Multi Point Intelligent Temperature Synchronous Monitoring System Based on 5G Internet of Things Technology

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Abstract. A temperature monitoring and early warning system based on multi-point intelligent transmission is designed to monitor and early warn the temperature and reduce the risk and probability of fever. Combined with the clinical research data, the key factors and general range of temperature threshold setting were determined, and the system was designed by modules. The system is divided into individual temperature monitoring unit and system monitoring unit, and 2.4 GHz frequency band transmission technology is selected as the data transmission mode. In addition to the temperature of a single monitoring terminal exceeding 38.5 °C as the threshold to trigger the alarm, the temperature of a single monitoring terminal rises too fast and the temperature of several monitoring terminals is abnormal as the warning basis. The system data transmission is stable, and the fever warning is more sensitive, accurate and real. The system design can not only meet the monitoring needs of key units, but also adapt to the monitoring needs of groups.

Keywords: 5G Internet of things · Intelligent body temperature · Body temperature monitoring

1 Introduction

Body temperature refers to the internal temperature of the body, which is an important condition for the body to play its normal functions. It is also of great significance in daily health care, patient monitoring, clinical diagnosis and prevention and control of large-scale infectious diseases [1]. Accurate diagnosis of body temperature is helpful to understand the health status of the body, make a correct judgment of the disease, and facilitate the timely development of treatment. At present, the vast majority of hospitals collect the temperature of clinical patients mainly through manual timing measurement. The medical staff measure the temperature of each patient through the traditional mercury thermometer, record and draw the temperature curve manually, so as to help doctors analyze the patient's condition [2].

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This method not only consumes a lot of manpower, but also can not achieve large-scale measurement, real-time monitoring of the patient's temperature changes, so it can not find abnormalities in time, which may make patients miss the best opportunity for treatment, and frequent contact, for infectious diseases, it is easy to cause infection of medical staff [3]. In order to solve the above shortcomings of traditional medical monitoring, this paper is committed to applying the emerging multi-point intelligent sensor network technology to the medical industry in recent years, and designs and implements a body temperature monitoring system based on 5G Internet of things technology. According to the actual application needs of the system, 5G Internet of things tree structure network is adopted to realize large-scale, fast and accurate monitoring of group body temperature [4]. Timely detection of abnormal body temperature.

This research is based on a multi-point intelligent temperature stick. Through the mobile phone or hospital equipment, the body temperature can be monitored 24 h without interruption, and the high temperature or low temperature alarm function can be set at the same time.

2 Related Work

In reference [5], the design of multi-point temperature monitoring system for injection molding machine based on Lora technology is proposed. In the design of the system, a set of multi-point temperature monitoring system for injection molding machine based on Lora technology is designed. The system mainly controls the barrel temperature, inlet temperature, nozzle temperature, mold temperature and oil temperature. The temperature sensor collects the temperature signal and transmits it to the controller through Lora module, The results show that: the system can realize the accurate monitoring of multi-point temperature, provide accurate data for the temperature control of injection molding machine, which is of great significance to the temperature control of injection molding machine. The system can also be applied to the temperature collection, but the accuracy of the information collected by the sensor in the design of the system has some limitations, which needs further improvement.

Reference [6] proposed the research of ambient temperature compensation algorithm for two-dimensional optical codec link monitoring system. In order to solve the problem that the reflected optical pulse signal changes with temperature in the link monitoring system of two-dimensional optical codec access network, a temperature compensation algorithm is proposed. The interaction process between the retrieval pulse optical signal and two-dimensional optical encoder is analyzed dynamically, and the expressions of temperature drift of the center wavelength of coded fiber grating and the waveform of the reflected optical signal are derived, The dynamic relationship with temperature is given. The experimental system is set up, and the temperature coefficient of coded fiber grating center wavelength is 0.009 32 nm/°C. The system can work normally in –30–80 °C environment through temperature compensation, and realize accurate judgment of fiber link state. This method effectively compensates the temperature monitoring results and has a certain effect.

