

ORIGINAL RESEARCH ARTICLE

Study on research mode of smart safety outfits system for children

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ABSTRACT

According to the special characteristics of children's body and mind and the concept of human-computer interaction, the research and development model of children's intelligent safety clothing is explored and a practical research model. Based on the multi-dimensional needs of consumers for children's clothing and the performance of smart components, we explore the combination of smart wearable equipment and children's safety clothing, and propose a design process architecture that takes into account function and aesthetics. Through the analysis of the connection technology between smart clothing and mobile terminals, we propose the idea from single interaction to multi-device co-connection, and establish a multi-interaction smart clothing based on the optimal allocation of energy and high. Through the analysis of the connection technology between smart clothing and mobile terminals, we propose the idea of moving from single interaction to multi-device co-connection, and establish the R&D process of multi-interaction smart wearable devices based on optimal energy allocation and efficient information transmission.

Keywords: childrens safety; smart clothing; multi-dimensional need analysis; intelligent interaction

1. Introduction

In recent years, there has been an upsurge of intelligent wearable devices in the field of industrial design. Intelligent wearable device^[1] is the general name of wearable devices developed by applying wearable technology to intelligently design products that people wear and carry daily, such as various popular glasses, gloves, watches, clothes with intelligent concepts and functions. With the help of various intelligent devices, consumers have obtained unprecedented convenience in life and work. How-

ever, no intelligent wearable device can be omnipotent. At present, researchers mainly develop products that can solve specific problems for specific groups of people. Children's safety has always been the focus of the whole society, but the physiological weakness of children determines that any traditional safety equipment for mature limbs is difficult to meet the needs of children. How to provide proper supervision for children on the one hand and not affect the comfort necessary for children's healthy growth and daily life on the other hand is an important topic of children's safety clothing design. The upsurge of research and development of intel-

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Intelligent wearable devices provides a broader space for the design of children's safety clothing.

By analyzing and summarizing the research results of multi-dimensional requirements of man-machine interactive wearable equipment, the combination mode of intelligent wearable equipment and children's clothing, and the multi interaction between intelligent wearable equipment and mobile terminal, this paper attempts to put forward the system R&D mode of the combination of intelligent wearable equipment and children's safety clothing, hoping to provide practical and effective theoretical guidance for the design and production of children's safety clothing in the Internet era.

2. Key technologies and development status of intelligent wearable research

The development of intelligent wearable research is inseparable from the progress of fiber and material science. In recent years, various smart textile materials developed by new fibers through special weaving technology have become the main force in the field of intelligent wearable (especially in the field of intelligent clothing)^[2]. Mondal's^[3] uses phase change materials and microcapsule technology to produce intelligent textiles with heat storage and regulation performance, which can greatly improve the wearing comfort. The intelligent nano textiles developed by Coyle's and others^[4] expand the functionality and potential of environment, clothing and fabrics. The smart textile developed through nanofibers has the functions of automatic cleaning, sensing, driving and communication, and the wearer can communicate with the surrounding environment in a harmless way; at the same time, the system can constantly update personal health status or resist environmental hazards. Shim BS et al.^[5] used polyelectrolyte to coat carbon nanotube adult biological monitoring intelligent electronic yarn wear-resistant fabric. The combination of this material and intelligent wearable devices can be used for the monitoring of hemoglobin and the transmission of remote information. Lymberis A et al.^[6]

discovered the fibrous structure of intelligent fabrics and interactive textiles, which are used for sensing, driving, power generation, energy storage and interaction. Radetic M^[7] proposed that silver nanoparticles and textile fibers are blended into textiles, and the current can be connected with wearable devices through specific fiber lines. Park S et al.^[8] proposed a wearable biomedical system based on intelligent textile design to improve personal quality of life by enhancing the effect of real-time biomedical monitoring.

In addition to combining conductive elements with fibers and weaving them into intelligent textile materials, a more typical intelligent textile technology is to organically combine the formed clothing as a carrier with intelligent modules, cooperate with specific communication technologies, and establish the information exchange between the human body and the outside world, so as to realize the corresponding human auxiliary functions^[9]. This kind of research mainly involves intelligent clothing technology. A complete intelligent clothing system usually includes three components: intelligent module (including intelligent sensing elements, signal transmission system, energy module, etc.), function carrier clothing and information processing module^[10]. The intelligent module can be used to obtain human body data and transmit external signals to the human body to realize the two-way feedback between the human body and the external environment. It is the key module for intelligent clothing to perform its specific functions. Clothing is the carrier of intelligent wearable technology. Because of its inseparable relationship with human body, intelligent clothing has incomparable advantages in human machine interaction. Information processing terminal is the brain of intelligent clothing, which undertakes the task of collecting, analyzing and making decisions on the transmission data of intelligent originals.

