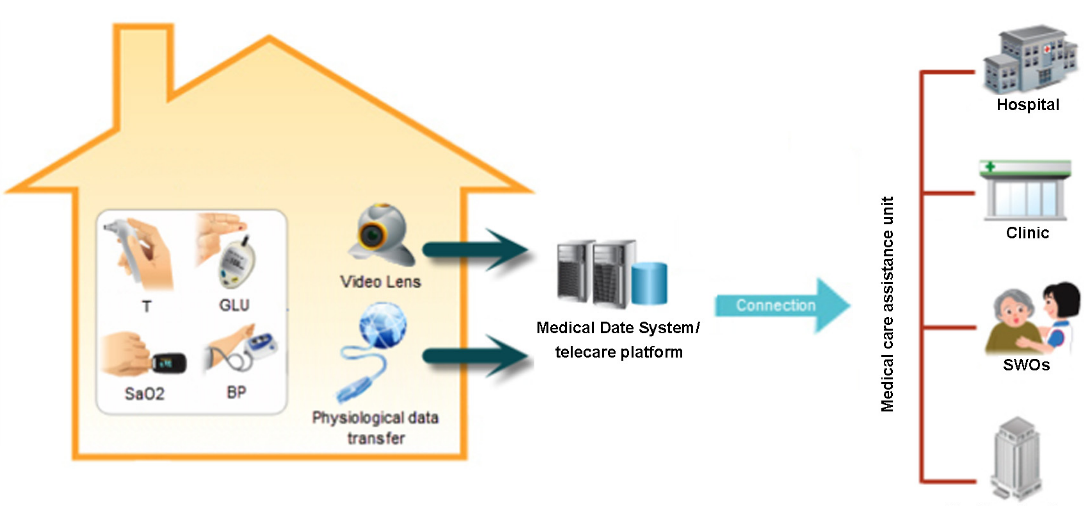

Fig. 4. Physiological information tracking and physically interactive system application scenarios.

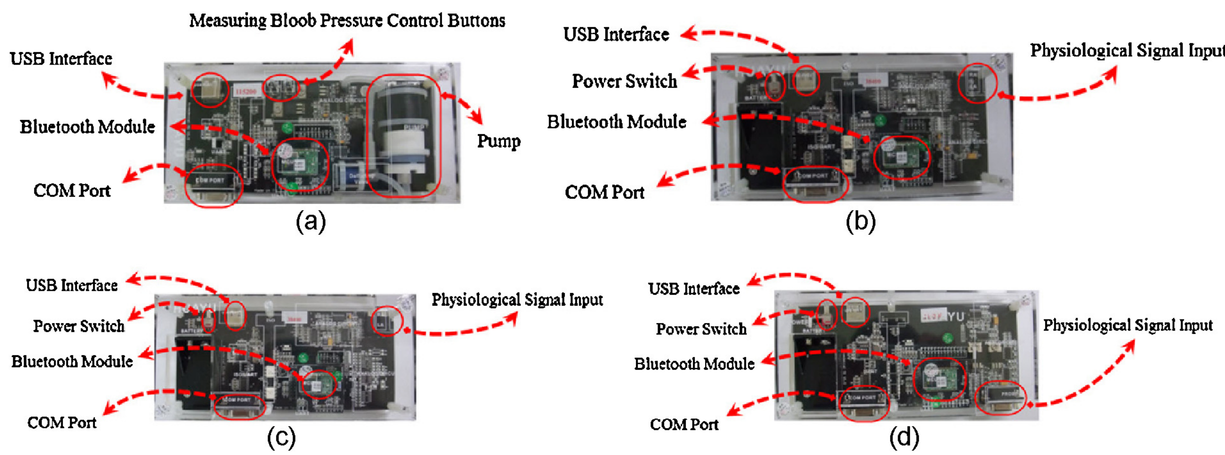

Fig. 5. (a) Blood pressure module, (b) breathing module, (c) ECG module and (d) oxygen saturation module.

rehabilitation actions for acceptance and also improve the rehabilitation effect [11,12].

In simple terms, physiological sensors can be worn on the body in several formats. The sensors will automatically collect and send data via wireless sensor networks to the home gateway hospitals. Doctors can determine what action should be taken based on the data. A visual interface with the home will allow doctors to give advice and instructions directly to the patient or caregiver. This approach has the advantage of eliminating unnecessary hospital visits. Future life, food, medicine, shelter, transportation, entertainment will have its optimization technology into in which and through these technologies bring a more comfortable and convenient digital life.

This study uses the Android platform to establish a family community health care of things, using RFID and ZigBee wireless sensor network technology to build a remote medical care system. The measured physiological signals are collected and analyzed with the results processed through ZigBee wireless device to the host central monitoring system network server host. The user will be able to use a smartphone for medical queries. Due to a variety of physiological and home users using a variety of devices with large RS-232/485 serial communications interfaces, this study used this interface basis. Home users will use the existing wireless sensor network environment to set up User physiological signal sensing monitoring, such as blood pressure, ECG, pulse and body temperature. The establishment of a cloud computing management platform in conjunction allows database system operation and remote monitoring [13–15].

3. Hardware architecture and system components

The main equipment is divided into four parts, physiological signal acquisition equipment, transmission equipment, back-end display devices, cloud server, physiological signal acquisition devices connected to electrical modules, blood pressure module, oxygen concentration module, respiratory rate module, as shown in Fig. 5. Physiological data is captured through the transmission module (RS-232, WiFi, Bluetooth) to the back-end display devices

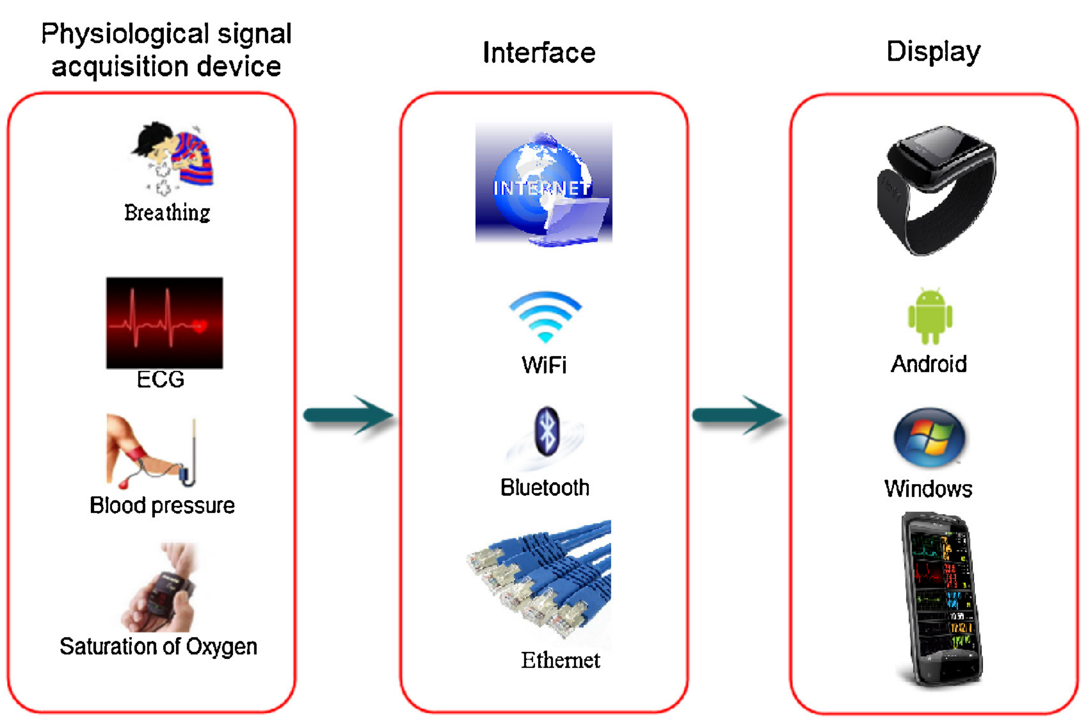

Fig. 6. System function diagram.

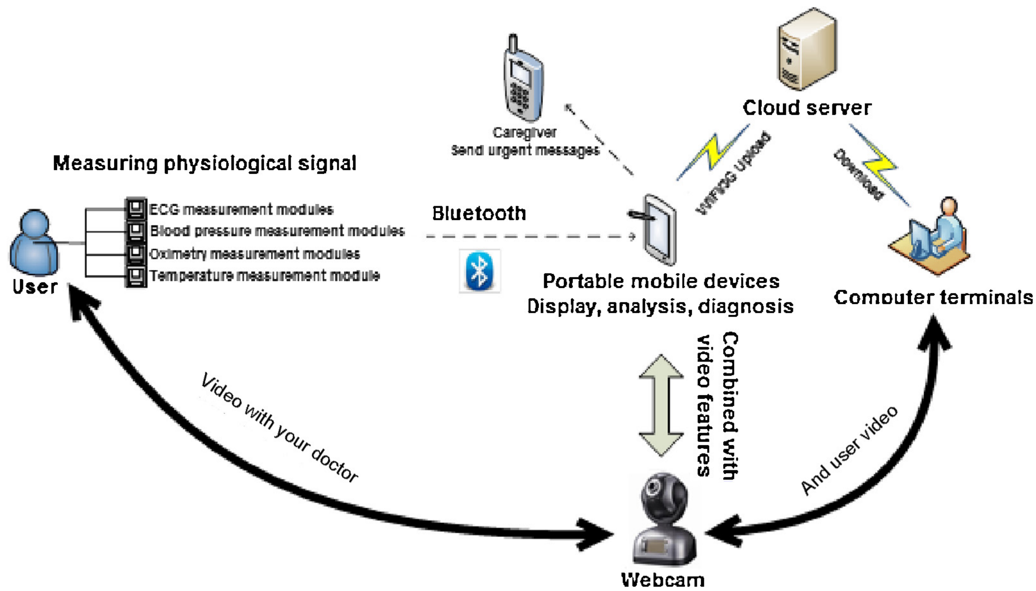

Fig. 7. System architecture diagram.

(mobile handheld device), and finally through our network road uploaded to the cloud server and back-end systems using evidence theory to find the optimum physiological data values, as shown in Fig. 6.