In reference [7], a wireless monitoring system of blast furnace hearth temperature field based on mesh wireless network is proposed. In order to improve the data transmission reliability and stability of the temperature field monitoring system of blast furnace hearth, and reduce the construction cost and operation and maintenance cost of the temperature field monitoring system, a wireless monitoring system of blast furnace hearth temperature field based on mesh wireless network is proposed. The data acquisition node of the system is installed on the outer wall of blast furnace hearth, and the analog signal of thermocouple is converted into digital signal, The transmission distance of thermocouple analog signal is greatly shortened, and the external interference is reduced. Then the temperature data is transmitted to the monitoring center through the mesh wireless network for analysis and modeling and monitoring of blast furnace hearth state. The mesh wireless data transmission network is based on IEEE802.11, Based on the optimized link state routing protocol, an adaptive routing protocol of dual path backup and an adaptive switching mechanism of active and standby routes are designed. A prototype system is built based on open wrt open source platform, which is installed and tested in a blast furnace of Laiwu Iron and steel plant. It can run stably for a long time and meet the needs of blast furnace hearth temperature field monitoring.

In view of the above problems, this paper designs a new multi-point monitoring system. The system designs a temperature monitoring and early warning system based on multi-point intelligent transmission to realize temperature monitoring and early warning and reduce the risk and probability of heating. Combined with clinical research data, the key factors and general range of temperature threshold setting are determined, and the system is designed by module. The system is divided into single temperature monitoring unit and system monitoring unit, and 2.4 GHz frequency band transmission technology is selected as the data transmission mode. Except that the temperature of a single monitoring terminal exceeds 38.5 °C as the threshold to trigger the alarm, the temperature of a single monitoring terminal rises too fast, and the abnormal temperature of multiple monitoring terminals is used as the basis for early warning. The data transmission of the system is stable, and the fever warning is more sensitive, accurate and real. The system design can not only meet the monitoring needs of key units, but also adapt to the monitoring needs of each group.

3 Methodology

3.1 Hardware Configuration of Multipoint Intelligent Temperature Synchronous Monitoring System

5g communication technology is the latest generation communication technology developed from the previous generation communication technology. At present, the two key technologies are wireless technology and network technology. At present, 5g technology is the focus of R & D worldwide. Different from the previous four generations of communication technologies, 5g technology has a variety of applications. In the future, the full use of 5g technology will greatly promote the development of relevant communication technology applications and drive the application development of some basic industries, such as relevant software chips and devices. In addition, the steady development of the Internet of things in the 5g technology era will lead to new progress in ICT Information Technology.

The smart body temperature sticker is divided into two parts: the battery module and the core module of the Internet of things. The core module is the development of China Mobile nbot technology chip. Multipoint intelligence is an emerging technology, which supports the cellular data connection of low-power devices in Wan. Its devices have the characteristics of long standby time and low power consumption. Through the temperature signal acquisition, the signal is digitized and stored in the nbot chip register [8]. After intelligent calculation, the number is sent to the antenna module, and sent to the relevant receiving equipment through the antenna. Signal interference screen is added to the equipment to avoid external signal interference and increase data accuracy. The multi-point intelligent temperature monitoring system uses the wristband terminal, which is the terminal collection node worn by the tested personnel, to measure the temperature data [9]. The multi-point intelligent temperature monitoring system is composed of coordinator data gathering and uploading and command sending node, routing data relay and forwarding node, and terminal collection node.