In recent years, intelligent clothing technology has developed very rapidly. Park S et al.^[11] proposed implanting micro monitoring equipment and sensors into ordinary shirts to make telemedicine monitoring

possible. The research methods of wearable intelligent device^[12] are discussed. Radetic M^[13] proposed the design of wearable antenna to provide all-round monitoring and communication for the wearer. D-shirt sports wear^[14] is a high-tech sportswear developed by French citizen sciences. Its fabric embedded sensor is connected with Bluetooth transceiver to track user activities and transmit the collected data to smart phones. After the transceiver is taken out, it can be washed and ironed. The quality of sportswear is no different from that of ordinary T-shirts. Many companies have launched smart clothing for the elderly, which combines smart phones, sensors and positioning elements to store and process information through wireless communication means (such as Bluetooth), so as to provide real-time security protection for the elderly^[15]. Li H et al.^[16] studied a wearable sensor of new intelligent clothing for human body temperature measurement. Intel has teamed up with clothing designer chromate to launch so-called “responsive clothing” that can be deformed according to users’ questions, adrenaline or stress levels^[17]. Ohmatex, a Danish design company, has designed a smart sock that can detect leg edema and predict heart failure and epileptic aura in advance^[18].

Because of their physical and mental particularity, children belong to relatively vulnerable groups and are important service objects of intelligent wearable devices. At present, the intelligent equipment for children seen in the market is mainly from the perspective of safety monitoring, such as smart schoolbags, shoes, foot rings, watches, telephones, urine humidity sensing shorts, infant vital signs monitoring underwear and pajamas with positioning function (i. e. anti-loss function)^[19]. Other smart wearable devices focus on children’s psychological growth, such as storytelling T-shirts, luminous skirts, singing pajamas, etc.^[20]. The successive emergence of all kinds of children’s wearable products reflects the care and attention of the whole society to children’s physical and mental health. However, most of the children’s wearable products currently on the market have single function and uneven quality^[21]. Other slightly forward-looking

products can not reflect their due value because the technology is not mature or cannot meet the actual needs of children. In addition, the market share of intelligent accessories far exceeds that of intelligent services pack.

This also reveals the technical bottleneck of today’s intelligent wearable products to some extent. Because, compared with intelligent accessories (such as watches, shoes and socks, accessories, etc.), the compatibility between technology and clothing needs to be considered in the development process of intelligent clothing. On the premise of meeting specific functions, it is necessary to ensure the basic wearing performance of clothing (which is difficult to achieve), which is particularly important for children’s intelligent clothing. Due to the immature physical and mental development of infants and young children, compared with adults, they have higher requirements for clothing comfort and safety, which undoubtedly increases the difficulty of intelligent clothing development. So far, there is no systematic and feasible research and development mode (or idea) in the field of children’s intelligent safety, which provides guidance for the good combination of intelligent wearable technology and children’s clothing safety research.

3. Research and development mode of smart clothing based on children’s safety

On the basis of extensive market research and in-depth analysis of previous and existing relevant research, this paper puts forward three main aspects involved in the research and development of children’s intelligent safety clothing, namely, the demand of children’s intelligent safety clothing, the combination mode of intelligent wearable components and children’s clothing, and the information interaction mode of intelligent children’s safety clothing.

3. 1. Demand for children’s intelligent safety clothing

The research and development of smart clothing is a typical human centered product design^[22,23].

A very important link in its R&D process is to conduct in-depth investigation and analysis on the multi-dimensional needs of product users (i.e. smart clothing wearers), i.e. human factors. Only by accurately grasping the needs of users can we design and develop satisfactory products. The research and development of children's intelligent safety clothing needs to take into account the needs of users (children themselves), their guardians (parents) and the society for the wearability, functionality, safety, aesthetics, social acceptance and so on.

