J. Electrical Systems 20-10s (2024): 746-758

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Exploring Human-Computer Interaction and Product Design of Military Smart Wearable Devices in a Digitalized Environment

Abstract: - This paper designs a military intelligent wearable device, aiming at realizing human-computer interaction and monitoring military status signs and data characteristics through this device. First of all, the overall system of the product contains temperature and humidity module, blood pressure detection module, heart rate measurement module and display module, and the extracted feature data are subjected to data intelligence preprocessing. Then the pre-processed feature data is functionally compressed and an artificial intelligence feature classification model is constructed, through which the compressed feature data is analyzed and displayed. Finally, the interactive performance of the wearable device is completed through data intelligent processing and device relevance calculation. After application analysis, it is found that the actual monitoring error is below 0.1 under different fatigue levels, and the specificity and positive prediction value of the wearable system can reach up to 100%. The highest accuracy of monitoring the physical state of military personnel is 99.31%, in addition to monitoring the heart rate in sedentary state and exercise state, with an average error value of 1.24 and 1.29. Therefore, the smart wearable device designed in this paper can well realize human-computer interaction, and the performance of product design is superior.

Keywords: smart wearable device; human-computer interaction; military status signs; blood pressure detection; product design

1. Introduction

With the rapid development of high technology and the gradual improvement of the public's living standard and consumption level, smart wearable products such as Google Glass, smart bracelet, VR, etc. have entered the public's vision one after another, and smart wearable devices are gradually leading the new hotspot of electronic consumption [1-2]. In addition, these smart wearable devices can better help soldiers perceive the external environment they are in, process information more efficiently with the assistance of computers, networks or other facilities, and realize seamless communication [3]. The future battlefield is gradually to informationization, digital direction change, in this new war mode, the concept of the traditional soldier combat unit has produced a qualitative leap, the high and low level of the combat capability of the warfighting system of the single soldier directly determines the battlefield overall combat power of the strong and weak [4]. Intelligent wearable devices as the typical equipment of the warfighter system in the military field is also more and more prominent in the demand [5]. Military equipment pays more attention to the easy operation of the equipment, easy to carry, and can ensure the fast and accurate transmission of data and the timely and long-lasting supply of energy.

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This paper studies the design of military smart wearable device products, in the design process, the temperature and humidity module uses temperature and humidity sensors to achieve the measurement of temperature and humidity, and sends the resulting data to the display screen to show, and through the program to determine whether it is abnormal and whether it is alarmed. The blood pressure detection module adopts pressure sensor and oscillometric method to realize blood pressure signal acquisition, and the final data is also shown through the display. The heart rate measurement module measures the instantaneous heart rate by measuring the pulse and calculates the heart rate per unit time, and the result is sent to the LCD display. The display module is a dot matrix LCD module specialized in displaying letters, numbers, symbols, etc., providing various control commands. Through the multi-module collaboration and the human-computer interaction technology of military smart wearable devices, the human-computer interaction and product design of military smart wearable devices are realized to explore and provide a theoretical basis for the product design of future military smart wearable devices.

2. Related Words

Wang, T. et al. used Shinjuku analysis to examine the heart rate monitoring performance of a smart bracelet for wearable devices in military environments, emphasizing the uncertainty of wearable technology at this stage during high-intensity exercise [6]. Zhang, X et al. are working on wearable devices by designing hiking shoes based on a solar energy device, and the idea of this solution design can be used as a reference for the military field [7]. Kuo, C et al. designed a sensor-based wearable device for military activities for real-time monitoring of head impact injuries and so on. After inputting the head time, video fit and post-processing techniques to improve the performance of head impact injury research [8]. Sharma, P. K et al. proposed that 5G network has a positive effect on the performance enhancement of military wearable devices.Firstly, they explained the classification of wearable technology and the correlation between each attribute. Then designed a wearable smartwatch architecture and finally showed that 5G networks can be utilized for military applications [9].