The system takes the ward building as the monitoring unit, and sets up a multi-point intelligent temperature monitoring network based on 5G Internet of things technology in each ward building. The clinical patients use the mobile temperature terminal node to measure the temperature [10]. The temperature data is transmitted and gathered through 5G Internet of things network, and finally connected to the computer of nurse station in each building through the serial port of the coordinator, The temperature data will be displayed on the computer connected to facilitate the observation, analysis and processing of temperature data by the nursing staff. Meanwhile, the temperature threshold value shall be set [11]. If the temperature of the wearer of the terminal node of temperature is higher or lower than the temperature threshold, an alarm signal will be sent to facilitate the timely occurrence of the condition. The terminal acquisition part is the lowest level of the whole system, which is mainly responsible for collecting the temperature information parameters of the wrist of the tested personnel [12]. When receiving the request of uploading the temperature data instruction, the measured data is uploaded to the coordinator node through 5G Internet of things network [13]. The terminal acquisition node integrates the temperature measurement part and data receiving and receiving part on the wrist strap terminal worn by the person under test. Although the size of the wrist strap terminal is small, its internal structure is not simple, including microprocessor, temperature sensor, power supply, etc. [14]. The transmission range of 5G Internet of things technology is generally 10–100 m. The upper computer can not only display the patient's temperature measurement data, but also display other data of the patient, but also can save the temperature data, and draw the temperature change curve according to the temperature data. The utilization of upper computer system C++ language is written [15]. Each patient is assigned a terminal acquisition node, and routing nodes are arranged in the appropriate places such as ward and corridor. A coordinator and a P are arranged in the office area of each ward building forms a separate network. The network nodes of the temperature monitoring system based on 5G Internet of things are divided into three types: the block diagram of terminal acquisition node, routing node and co node is shown in the Fig. 1.

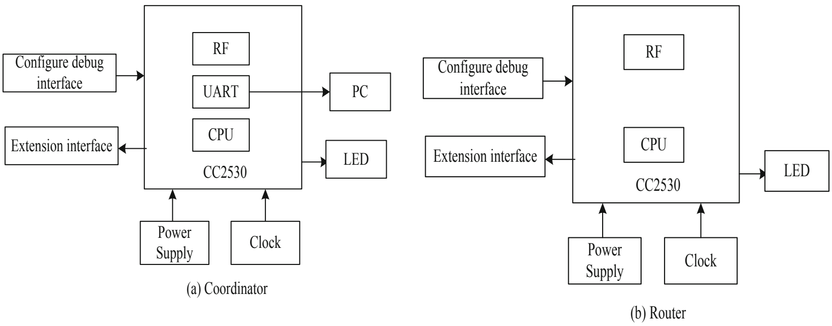

Fig. 1. System coordinator framework

The main function of coordinator node is to start 5G Internet of things multipoint intelligent network, receive data sent by terminal collection node and routing node, realize data aggregation and serial communication with PC in the system, which is simple in hardware structure. The routing node and coordinator node constitute a data transmission network, which is mainly responsible for receiving the data packets sent by the collection node, routing the data packets and sending them to the coordinator Routing nodes do not need to communicate with P °C machine communication, the hardware part can not contain the serial part. The functions of the terminal acquisition node mainly include status indication, data acquisition, body temperature data transmission with routing nodes, and reduce power consumption as much as possible while ensuring the performance. In order to be portable, the terminal acquisition node is required to be miniaturized. In this system, it is designed as a wristband terminal, which requires the hardware design to reduce peripherals as much as possible. Therefore, the acquisition node module does not include the debugging interface. When designing the circuit board, it adopts the button board type, which is connected to the power board. When using, the main control board is removed from the power board, Connect to the power expansion board with debugging interface, download the application program, and then reassemble it to normal use. Considering the working voltage range of 2 v–3.6 v, the system uses 3V button battery power supply, which can ensure the normal operation of the module and reduce the physical volume of the node. The sensor module is divided into analog sensor and digital sensor. The analog sensor converts the changing information into voltage or current output. The amount of data is often very small, and it needs to be processed by amplification circuit and conditioning circuit. In this way, the increase of external circuit will not only increase the physical volume of the node, but also reduce the accuracy of the measurement results. The system adopts the single bus digital temperature sensor TS1 of ist company, the output of the sensor is digital output mode. Only one data line is needed between the sensor and the microprocessor to realize two-way communication. The sensor is fixed on both sides of the lower abdominal trunk of the patient for temperature measurement.