Specifically, as a special kind of functional clothing, intelligent clothing first needs to meet the designer's requirements for its preset functions, and ensure the stability of intelligent component installation, the convenience of interaction, the effectiveness of information transmission, the accuracy of data acquisition, the durability of energy consumption, etc. Secondly, due to the tightness of the combination of smart clothing and human body, the design of smart clothing also needs to meet the basic characteristics that it should have as clothing itself, such as comfort, aesthetics, safety, durability (such as washability)^[24], and sometimes even consider the social acceptance of smart clothing and its use behavior.

The research and development of children's intelligent wearable products often starts from the perspective of safety monitoring. The so-called safety monitoring not only covers the monitoring of life safety, but also includes the attention to children's mental health and growth. The former includes various intelligent wearable products that help prevent children from getting lost, injured and ill, while the latter includes various products that bring psychological comfort and intellectual interest guidance to children. Therefore, based on the particularity of children's body and mind, the research and development of children's intelligent clothing should also consider a series of special requirements, such as the visualization of information interaction and the safety level of electronic components (higher than that of adults), in addition to meeting its functional and wearability requirements.

In terms of research methods, demand research is divided into two aspects: demand acquisition and demand analysis. In addition to literature study, the most commonly used methods to obtain needs are some psychological research methods, such as questionnaire, personal interview, expert discussion and so on. On this basis, demand analysis is to study the obtained qualitative or quantitative demand data through analysis and summary or data mining methods, and finally extract a series of research basis with guiding significance for follow-up work^[25,26].

3. 2. Combination mode of intelligent wearable elements and children's clothing

Intelligent wearable devices can be divided into four categories according to the wearing mode: headwear, wristband, portable and wearing^[27]. No matter what kind of device, the research goal is to improve the portability, wearability (to some extent, comfort) and wearing performance of the product on the premise of meeting the preset functions of components and according to the particularity of children's physiological, psychological and life situation.

Smart clothing belongs to category 4 of the above intelligent wearable devices, which is also a kind of intelligent wearable devices with higher difficulty in implementation. At present, most smart clothing is based on sensors. With the improvement of sensor integration, functionality and intelligence, the location of wearable components is not limited to a certain part of the human body, but is being laid out all over the body, making them have medical significance in addition to information interaction and communication, and even have the functions of data collection, monitoring and transmission of external environment, buildings and other data^[28].

How to reasonably combine intelligent wearable components with clothing, so as to give full play to specific functions and make the wearer feel physically and mentally comfortable, is the key and difficulty of intelligent clothing research and development. This paper puts forward the research idea as shown in **Figure 1**. In short, the starting

point of intelligent children's safety clothing research is to meet the multi-dimensional needs of children for clothing in specific safety situations. After analysis and summary, in addition to the function of the component itself, this study puts forward six indicators of the compatibility between intelligent components and children's safety clothing, namely, appearance acceptance, physiological fit, physiological harm, wearing comfort, obstruction to activities, and consideration of the safety and reliability of the component. Therefore, the key to the research and development of intelligent children's safety clothing is to select appropriate intelligent wearable components (function type, performance parameters, shape, size, etc.) according to the functions to be realized, that is, the research and development concept, reasonably transform the components if necessary, and then explore the specific combination parts and forms of the components and children's clothing.

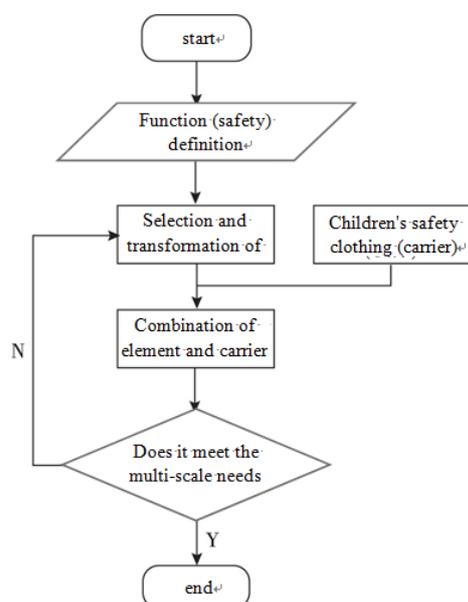


Figure 1. Basic process of the research on the combination of smart devices and children's safety clothing

Intelligent clothing system takes clothing as the carrier and intelligent wearable components as the function realization module. In order to organi-

cally combine functional modules with carriers, researchers need to apply multi-disciplinary knowledge such as clothing aesthetics, physiology, psychology, ergonomics, electronic informatics and so on.

The research on the combination of intelligent components and clothing is the central link of intelligent clothing design, which plays a connecting role in the whole research and development mode.

