Development and evaluation methods of smart wearable clothing

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Abstract. With the development of technology and the increase in customer demand, smart clothing has become an indispensable part of the clothing field. Smart clothing is also gradually being applied to many aspects such as medical monitoring, daily protection, entertainment and sports. Based on the original wearing needs, sensors are integrated into the clothing to meet the miniaturization and convenience of electronic products. As a result, it has an impact on the comfort and aesthetics of clothing materials. During the research and development process, hardware devices such as sensors were added to the fabric, resulting in changes in the original structure and design of the clothing itself. There is no complete set of standards for smart clothing. This article starts with the development of smart clothing, classifies it, and sorts out some evaluation methods of smart clothing.

1. Introduction
Smart clothing is a functional clothing that undergoes perception, feedback and reaction. The smart wearable surface is a hardware device. In fact, it is a terminal that realizes functions through software support and cloud data interaction, supported by a huge database. Smart wearable embeds technologies such as sensors, wireless communication and multimedia into wearable devices, such as clothing, bracelets, glasses, etc., and supports gestures and other interactive methods. With the innovation and development of technology, smart wearable technology has also received great attention in the field of clothing. Although it is not as popular as smart products, the development of smart clothing in recent years has also been rapid. The form of smart wearable clothing is becoming more and more diversified, showing remarkable development in medical, military, sports and other fields.

2. Classification of smart wearable clothing
The use of smart clothing in different fields is different. According to different uses, smart clothing can be divided into four categories: positioning, medical monitoring, military protection, and life entertainment.

2.1. Smart positioning clothing
The main target groups of smart positioning clothing are children and elderly people who are easy to lose, and outdoor athletes who often climb mountains and explore, but the needs of these two types of groups are different. The positioning required by children and the elderly is a real-time location, and family members can receive their location to know exactly where they are; while outdoor athletes need positioning and navigation like a map, they need to know where they are from their destination, how
far is it, and how long will it take to arrive. Therefore, it is necessary to have real-time communication, alarm and other functions in the positioning equipment to ensure the safety of customers.

Jiangnan University's "Intelligent Children's Safety Clothing Based on Interactive Technology" project adopts the 1T2F design model, uses data interactive communication sensing technology, and uses digital products and information service signal exchange interactive feedback methods, combined with NFC, iBeacon, GPS, Bluetooth, Luminous fiber and other new technologies design smart clothing with special safety functions.

2.2. Intelligent medical monitoring clothing
The main target group of smart medical monitoring apparel is those who need rehabilitation training. As the aging society intensifies, the demand for the elderly to monitor their physical data also increases. Through the monitoring equipment in the clothing, you can monitor the user's conventional body data such as heart rate, pulse, body temperature, body fat, etc., and the user can understand his own physical condition in real time. Arrange nodes on clothing, connect sensors, set up a wireless network, and build a wearable wireless sensor network that can detect physiological signals such as human body temperature, blood pressure, and pulse.

In order to achieve remote diagnosis and long-term health monitoring, some communication technology and flexible sensors are needed. Lee and Chung developed a smart shirt for measuring physiological electrocardiogram data and sports activity data. These data are transmitted to the base station through the network, and the guardian performs remote monitoring through the server. Paradiso, R and others have developed a wearable health-care system based on a knitted fabric with integrated sensors, in which six ECG electrodes have been realized by a textile yarn, and transmit the collected signals through wireless from the portable patient unit (PPU) to a remote monitoring system based on GPRS communication.

2.3. Military protection
The combination of intelligent textile technology and military technology has promoted the development of smart clothing in the military field, and the most basic function is protection. Soldiers are often injured by bullets, germs, harmful gases and other external injuries in their operations. This requires smart clothing to automatically recognize the external environment and provide protection to prevent military personnel from being injured. North Carolina State University and the University of Puerto Rico have jointly developed a nano-smart textile composed of different kinds of polymers and a 20-nm nano-layer, which can screen a variety of substances from the outside world, hindering mustard gas, nerve poison gas and harmful chemicals. At the same time, it allows air and moisture to pass through and keeps the fabric breathable. The protective clothing developed by the I-Protect project has a built-in sensor module for monitoring environmental parameters. It can monitor the concentration of toxic gases, external temperature and oxygen concentration, and transmit data through wireless communication technology. It can be used by soldiers in chemical military operations. In addition to basic protective clothing, clothing used to avoid camouflage has also been developed in the military field, similar to traditional camouflage clothing. Military equipment emits visible light such as infrared rays and lasers to detect enemy situations. Traditional clothing cannot meet the requirements in this environment. In the United States, polyaniline/polydianiline is applied to fabric surface to develop electrochromic camouflage clothing. In addition to showing different camouflage camouflage effects, it can also be manually controlled to change the infrared emissivity to achieve the effect of infrared camouflage throughout the day and night. The "multi-spectral active skin" color-changing bionic camouflage material developed in France has the functions of electroluminescence, electro-reflection and electro-radiation at the same time, so that the target can be integrated into the background through dynamic color change like a "chameleon" even if the material is penetrated by a bullet, does not affect the color change effect, can be widely used in the military field.