3.2 System Software Function Optimization

In order to achieve high-precision and reliable measurement, the human body basic temperature real-time monitoring system needs to have six functions: data receiving, data filtering, real-time data display, body temperature historical data query, body temperature monitoring node maintenance. As shown in the figure, the PC client completes the above six functions through four modules: real-time monitoring interface, database operation, historical data query and node maintenance.

The real-time monitoring interface completes the setting of serial port parameters, the real-time display of data received by serial port, the display of node information, the control of data storage and the display of multi-channel data waveform. The database operation module includes three functions: querying the historical data table, creating a new data table to store and historical node to continue to store. It is mainly used to determine the location of the data to be stored after starting mysql. If it is a new node, create a new data table in the MySQL database; If it is an existing node, you can query the original data table of the node and continue to store it. Body temperature data query includes three functions: obtaining historical data list, data list display, and data waveform display. It displays the patient's body temperature data in different ways, which is convenient for medical staff to better understand the patient's body temperature change trend. Node maintenance includes node maintenance instruction sending, node maintenance countdown, node status parameter display and node status diagnosis result list display. It is mainly used to detect the node battery power to avoid the impact on the measurement accuracy when the node power is insufficient.

The goal is to establish a temperature monitoring system based on multi-point intelligent transmission, covering the main parameters of the system operation. The temperature monitoring and early warning system includes the determination of temperature alarm threshold, the selection of sensors, the evaluation of human-computer interaction performance, and the design of data transmission system.

In this system, the coordinator is responsible for the establishment of the network, data aggregation and serial communication with the host computer. After the coordinator establishes the network, it will broadcast beacon frames to the adjacent 5G IOT device nodes in the network, and then enter the multi-point intelligent monitoring state. After the routing node and the terminal acquisition node are powered on, they will first send beacon requests to find the network, and then receive the response from the coordinator, send network access requests, and only when they receive the permission response from the coordinator, can they join the network, At the same time, the coordinator adds it to its neighbor list as a child node and assigns it a unique 16 bit short network address.

After the coordinator establishes the network, it is always in the monitoring state, whether there are nodes joining and exiting, whether it receives the instruction information from the serial port, whether it receives the temperature data information uploaded by the terminal collection node or the routing relay node, and makes corresponding processing according to the information type. The terminal collection node is mainly responsible for collecting the body temperature of the wearer, The main function of the software program is to provide initialization of the system acquisition node, temperature acquisition and communication with the parent node. After power on, the initialization operation is carried out first, and then the network is added. The network access process is shown in the Fig. 2.

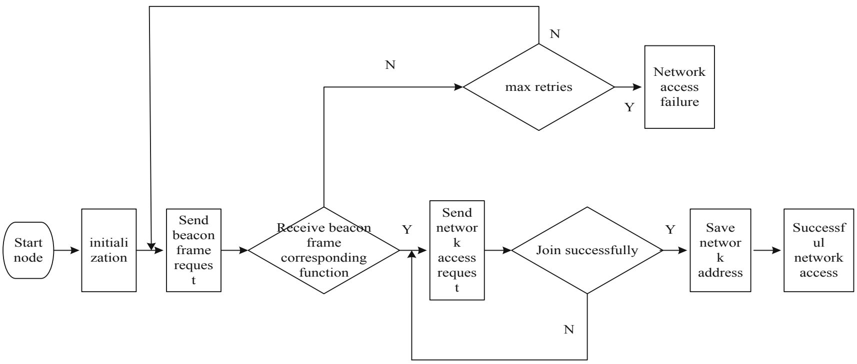

Fig. 2. Information retrieval process of terminal node accessing network

In the aspect of body temperature acquisition, this design provides two methods of body temperature data acquisition, instruction acquisition and timing acquisition. In this system, the timing function is called to set the timing time and the events to occur. When the timing time is up, the events will occur. After entering the network, the terminal acquisition node starts to judge whether it has received the data acquisition instruction from the coordinator, or whether it has reached the timing time. If it has not received the acquisition instruction and has not reached the timing time, the node enters the sleep mode to reduce the power consumption. In the timing mode, the temperature sensor constantly reads the temperature value, and does not send data upward when the body temperature is normal, In this mode, the terminal collection node packs and uploads the temperature data, and the temperature data is finally transmitted to the PC, which can ensure the timely detection and processing of abnormal body temperature.