3.3. Information interaction mode of intelligent children's safety clothing

With the popularity of mobile terminals such as smart phones and tablets (pads), most wearable smart devices rely on mobile terminals for data transmission and analysis. Sensor detection nodes and mobile terminals generally communicate data through short-range wireless transmission, such as low-power bluetooth, zigbee, WiFi, etc. The interaction mode between intelligent wearable devices and mobile terminals is usually single, that is, they only tend to establish a single connection between devices and mobile terminals, and the degree of information sharing is low (which directly leads to low information utilization), which affects the function maximization of intelligent products. Therefore, in order to better realize the efficiency of intelligent information processing and serve specific people (device wearers) to the greatest extent, it is necessary to conduct diversified research on the transmission and interaction modes of information between intelligent devices and between intelligent devices and mobile terminals, that is, the research on multi interaction. Therefore, this paper puts forward the research framework of intelligent clothing as shown in **Figure 2**.

In **Figure 2**, the whole framework consists of three parts: function end, analysis end and sharing end. The function end is the combination end of intelligent components and clothing.

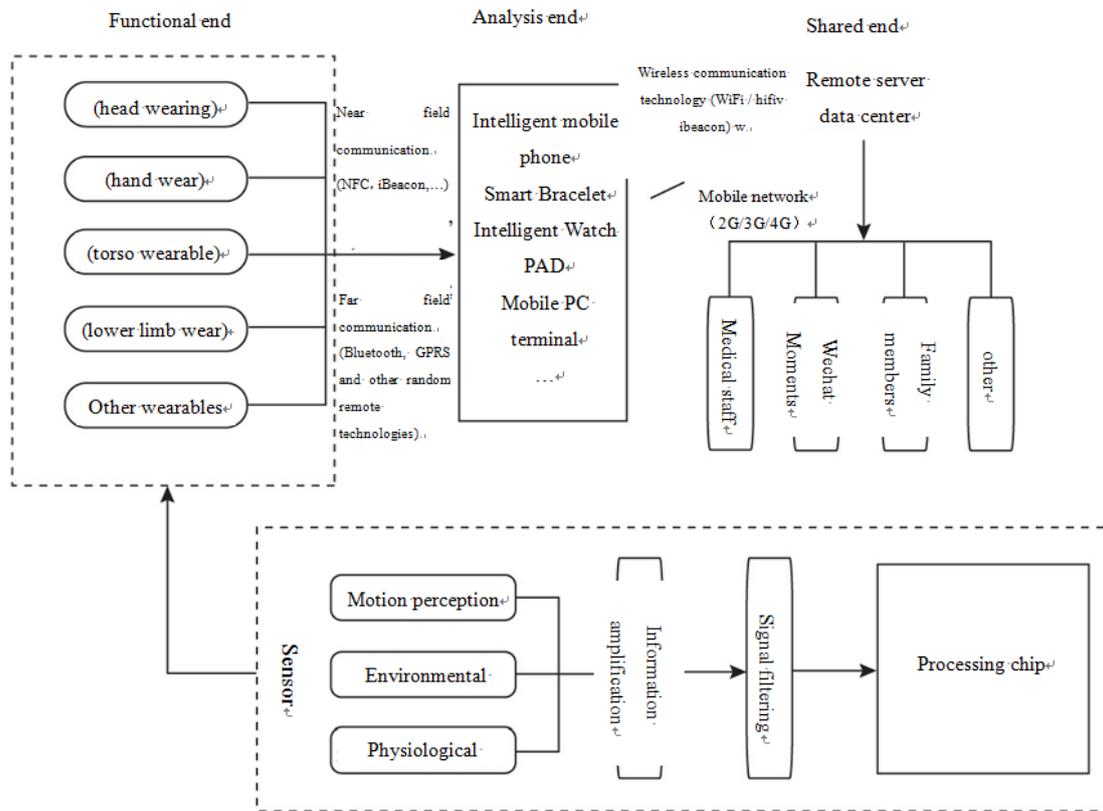


Figure 2. Framework of multi-interactive information sharing

It is the function realization unit of the whole intelligent clothing and is responsible for information detection and feedback. Among them, all kinds of sensors have become an important part of the functional end, and they are also one of the core components of the whole intelligent clothing system. The analysis terminal is the information terminal, which is the unit that reads and analyzes the data information transmitted by intelligent components. If the smart clothing system is regarded as the human nervous system, the functional end is the sensory organ (sensor, i.e. receptor), and the analysis end is the nerve center (brain). The information exchange between the functional end and the analysis end is realized through various wired and wireless communication technologies, such as the commonly used near-field (NFC, iBeacon technology, etc.) and far-field communication methods (Bluetooth, FM technology, etc.). Information is transmitted from intelligent components (sensors, etc.) to the analysis end through the communication network, just as sensory information is transmitted from the sensor

