



**International Journal of Computational Systems Engineering**

ISSN online: 2046-3405 - ISSN print: 2046-3391

<https://www.inderscience.com/ijcsyse>

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**DOI:** [10.1504/IJCSYSE.2027.10070035](https://doi.org/10.1504/IJCSYSE.2027.10070035)

**Article History:**

Received:	10 October 2023
Last revised:	12 March 2024
Accepted:	15 March 2024
Published online:	26 June 2026

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# Research on intelligent clothing design integrating visual communication and embedded system – taking the blind safety clothing as an example

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**Abstract:** This study aims to design an intelligent clothing that integrates visual communication. The clothing has an embedded system of alarm and safety detection, which can protect the travel safety of the blind. The result shows that the clothing has good warning function, and it still has warning effect at 30 metres without natural light. The fall detection and protection function has a separate detection module for judgment, and the judgment time is within 0.5 seconds. However, there are still shortcomings in the research and design of clothing. Due to the existence of embedded devices, intelligent clothing is less comfortable than ordinary clothing. The hardware quality of different embedded devices cannot be fully guaranteed during mass production, and some products have not been tested for their service life. In the future, user group management and services can be carried out through the cloud platform.

**Keywords:** visual communication; smart clothing; embedded equipment; clothing for the blind.

**Reference** to this paper should be made as follows: Sun, Z. (2026) 'Research on intelligent clothing design integrating visual communication and embedded system – taking the blind safety clothing as an example', *Int. J. Computational Systems Engineering*, Vol. 10, No. 10, pp.1–9.

**Biographical notes:** Zhenzhen Sun is currently working in the School of Art and Design in Zhengzhou University of Industrial Technology as a senior experimentalist. She was graduated from Zhengzhou Huaxin College with a Bachelor of Arts degree in Art Design in July 2014. Her areas of interest are fashion and apparel design as well as visual communication design.

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## 1 Introduction

In addition to the traditional sense of warmth preservation, decoration and beauty, clothing can also meet the needs of human perception, feedback and response by adding different built-in systems. With the rapid development of science and technology, more non-clothing technologies are applied to ordinary clothing. Compared with wearable devices, such as watches and walking sticks, smart clothes are more adaptable to the human body (Alabduljabbar, 2022; Yu et al., 2022; Wang et al., 2022). At present, there are few types of smart clothing, and its functions focus on action analysis, health management, etc. through monitoring and perception of the environment, information feedback, data transmission and other functions. On the premise of ensuring the comfort of clothing, meet the needs of users for certain functions (Canio et al., 2022; Phelps et al., 2019; Yang et al., 2019). However, in society, there are a large number of special groups, such as the blind group, who will encounter great difficulties in their daily life due to visual impairment. At present, the travel equipment for the blind group has been gradually completed, such as blind staff, blind guide products, etc. However, because the blind staff will shake when used, it will have a certain impact on the accuracy of environmental monitoring data. Due to the

detection principle and function limitation of the distance sensor used, more hand-held blind guide products are used in the home environment, and are not suitable for outdoor blind guide with strong light. And because of different guidance devices, they are more concentrated in avoiding obstacles and having navigation functions. However, there is a lack of research on the hazard avoidance function, safety protection and alarm function that blind people may encounter during travel (Khambhati, 2021; Liu et al., 2022; Kuriakose et al., 2022). Therefore, the research and design of an intelligent blind clothing with safety protection function has broad development prospects. In the design process, the washability, comfort, safety and reliability of smart clothing should be increased. On the premise of meeting the need for blind people to avoid obstacles in their daily travel, increase the safety protection function, improve the physical and psychological safety of blind people, and reduce the economic burden and social resource output of blind people.

## 2 Related works

The embedded system had the characteristics of simplicity, small core, strong specificity, high real-time and small size.

Therefore, embedded systems and embedded devices had gradually developed from industry and transportation to various industries. YY Lin et al. designed a cloud platform model for real-time detection of parking status and determination of parking space availability. On this basis, LSTM model was integrated into the experiment for in-depth learning. After using this embedded system, users could not only reserve parking spaces in advance, but also effectively increased the utilisation rate of parking spaces by nearly 50% (Lin et al., 2022). Qiu (2022) proposed a neural network embedded architecture based on shared memory and bus structure. This structure was applied to the function, performance and interface of the computer distance education system. In online computer education, it can effectively improve the running speed and extend the students' learning time in their spare time. To improve energy efficiency and monitor real-time energy consumption, OHA Junior designed a self-calibration embedded system. The system can be used to measure, monitor, control and predict the consumption of power load, so as to improve energy efficiency by managing the load executed by the demander. By comparing the reading of the device with the reading obtained by the evaluation system developed by the existing company. Relative to the full scale, it is less than  $\pm 1\%$ , which is a feasible solution. Compared with the full scale, it is less than  $\pm 1\%$ , which is a feasible solution (Junior, 2022). In medicine, Riaz et al. (2021) studied and proposed a portable and low-cost embedded system for the classification of heart murmur-related heart diseases. After comprehensive experiments, the average accuracy of the system is more than 90%. The software application program with interactive graphical interface can enable patients to judge their physical condition at any time during use and feed back to doctors. And the developed intelligent system has low cost and strong mobility. The system can be used by people in remote and poor areas under regular patient monitoring, and the clear and simple interface makes it convenient for different doctors to operate (Riaz et al., 2021).