Medical modular and portable mobile devices (Android system) are combined in the electrocardiogram, blood oxygen, blood pressure and temperature modules. Physiological data is measured by the A/D converter using a serial port sent to the Bluetooth and portable mobile devices (Android system) for display, analysis and preliminary judgment. If the physiological signals are normal, SMS notification is sent to the caregiver, and the data from the network cloud server can be downloaded by physicians. If necessary, a video chat can be conducted between the physician and caregiver to give the greatest help, as shown in Fig. 7 [16].

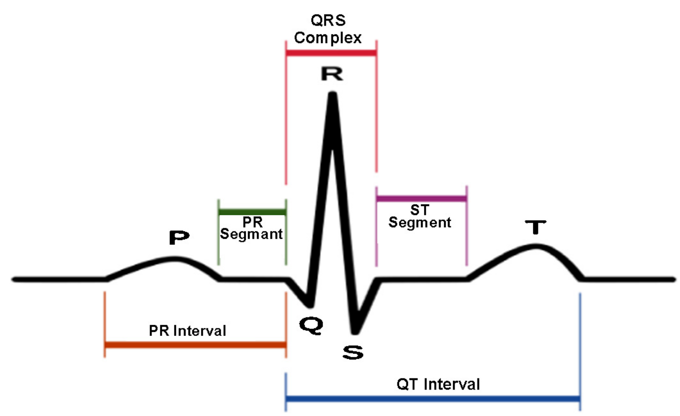

Fig. 8. Normal PQRST waveform chart patterns.

3.1. ECG module

When cardiac depolarization is induced on the skin surface a small change in the electrical signal occurs. This small change is amplified by the ECG recording device and shown in Fig. 8 [17].

P wave: atrial depolarization in the normal course, ECG vector pointing from the sinus node atrioventricular node.

PR interval: measured from the beginning to the P wave QRS complex begins. PR interval reflects the electrical impulses sent by the sinus node, atrioventricular node incoming ventricle caused by ventricular depolarization required time.

QRS complex: QRS wave group reflects the rapid left and right ventricular depolarization. Because atria develop in the left and right ventricular muscle tissue the QRS complex is much higher than the P-wave amplitude.

T wave: represents the fast ventricular repolarization process, from the beginning of the QRS complex to the highest point of the

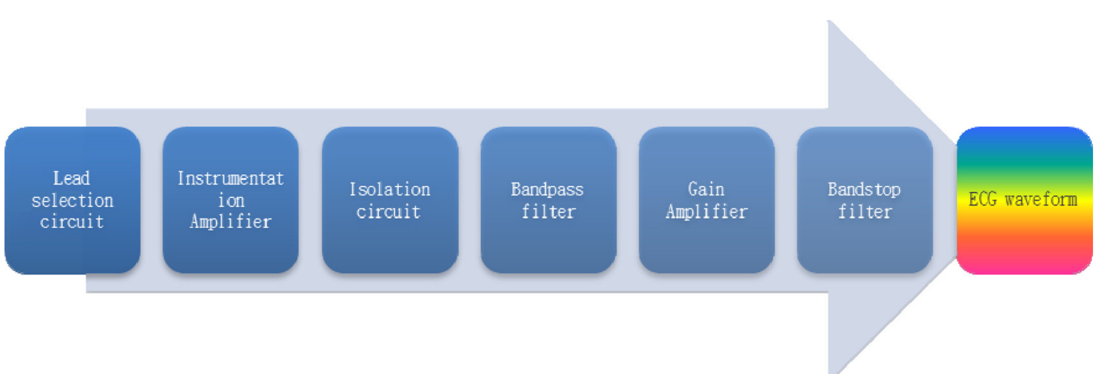

Fig. 9. ECG module schematic diagram.

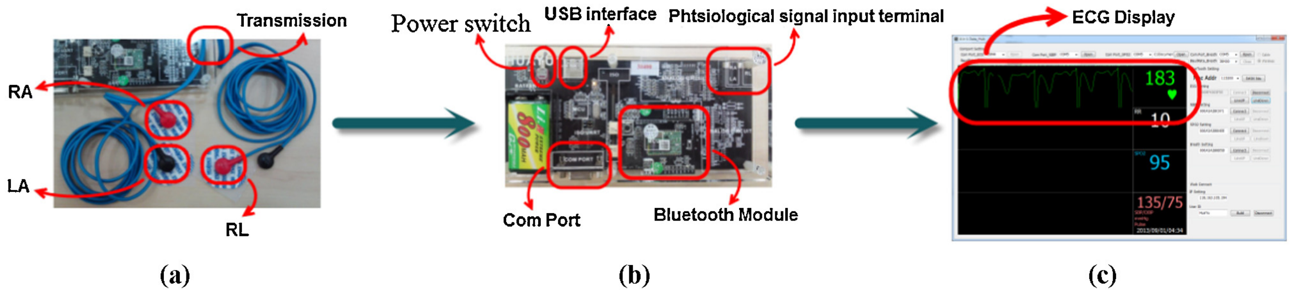

Fig. 10. (a) ECG lead retrieve line, (b) ECG module and (c) display interface.

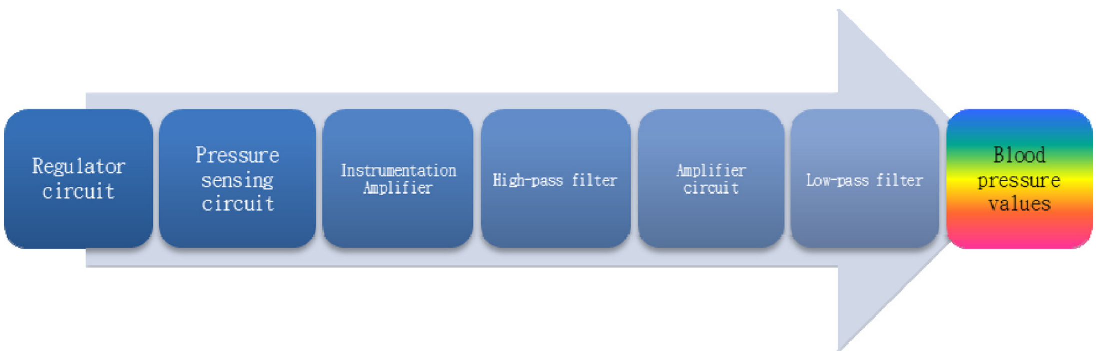

Fig. 11. Blood pressure module schematic diagram.

period T wave of the heart called the absolute refractory period, and half of the T-wave is called the relative refractory period (also known as bowel period).

QT interval: QT interval is prolonged ventricular tachycardia risk factor may cause sudden death.

ECG module schematic shown in Fig. 9, Fig. 10 is a flow chart of the ECG test. Measured by the electrode patch study the potential difference changes to a weak, by instrumentation amplifier module as ECG preamplifier, and the resulting measurement signal 100 times magnification, using ISO122 isolated areas isolation circuit IC, the measurement can be protected by leakage current shock after being band-pass filter, and then filtered weak physiological signals amplified 10 times in the last pass band reject filter can produce electrocardiogram.

3.2. *Blood pressure module*

Clinical blood pressure (Blood Pressure, BP) refers to the contraction of the left ventricle in arterial pressure exists within the blood pressure (sphygmomanometer) in the left brachial artery. Blood pressure measurements can be obtained using the systolic blood pressure and diastolic blood pressure. Systolic blood pressure refers to the blood in the left ventricle further contraction force

Table 1
Classification of blood pressure values.

Classification		Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)
Normal blood pressure		<130	<85
Blood pressure slightly higher		130–139	85–89
Hypertension	Mild	140–159	90–99
	Moderate	160–179	100–109
	Severe	180–209	110–119
	Very severe	≥210	≥120

acting on the arterial wall. Diastolic blood pressure means the relaxation of the blood in the left ventricle, showing the strength of the arterial wall [18] (see Table 1).

A two-way serial communication module, with high accuracy and high reliability provides fast, accurate blood pressure measurements. The blood pressure module principle is shown in Fig. 11. Fig. 12 is a blood pressure measurement experiment FIG. Pressure sensors, electronic components and electronic circuit theory, design, normalization of blood pressure measuring physiological data acquisition module circuit, voltage regulator circuit controlled by 3 V, so that the pressure sensor voltage is not changed geopolitical changes, reuse pressure sensor impedance control 0–200 mmHg

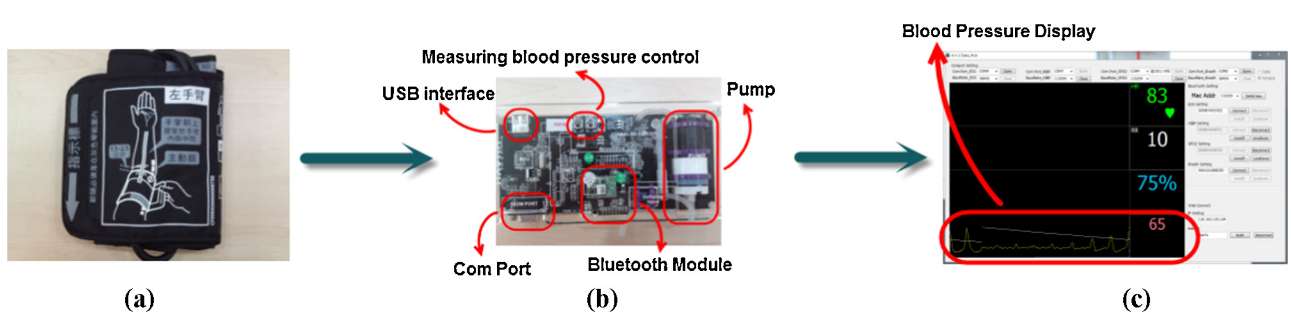

Fig. 12. (a) Blood pressure arm band, (b) blood pressure module and (c) display interface.

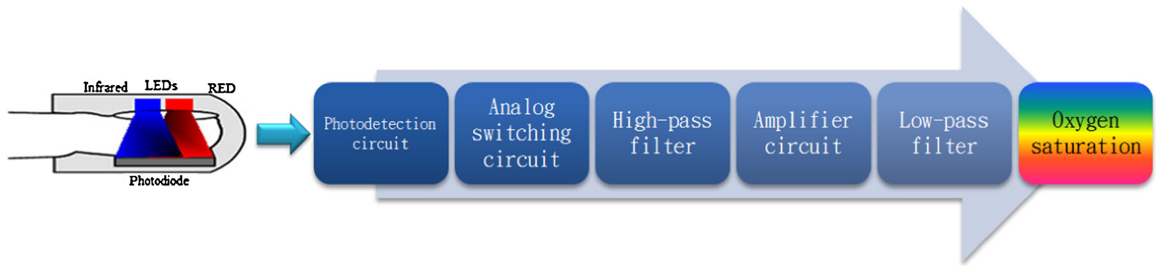

Fig. 13. Saturation of oxygen schematic diagram.