to the brain through the sensory pathway. Common information terminals in the market include mobile phones, watches, bracelets, mobile PC terminals, tablet computers, etc. At present, most intelligent wearable devices are composed of function end and analysis end.

On this basis, this paper puts forward the third important module of intelligent clothing system, namely sharing end. Generally, the one-to-one (i.e. one functional end and one analytical end) information interaction mode leads to low information utilization. The shared end can be a remote server or a virtual data center. The role of the sharing end includes two aspects: a. By means of communication, multiple data terminals are interconnected to form a multi interactive network to maximize information exchange and improve information utilization. Specifically, the mobile terminal makes appropriate decisions and feedback on information through the role of internal decision-making modules (such as app applications with various functions installed in smart phones). The feedback in-

formation will be shared to the pre associated network community in the wireless network through the preset mode, that is, different types of mobile terminals, or shared by multiple devices to realize information sharing. Through the sharing end, the information obtained by smart devices can be easily shared with friends, family, medical institutions, etc. The significance of information sharing is not only to improve the utilization of information, but also to improve the controllability and security of intelligent clothing. b. The existence of sharing end also means that the analysis end of smart clothing can be expanded. The sharing network can not only share the information of the analysis end to different users, but also interconnect different intelligent systems to maximize the function of intelligent clothing. The data of different analysis ends are summarized in the remote data center through interactive technology to form a massive database. According to the principle of statistics, to a certain extent, the larger the sample size, the higher the accuracy and reliability of the analysis results. The expanded analysis end can improve the decision precision of the intelligent clothing system to a greater extent. In today's big data era, massive data storage and analysis technologies such as cloud computing are ideal means to establish the sharing end of intelligent clothing system^[29,30].

The above framework is applicable to the research and development of different types of smart clothing and smart wearable devices. Based on the physical and mental particularity of the wearer, the R&D personnel should also consider the following factors in the design of intelligent interaction mode: a. Limited to children's poor situational judgment ability and perceptual expression ability, children's intelligent clothing should strengthen the design of auxiliary decision-making, real-time monitoring, automatic response and other functions. b. Smart clothing is usually equipped with various electronic components, which is easy to produce sound, light and electric pollution in the process of operation, thus causing harm to human body. Children are physically and mentally fragile and particularly vulnerable. Therefore, the research and develop-

ment of children's intelligent clothing should put forward higher requirements for the safety of components, especially in the design of information interaction mode, the components with low power consumption and low radiation should be considered. c. According to children's psychological needs, smart clothing should follow the principles of simplicity, beauty and children's interest in the design of human "clothing" interaction mode and interaction interface.

3. 4. Construction of R&D mode of intelligent children's safety clothing

This paper puts forward the R&D mode of children's intelligent safety clothing as shown in Figure 3.