Temperature data acquisition is mainly by means of temperature sensor. TSI is selected in this design digital temperature sensor, Kalman filter algorithm, takes the optimal estimation x–1, k–1 at k–1 as the criterion, predicts the state variable x (k | x–1) at the time, and at the same time observes the state to get the observation variable / x), then analyzes between prediction and observation, or corrects the prediction by observation, Thus, the optimal state estimation x (k | x) at time e is obtained. Based on the previous state, the current state x (klk–1) is predicted as follows, where x (k–1 | k–1)) is the initial state of the previous state.

$$x(k|k-1) = Ax(k-1|k-1) + Bu(k) \tag{1}$$

The previous state calculates the covariance P (k | k–1) of the current state prediction, where p (k–1 | x–1) is the covariance of the previous state, as shown in the formula, A2 represents the transpose matrix of A, and Q is the covariance of the system process.

$$P(k|k-1) = AP(k-1|k-1)A^T + Q \tag{2}$$

The optimal estimation of current state is as follows:

$$x(k|k) = x(k|k-1) + kg(k)(z(k) - Hx(k|k-1)) \tag{3}$$

The results show that:

$$kg(k) = P(k|k-1)H^T / \left(HP(k|k-1)H^r + R\right) \tag{4}$$

3.3 The Realization of Intelligent Temperature Synchronous Detection

The flow chart of the improved Kalman filter algorithm based on SVM is shown in the figure. The real-time data is input to the support vector machine classification model, and the model outputs a value. If the value is 1, the input data is basically stable, and the Kalman filter algorithm can be started; If the input value is not equal to 1, the input real-time temperature data will be judged again until the input temperature data is stable and the Kalman filter will be turned on.

The flow chart shows that the original temperature data is processed into four characteristic values and one label sample. The samples are divided into training set and test set. The training model is used to verify the model error by testing set and training set direction. The classification model with minimum training error and minimum test error is selected by adjusting the training parameters of the model. The actual data collected is sent to the classification model, and the input data is normal data/interference signal according to the output result of the model 1/11 (Fig. 3).

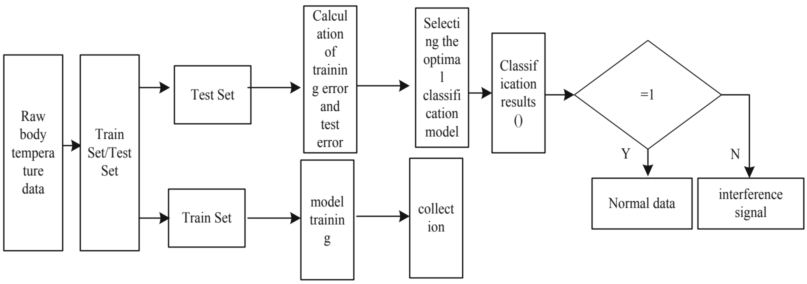

Fig. 3. Implementation process of support vector machine classification filtering algorithm

Because the appearance of interference signal is random, the probability of occurrence is small in the long-term measurement process. In order to improve the recognition accuracy of the classification model for the interference signal, according to the characteristics of the human body basic temperature measurement environment, more samples with the label of 0 containing the interference signal are generated. The expansion of sample data includes two steps: first, analyzing the characteristics of interference signals in historical data; In step 2, the sample is composed of four data. The first three data are normal data continuously measured in historical data. In the fourth data, according to the interference signal characteristics analyzed in step 1, 4000 samples with random interference signal in the temperature range of 250 c–420 c are generated by using random function, and each sample is labeled 0, The table shows the sample data with the label of 0 (Table 1).