Intelligent clothing, as a new type of clothing with interdisciplinary research and development, has more extensive expanded functionality than traditional clothing. In the design process, it is necessary to integrate advanced materials, textile technology, small processors, etc. into the clothing. On the basis of ensuring user comfort, it is necessary to meet the living or working needs of certain specific groups. BA and others designed an intelligent clothing for sports crowd, and installed a processing unit for display and interaction in a jacket. The sensor unit can remotely read the data provided by the sensor to ensure human body monitoring and environmental monitoring of the wearer's body temperature and humidity, atmospheric temperature, pressure and altitude. In order to facilitate operation, the gesture sensor is used as the system wake-up device (BradAnaBradMariamaria.brad@gmail.com, 2021). Shen et al. (2022) aim to improve data sharing, accuracy and reliability of wearable device monitoring. This paper

summarises the requirements and key technologies of intelligent clothing body area network transmission, and puts forward the standard evaluation system of intelligent clothing body area network. The optimised structure of intelligent clothing body area network proposed by the research is efficient, convenient and mobile, meeting the characteristics of security, reliability, low power consumption, portability of intelligent clothing (Shen et al., 2022). In order to protect the safety of medical personnel during the COVID-19 epidemic, OJ et al. proposed a functional medical coat with antibacterial and waterproof properties, using titanium dioxide and fluoropolymer-based precursors as coating materials. The inhibition zone test shows that this method can effectively inhibit the growth of bacteria, especially *Staphylococcus aureus* and *Klebsiella pneumoniae*, before and after the smart medical coat is washed for ten cycles. In the measurement of wetting angle, the contact angle of water droplets on the fabric ranges from  $120^\circ$  to  $139^\circ$ . After the waterproof performance test, the coating coat still maintains its waterproof performance after 10 washing cycles (Jongprateep et al., 2021). Xin et al. (2021) applied nanotechnology to the clothing industry. They summarised a complete set of nanometer dispersion theory and determined the best experimental scheme based on the combination of theoretical guidance and experiment. Then, the anti-bacterial effect and anti-mite effect of finished clothing were tested by standard test method. The longitudinal density reduction rate of the processed smart clothing is 10.77%, and the transverse density reduction rate is 8.43%. In terms of antibacterial properties, the antibacterial rate of *Staphylococcus aureus* is more than 50%. The mite prevention and dust prevention rate of the smart clothing can reach more than 50%.

To sum up, the current smart clothing is more used in special operations or sports crowd. For example, intelligent clothing for mountaineers, safety protective clothing for medical personnel, etc. There is insufficient research on intelligent clothing for blind people. Although there are sufficient auxiliary equipment, there is a lack of research on the functions of hazard avoidance and safety protection during travel. Therefore, this study starts with the analysis of the travel environment and needs of the blind, and divides clothing design into clothing carrier design and embedded system design. In the process of meeting the daily travel needs of blind people, the functions of road detection, fall detection, fall protection and fall alarm are realised.

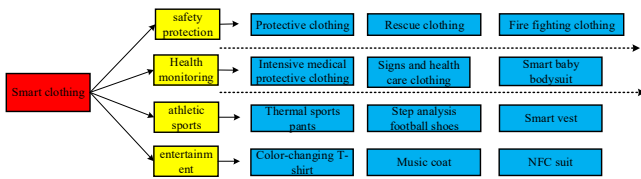
### 3 Visual communication and embedded system-based clothing design

#### 3.1 Basic design of intelligent clothing for embedded system

The embedded system has gradually developed from the field of environmental monitoring to the field of individual user life. The embedded system has the advantages of real-time computing ability and high-precision computing.

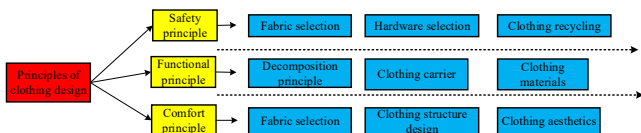
Therefore, the application of embedded system in intelligent clothing design can perfectly fit the perception and feedback of human body. Figure 1 shows the common types of smart clothing applications.

**Figure 1** Types of smart clothing (see online version for colours)



Intelligent clothing can be divided into four categories according to its functions. They are smart clothing for safety protection, smart clothing for health monitoring, smart clothing for sports and smart clothing for leisure and entertainment. Safety protection smart clothing provides protection functions for specific users in specific environments. At present, most of the safety protective clothing is designed for special operators, and there are also fall-proof intelligent clothing and intelligent cycling clothing for people who are not easy to move. Health monitoring smart clothing is more used in the medical and health industry for the purpose of detecting various data indicators of the human body. Health monitoring smart clothing can monitor blood oxygen, ECG and other physiological indicators for a long time, such as critical medical protective clothing, physical sign health monitoring clothing, etc. Health smart clothing tends to monitor patients' physical condition and track drug use. For example, smart shirts, smart baby bodysuits and other sports smart clothing can be used to detect user movement data, and help users have better movement effects when exercising. Common sports smart clothes include thermal insulation sports pants, step analysis football shoes, smart vests, etc. Leisure and entertainment smart clothing provides users with better leisure and entertainment experience in life. For example, colour change T-shirts, music jackets and NFC suits. The principle of intelligent clothing design for blind people based on embedded system should follow the principle of ordinary clothing design. Figure 2 shows the principle dimension of smart clothing.