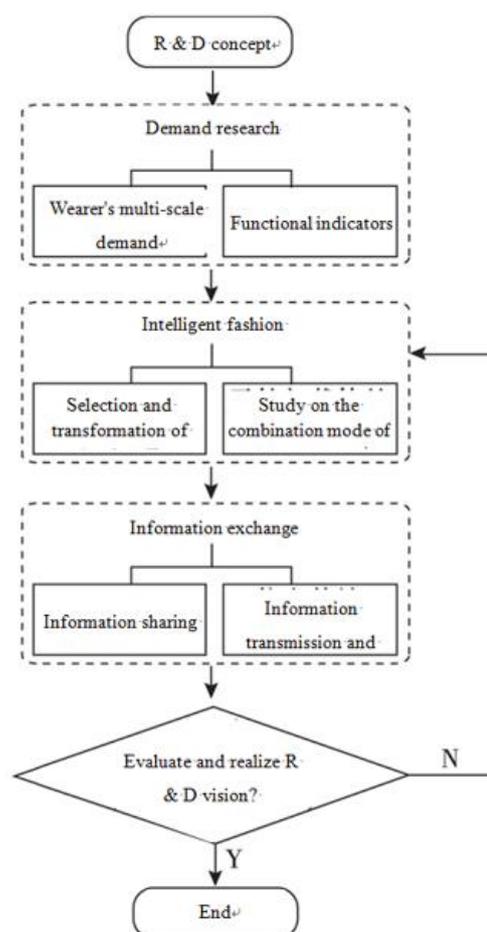


Figure 3. Research model of intelligent safety clothing for children

The pattern in **Figure 3** follows the basic principles of “needs determine design”. Firstly, according to the functional requirements of smart children’s clothing, comprehensively consider the multi-dimensional needs of children wearing smart safety clothing, that is, demand research. On the basis of demand analysis, formulate the technical (Design) indicators for the research and development of children’s intelligent safety clothing, and explore the combination mode of intelligent components and children’s clothing, that is, determine the specific design parameters such as the form and position of the combination of the two. Organically integrate functionality, design aesthetics and comfort, and design and develop smart clothes that meet children’s physical and mental particularity and wearing needs. The third part of the research model involves the study of interaction mode. The intelligent components of children’s clothing are interconnected with the analysis end of the intelligent clothing system through various communication technologies (near-field or long-distance transmission technology) to realize information interaction and complete the preset function. At the same time, set a sharing end for the smart clothing system, share the analysis end data to a wider community through the communication network, realize the common connection of different information terminals, improve the utilization rate of information, increase the controllability and security of the smart clothing system, and realize the common connection of different smart clothing systems. The establishment of massive information center and big data analysis means will greatly improve the decision-making effectiveness and functionality of intelligent clothing system.

The last link of the whole R&D model is very important, that is, to evaluate the efficiency of the children’s intelligent safety clothing, and verify whether it meets the indicators and ideas formulated in the early stage of R&D. The evaluation link includes two parts: a. Functional evaluation of clothing. Researchers need to test and evaluate the functional indicators of products from an objective and mechanical point of view, that is, the test method is determined by the nature and function of each functional module of intelligent clothing system. If the preset function of the intelligent system is to detect the vital signs of the wearer, this evaluation link needs to evaluate the working state of each sensor (such as temperature, heartbeat, blood pressure sensor, etc.), the accuracy of the data at the analysis end, and the efficiency and accuracy of the information feedback system under the condition that the real person (or simulated real person) is dressed. b. Comfort evaluation. Smart clothing system takes clothing as the basic carrier, so it needs to meet the requirements of wearers for their physical and mental comfort. Sensory evaluation is a commonly used method for comfort evaluation^[31,32]. Participants in sensory experiments usually include experts in textile (clothing) design and production, as well as ordinary wearers. The former evaluates the rationality of fashion design and production from a professional perspective (such as physiology, psychology and ergonomics). The latter evaluates the beauty and comfort of clothing from the perspective of their own needs. The research object in this paper is children, who usually do not have mature perceptual expression ability, so it is necessary to design a set of sensory experimental methods suitable for children. At the same time, according to the physical and

mental particularity of children, it is also necessary to combine children's perception with parental intervention to obtain the wearer's perceptual evaluation of the beauty and comfort of clothing.

If the product meets the R&D concept, the R&D ends. If the product fails to pass the evaluation, the researcher must analyze the specific links and causes of the problem, and redesign the specific technical indicators of the problem until the indicators meet the requirements.

4. Conclusions

Based on the grasp of the development status and trend of intelligent wearable devices, this paper puts forward the general mode of children's intelligent safety clothing research and development. The whole model follows the basic concept of "demand determines design".

(1) Take the needs of smart clothing wearers (here children) as the driving force of R&D. Grasp the multi-dimensional needs of children's dressers and translate them into key technical parameters. (2) Design smart clothing. Select and reasonably transform the intelligent components according to the functional indicators, and explore the combination mode of components and carriers (i. e. safety clothing), so as to make the products have "functionality, beauty and comfort". (3) The information interaction mode of intelligent clothing system is designed. It includes one-to-one information interaction design (information transmission and analysis feedback) of function end (smart clothing) and analysis end, and multi device joint design to realize the multi interactive control of smart clothing system. On the basis of improving the controllability, security and utilization of information, the decision-making accuracy and efficiency of smart clothing system are improved through massive data storage and operation technology. (4) Verify the functionality and comfort of the smart clothing.

Conflict of interest

The authors declare no conflict of interest.

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