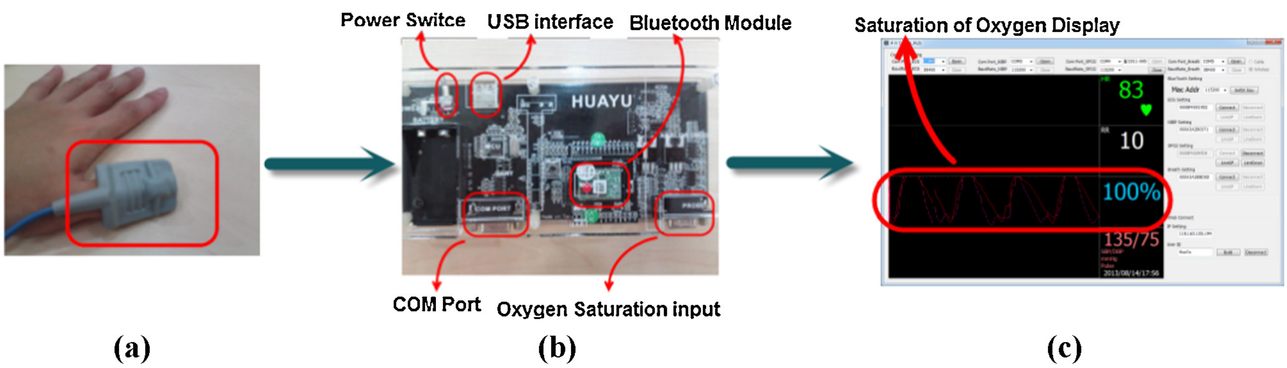

Fig. 14. (a) Saturation of oxygen sensor, (b) saturation of oxygen module and (c) display interface.

pressure, the output voltage of 1–5 V, followed by second-order high-pass filter circuit, −3 dB turning point chosen in order to avoid transient problem at 1 Hz, transmitted via the second non-inverting amplifier low-pass filter circuit, −3 dB turning point was chosen to avoid distortion at 40 Hz. Finally, the pressure sensor voltage values obtained, blood pressure and pulse filter circuit obtained information can be obtained through the PC computing systolic and diastolic blood pressure.

3.3. Oxygen saturation module

Oxygen saturation: SO_2, expressed in blood hemoglobin carries oxygen saturation level. Currently using spectrophotometric colorimetry was measured oxyhemoglobin (O_2Hb) and Restore hemoglobin (reduced hemoglobin: HHb) then calculate SO_2. Normal arterial oxygen saturation greater than 95%, PO2 decreased hemoglobin to carry oxygen or there is a problem with abnormal hemoglobin [19].

$$\text{Saturation of oxygen}(SO_2) = \frac{O_2Hb}{O_2Hb + HHb} \times 100\% \quad (1)$$

Human hemoglobin in red blood cells in vivo combines with oxygen. The combination of blood and oxygen makes patterns divided into two types. The first one is a reversible binding with hemoglobin called oxyhemoglobin (oxygenated hemoglobin, HbO_2). The second is unbound hemoglobin and oxygen molecules called to restore blood red hormone (reduced hemoglobin, Hb), in normal circumstances, the human body is almost oxygen molecules combine with hemoglobin to do (see Table 2).

Table 2
Oxygen degree classification [20].

Severity	Lowest oxygen saturation
Mild	85–89%
Moderate	80–84%
Severe	<80%

The sensors used in the study are set using the fingertip, as shown in Fig. 14(a). In order to fix the upper wall and the following two light diodes, the light emitting wave lengths is 660 nm and 940 nm infrared light red. The wall has a photodetector and the transmittance of infrared light red finger into an electrical signal. The detected signal is weaker, which means when the optical signal passes through the fingertip is thereat to the bone, tissue and blood, the more absorbed. Oxygen saturation module principle shown in Fig. 13, Fig. 14 is a flowchart of oxygen saturation experiments.

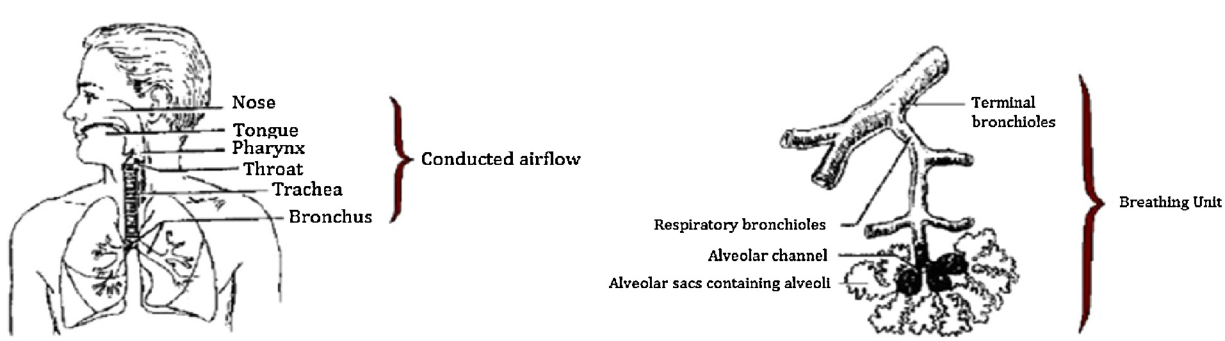

Fig. 15. Respiratory physical structure diagram.

Table 3
Measuring temperature classification table.

Position	Temp.			
	Body temperature		Body temperature of the time	
	The normal temperature range (average temperature)	Fever (°C)	Mercury thermometer	Electronic
Axillary	35.3–37.1	37.2	5 min	40 s
Oral	35.9–37.6	37.6	5 min	30 s
Rectal	36.0–37.9	38.0	3 min	30 s
Ear	35.7–37.5	38.0		15 s

3.4. Respiration rate modules

Respiratory gas exchange is done by the lungs. The lung is an intrathoracic soft, flexible balloon, with absolutely no muscle, relying on the breathing muscles to assist when the pleural pressure decreases. The gas pressure in the lung is less than atmospheric pressure. The air is sucked into the lungs naturally. This action is called breathing. During a breath oxygen molecules are drawn into the mitochondria to produce adenosine triphosphate (adenosinetriphosphate, ATP) as a source of energy for the body. The physiological role of the respiratory system is divided into two different sub-elements: conducting airways (conducting airways) and respiratory units (respiratory units). Conducting airways is including the nasal cavity, oral cavity, pharynx, larynx, trachea and bronchial A. As the name implies, the function of the elements constitutes a breathing gas delivery unit. Respiratory units include bronchioles, alveolar and alveolar channel (terminal airbags B). Alveolar gas is inhaled gas exchange with the blood issue anatomical location. Inhaled gas along the conducting airways reach the alveoli, the average speed of the gas flow due to cross-sectional area can be increased using reduced significantly. For example, in the normal adult human tracheal cross-sectional area is about 2.0 cm^2 in alveolar amounted to 700,000 cm^2. This area produced significant changes in the speed of air flow which affects the respiratory system deposition of particles and gases. Fig. 15 shows a configuration diagram of respiratory physiology [21].

A variable capacitor with changes the capacitance value to produce inspiratory and expiratory changes. The capacitance value increases inspiratory and the expiratory capacitance value decreases. The remaining human pleural tissue can be regarded as resistance. Fig. 16 is a thoracic impedance model that represents a simple cross between two points thoracic impedance model, in which RA, RB and RC represent the general resistance of human tissue, while RL and CL represents the lung impedance. Figure (a) a reduction of the figure (b). When between two points in a cross-chest adding a known frequency AC current tiny, you can calculate the lungs with respiration impedance changes, this principle is called Impedance Pneumography, and respiratory rate principle shown in Fig. 17, Fig. 18 is respiration experimental procedure Figure.

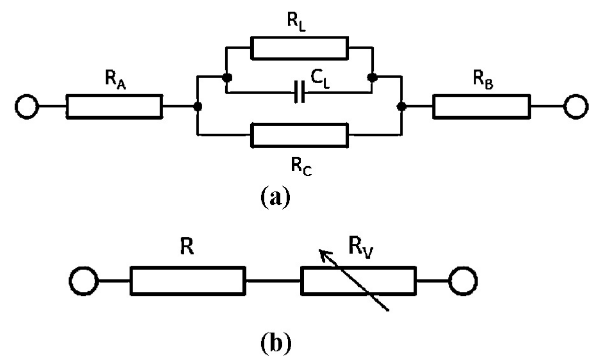

Fig. 16. (a) Thoracic impedance model and (b) simplified model.

3.5. Body temperature modules

Body temperature is defined as the inner core body temperature. Body heat production and heat dissipation are designed to produce a balanced outcome. Body heat is generated mainly by food intake in vivo metabolism, followed by muscle movement. The thyroid hormones in the adrenal medulla regulate body heat. Body

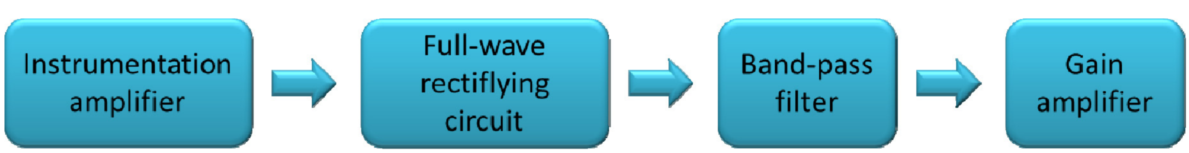

Fig. 17. Breathing module schematic diagram.