**Figure 2** Principles of clothing design (see online version for colours)



In the principles of clothing design, we should follow the principles of safety and environmental protection, modular functional design, beauty and comfort, and scientific market demand. In the dimension of safety and environmental protection principles, there are three subdivision principles: fabric selection and production dimension, intelligent system hardware selection dimension and clothing recycling. In the dimension of modular functional design

principles, there are three subdivided dimensions: modular decomposition principle, clothing carrier, and clothing material selection. In the dimension of beauty and comfort principle, it can be divided into four sub-dimensions. They are fabric selection, clothing structure design, scientific clothing aesthetics and functional extroversion. Therefore, based on these four principles, an intelligent safety protective clothing is designed for the visually disabled.

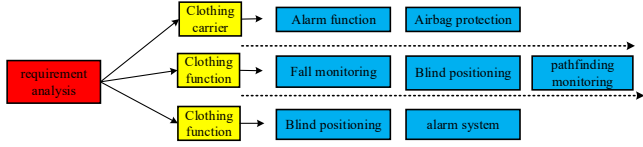
### 3.2 Intelligent clothing design to meet the travel needs of the blind

At present, blind people have different travel problems. Although China is the country with the longest blind track construction in the world, due to different design reasons and other factors, the utilisation rate is low. Therefore, designing an intelligent clothing for the blind can effectively improve the travel needs of the blind. Because blind people cannot effectively identify objects around them in their daily life, they cannot avoid the dangers around them in advance. For example, they cannot protect themselves in time when they encounter danger and fall, and cannot judge the surrounding environment reasonably after falling, and cannot save themselves correctly. Therefore, the design of intelligent clothing to meet the travel needs of blind people needs to consider the above issues. Figure 3 shows the overall design process of intelligent clothing for blind travel.

Figure 3 shows the design route of intelligent clothing for the blind. In the embedded system, there are three main systems. In the part of clothing carrier design, pay attention to the warning function and protection system. In the functional design of clothing, attention should be paid to whether the blind person falls down and walks normally, as well as blind person positioning and path finding monitoring. Finally, for the web page design part, the blind location and alarm system are displayed through APP and other software. Finally, the various functions are tested, improved and put into use. When designing the embedded hardware system, the Arduino Lite development board is selected as the processor, and the ADXL345 sensor is used as the smart clothing sensor. The judgment of whether the blind person falls down on the way is determined by the acceleration and angular velocity changes of the sensor. Formula (1) is the calculation formula of angular velocity.

$$Deg = \frac{v - v_0}{0.667 \times 10^{-3}} \quad (1)$$

Deg is the angular velocity in formula (1), v is the current voltage, and v<sub>0</sub> is the voltage at the last measurement time. When the angular velocity is output as an electrical signal, the output voltage decreases by 0.667 for every 1° deflection of the sensor in the negative direction, and vice versa. The acceleration change is output as a six-bit floating point number. To distinguish between normal action and falling action, a generalised linear classifier – SVM algorithm is used to distinguish.

**Figure 3** Design process of smart clothing (see online version for colours)

Blind people have special physiological characteristics, and generally have less extensive exercise and intense running. Therefore, daily actions can be divided into the following categories.

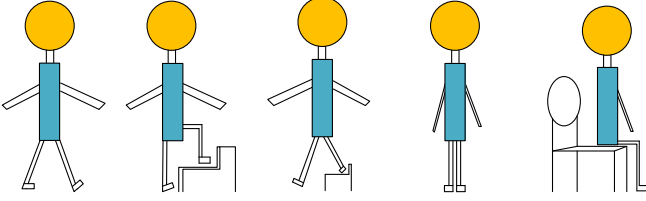
**Figure 4** Schematic diagram of daily movements of blind people (see online version for colours)

Figure 4 is a schematic diagram of the daily movements of the blind group. There are five movements in total, including normal walking, going upstairs, going downstairs, standing and sitting down. The five movements are regarded as a movement set  $B$ . The fall action is divided into forward fall, backward fall, side fall and bump fall according to the fall position, and the fall action is regarded as a action set  $D$ . In the process of designing intelligent clothing for the blind, 25 normal college students were selected for data collection. After each person executes action set  $B$  and action set  $D$  for 10 times, wear sensors and processors at the back neck to collect data as test data. Table 1 shows the test data table.

**Table 1** Action dataset table

Name	Wearing position	Number of testers	Action type	Effective collection number
B	Neck	25	5	1,865
D	Neck	25	4	1,206

After the test data is obtained, the data should be pre-processed. The experiment needs to select Kalman filter to pre-process the data in order to eliminate the data noise. Formula (2) is a prior estimate update equation of Kalman filter.

$$\hat{x}_k^- = D\hat{x}_{k-1} + Bu_{k-1} \quad (2)$$

In formula (2),  $\hat{x}_k^-$  is the posterior state estimate at a certain time,  $D$  is the state transition matrix, and  $B$  is the process excitation noise covariance. Formula (3) is the prior estimation covariance of Kalman filter.

$$P_k^- = DP_{k-1}D^T + Q \quad (3)$$

In formula (3),  $Q$  represents the transformation output state matrix. In the posterior part of the Kalman filtering algorithm, the calculation formula of the posterior state estimation is shown.