Table 1. Extended samples and labels

sample	x1	x2	x3	x4	label
y1	36.50	36.53	36.51	43.5	0
y2	36.50	36.53	36.51	42.5	0
y3	36.50	36.53	36.51	49.5	0
y4	36.50	36.53	36.51	41.5	0
y5	36.50	36.53	36.51	55.5	0
y6	36.50	36.53	36.51	13.5	0
y7	36.50	36.53	36.51	21.5	0
y8	36.50	36.53	36.51	39.5	0
y9	36.50	36.53	36.51	18.5	0
y10	36.50	36.53	36.51	56.5	0

When the node starts up for the first time, it will initialize the system, and then automatically search for 5G Internet of things network signal. When searching the network formed by router or coordinator, it will send the network access request, and receive the reply, it will get an 8-bit ID number assigned by route or coordinator. At this time, it can collect and transmit the relevant data. After the temperature sensor array collects the temperature data, the data is packaged according to the data frame format shown in the table and sent to the routing or Coordinator (according to the network of the node). In practice, patients wearing data collection nodes can move freely, and the nodes will be separated from a subnet. At this time, the node network status is generic app_ NWK state judgment. When the state is devnwk-orphan, execute system reset() system restart, and then automatically join the new network again (Fig. 4).

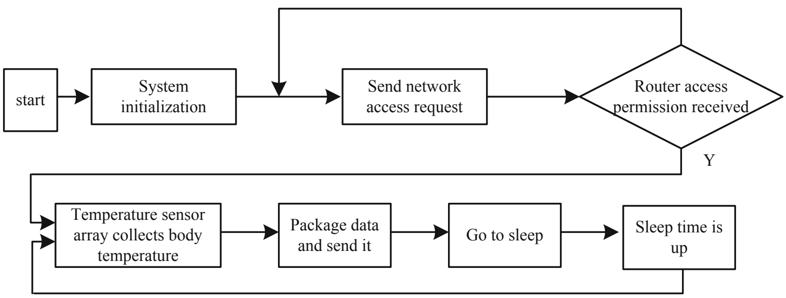

Fig. 4. Temperature data acquisition node control program

Temperature monitoring client software is based on Visual Studio 2010 platform MFC, using C++ high-level programming language development. Microsoft's visual studio 2010, which supports multi language development, is mainly used for the development of Windows platform applications. MFC is a basic class library provided by Microsoft. It provides a large number of windows APIs encapsulated in C++ classes, and also includes an application framework. By using this framework, software developers can simplify a series of routine and tedious work, such as windows AP worker registration, windows AP registration, and so on Generation and management router in this system is mainly responsible for data forwarding, and the control program flow chart is shown in the figure. After the system is initialized, a subnet is set up and a routing table is set up. After receiving the data, judge the data. When the data is a node's network access request, verify the legitimacy of the node, assign an 8-bit network ID and send the network access permission to the node; When the data is forwarded by the node or the upper route, the router will forward the data again or directly send it to the coordinator according to the routing table information, so as to realize the real-time collection and monitoring of body temperature changes, and ensure the operation effect of the system.