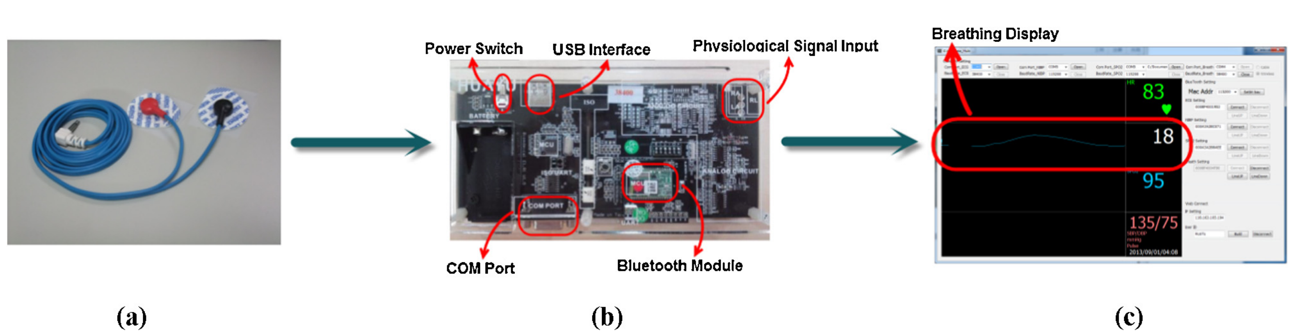

Fig. 18. (a) Breathing line, (b) breathing module and (c) display interface.

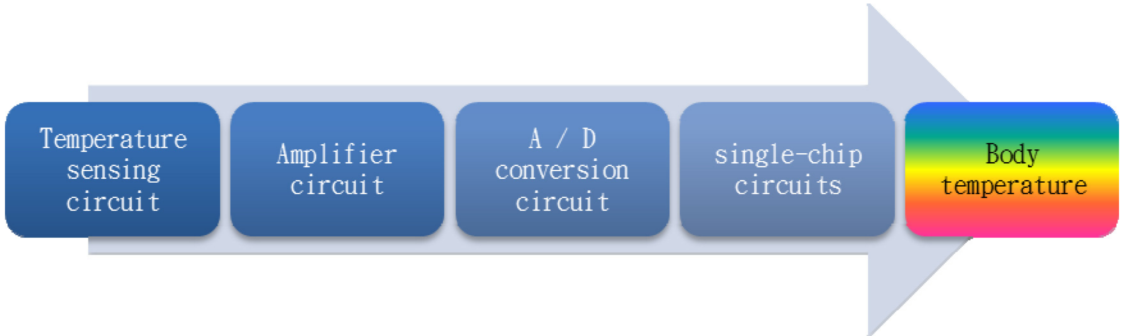

Fig. 19. Temperature measurement circuit flow.

heat dissipation is circulation driven mainly through four channels; radiation, conduction, convection and evaporation. Temperature is not a single point, but is a range of normal body temperature maintained at 36.5–37.5 °C Celsius and does not change more than −1 °C. The normal body temperature values will vary with age and may be different at various time periods within a day. Extreme exercise or ambient temperature changes may produce a different body heat distribution.

By measuring the different parts can be divided;(refer to Table 3 and Fig. 19)

a. Capacity axillary temperature: the safest way, but it is the easiest way disturbed.
b. Capacity oral temperature: an approximate core temperature, but will be affected by the temperature of the food inside the mouth.
c. Capacity rectal temperature: comparison unsafe manner, but not sweat or outside influence.
d. Capacity ear temperature: infrared detector to measure blood flow in body temperature, so the most accurate measured values [22].

We used AD592CN to make simple temperature sensing devices. At room temperature under 25 °C Power Supply for AD592CN for stable DC voltage input, through 10k precision resistor output current is converted into a voltage, and with a precision digital voltmeter (shown to the third decimal place) to do for measurement of the output voltage [23].

3.6. Wi-Fi modules

Wi-Fi (Wireless Fidelity) technical specifications for the IEEE proposed, is now considered synonymous with 802.11 wirelesses LAN. Wireless Ethernet Compatibility Alliance (WECA), the process of creating wireless Internet Protocol (WLAN), developed initially developed flow, and momentum is far off Bluetooth (Blue-tooth) afterwards. 1999, WECA renamed the Wi-Fi Alliance, once again a certification standard architecture proposed wireless Internet access industry technical −802.11 range of specifications, including 802.11.b, 802.11.a, 802.11n, etc. Fig. 20 is a Wi-Fi module and antenna.

Fig. 20. Wi-Fi module.

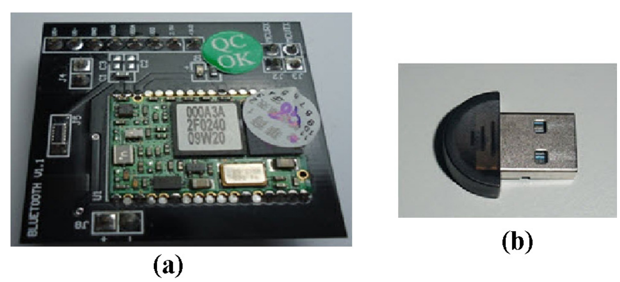

Fig. 21. (a) Bluetooth module and (b) bluetooth receiving module.

3.7. Bluetooth modules

Bluetooth is a new generation of wireless connectivity technology, but also access the world of wireless connectivity standards, this wireless transmission technology was in 1998 by the Bluetooth Special Interest Group SIG (Special Interest Group) developed by the specifications, its purpose in the use of low-cost, low-power radio transmission technology, allowing different products (such as a printer, PDA, keyboard, mouse, PC, Notebook) via Bluetooth technology to remove disturbing transmission line [10]. At this stage, including Bluetooth wireless networks, including transmission technology, are facing the problems, large or small; respect Bluetooth itself: first, the small power susceptible to other electrical interference, especially Bluetooth and mobile interaction; second, governments on the use of radio bandwidth requirements vary, causing problems for wireless communication; third, not all brands are fully compatible with Bluetooth specification. Short-range wireless networks remains to be seen who will play the leading role, but Bluetooth is undoubtedly one of the most promising technologies (see Table 4).

Bluetooth appeared in the May 20, 1999, by Sony Ericsson and easy, IBM, Intel, Nokia and Toshiba, and other industry leading founded the “Special Interest Group” (Special Interest Group, SIG), the predecessor of the Bluetooth SIG, aim is to develop a low cost, high efficiency, can be random within a short distance of Bluetooth wireless connectivity technology standard. Bluetooth is a wireless data and voice transmission open standards, it will a variety of communications equipment, computers and terminal equipment, all kinds of digital data systems, and even household appliances to link up wirelessly. Its transmission distance of 10 cm–10 m, if the increase in power or add some peripherals can reach 100 m transmission distance. In this study, the data can be transmitted using Bluetooth explicit interface is accessible through the display device for a network of remote monitoring, and Fig. 21, respectively

Table 4
Comparison of various protocols [24].

Items	Application	Transmission rate	Advantages	Disadvantages
Bluetooth	Wireless phones, wireless synchronization	version 2.0 3 Mbit/s	Hands-free operation	High power consumption
Wi-Fi	High Speed B/W Internet, Internet telephony	802.11 g is 56 kbit/s or more	Universal	High power consumption
Infrared	POS transactions, transfer of personal data	1–16 Mbit/s	Convenience	A short distance
ZigBee	Industrial monitoring and control, medical equipment	2.4 GHz: 250 kbit/s	Low power consumption	Slow transmission

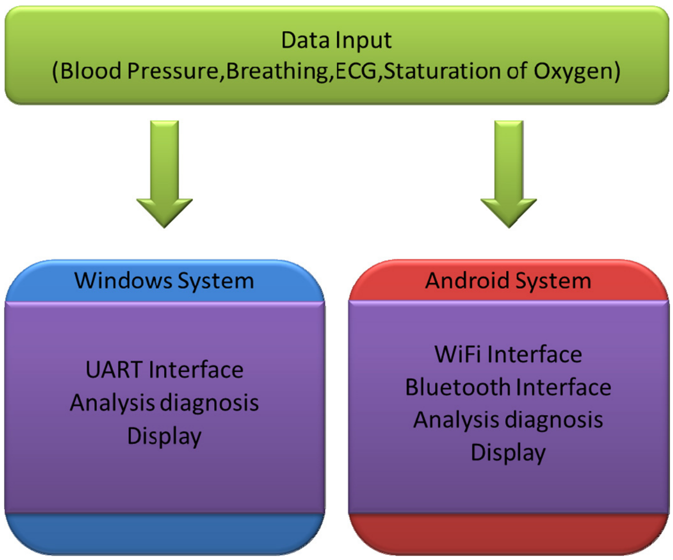

Fig. 22. Software architecture flowchart.

Bluetooth module and Bluetooth receiver, the receiver unit can be done on a personal computer links, such as the device itself has a Bluetooth device may not have the receiver [25].

3.8. *Software architecture*

Achieved by the physiological platform physiological signals captured after the original, with software algorithms to calculate the index of more value judgments such as heart rate, blood pressure, oxygen saturation, respiration rate and other values. We measured the amount of data displayed on the terminal and mobile handheld devices, mobile handheld devices, there are two ways to monitor local and remote, respectively. Local monitoring are applied directly to mobile handheld devices with the front of the physiological signal acquisition platform links immediately displayed on a mobile handheld device physiological data, Fig. 22 is a flowchart of the software architecture.

4. Evidence-based multi-sensor information fusion theory

Evidence Theory was originally proposed in 1967 by Dempster using multiple functions derived probability bounds, and later by Shafer in 1976 to promote the formation of evidential reasoning, therefore, also known as D–S evidence theory. Similar to Bayesian inference, D–S evidence theory with a priori probability assignment function to indicate evidence of posterior interval quantified proposition credibility and likelihood ratio [26,27].

In the multi-sensor system, the sensor accuracy, system consisting of many links, the external environment and post-processing of data and other factors may cause the system uncertainty. Therefore, the study needs to adopt uncertainty reasoning methods to solve the data integration problem. Dempster–Shafer evidence reasoning theory (D–S reasoning) is ideally suited for target identification field of application of an inexact reasoning method. This section discusses the evidence-based theory of multi-sensor information fusion. Evidence-based multi-sensor information fusion theory involves information collected by each sensor as evidence to establish a corresponding basic probability assignment function (or belief functions). In the same frame of discernment, evidence synthesis formula is used to synthesize different new evidence for making decisions based on decision rules [28,29].

For example, a multi-sensor system, target recognition, target species is the proposition to form the frame of discernment Θ. Implementation of environmental observation from each sensor, the target species is given a set of basic probability assignment function (or belief functions), constitute a set of evidence, which are the basis for decision-making.