$$\hat{x}_k = \hat{x}_k^- + k_k (z_k - H\hat{x}_k^-) \quad (4)$$

$H$  is the transformation matrix from the state variable to the measurement, and  $z_k$  is the input observation value in formula (4).  $k_k$  is the Kalman coefficient. Formula (5) is the calculation formula of Kalman coefficient.

$$k_k = \frac{P_k^- H^T}{HP_k^- H^T + R} \quad (5)$$

$R$  is the covariance of the measurement noise in formula (5). Formula (6) is the posterior estimation covariance calculation formula of Kalman filter.

$$P_k = (I - k_k H) P_k^- \quad (6)$$

$I$  is the identity matrix in formula (6). Because the actual action duration of each data is shorter than the acquisition time, the characteristic value is extracted from the pre-processed data. The resultant acceleration can represent the amplitude of human motion to some extent, and formula (7) is its calculation formula.

$$A = \sqrt{a_x^2 + a_y^2 + a_z^2} \quad (7)$$

$a$  is the output value of the sensor on three coordinate axes in formula (7). When the human body is standing, the  $y$  axis of the sensor is the direction of gravity. Formula (8) is the formula for calculating the resultant acceleration of the  $xz$  plane in this time.

$$A_{xz} = \sqrt{a_x^2 + a_z^2} \quad (8)$$

The change of the resultant acceleration during this period is reflected by the standard deviation of the resultant acceleration, and formula (9) is its calculation formula.

$$A_b = \sqrt{\frac{1}{N} \sum (A_i - \bar{A})^2} \quad (9)$$

$A_i$  is the combined acceleration value in formula (9), and  $\bar{A}$  is the average value of the combined acceleration within the time period. Through the above formula, we can calculate the other motion acceleration characteristic values of standing motion accidents. Using SVM to calculate the hyperplane of all the optimal classification, when the set is linearly separable, a maximum hyperplane can be divided. On the contrary, the set is mapped to a high-dimensional space through Gaussian kernel function, and formula (10) is its calculation formula.

$$K(m, n) = \exp\left(-\frac{\|m - n\|^2}{2\sigma^2}\right) \quad (10)$$

$m$  and  $n$  are eigenvectors in formula (10).  $\sigma$  is the Gaussian distribution variance. To facilitate the disassembly of the embedded system, it should improve the wearing comfort and washability. Figure 5 shows the specific installation location of the system.

**Figure 5** Detailed installation simulation diagram of embedded system (see online version for colours)

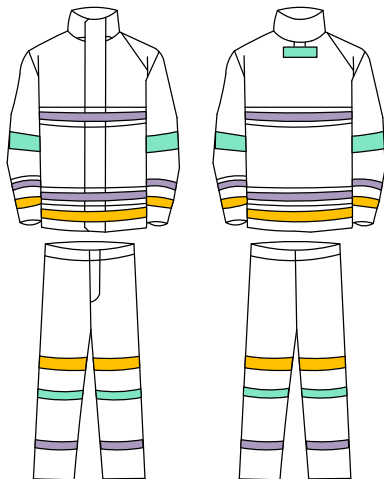


Figure 5 shows the layout of clothing structure and hardware location. The green part is the airbag, which will be inflated when the visually impaired person falls down. The yellow part is the buckle and high-pressure carbon dioxide cylinder. In the purple part, except the pants, there are sensors, buzzers and other embedded devices.

### 3.3 Construction of clothing comfort evaluation index system

The intelligent clothing for the blind integrated with visual communication needs to consider the intelligent degree of the embedded system. It is also necessary to examine whether the comfort of intelligent clothing can meet the requirements compared with ordinary clothing. Therefore, a comfort test for smart clothing is designed, which consists of subjective evaluation and objective evaluation. Among them, the objective evaluation is to measure the skin temperature and humidity data of the wearer to judge the clothing performance. The subjective evaluation is based on the objective evaluation, and the evaluation index is established for the comfort degree of all aspects of clothing. According to temperature, skin and body, clothing comfort can be divided into thermal and wet comfort index, contact comfort index and fitness comfort index. Formula (11) is the matrix of heat and humidity index.

$$R = \{r_1, r_2, r_3\} \quad (11)$$

In the matrix (11),  $r_1$  is humidity sense,  $r_2$  is heat sense and  $r_3$  is stiffness sense. Formula (12) is the contact comfort index matrix.

$$S = \{s_1, s_2, s_3\} \quad (12)$$

In the matrix (12),  $s_1$  to  $s_3$  are respectively thickness, softness, viscosity. And formula (13) is fitness index matrix.

$$T = \{t_1, t_2\} \quad (13)$$

In matrix (13), the two indicators are the sense of activity and the sense of tightness. After the index is constructed, the factor weight is determined by analytic hierarchy

process and scored by experts, and the data consistency test is passed. Formula (14) is a consistency check formula.

$$CI = \frac{\lambda - n}{n - 1} \quad (14)$$

$CI$  is the consistency index in formula (14),  $n$  is the matrix order, and  $\lambda$  is the maximum eigenvalue of the matrix. The consistency ratio calculation formula is shown in formula (15).

$$CR = \frac{CI}{RI} \quad (15)$$

## 4 Experimental analysis of embedded intelligent clothing for blind people with visual communication

### 4.1 Analysis of wearing effect of smart clothing

In order to verify the effectiveness and stability of intelligent clothing for the blind, it is necessary to test the intelligent clothing designed by the research. The test hardware and software configurations are shown in Table 2.