2.4. Life entertainment
The application of smart clothing in life is mainly for entertainment and intelligent life, so the demand for such smart clothing is not so big. Philips' Design Probes is dedicated to exploring trends and innovations that may eventually bring an important impact to business and become mainstream. It has designed a fun smart dress called Bubelle(Figure1), which can detect the wearer's emotional changes through the inner sensor, and project them on the outer layer, different emotions correspond to dresses of different colors, increasing the wearer's input. British wearable technology company Cute Circuit showed a smart little black dress in 2017(Figure 2), made of graphene material. In addition to the striped decoration of various colors, it can also change color according to the wearer's breath. When the wearer is short of breath, the skirt will turn purple. When the breath is smooth or deep, it will emit a pine green light. A sensor is also built into the chest of the dress. The wearer can perceive the breathing frequency through the sensor, which is both aesthetic and fun.

Figure 1. Bubelle dress

Figure 2. Cute Circuit black dress

3. Evaluation Methods
Although the main feature of smart clothing is intelligence, smart clothing also requires compliance with basic comfort principles. With the technology of the apparel industry, people are more focused on
the comfort of the clothing itself, and more emphasis on the safety of clothing materials, so regardless of the type of clothing, the most important evaluation method is comfort. Considering the particularity of smart clothing, research will be conducted from three aspects: heat and moisture comfort, contact comfort, and perceptual comfort.

3.1. Heat and moisture comfort
Heat and moisture comfort refers to the ability of the human body and the environment to maintain a stable transmission of heat and humidity, creating good conditions for the normal physiological function of the human body, so that the human body can maintain a comfortable feeling. Clothing plays a regulating role in the energy exchange through the process of heat and moisture transfer. It is the comprehensive balance of biothermodynamics between people, clothing, and the environment, and is also a basic factor that affects the comfort of clothing. In the ergonomics of clothing, the human body, environment, and clothing as three elements form an organic whole, which influences and balances each other. The main factors that affect the comfort of heat and humidity are the human body, environment, and clothing.

The heat production of the human body is different between the resting state and the exercise state. The heat generation during the exercise state is more, and the sweat evaporated on the skin surface also increases. As external factors, environmental factors cannot be ignored, the heat transfer between the human body and the environment will also affect the human body, we must consider the environmental climate of the wearer. The performance of clothing is the most important factor. The breathability of clothing materials directly affects the heat dissipation effect of the human body. Good ventilation performance has a cool and dry feeling. Poorly permeable fabrics will cause the body's heat to be difficult to dissipate, hindering the body and the outside world. The heat transfer process makes the wearer feel sultry. In addition to clothing materials, the structure of the clothing also affects the thermal and wet comfort. The structure of the clothing depends on the combination of material performance and environmental climate. For the wearer, the thickness of the clothing and the exposed parts are all reasonable considerations. According to research, 20%-40% of the exposed parts of the clothing can help heat dissipation. Outdoor sportsmen wear smart clothes and exercise outside. The clothing materials must play a protective role. This requires that the exposed parts should not be too much. It is best to use high-quality breathable fabrics.

3.2. Contact comfort
Contact comfort refers to the comfort level of the skin contacting the fabric when the human body is wearing clothing. Fabrics with poor materials will cause tingling and itching discomfort to the skin, and may even cause skin diseases. Therefore, the fabric fibers should be soft and smooth. The largest proportion of contact comfort is stress, and the degree of mechanics of clothing on the human body also needs to be within the tolerance range. There are many groups of smart clothing, including sports enthusiasts and patients who need medical rehabilitation. The pressure of clothing needs to take into account the physical factors of the group and make different changes for different situations. For example, patients who need rehabilitation are inconvenient to move and inflexible to wear and take off their clothes. The smart clothes they wear need to be loose. The equipment in the smart clothes should not be too heavy or too large. Micro-devices can be used to reduce their bodies burden. Normal people have a wide range of activities and flexible actions. Their smart clothing requirements are best similar to ordinary clothes, and they cannot affect daily activities. Therefore, it is recommended to use flexible sensors, which are light and flexible, and will not cause obstacles. Evaluation of contact comfort can be achieved through a combination of subjective and objective methods, through the subjective feelings of the wearer to identify the overall comfort, and then through the instrument test to measure the accurate pressure value for comparison.

3.3. Perceptual comfort
Perceptual comfort refers to people's subjective perception of the color and design of clothing. Everyday clothes will focus on color matching and design highlights to enhance the beauty of the clothes. Because smart clothing is limited by its special use, the style of the sensor device needs to be considered in terms of style, which is why most smart clothing is simple. In terms of color matching, smart clothing is still dominated by heavy dark colors, but with the popularity and youth of smart products, the brightness of colors can be appropriately increased to attract more young customer groups. In terms of style design, it cannot be limited to basic styles. It can try to innovate in design, combine with the current fashion, and do some trendy design.

4. Conclusion
Compared with smart products, the accuracy of smart clothing is relatively weak. Smart garments are susceptible to contamination during use. They require higher technical requirements for the built-in sensor, increase the service life of the sensor, and enhance the wearable performance of the sensor. In terms of information collection and processing, whether the data processing is accurate and fast can also be used as an evaluation indicator. In terms of clothing materials, whether the fabric has sufficient functionality to match the sensor device, and its wash-ability. In the future, smart clothing will gradually become productized, and with the support of technology, it will become a popular product like a smart-phone, improving the sense of technology in life.

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