Mo D H et al. proposed a digital dual human-machine interface sensor that can meet the needs of human-computer automation collaboration in Industry 5.0.DT-HMIS allows the user/patient to add, update, delete, query, and recall previous memories DT fingerprint models and programmable logic controllers, logic programs to be manipulated or recalled using the programmable controller input and output interfaces. DT computer vision based HMI sensors that reflect user commands without additional equipment help in interacting with the virtual world [10]. Snow L et al. adequately measure the human-computer interaction of quantum decision makers and controllers, given a series of human decisions over time, controllers can provide feedback to adapt these decisions to a specific decision [11]. Wang Y et al. provide a humanoid intelligent products by preparing suitable design, production and integration strategies for efficient user and human-computer interfaces. The sandwich structure of the platform consists of a dielectric light-emitting layer and surface electrodes made of silicone elastomer embedded with phosphor and silk protein ionomer, respectively. Both materials are stretchable and elastic, making the HIDP skin as suitable as any material for a wide range of weather conditions and complex mechanical stimuli [12]. Ismail M S focuses on the limitations of artificial intelligence and develops a game theory based model of human-computer interaction. It is argued that an AI system is considered generalized if it can perform well in both zero-sum and general games [13]. Miao J et al. prepared an ultrathin two-dimensional titanium carbide nanosheets with metallic conductivity, hydrophilic surfaces, and excellent flexibility as a new high-performance transparent conductor, which was further designed to be used in wearable electroskin. The solution MXene conductive ink was obtained by simply etching the AI in the MAX phase for large-area spraying to obtain the transparent material. The flexible, transparent and conductive MXene-based electrodes have a square resistance of 200 Ω/sq along with a high optical transparency of 60% @ 550 nm, which is sufficient for electronics-free applications [14].

In general, smart wearable devices can be divided into two categories, one is relatively independent and comprehensive functions, can not rely on computers or smartphones and other terminals to realize the complete or partial functions of the device. The other category focuses only on a certain type of application function, and needs to be used in conjunction with computers or smartphones and other terminals. Specifically, driven by the civilian field, the introduction of smart wearable technology into the military field has a certain practical value.

3. Overall system design of human-computer interaction equipment

3.1 System architecture

The design idea of human interaction device in digital environment is based on multi-module role collaboration. Figure 1 shows the overall framework of the system, in the military smart wearable devices to the main microcontroller, microcontroller usually choose the model for the AT89C52. DHT11 temperature and humidity sensors, pressure sensors MPXV5050GP, HK-2000A integrated pulse sensor detection of physiological signals, after the signal amplification, analog-to-digital conversion, sent to the microcontroller signal processing, the results of the process is transmitted to the LCD1602. The results are transmitted to LCD1602, and finally the program determines whether there is an abnormal condition, and if so, the alarm is raised. At the same time, in order to make it easy to wear, the system is centrally mounted on an elastic wristband in the shape of a wrist guard to realize the real-time detection of human body signs [15-16].