**Table 2** Software and hardware configuration table

Type	Name	Instructions
Hardware	Arduino Lite	It is used as the master controller for smart clothing, processing data and controlling other modules
	ADXL345	Acceleration sensor for detecting and analysing the user's movement
	Angular velocity sensor	Used to detect the angular velocity of the user's motion
	High-pressure carbon dioxide cylinders	For the rapid expansion of airbags
	Airbag	Expands when a fall is detected to protect the wearer
	Buzzer	It is used to sound alarms to alert people around
Software	NFC module	It is used for near field communication to identify clothing information for the visually impaired
	Arduino IDE	Used to write and upload code to the Arduino Lite development board
	SVM algorithm library	It is used to process sensor data and identify different motion states
	Kalman filter algorithm library	Used to pre-process acceleration and angular velocity data to reduce noise effects

When developing smart safety clothing for visually impaired people, the main controller is Arduino Lite, which is responsible for integrating sensor data and control logic to ensure efficient processing and response. The acceleration sensor ADXL345 monitors the dynamic motion of the wearer together with the angular velocity sensor to provide accurate motion state data. High pressure carbon dioxide cylinders and airbag modules constitute a protective mechanism in case of emergency, which can rapidly expand when a fall is detected to mitigate the impact, and a buzzer acts as an alarm system. The NFC module increases the interactivity of clothing and facilitates the visually impaired to obtain clothing information. In terms of software, Arduino IDE, as the development environment, works with SVM algorithm library and Kalman filter algorithm library to optimise the data processing process and improve the accuracy and reliability of the system.

In the experimental analysis part, the test of intelligent clothing is divided into clothing safety test, comfort test, interactive function test and so on. Six kinds of movements were selected for simulated activity test, as shown in Figure 6.

**Figure 6** Common motion simulation (see online version for colours)

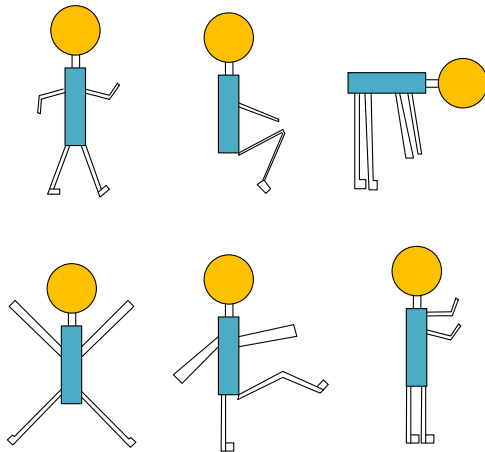


Figure 6 shows the simulation of common movements, including jogging posture, squat posture, bending posture, extended posture, high leg lift posture, and arm movement posture. The performance comparison results of safety clothing are shown in Table 3.

The performance evaluation of the intelligent blind safety suit in a variety of test environments is shown in Table 3, and the results show that it performs well in all environments. Static environmental testing showed that the garment was 94% accurate, 92% accurate, 91% recalled, 91.5% F1-score, 0.6 seconds reaction time, and 4.5 warning effectiveness score. In dynamic environment testing, accuracy improved to 96%, accuracy to 93%, recall rate to 94%, F1-score to 93.5%, response time to 0.5 seconds, and alert effectiveness score to 4.7. The low-light environment test further confirmed the highly efficient performance of the garment, with 97% accuracy, 95% accuracy, 96% recall rate, F1-score of 95.5%, response time of 0.4 seconds, and warning effect score of 4.8. In contrast, performance in

high-light environment tests decreased slightly, but remained high. The group interaction environment test and high noise environment test show the stable performance under complex conditions. Overall, the smart blind safety suit has shown excellent performance in various indicators, especially in dynamic, low-light and group interaction environments. In the experimental analysis of the comfort of smart clothing, the average temperature and humidity of smart clothing in summer are tested through objective evaluation. The specific evaluation data are shown in Figure 7.

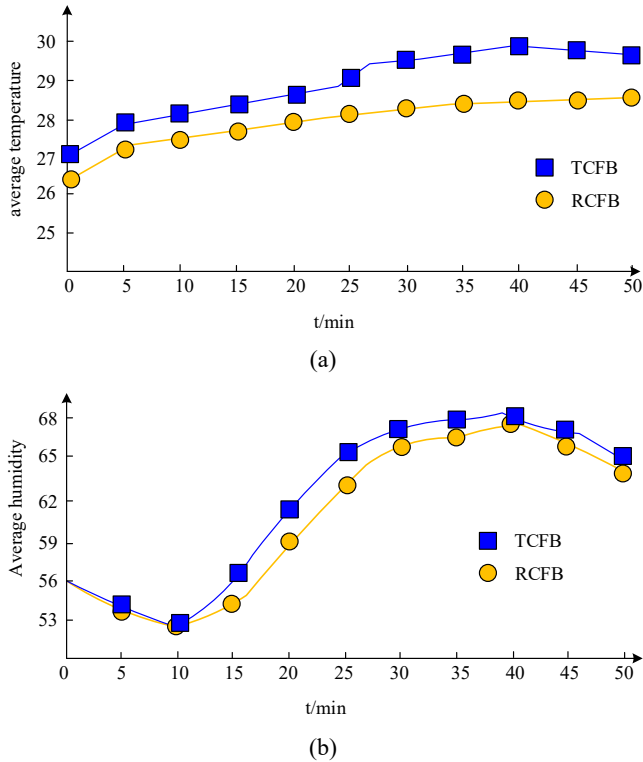
**Table 3** Comparison of performance indexes of safety clothing