4 Results and Discussion

The instrument monitoring was carried out according to the metrological technical specification "calibration specification for medical electronic thermometer" issued by the General Administration of quality supervision, inspection and Quarantine of the people's Republic of China. The monitoring objects are 10 temperature collection terminals and 1 indicator unit of multi-point intelligent continuous temperature monitoring system. The ambient temperature is 250 °C. The relative humidity is 35%. The temperature monitoring methods of critical patients were discussed. Firstly, a multi-point intelligent continuous temperature monitoring system is established; Secondly, the multi-point intelligent continuous temperature monitoring system is used to monitor the body temperature of healthy volunteers, and the feasibility of the system is verified; Thirdly, the multi-point intelligent continuous temperature monitoring system is applied to the temperature monitoring of patients after cardiac surgery and compared with the body core temperature; Finally, on the basis of the previous three parts, the multi-point intelligent continuous temperature monitoring system was applied to the temperature monitoring of critically ill patients. The temperature of the upper orbital temperature measuring point and axillary temperature measured by the multi-point intelligent continuous temperature monitoring system were compared with those measured by the mercury filled glass thermometer. The temperature of patients was measured every 4 h and every 1 h, And the relationship between the 24-h average body temperature and APACHE II score, white blood cell count, neutrophil percentage, procalcitonin and other blood test indexes. The measuring equipment includes: standard thermometer, constant temperature bath, water three-phase point bottle, reading telescope, outside micrometer, steel ruler, etc. The measuring equipment, technical requirements and application are shown in the Table 2.

Table 2. Measuring equipment and technical requirements.

measuring equipment	technical requirement	purpose
Thermostatic bath	The temperature difference between any two points in the working area shall not exceed 0.01 °C, and the temperature fluctuation at constant temperature shall not exceed ± 0.01 °C/min	Provide temperature source
Standard thermometer	Measurement range: (345 –445) °C Graduation value: no more than 0.05 °C	As measurement standard
Reading telescope	—	Read the indication of standard thermometer
Water triple point bottle	—	Zero position of measurement standard
Steel ruler	(0–300) mm	Measure the outer diameter of the temperature probe
Outside micrometer	(0–25)mm	Measuring the insertion depth of temperature probe

The indication error of the temperature monitoring system is calculated according to the formula.

$$\Delta t = E_t - (t_0 + t_\mathrm{d} - a_0) \tag{5}$$

Before calibration, the multi-point intelligent continuous temperature monitoring system is checked for measurement range, resolution, appearance and prompt function. The results of all inspection meet the standard requirements.

The calibration results of indication error meet the specification requirements. The calibration results of indication error are shown in the Table 3.

Table 3. Calibration results of the indication error

Calibration temperature point (°C)	Expanded uncertainty (°C)	Indication error of calibrated temperature monitoring system (°C)	freedom
25	0.008	0.01	50
35	0.005	0.00	50
37	0.003	0.00	50

(*continued*)

Table 3. (*continued*)

Calibration temperature point (°C)	Expanded uncertainty (°C)	Indication error of calibrated temperature monitoring system (°C)	freedom
39	0.005	0.00	50
41	0.001	0.01	50
45	0.010	0.01	50

The mean axillary temperature measured by multi-point intelligent continuous temperature monitoring system was 36.31 ± 0.79 among the 200 measurements in 100 patients °C. The average temperature of the intraorbital temperature measurement point was (36.33 ± 0.80) °C. The mean axillary temperature measured by mercury filled glass thermometer was (36.39 ± 0.78) 0C. The temperature results measured by the three methods are shown in the Tables 4 and 5.

Table 4. Temperature measurement results of three temperature measurement methods

Temperature measuring tool	Temperature measuring part	Mean ± Standard deviation (°C)	Mean ± Standard deviation (°C)	95% confidence interval (°C)
Wireless continuous temperature monitoring system	Intraorbital and supraorbital thermometry	36.39 ± 0.78	35.15,38.10	35.60 – 37.35
Mercury filled glass thermometer	armpit	36.31 ± 0.79	35.10,37.90	35.50 – 37.10
Wireless continuous temperature detection system	armpit	36.33 ± 0.80	35.10,38.00	35.55 – 37.15

Table 5. Pearson correlation analysis of two measurement tools

group	Correlation coefficient (r)	P value
Axillary temperature of thermometer and monitoring temperature of upper orbital thermometer	0.941	0.000
Thermometer axillary temperature and monitoring axillary temperature	0.970	0.000

The paired t-test results of axillary temperature measured by multi-point intelligent continuous body temperature monitoring system and mercury filled glass thermometer showed that the axillary temperature measured by the two methods was at a = 0.05 level, and the difference was not statistically significant (P > 0.05), as shown in the Table 6.