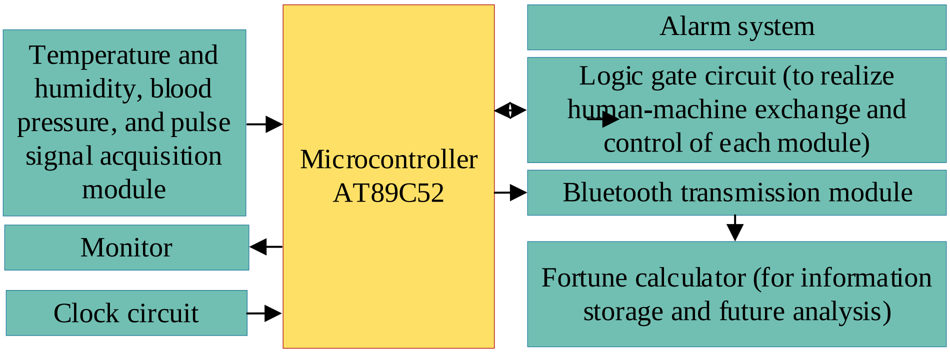

Figure 1 System overall architecture

3.2 Module Composition

3.2.1 Temperature and humidity module

Intelligent sensing equipment, the use of DHT11 temperature and humidity sensors to achieve temperature and humidity measurement. DHT11 is a single-wire serial interface, so that the system integration becomes easy and fast, small size, low power consumption, signal transmission distance of up to 20 meters or more. Its measurement range is 20-90% RH, 0-50 ℃. Measurement accuracy control in ± 5% RH, ±2℃. Measurement resolution is 8bit temperature, 8bit humidity respectively.DHT11 outputs digital signals with high reliability and excellent long-term stability. The sensor consists of a resistive humidity sensing element and an NTC temperature measuring element, and is connected to a high-performance 8-bit microcontroller. When the system is in operation, the DATA pin is used for communication and synchronization between the microcontroller and the DHT11, with a communication time of 4ms, and the data is divided into a decimal part and an integer part.DATA transmits the 40-bit data in the order of the high first, and the data format is an 8-bit humidity integer, a humidity decimal, a temperature integer, a temperature decimal, and 8-bit checksum data. If the data is transmitted correctly, i.e., the check data is equal to the last 8 bits of the 40-bit data result. Then the microcontroller will send the resulting data to the display to show, and through the program to determine whether the exception and whether the alarm.

3.2.2 Blood pressure detection module

This design uses the pressure sensor MPXV5050GP and the oscillometric method to realize blood pressure signal acquisition, Figure 2 shows the MPXV5050GP and its peripheral circuit. The microcontroller is programmed to control the speed of inflation and deflation to realize the automatic inflation and deflation of the airbag by the PUMPKPMl4A air pump.The blood pressure digital signal output from the MPXV5050GP is directly sent to the microcontroller for processing, and the result is sent to the LCD screen for displaying. The MPXV5050GP internally integrates an X-type pressure-sensitive sensor, a resistor compensation network for correcting the size of the output error, an op-amp, and an output circuit.The MPXV5050GP sensor integrates a X-type pressure-sensitive sensor, an op-amp, and an output circuit. MPXV5050GP sensor through the sensor's internal operational amplifier output cuff pressure signal from the ADC809 IN0-IN7 in any one of the inputs, through the A/D converted to digital values, the outputs D0-D7 and the microcontroller port P0 connected to the EOC through the inverse gate and the microcontroller's INT1 connected to the CLK and the microcontroller ALE after the bisection connected to the frequency. EOC is connected to INT1 of the microcontroller via inverse gate, and CLK is connected to ALE bisection of the microcontroller. In summary, the blood pressure acquisition and detection in smart wearable devices is completed [17].

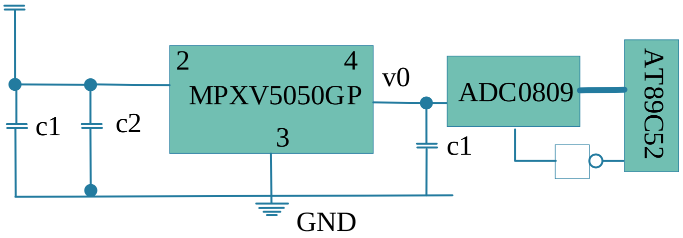

Figure 2 MPXV5050GP and its peripheral circuits

3.2.3 Heart rate measurement module

Digital environment, the method of measuring pulse to measure the instantaneous heart rate, usually the heart beat is synchronized with the pulse, so only need to measure the number of pulse beats per minute [18]. Pulse sensor selection HK-2000A integrated pulse sensor, piezoelectric principle of signal acquisition, analog signal output, the output is synchronized with the pulse fluctuations in the pulse signal, pulse fluctuations once output a positive pulse. The power supply voltage is 3-12VDC, the pressure range is -50-+300mmHg, and the overload is 100 times. Output high level > VCC-1.5V, output low level < 0.2V. Pulse waveform output from the pulse sensor is sent to the external interrupt interface P3.2 of the microcontroller, and an interrupt is generated for every positive pulse. The number of interrupts is counted and the number of interrupts per unit time, i.e. heart rate, is calculated and the result is sent to the LCD display.