Experiment name	Accuracy (%)	Recall rate (%)	F1-score (%)	Response time (s)	Warning effect score
Static environment testing	94	91	91.5	0.6	4.5
Dynamic environment testing	96	94	93.5	0.5	4.7
Low light environment test	97	96	95.5	0.4	4.8
High light environment test	95	92	93	0.5	4.6
Group interactive environment testing	98	97	96.5	0.3	4.9
High noise environment test	96	94	93.5	0.4	4.7

Figure 7 shows the comparative analysis of comfort between the intelligent clothing designed in the study and a blind clothing selected on the market. From the comparison of the average skin temperature of the wearer in Figure 7(a), the average temperature difference between the standing state and the sitting state in the first 20 minutes is within 1 degree. And the average skin temperature of the smart clothing researched and designed is lower. In the last 20 minutes of movement, the temperature rise rate of the smart clothing researched and designed is slow. However, the temperature of the clothing selected for comparison rises faster. And with the passage of time, the temperature difference between the two types of clothes becomes larger and larger, and finally reaches the maximum in 40 minutes. The last 10 minutes are for the wearer to enter the rest state, and the heat dissipation performance of the clothing researched and designed is more excellent. Figure 7(b) shows the average skin humidity change of the two clothes. In the first 20 minutes of the static state, the humidity of the two clothes does not change much. When entering the 20-minute movement state, the average humidity of the smart clothing studied is lower. During the last ten minutes

of rest, the humidity of the smart clothing studied decreased by 3% compared with that of the contrast clothing. In general, the intelligent clothing for blind people researched and designed has better heat dissipation and water absorption. When testing the security of intelligent clothing for the blind, the first step is to test the pathfinder function of clothing. Specifically, it simulates the recognition effect of obstacles in the daily travel environment. Figure 8 shows the specific recognition rate.

**Figure 7** Comparative analysis of comfort of two smart clothes (see online version for colours)



**Figure 8** Comparison of success rate of path finding function (see online version for colours)

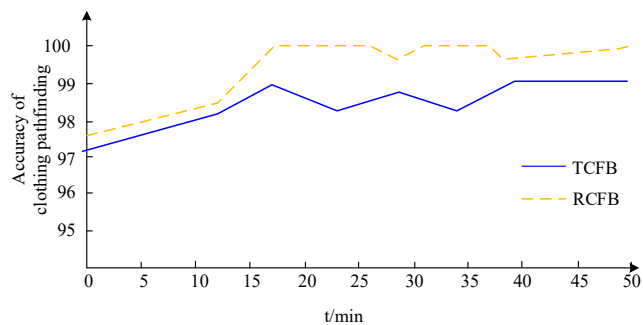


Figure 8 is a comparison of the success rate of the path-finding function between intelligent clothing and a certain type of guide clothing on the market at present. When the test site is an area with blind roads, the main obstacles are trees, vehicles, pedestrians, garbage cans, etc. The overall accuracy rate of the intelligent clothing studied is above 97, and the accuracy rate can be maintained at 100% on average after walking for 15 minutes. When the recognition rate is not high, the recognition effect is poor

because some obstacles are lower than the recogniser. Later, the problem of recognition rate less than 100% can be solved by adjusting the sensor height. In the clothing warning effect test, aiming at the eye-catching degree of smart clothing under dark conditions, the eye-catching effect of the two kinds of clothing is compared through the five-point scoring standard. Table 4 shows the specific test data.

**Table 4** Average score of different clothing in dark environment

Distance (m/time)	5 m/ evening	10 m/ evening	20 m/ evening	50 m/ evening	30 m/ night
Research clothing score	4.8	4.3	3	2.9	3.4
General clothing score	4	3.4	1.6	0.5	0

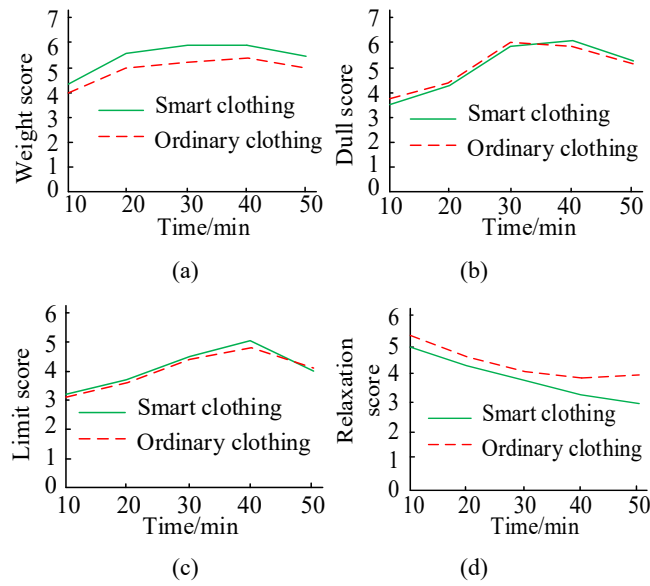
According to the average score of clothing eye-catching under dark conditions in Table 4, the average score of research clothing in the evening is 4.8 within 5 metres, 4.3 at 10 metres, and 2.9 at 50 metres. When the test time is midnight and the distance is 30 metres, the score of 3.4 can still be reached. However, the common clothing for the blind has almost no eye-catching warning effect under dim conditions. Especially when the distance is 50 m, the eye-catching effect score is only 0.5. When the distance is 30 metres and the time is midnight, it is impossible to identify whether there is anyone. Therefore, the research clothing eye-catching test standard is good, and the warning effect reaches the best when the distance is less than 20 metres.