(1) Evidence-based theory of multi-sensor information fusion general process shown in Fig. 23.
(2) The calculated for each sensor's basic probability assignment function, belief function and plausibility function.
(3) The use of evidence and success is obtained under the combined effects of all the sensor's basic probability assignment function, belief function and plausibility function.
(4) In a certain decision rules, select the target with maximum support.

Basic probability assignment evidence uncertainty carrier function is used to obtain evidence. Evidence theory is applied to information fusion as a key part. Basic probability assignment function is that people assume that the credibility of the target of an inference is a person's judgment. This judgment is affected by various factors. Different ideas would constitute the basic probability assignment function of different structural formula. The sensor correlation coefficient obtained as evidence to construct basic probability assignment function, which means that each target hypothesis credibility. Indicates that the sensor on the target type of a *i*.

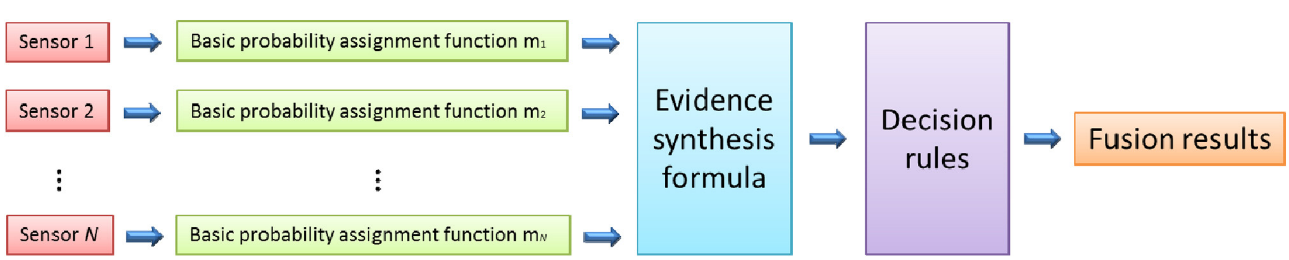

Fig. 23. Evidence-based theory of multi-sensor information fusion diagram.

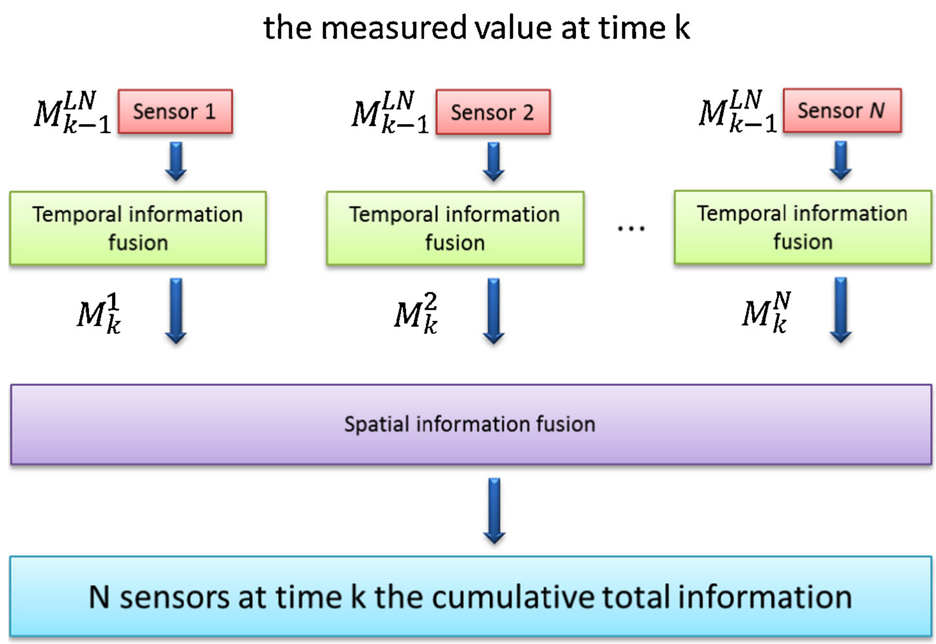

Fig. 24. Distributed information fusion diagram with feedback.

Let $c_i(q_j)(i = 1, 2, \ldots, N_s, j = 1, 2, \ldots, N_c)$ indicates that the sensor i on the target type of q_j correlation coefficient; $N_c(N_c \geq 2)$ is a number of target type; N_s is a total number of sensors $\omega_i \in [0, 1](i = 1, 2, \ldots N_s)$ is a weighting coefficient sensor i environment. Definition:

Sensor i and target maximum correlation coefficient

$$\alpha_i = \max_{j=1,2,\ldots,N_c} \{c_i(q_j)\} \quad (i = 1, 2, \ldots N_s) \tag{2}$$

Sensor i with the target distribution coefficient of correlation coefficient

$$\beta_i = \frac{\left(\left(N_c\omega_i / \sum_{j=1}^{N_c} c_i(q_j)\right) - 1\right)}{N_c - 1} \tag{3}$$

or

$$\beta_i = \frac{\alpha_i}{\sum_{j=1}^{N_C} c_i(q_j)} \tag{4}$$

The reliability coefficient of the sensor i is:

$$R_i = \frac{\omega_i\alpha_i\beta_i}{\sum_{j=1}^{N_c} \omega_j\alpha_j\beta_j} \tag{5}$$

Sensor gives the basic probability value of the target j is:

$$m_i(q_j) = \frac{c_i(q_j)}{\sum_{j=1}^{N_c} c_i(q_j) + N_s(1 - R_i)(1 - \omega_i\alpha_i\beta_i)} \tag{6}$$

$(i = 1, 2, \ldots, N_s, \quad j = 1, 2, \ldots, N_c)$

Sensor i identification frame Θ gives the basic probability value, which is the uncertainty of the probability of the sensor i is:

$$m_i(\Theta) = \frac{N_s(1 - R_i)(1 - \omega_i\alpha_i\beta_i)}{\sum_{j=1}^{N_c} c_i(q_j) + N_s(1 - R_i)(1 - \omega_i\alpha_i\beta_i)} \tag{7}$$

$(i = 1, 2, \ldots, N_s, \quad j = 1, 2, \ldots, N_c)$

The evidence combination formula, N_s sensors (evidence) were synthesized, get $m_i(q_j)$ and $m_i(\Theta)$. Sensors can be used multiple times repeatedly to scan results integrated to achieve the same batch evidence. A recursive formula is used to complete each batch.

Assuming identification framework Θ, $m_j(A_i)$ represents the j-th sensor measurement cycle gained ground on the target A_i basic probability assignment function, where, $j = 1,2,\ldots,N$. Evidence synthesis using the formula for the time domain of the sensor information fusion (here Dempster combination formula, for example, are introduced), with M_N indicates that the sensor in the N measurement cycle after fusion of the cumulative proposition A basic probability assignment function,

$$M_N(A) = \frac{\sum_{\cap A_i = A} \prod_{1 \leq j \leq N} m_j(A_i)}{1 - K} \tag{8}$$

Among

$$K = \sum_{\cap A_i = \phi} \prod_{1 \leq j \leq N} m_j(A_i) \tag{9}$$

This study does not consider each sensor at different times of the measured data. That is, the domain information of sensor is data fusion via multiple sensors (i.e. spatial integration of information). Assuming the identification frame Θ, $m^s(A_i)$ provided that the s-th sensor on the target A_i basic probability distribution function $s = 1,2,\ldots,N$. Indicated with M^{LM} is N sensors fusion proposition A cumulative probability distribution of the basic function that is obtained by N sensors accumulated information:

$$M^{LN}(A) = \frac{\sum_{\cap A_i = A} \prod_{1 \leq s \leq N} m^s(A_i)}{1 - K} \tag{10}$$

Among

$$K = \sum_{\cap A_i = \phi} \prod_{1 \leq s \leq N} m^s(A_i) \tag{11}$$

Combining these two methods can introduce multiple measurement cycles multiple sensors information fusion method, instant – spatial information fusion. This approach also reduces the uncertainty of the system, provide more reliable fusion results. Distributed fusion algorithm with feedback block diagram shown in Fig. 24. No feedback algorithm it is different for each sensor, the current measured value to the entire system, the information previously accumulated integration [30].

First, the N sensors at time $k-1$ accumulation information of all the sensors and the measured value at time k respectively integration, namely:

$$M_k^s(A) = \frac{\sum_{B_i \cap A_i = A} M_{k-1}^{LN}(B_i)\, m_k^s(A_i)}{1-k} \tag{12}$$

Among

$$k = \sum_{B_i \cap A_i = \phi} M_{k-1}^{LN}(B_i)\, m_k^s(A_i) \tag{13}$$

The various sensors in the accumulation information for time k spatial information fusion (i.e. between the sensor fusion), get the final fusion results:

$$M_k^{kN}(A) = \frac{\sum_{\cap A_i = A} \prod_{1 \le s \le N} m_k^s(A_i)}{1-k} \tag{14}$$

Among

$$K = \sum_{\cap A_i = \phi} \prod_{1 \le s \le N} M_k^s(A_i) \tag{15}$$

Formula (14) is used to obtain the N sensors accumulation information for time k spatial information fusion, fusion to obtain the final result. The above kinds of recursive calculation can be achieved N sensors can be achieved in the integration of the M measurement cycle.

5. Implementation experiments

The physiological measurement platform is used to measure ECG, blood pressure, oxygen saturation, respiration rate and other values. The ECG measurements require to subjects to apply adhesive electrode patches. The ECG acquisition module will crawl out of the filtered signal and show the correct ECG. Blood pressure measurement requires the arm to wear a blood pressure cuff. The sensing module will measure and calculate the pressure values obtained and compare them with blood pressure values. Oxygen concentration measurements require the patient to wear an oxygen concentration sensing pad on the index finger. The oxygen concentration sensing element measures using two different LED wavelengths. The Lambert – Beer law of light absorption intensity is used to detect the blood oxygen concentration. An oximetry module calculates the measured value to obtain accurate oxygen concentration values. When measuring the respiration rate in subjects adhesive electrode patches are required. The respiration rate acquisition module will crawl out the signal filter and calculate the correct rate of respiration. The final results will be displayed on computers, mobile terminals and handheld devices, such as tablet PCs and mobile phones.