3.2.4 Display module

The content displayed by the display module is mostly in the form of data, words, symbols, etc., and the number displayed each time is in the range of. If there are 16 characters per line, two lines need to be displayed. In the display module, there are many dot matrix character bits, because one character can be obtained through a dot matrix character bit, and there are intervals between dot matrix character bits, and there are also intervals between the displayed lines. Therefore, the main purpose of the dot matrix character bit is to space characters and lines.

4. Realization of human-computer interaction for military smart wearable devices in a digital environment

4.1 Intelligent preprocessing of data

Based on the actual role of military intelligent wearable devices, artificial intelligence data preprocessing is applied. First, feature data must be obtained and multiple feature data must be classified, resulting in feature data being distributed in various regions. Data monitoring is performed through widely distributed feature data [19]. At this time, if the feature attributes, test sets, and training sets are all in a widely distributed state, these data sets have a significant impact on the feature classification of military intelligent wearable devices and affect the classifier performance to a certain extent [20]. Therefore, it is necessary to perform regional segmentation on the feature data of human information to promote the wide distribution of feature data.

Because human function data is complex and dynamically changing, the data weight cannot be completely unified. Therefore, the improved feature data selection is shown in formula (1):

$$tf_{ik} = \frac{f_{ik}}{\sum_{j=1}^{t} f_{ij}} \tag{1}$$

Where: tf_{ik} represents the frequency of the meta-data in the k rd of the wearable device feature data sample x_i, and f_{ik} represents the number of times the meta-feature data appears in this sample.

$$idf_k = \log\frac{N}{n_k} \tag{2}$$

Where: N represents the total number of sample points of the wearable device feature data and n_k represents the number of occurrences of the source data samples. The final weights are calculated as shown in equation (3):

$$\omega_{ik} = \frac{(\log(f_{ik})+1)\cdot\log(N/n_k)}{\sqrt{\sum_{k=1}^{t}\left[(\log(f_{ik})+1.0)\cdot\log(N/n_k)\right]^2}} \tag{3}$$

In the human-computer interaction technology of military smart wearable devices, the weights of feature sample frequencies cannot be 0, so the initial value is assumed to be 1 in this study.

4.2 Calculation of equipment relevance

In the process of simplifying the feature vector of body function, it is necessary to effectively distinguish the importance of data and accurately select the feature data with strong importance [21]. To distinguish the importance of data, it is necessary to obtain the corresponding feature information data through the estimation of feature data information and decompose the process of selecting important feature data. Assume that term $T=\{t_1,t_2,t_3,\ldots,t_n\}$ is the complete set of features obtained after word segmentation of big data, and use $\{1,2,3,\ldots,m\}$ to represent the weight M set. Its feature selection is to determine a mapping from to , that is:

$$F-Selection: T \to M \tag{4}$$

This projection function is a function of the computation of the weights of the feature data of the smart wearable device, and subsequently a value of N is taken, and it is considered that some of the feature data in T with weights greater than N are the selected features, denoted as T_s. It is T_s that is used as the basic reference standard feature for the representation of the big data in the subsequent intelligent classification process. According to the algorithm to compare the correlation in the vectors of modules to be tested with the vectors of feature samples, the samples with the highest correlation are taken as the categories of the instances to be tested in order to realize the compression of the AI features.

4.3 Interactive Performance Enhancement

To improve the product interaction performance, this paper introduces Bayesian theorem in military smart wearable products.

If the training set and its single category are combined to form T, if the single category is $c \in C$, and the number of attributes is n, then $x=(a_1,a_2,\ldots,a_n)\in X$ exists, and $x=(a_1,a_2,\ldots,a_n)\in X$ is satisfied.