#### 4.2 Subjective evaluation and analysis of intelligent clothing

In the subjective evaluation and analysis part of intelligent clothing for the blind, volunteers who participated in the objective evaluation were tested. The test objects are also intelligent clothing for the blind and ordinary clothing. The evaluation standard is a seven-level difference scale. The higher the score is, the less ideal it is. Figure 9 shows the subjective scoring results of different aspects.

Figure 9 shows the subjective scoring results of two kinds of clothing from different aspects. In the weight score of Figure 9(a), intelligent clothing is not as comfortable as ordinary clothing because of the embedded system. In the boredom score of Figure 9(b), the range of activities of smart clothing is the same as that of ordinary clothing, with almost no difference. In the score of Figure 9(c), the longer wearing time, the smaller the sense of restriction of smart clothing. In the score of Figure 9(d), the degree of relaxation also decreased slightly due to the embedded system implantation. When the intelligent blind clothing studied is tested for fall detection and protection function, the resultant acceleration change and angular acceleration change monitored by the serial port during the fall are measured. Figure 10 shows the specific test results.

**Figure 9** Results of subjective scoring of different clothing (see online version for colours)



**Figure 10** Combined acceleration change and angular acceleration change diagram (see online version for colours)

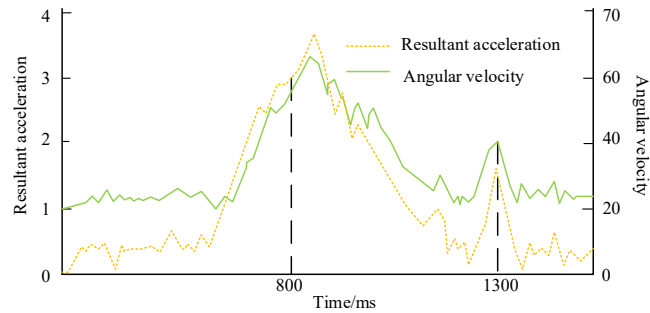


Figure 10 shows the angular velocity and acceleration changes monitored by the serial port when a test falls with the assistance of AL software. Because it takes 0.1 seconds for the airbag to inflate and puff up, it is determined that the fall is 0.1 seconds later. Therefore, the processor determines the process of falling between 800 milliseconds and 1300 milliseconds, with an interval of about 0.5 seconds. The time reserved by the embedded system for airbag deployment can meet the actual time when the blind group falls.

## 5 Discussion

The research of intelligent clothing design integrating visual communication and embedded system can effectively improve the life difficulties of people with special needs and improve the quality of life. Through the comprehensive application of warning, environmental obstacle recognition, fall detection and protection functions, the research effectively improves the physical and psychological security of the target group. However, the study also reveals the challenges of smart clothing design in terms of comfort, hardware quality assurance and product life testing. In

addition, the current design only focuses on individual protection, and the future development direction can consider group management and services through the cloud platform to further expand the application field of smart clothing. In terms of smart clothing design costs, designing and manufacturing smart clothing involves high research and development costs, including integrating advanced sensors and processing units, as well as developing software interfaces. However, as technology advances and production scales up, costs are expected to decrease, thereby improving its market scalability. In addition, the design needs to consider the needs of different consumers to ensure that smart clothing can meet a wide range of market needs.

In terms of privacy and ethics, the smart clothing researched and designed has effective and corresponding privacy protection measures, which can reduce potential negative effects and ensure the responsible use of technology. For the relevant regulations, there are only safety manuals and customer service popularisation, so it is necessary to improve the construction of specific regulations.

In view of the security vulnerability of smart clothing, the smart clothing designed by research has a simple protection system, which can organise a certain degree of hacker attacks, but the development of a strong security mechanism is still an important aspect of clothing security, and effective design countermeasures must be taken, such as enhancing data encryption, implementing access control and conducting regular security audits. These potential security concerns, including data breaches, unauthorised access and system tampering, need to be more fully considered and addressed at the design stage.

Despite the potential social and economic impact of smart clothing, research in this area has been relatively limited. Through a practical case to show that the application of the smart clothing in disabled athletes to ensure their normal sports training safety, but also need to carry out more detailed clothing design.

In general, as an innovative technology, smart clothing has a broad application prospect, but it also brings a series of challenges and problems. Through continued technological innovation, ethical discussion and regulation development, the future development of smart clothing can be ensured to be both safe and beneficial.