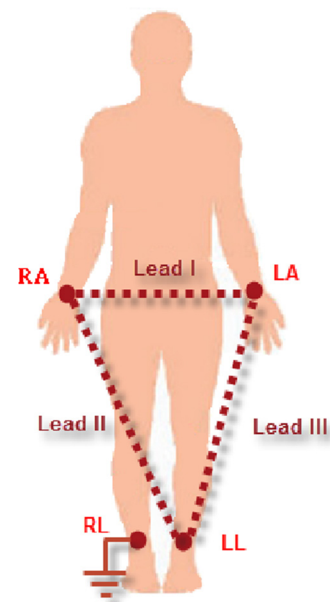

Fig. 25. Three kinds of lead connection.

5.1. ECG measurement

The measurement methods used for the standard bipolar limb induction represents the potential difference between two places, right leg (RL) used as a ground in the left arm (LA), right arm (RA), left (LL) selected to measure the potential difference between two points, Since the selection of points can be divided into Lead I, Lead II, Lead III three lead, Fig. 25 is a three-lead of the connection. Figs. 26–28 respectively Lead I, Lead II, Lead III measurement

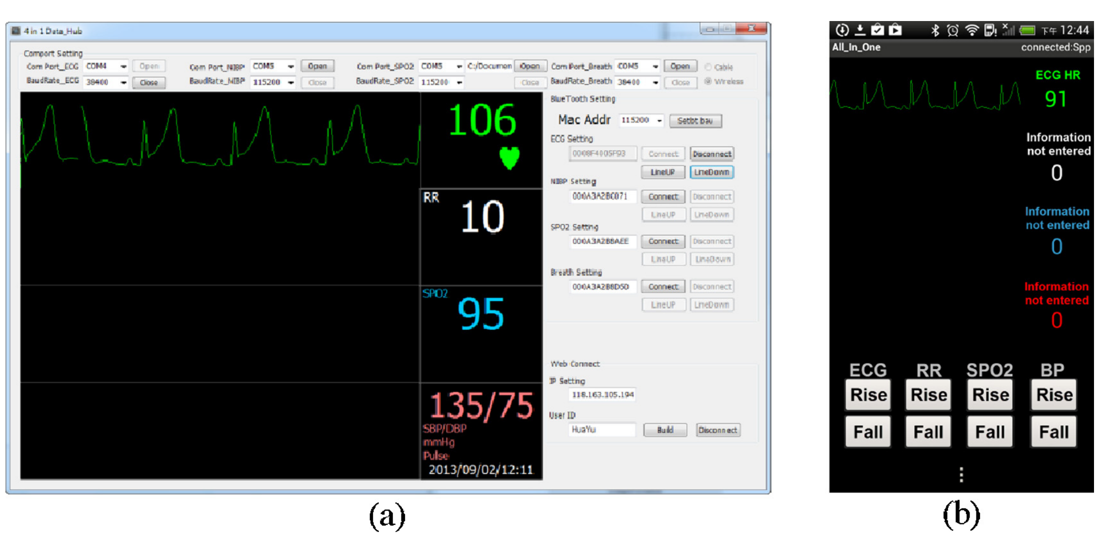

Fig. 26. The Lead I measurements.

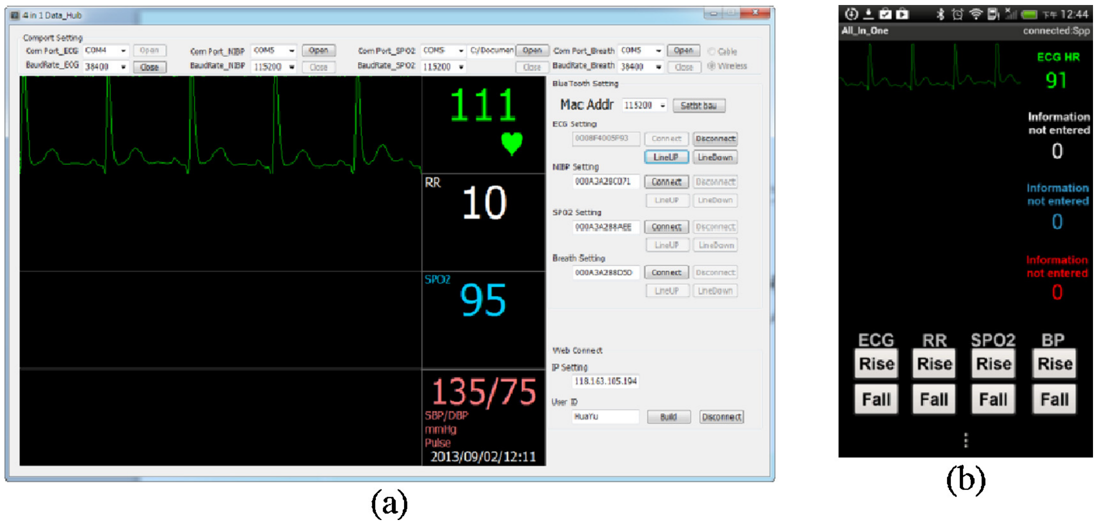

Fig. 27. The Lead II measurements.

Fig. 28. The Lead III measurements.

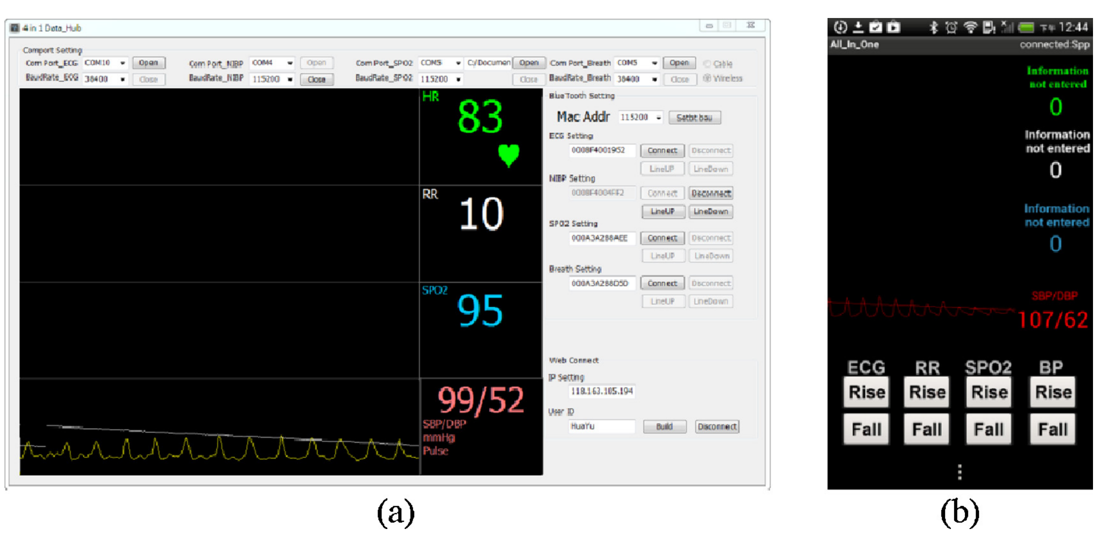

Fig. 29. Blood pressure measurement.

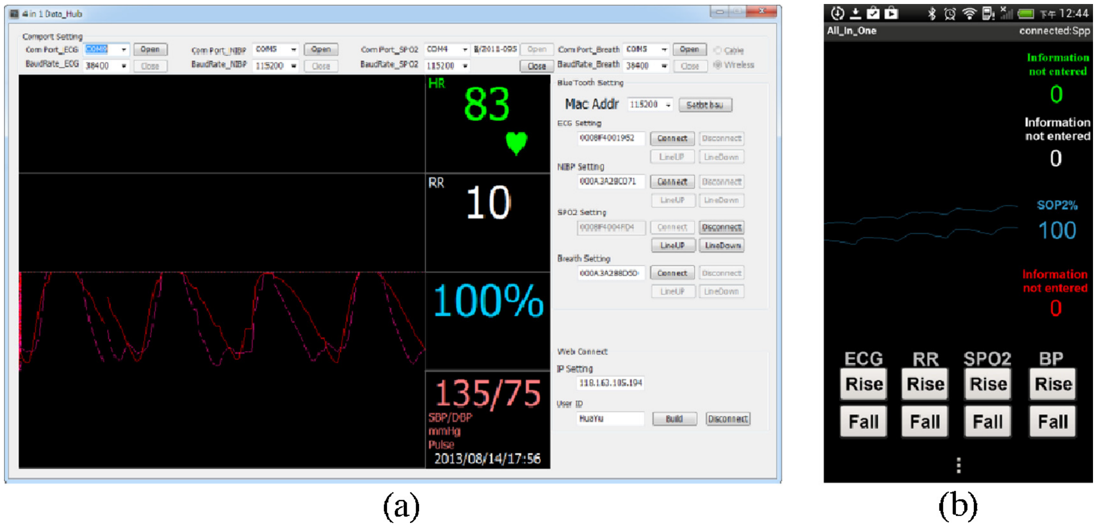

Fig. 30. Saturation of oxygen measurement.

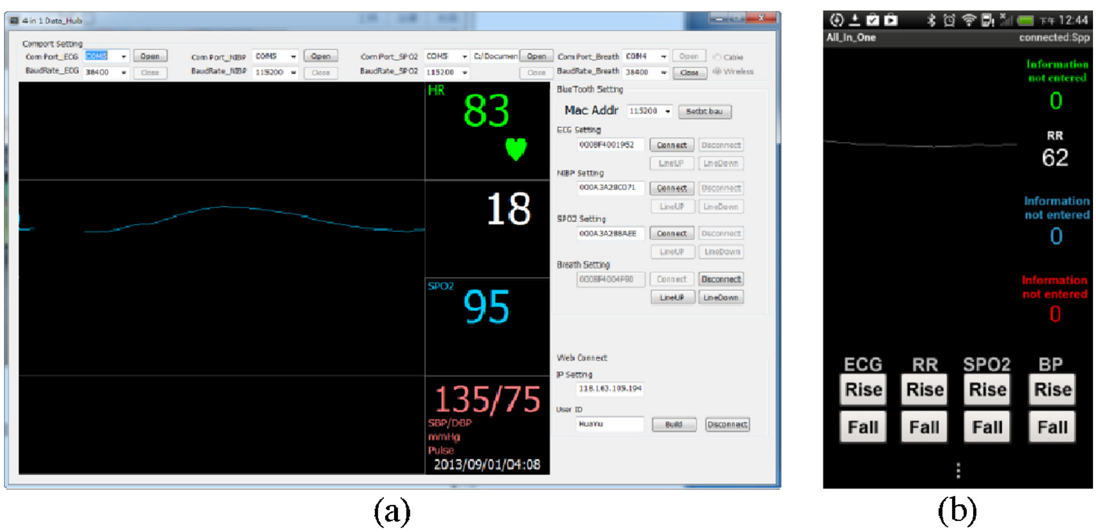

Fig. 31. Respiratory rate measurement.