Taking the set of n quantitative attributes as a reference, the operation of $p(x\,|\,c)$ is obtained. At this time, the Bayesian classifier will consider that all attributes are independent individuals that are not connected. At this time, the operation of $p(x|c)$ can be expressed as:

$$p(x|c)=\prod_{k=1}^{n} sim(U,V) \tag{5}$$

After classification, the personal information is obtained:

$$p(c|x)=\frac{p(a_1|c)p(a_2|c)\ldots p(a_n|c)p(c)}{p(x)} \tag{6}$$

The calculation weights for each category $p(x)$ in formula (6) are the same. In the process of sample classification, the ideal state of the smart wearable device is as follows:

$$N(x)=\max\frac{p(c)\prod_{k=1}^{n} p(a_k|c)N(c)}{N(c,a_k)} \tag{7}$$

After obtaining the ideal state, interactive design can be realized through the calculation of $N(c)$ and $N(c,a_k)$, thereby improving the performance of the entire system.

If all the dimensional attributes of a sample data A of the test object are expressed as A_i, then:

$$cate\Pr o^{*}=N(c_j,a_i) \tag{8}$$

$$cate\Pr o/N(c)^{n-1} \tag{9}$$

Next, sort the N -type interaction values, and the attribute corresponding to the maximum probability value is the human body function information. In the design of military smart wearable devices in a digital environment, the application of artificial intelligence extraction can make information transparent and analyze body functions more intuitively. The proposed source group is divided into m categories. c_m compared with the problem of dividing the test information into m categories, adhering to the best design principles, get:

From the above, it can be concluded that the Simple Bayesian Intelligent Classifier is a classifier that can save a lot of classification time and is less error tolerant, and the proposed source group is partitioned into m category. c_m As opposed to the problem of classifying the test data into m categories, it can be calculated by constructing the following classification model. The inference can be obtained:

$$B(x) = \arg\max \frac{\prod_{k=1}^{n} N(c, a_k)}{N(c)^{n-1}}, x = (a_1, a_2, \ldots, a_n) \tag{10}$$

In the formula, N is the total index of physical function, $N(c)$ is the value of item c, and $N(c, a_k)$ is the frequency of human-computer interaction a_k in item c. Through the above calculation, artificial intelligence algorithms can be introduced into the human-computer interaction design of military smart wearable devices, so as to develop a new way of human-computer interaction for military smart wearable devices that is more in line with human needs [22].

5. Military smart wearable device interaction design application analysis

5.1 Wearable device performance testing

Selected 1000 samples as test samples, including military personnel signs of a variety of information combined, a variety of information fusion subjective fatigue level grade and fusion model prediction results comparison, Figure 3 for a subject military personnel exercise the whole process of fatigue level prediction results. It can be seen that the fatigue level assessed by the method of this paper is basically consistent with the results of subjective discrimination of fatigue level, the error is below 0.1, and the wearable device can better meet the needs of human-computer interaction.

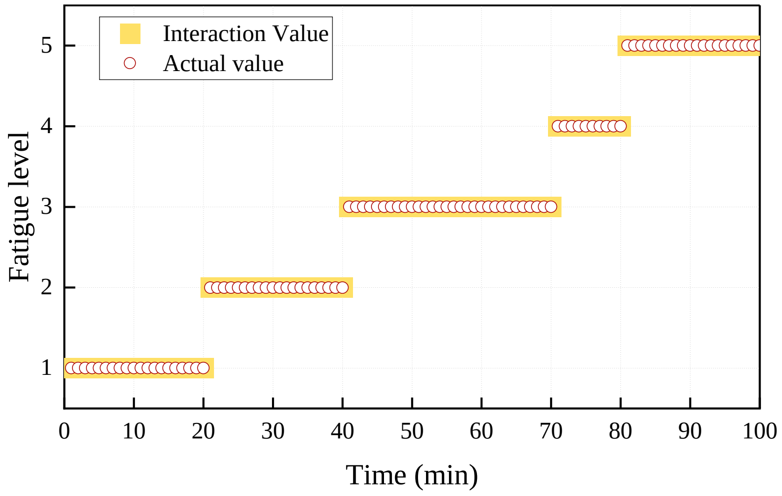

Figure 3 Comparison of fatigue assessment results and subjective judgment

In order to visually quantify the performance of the system in this paper, the subjective judgment of fatigue level was divided into five levels, and the wearable device was evaluated using several indexes of sensitivity, specificity, positive predictive value, and accuracy. The results of the evaluation metrics are shown in Figure 4, where the sensitivity of the wearable system is above 90% for different fatigue levels, and the specificity and positive predictive value can reach up to 100%. It is verified that the proposed wearable device design method has obvious advantages in determining the fatigue level of military personnel in the digital environment.