Table 6. Comparison of axillary temperature measured by different methods

group	df	T value	P value	Difference(°C)	95% confidence interval (°C)
Thermometer axillary temperature and monitoring axillary temperature	199	1.519	0.604	– 0.041 ± 0.283	– 0.859 – 0.003

Pearson correlation analysis showed that the axillary temperature measured by the multi-point intelligent continuous temperature monitoring system was highly positively correlated with that measured by the mercury filled glass thermometer (r = 0.970, P < 0.05, the scatter plot had a linear trend, the simple linear regression model was fitted, and the regression equation was listed, Within the 95% consistency limit, the maximum absolute value of the difference between the two is 0.320 c, and the average difference is 0.070 c, indicating that the two have good consistency, as shown in the figure below (Figs. 5 and 6).

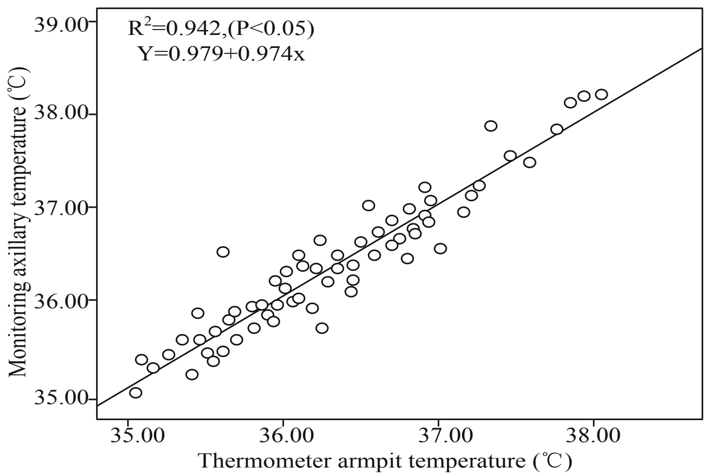

Fig. 5. Scatter analysis of relationship between axillary temperature of thermometer and monitoring axillary temperature.

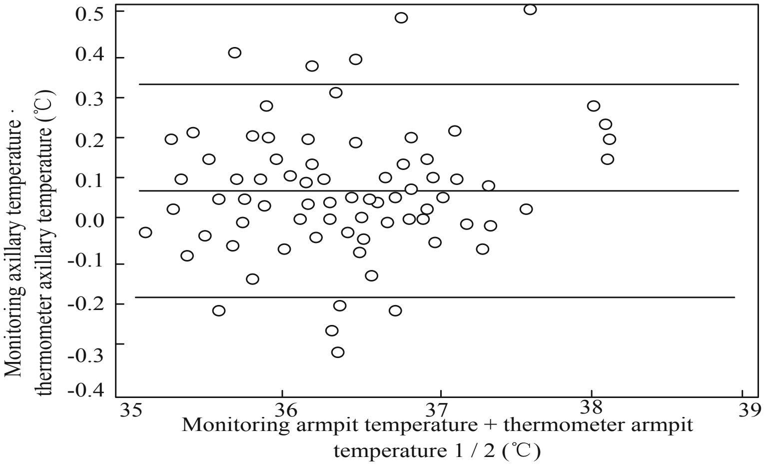

Fig. 6. The dispersion value of thermometer axillary temperature and monitoring axillary temperature.

5 Conclusions

In the current medical practice, real-time monitoring of physiological parameters can effectively obtain the specific physiological conditions of patients, which has positive significance for early detection and treatment of diseases. As an important data in patient monitoring, body temperature has outstanding reference value for specific disease diagnosis and treatment. This paper studies and designs a temperature monitoring system based on multi-point intelligent transmission technology, and makes a specific analysis of the hardware design and software design of the system, which has a prominent guiding role in the practical work.

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