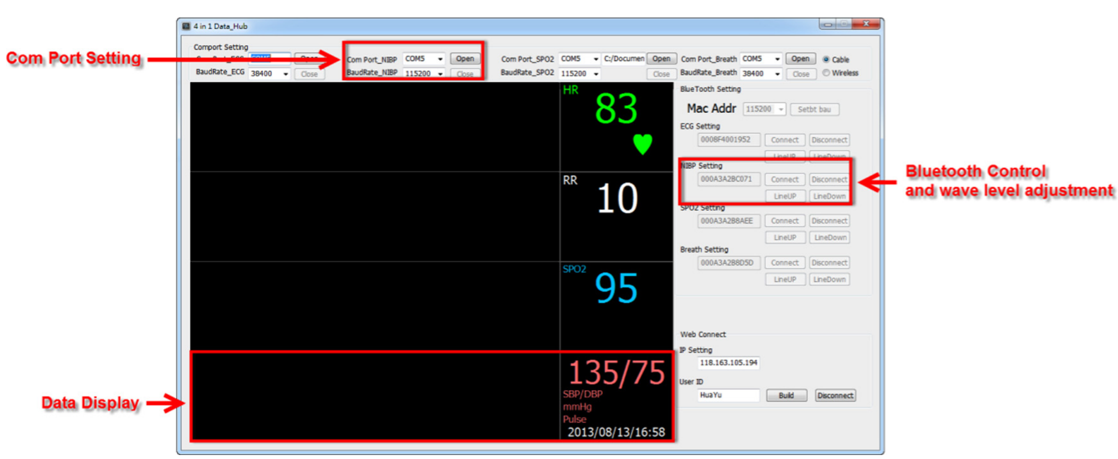

Fig. 32. ECG measurement interface.

screen, (a) for the Windows OS interface, (b) for the Android OS interface

5.2. Blood pressure measurement

The measurement methods used for the oscilloscope amplitude method will be inflated until the artery cuff blood vessels fill due to compression to achieve complete occlusion of the state. The pressure in the cuff is then slowly bled off until the pulsation crescendo, when the cuff pressure is the maximum amplitude of the bag when the measured pressure is the average pressure to the maximum amplitude of 50% compared to the center Previous systolic, diastolic next 80% compared to pressure, Fig. 29 is a blood pressure measurement screen, (a) for the Windows OS interface, (b) for the Android OS interface

5.3. Measured oxygen concentration

This study measured the oxygen concentration using sensors set on top of the subject's index finger. The oxygen concentration sensor is issued in two different wavelength light-emitting diode (Light Emitting Diode, LED) light sources. The emission wavelength was 660 nm red and 940 nm infrared light. A photo detector is set on lower end that transforms s the red and infrared light into an electric signal (A/D converter). The optical signal is where the tissue, bone and blood are absorbed more. Fig. 30 is an oxygen concentration measurement screen, (a) for the Windows OS interface, (b) for the Android OS interface.

5.4. Respiratory rate measurement

The electrode is affixed to the subjects at a location about three fingers width below the collarbone. The sensor uses the Impedance Pneumographym principle. The AC power is calculated using the slight changes in pulmonary impedance. By calculating the change in impedance the subject's respiration rate can be obtained. Fig. 31 is a screen measuring respiration rate, (a) for the Windows OS interface, (b) for the Android OS interface

6. Experimental results and analysis

This investigation used an Android application to write the operation interface and the major function for the heart electrical signal gauging and the blood pressure pulse signal; the eyeball rotation wave mode demonstrated it and automatically carried out long term data storage of a patient's disease for observation by a doctor.

6.1. ECG measurement interface

Automatic ECG storage and control, as shown in Fig. 32, can randomly set the interval. Automatic archiving can be saved by ECG intervals, and stored in the archive path set by individual folders. Manual ECG storage and control: when you press the archive button, the ECG can be stored in the archive path set up for individual folders.

Fig. 33 indicates the twelve ECG Lead measurement results. The ECG measurement process is the main reason because each ECG waveform lead works in three-dimensional space in different directions for the left atrium and left ventricle, right atrium and right ventricle location to be observed. In other words, limb lead (of the first six) is the heart, down, left and right two-dimensional space constituted by the vector direction of the variations observing the heart must lead with the chest (after the six-lead) up, down, before and after the observation of the vector direction in order to construct a complete three-dimensional space, in order to facilitate observation; doctors diagnose the necessary information to improve the accuracy and completeness.

6.2. Blood pressure measurement results

In the time measurement the cuff inflates until the arteries are compressed to achieve complete occlusion. The pressure in the cuff

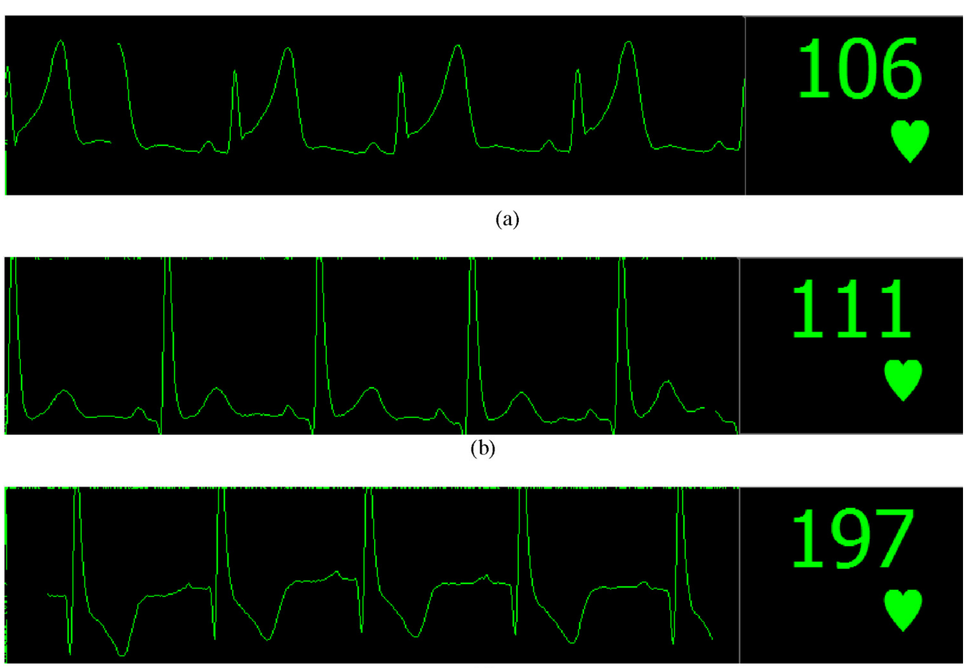

Fig. 33. (a) Lead I, (b) Lead II and (c) Lead III.

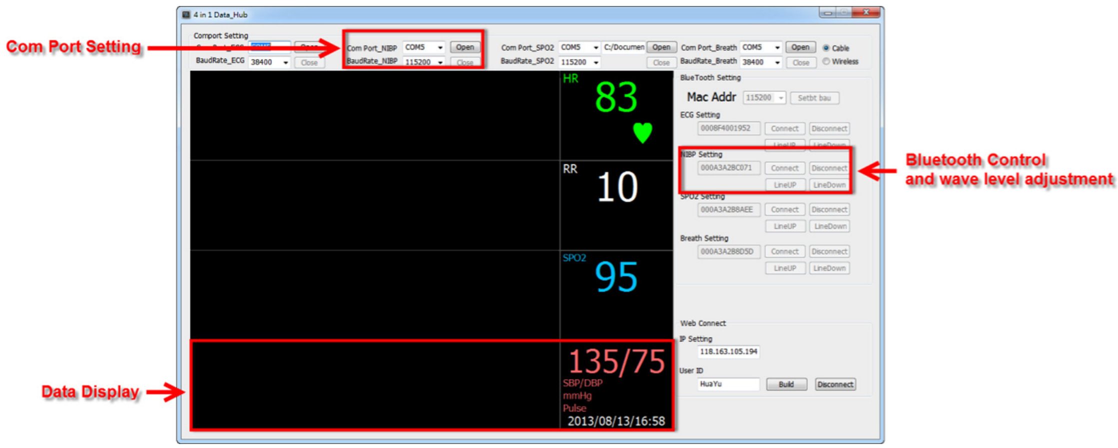

Fig. 34. Blood pressure measurement interface.

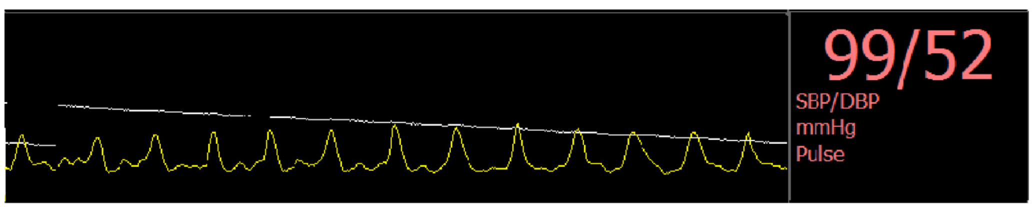

Fig. 35. Blood pressure measurement curve.

bag is slowly bled off until a pulsating crescendo is reached. When the maximum amplitude in measured in the bag pressure cuff, the pressure is the average pressure. The maximum amplitude of the center forward 50% compared with systolic blood pressure, diastolic blood pressure, compared to 80% later. Fig. 34 is a blood pressure measurement interface; Fig. 35 is a blood pressure measurement curve.