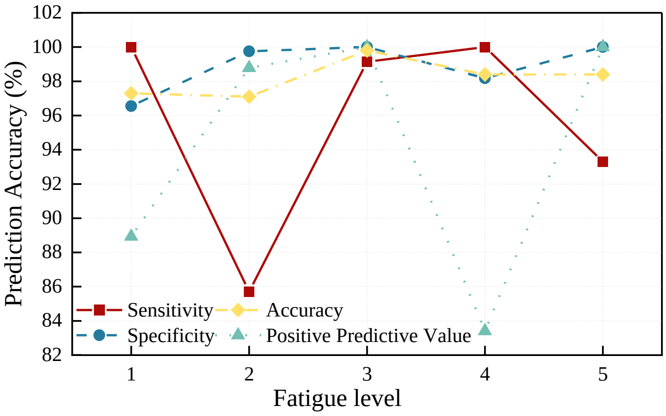

Figure 4 Evaluation index results

5.2 Monitoring accuracy tests

In order to verify that the military smart wearable detection product designed in this paper accurately monitors the body state of military personnel, four experiments are conducted on four military personnel. The monitoring system constructed based on MATLAB, the monitoring system constructed based on BP neural network, and the monitoring system designed in this paper are used respectively. The first experiment was conducted to monitor the body state of each soldier standing silently, and the second experiment was conducted to monitor the body state of each soldier running 100 meters. The third experiment was conducted to monitor the physical state of each soldier running 1000 meters, respectively. The fourth experiment was conducted to monitor the physical state of each soldier who had not slept for 24 consecutive hours, respectively, and the data monitored by each system was eventually averaged. The accuracy of military personnel's physical state monitoring under the three monitoring systems is shown in Table 1. The monitoring system constructed based on MATLAB has the highest accuracy of 83.41% for monitoring the physical state of military personnel in the 4 groups of experiments, while the monitoring system constructed based on BP neural network has the highest accuracy of 77.37% for monitoring the physical state of military personnel, and the monitoring equipment designed in this paper has the highest accuracy of 99.31% for monitoring the physical state of military personnel, which shows that, although after the 4 groups of experiments, the monitoring system designed in this paper has the highest precision for each group of experiments.

Table 1 Results of accuracy of soldiers' physical status monitoring

Experimental times	Accuracy of monitoring the physical condition of soldiers/%		
	Monitoring system based on MATLAB	Monitoring system based on BP neural network	The monitoring system designed in this paper
1	83.41	76.42	98.61
2	79.62	77.37	98.53
3	82.14	76.87	99.12
4	80.13	76.54	99.31

5.3 Heart Rate Test

In the test to oxygen saturation test instrument measurement data as a standard value for comparison, respectively, generals in a sedentary and pedal state to record the current heart rate data. Which keep the ambient temperature between 20 ℃ - 25 ℃ to reduce other interference factors. The dynamic test of heart rate of military smart wearable device is shown in Table 2, the military smart wearable device designed in this paper has a good monitoring effect on the heart rate of military personnel in both sedentary state and exercise state. After five experiments, the monitoring results are very close to the monitoring results of the oxygen saturation test instrument, and the average value of the error of the heart rate monitoring in the sedentary state is 1.24, and the average value of the error of the heart rate monitoring in the exercise state is 1.29, which shows that the military smart wearable designed in this paper can realize the heart rate monitoring of the military personnel, and the accuracy rate is ideal. The accuracy of the test is slightly lower than that in the stationary state, which is mainly due to the fact that the monitoring device and the surface of the human skin do not fit completely, so it causes such an error.