## 6 Conclusions

As an important branch of new clothing, intelligent clothing based on embedded technology is still in the early stage of development. Due to their own problems, special groups need external assistance to carry out normal life and rest. The research aims to design a set of smart clothes for the visually disabled, which will help the blind people solve the travel problems. Therefore, the embedded system intelligent clothing based on visual communication is studied to assist the blind people in daily travel. A set of intelligent service scheme is researched and designed. The carrier is clothing, and the embedded system with alarm and security detection

is embedded to protect the travel safety of the blind. The designed clothing performs well in warning function after being tested. The warning effect is excellent in dim conditions, and it still has warning effect in 30 metres without natural light. Clothing has a high degree of recognition of environmental obstacles, and the problem of insufficient recognition of some obstacles can be solved by adjusting the sensor. The safety protection performance is excellent. The fall detection and protection functions have separate detection modules for judgment, and the judgment time is within 0.5 seconds. The time reserved for the deployment of the airbag by the embedded system can meet the actual time of the blind people in danger. However, there are still shortcomings in the research and design of clothing. In terms of clothing comfort, the existence of embedded devices will still affect the comfort. The selection of embedded device hardware quality is insufficient, and some product life has not been tested. The current security protection is a single personal protection. In the future, user group management and services can be carried out through the cloud platform.

## References

- Alabduljabbar, R. (2022) 'An IoT smart clothing system for the visually impaired using NFC technology', *International Journal of Sensor Networks*, Vol. 38, No. 1, pp.46–57.
- BradAnaBradMariamaria.brad@gmail.com (2021) 'Development of a smart clothing product using an Arduino platform', *International Journal of Advanced Statistics and IT&C for Economics and Life Sciences*, Vol. 11, No. 1, pp.38–61, Politehnica University Timisoara, Romania.
- Canio, F.D., Martinelli, E., Peruzzini, M. and Cavallaro, S. (2022) 'Experiencing a food production site using wearable devices: the indirect impact of immersion and presence in VR tours', *Sustainability*, Vol. 14, No. 5, pp.3064–3081.
- Jongprateep, O., Mani-Lata, C., Sakunrak, Y., Audcharuk, K., Narapong, T., Janbooranapinij, K., Pitiphattharabun, S., Lertworasirikul, A., Laobuthee, A. and Thengchaisri, N. (2021) 'Titanium dioxide and fluoropolymer-based coating for smart fabrics with antimicrobial and water-repellent properties', *RSC Adv.*, Vol. 12, No. 1, pp.588–594.
- Junior, O. (2022) 'Development of a self-calibrated embedded system for energy management in low voltage', *Energies*, Vol. 15, No. 22, pp.8707–8728.
- Khambhati, V. (2021) 'Smart shoes for blind person', *Compliance Engineering*, Vol. 12, No. 7, pp.68–71.
- Kuriakose, B., Shrestha, R. and Sandnes, F.E. (2022) 'Tools and technologies for blind and visually impaired navigation support: a review', *IETE Technical Review*, Vol. 39, No. 1, pp.3–18.
- Lin, Y.Y., Wei, M.C., Sun, C.C., Kuo, W.K., Chan, F.C. and Liu, Y.C. (2022) 'Millimeter wave radar combines long short-term memory and energy storage embedded system for on-street parking space prediction', *Sensors and materials: An International Journal on Sensor Technology*, Vol. 34, No. 4 Pt. 2, pp.1401–1407.
- Liu, X., Miao, J., Fan, Q., Zhang, W., Zhou, X., Tian, M., Zhu, S., Zhang, X. and Qu, L., (2022) 'Recent progress on smart art fiber and textile based wearable strand sensors: materials', fabrics and applications', *Advanced Fiber Materials*, Vol. 4, No. 3, pp.361–389.
- Phelps, H.L., Watt, S.D., Sidhu, H.S. and Sidhu, L.A. (2019) 'Using phase change materials and air gaps in designing fire fighting suits: a mathematical investigation', *Fire Technology*, Vol. 55, No. 1, pp.363–381.
- Qiu, Q. (2022) 'The application of neural network algorithm and embedded system in computer distance teach system', *Journal of Intelligent Systems*, Vol. 31, No. 1, pp.148–158.
- Riaz, U., Aziz, S., Khan, M.U., Zaidi, S.A.A., Ukasha, M. and Rashid, A. (2021) 'A novel embedded system design for the detection and classification of cardiac disorders', *Computational Intelligence*, Vol. 37, No. 4, pp.1844–1864.
- Shen, L., Ren, X., Wu, J., Chen, H. and Ouyang, J. (2022) 'Study on body area network of smart clothing for physiological monitoring', *International Journal of Distributed Sensor Networks*, Vol. 18, No. 2, pp.29–36.
- Wang, Y.C., Xu, X., Hajra, A., Apple, S. and Faillace, R.T. (2022) 'Current advancement in diagnosing atrial fibrillation by utilizing wearable devices and artificial intelligence: a review study', *Diagnostics*, Vol. 12, No. 3, pp.689–703.
- Xin, Y., Zhang, D. and Qiu, G. (2021) 'Application of nanomaterials in safety intelligent clothing design', *Integrated Ferroelectrics*, Vol. 216, No. 1, pp.216–275.
- Yang, J., Zhou, J. and Tao, G. (2019) 'Wearable 3.0: from smart clothing to wearable affective robot', *IEEE Network*, Vol. 33, No. 6, pp.8–14.
- Yu, F., Chen, Z., Jiang, M., Tian, Z., Peng, T. and Hu, X., (2022) 'Smart clothing system with multiple sensors based on digital twin technology', *IEEE Internet of Things Journal*, Vol. 10, No. 7, pp.6377–6387.