6.3. Saturation of oxygen measurement result

The common optical pulse oximeters are done using the optical properties of this oxygen concentration measurement. Fingers and earlobes site tissue layer is thin and full of blood capillaries and tubular, very suitable for measuring oxygen concentration measurement points and taking into consideration the use of convenience, most products using your finger as a measuring point. Oximeters may be issued on the installation of two different wavelengths of Light Emitting Diode (LED) light to 805 nm (or 940 nm) near-infrared light as H_b and H_bO_2 absorption rate benchmark. Another 660 nm red light is used to detect the Hb and HbO_2 difference in light absorption. When the two light sources alternately measuring radiation, penetrating finger tissue and blood source consists of a light sensor (photo detector) received. Using optical sensing and optical modulation techniques to compare two different intensity light penetrating through the signal processing, the oxygen concentration can be converted value. In addition, when systolic and diastolic pressure occur the arterial blood and skin tissue to light absorption rate is cyclical changes. Venous blood in the light absorption rate of change is small; arterial blood by the light absorption rate changes can know the pulse of the beating. Therefore, in addition to optical oximeter oxygen saturation measurements, but also provides pulse detection. Fig. 36 is a saturation of oxygen measurement interface; Fig. 37 is a saturation of oxygen measurement curve.

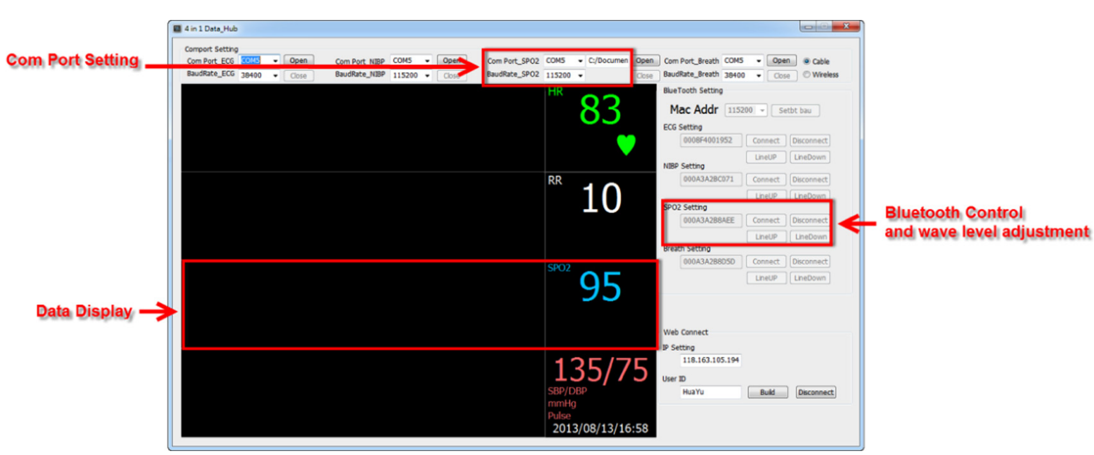

Fig. 36. Saturation of oxygen measurement interface.

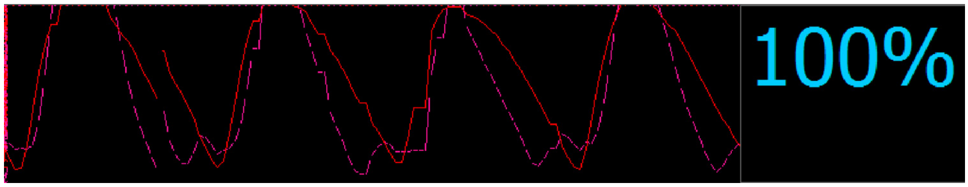

Fig. 37. Saturation of oxygen measurement curve.

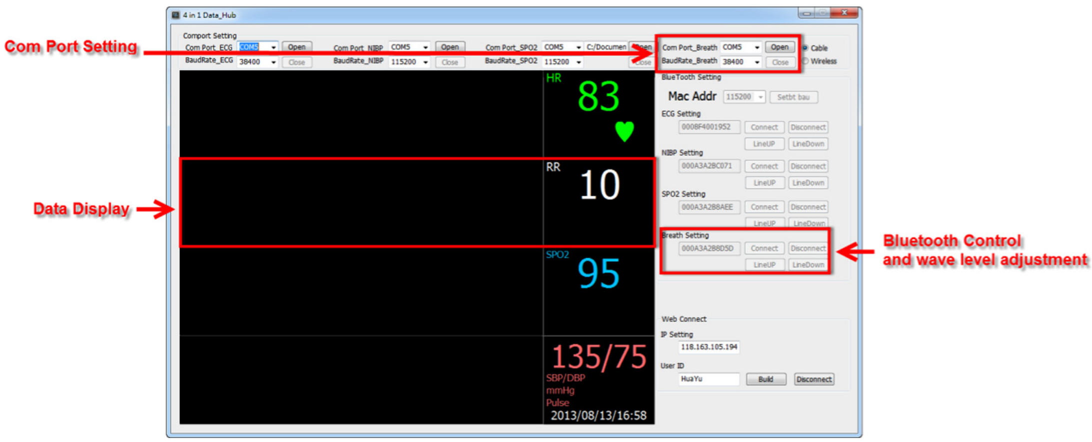

Fig. 38. Breathing measurement interface.

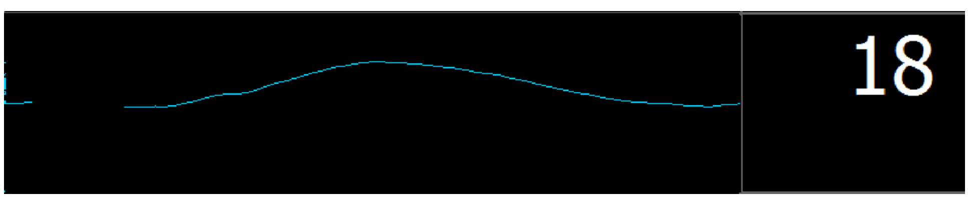

Fig. 39. Breathing measurement curve.

6.4. Breathing measurement result

This study used breathing sensors to monitor the breathing chest or abdominal breathing. It can be applied to stress management or relaxation training. In addition to measuring respiratory rate, this sensor can provide information about the depth of breathing. Finger blood flow is measured simultaneously using pulse change. This is a powerful tool that can be used to monitor a variety of heart rate variability (HRV) situations. When the respiratory rate is about 6 times per minute, the individual will find inspiration and exhalation will make the heart beat faster heartbeat slowed. Breathing out in the clothes wearable sensors are usually placed in the abdominal region, the sensor is placed in the middle of the area above the navel. Essay measured elastic straps attached to facilitate different size subjects' use. Various other methods to measure respiratory rate are commonly used, including impedance pneumography, and capnography which are commonly implemented in patient monitoring. Fig. 38 is a breathing measurement interface; Fig. 39 is a breathing measurement curve.

6.5. Application examples

Assuming the frame of discernment: Θ = {ECG, BP, Oxy, Breathing}, four different sensors on three measurement cycles. The measurement probability distribution functions are listed in Table 5.

The general information fusion algorithm, centralized and distributed fusion algorithm is compared with feedback fusion based on evidence theory computing, this study obtained fusion results after three measurement cycles be shown in Table 6.

Table 6 shows the general approach and centralized fusion result is almost the same. Accumulation of the "unknown" information in order to reduce to a 10^{-3} of this order of magnitude that it can be confirmed through the fusion of the uncertainty is reduced. The experiment uses a centralized approach requires only one

Table 5
Sensor measurement value.

Cycle	Items											
	ECG 1			Blood pressure 2			Saturation of Oxygen 3			Breathing 4		
	Normal	Abnormal	Unknown	Normal	Abnormal	Unknown	Normal	Abnormal	Unknown	Normal	Abnormal	Unknown
First cycle	0.5	0.4	0.2	0.5	0.2	0.3	0.8	0.1	0.1	0.6	0.1	0.3
Second cycle	0.6	0.3	0.1	0.7	0.1	0.2	0.9	0.05	0.05	0.7	0.1	0.2
Third cycle	0.7	0.2	0.1	0.6	0.4	0.1	0.9	0.03	0.07	0.8	0.1	0.1

Table 6
Evidence-based information fusion results after three measurement cycles.

Algorithm	Normal	Abnormal	Unknown
General	0.732	0.210	0.058
Centralized	0.812	0.152	0.036
Distributed	0.863	0.131	0.006

processor, but the state of the data integration space is large and the processor specifications is very high class. This study determined a centralized approach is better than the general method in calculating the amount. Table 6 clearly shows the fusion algorithm feedback distribution benefits. It significantly reduces the uncertainty of information, even such a small number of very negligible. If you want to measure whether the person is the goal of identifying risk groups and decision-making, so that the integration of those results can be fully explained by the measurement is a high-risk ethnic group. Of course, there are three feedback algorithm distributed algorithm to calculate the largest. It is recognized as the number of propositions in the framework of exponential growth. This study can be specified in the integration process of a certain threshold value, the probability distribution function in those countries below this value proposition is removed in order to reduce the dimension of the integration process, reduce complexity.

7. Conclusions and future works

This study measured physiological integration platform transmission equipment (Bluetooth, WiFi) will be sent to mobile handheld devices physiological signals (such as: personal computers, smart phones) on the display. We can also complete remote monitoring through a network of power and the establishment of a medical cloud system. The subjects' personal medical data storage is conducive for disease symptoms medical units' judgment and to save unnecessary waste of medical resources. This study measured physiological integration platform transmission equipment (Bluetooth, Wi-Fi) will be sent to mobile handheld devices physiological signals (such as: personal computers, smart phones) on the display. We can also complete remote monitoring through a network of power and the establishment of a system of medical cloud.

Backend Evidence-based analysis was used to identify the best physiological data subjects. A method to set the degree of risk, identify potential caused by the sudden death of cardiovascular disease, stroke and other diseases of the risk group was devised. Cloud computing, Android and wireless sensor network technology was used to achieve a variety of physiological signals that correctly classified Instant Screenshot Collection. The importance of the physiological signals measurement results reflected the actual image of the physiological behavior, for use by medical personnel for assisted diagnosis. Medical research institutes are participating in this research. Our findings will provide health care institutions for the elderly or mental patient behavior learning and rehabilitation assistance. A home healthcare networking community system can be set up, providing access to behavioral knowledge base services. Yang Feng Automation and Terasic Company will provide a test platform and testing personnel to help test and modify programs and make recommendations. Professional engineers are participating in research and development and consulting. This study contributes to interdisciplinary and integrated medical, psychological and physiological electronic information technology.

Acknowledgments

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