Table 2 Heart rate dynamic test of military smart wearable devices

Acceptance items		Heart rate measurement range and accuracy						
Acceptance equipment		Blood oxygen saturation meter						
Prototype number		1-3			Ambient temperature		25	
Personnel number	Sitting state				Movement status			
	Blood oxygen saturation test instrument	This articl	Error (%)	Mean error (%)	Blood oxygen saturation test instrument	This article	Error (%)	Mean error (%)
1	86	86	0	1.24	97	98	1	1.29
	89	89	0		111	109	1.8	
	86	86	0		107	107	0	
	90	89	1.1		108	104	3.8	
	87	88	1.1		110	109	1.8	

5.4 Breath test

In the respiration test, due to the limited experimental conditions, an external instrument was not used for the test, and the tester himself was used as a benchmark test based on the number of times he inhaled and exhaled. The test results do not fully characterize the respiratory measurement performance of the monitoring suit, and are only used as a reference for device evaluation. As shown in Table 3, the military smart wearable device designed in this paper has good monitoring effect on the respiratory dynamics of military personnel in both sedentary state and exercise state, and the average error value of the respiratory dynamics monitoring in sedentary state is 4.3, while the average error value of the respiratory dynamics monitoring in exercise state is 2.93, which shows that the military smart wearable designed in this paper has a better monitoring accuracy in the exercise state of the military personnel. This shows that the military smart wearable device designed in this paper has better monitoring accuracy in the exercise state of military personnel.

Table 3 Dynamic respiratory monitoring of military smart wearable devices

<table>
<tr><td colspan="2">Acceptance items</td><td colspan="7">Respiration rate measurement range and accuracy%</td></tr>
<tr><td colspan="2">Acceptance equipment</td><td colspan="7">None</td></tr>
<tr><td colspan="2">Prototype number</td><td colspan="3">1-3</td><td colspan="2">Ambient temperature</td><td colspan="2">23</td></tr>
<tr><td rowspan="2">Personnel number</td><td colspan="4">Sitting state</td><td colspan="4">Movement status</td></tr>
<tr><td>Blood oxygen saturation test instrument</td><td>This articl</td><td>Blood oxygen saturation test instrument</td><td>This articl</td><td>Blood oxygen saturation test instrument</td><td>This articl</td><td>Error (%)</td><td>Mean error (%)</td></tr>
<tr><td rowspan="5">1</td><td>18</td><td>18</td><td>0</td><td rowspan="5">4.3</td><td>20</td><td>19</td><td>5.2</td><td rowspan="5">2.93</td></tr>
<tr><td>18</td><td>17</td><td>5.8</td><td>20</td><td>19</td><td>5.2</td></tr>
<tr><td>16</td><td>16</td><td>0</td><td>23</td><td>22</td><td>4.5</td></tr>
<tr><td>16</td><td>15</td><td>0</td><td>23</td><td>23</td><td>0</td></tr>
<tr><td>16</td><td>15</td><td>6.6</td><td>22</td><td>21</td><td>4.7</td></tr>
</table>

6. Conclusion

The military smart wearable device designed in this paper has a good advantage in detecting the characteristic data of military personnel as well as their combat status. It is verified that the sensitivity of the wearable system for the monitoring of military personnel's physical state by the device designed in this paper is above 90% for different fatigue levels, and the specificity and positive predictive value can reach up to 100%. The average error of heart rate monitoring in sedentary state is 1.24, and the average error of heart rate monitoring in exercise state is 1.29. The average error of respiratory dynamics monitoring in sedentary state is 4.3, and the average error of respiratory dynamics monitoring in exercise state is 2.93, therefore, the smart wearable devices designed in this paper are more accurate in monitoring.

Intelligent wearable devices as today's rapid development of high-tech products of the times, all kinds of wearable products are surging, and gradually set off a wave in the field of intelligent wearable devices. As the competition for comprehensive national power intensifies, the competition for national defense and military power is diversified and technologized. At the same time, the user of military smart wearable devices is the main body of soldiers, the formation of a series of products installed troops will be in great demand, with a high market application prospects. In the future, with the development of technology in the field of sensors, power supply and other areas and the progress of the manufacturing process, smart wearable devices will certainly play a huge role in the battlefield.

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FUNDING

This work was supported by National Natural Science Foundation of China (Grant No. 52201385).

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