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0272.2023.1.2<sup>1,2</sup>CHEN Y., <sup>2</sup>PASHKEVYCH K. L., <sup>2</sup>PROTSYK B. O.<sup>1</sup>Kyiv Institute at Qilu University of Technology, Jinan, China<sup>2</sup>Kyiv National University of Technologies and Design, Kyiv, Ukraine**INTELLIGENT WEARABLE TECHNOLOGIES IN CLOTHING  
DESIGN: MODERN DIRECTION AND STRATEGIES  
OF DEVELOPMENT**

**Purpose.** This paper aims to explore the application of intelligent wearable technology in clothing.

**Methodology** research is conditioned by a comprehensive study of the subject and includes: methods of analysis, synthesis, comparison, method of analyzing sources, comparative method.

**Results.** This paper analyzes the application of intelligent wearable technology in clothing, and discusses the problems of electronic components and power supply, as well as the comfort and design of intelligent clothing. Intelligent wearable technology refers to electronic devices and computing systems integrated into clothing, providing users with enhanced functions and convenience. Intelligent wearable technology can be used to monitor human health, track sports activities, improve personal safety and enhance personal convenience. Research has found that intelligent wearable electronic components can help people track key health indicators and improve personal safety. In addition, intelligent wearable electronic components can also enhance personal convenience, such as controlling music, answering phone calls and monitoring information. From the perspective of fashion, intelligent wearable electronic components can be integrated into clothing design to create a unique and innovative fashion statement. However, electronic components and power supply are still the main difficulties of smart clothing.

**The scientific novelty.** This paper proposes some solutions to minimize the shortcomings of current smart clothing, and provides new suggestions for the application of smart wearable technology in clothing in the future.

**Practical significance.** The materials of the article can be used when studying the topic of clothing design using modern information technologies and innovations and when writing scientific papers.

**Keywords:** intelligent wearable technology; smart clothing; health monitoring; personal safety; personal convenience; fashion design; electronic component; power supply problem.

**Introduction.** Intelligent wearable technology has become increasingly popular in recent years. The use of wearable technology has revolutionized the fashion industry and has enabled the creation of new and innovative designs. Intelligent wearable technology refers to electronic devices and computing systems integrated into clothing, which provide the user with enhanced functionality and convenience [1]. The use of wearable technology has expanded beyond traditional accessories like watches and fitness bands to clothing. Intelligent wearable technology is a new and innovative way to bring technology closer to us, allowing us to benefit from its convenience while wearing stylish and fashionable clothes. This paper aims to explore the application of intelligent wearable technology in clothing.

**Analysis of previous researches.** Intelligent wearable technology refers to electronic devices that can be worn on the

body and have the ability to collect and transmit data [2]. This technology has found its way into clothing, where sensors and other electronic components can be embedded to provide various functionalities. The following are some of the most notable applications of intelligent wearable technology in clothing.

1. Intelligent wearable technology can be used to monitor a person's health by measuring various physiological parameters like heart rate, blood pressure, and body temperature. In an article by Wang Q. et al. explored textile-based biosensors for healthcare monitoring [3].

2. By embedding sensors in clothing, people can have their health monitored more efficiently and conveniently without having to wear a separate device. This technology can be especially useful for people with chronic health conditions like diabetes or heart disease, where continuous monitoring is essential. In their

work, the authors of the article [4] studied wearable technology for health monitoring.

3. In the article [11], the authors conduct a comprehensive survey of Internet of Things (IoT)-based technologies and solutions in the medical field and propose an all-in-one computing architecture for real-time Internet of health things (IoHT) applications and present possible solutions to achieving the proposed architecture.

4. Activity tracking is another application of intelligent wearable technology in clothing. By embedding sensors in clothing, the technology can track a person's movement, steps taken, and calories burned. For example, the intelligent fitness suit (Fig. 1) developed by Athos in 2012 allows users to exercise on the gym equipment using the muscle tracking sensor connected to the clothing, and send the user's posture data to the mobile phone to analyze the performance of the gym equipment. This feature is particularly useful for people who want to keep track of their fitness goals or those who need to monitor their physical activity for medical reasons [5].

The paper [12] reviews different types of wearable devices currently being used in the healthcare field. It also highlights their efficacy in monitoring different diseases and applications of healthcare wearable devices (HWDs) for diagnostic and treatment purposes.

5. Intelligent wearable technology can also be used to enhance personal safety. By embedding sensors in clothing, the technology can detect falls or accidents and alert emergency services or relatives [6]. Clothing with built-in GPS technology can also be used to track the location of children or elderly people [7].

For example, Yancheng Huaxuan Garment Co., Ltd. applied for a functional clothing with positioning function (Fig. 2). The functional clothing with positioning function is equipped with a wireless locator, when the ground personnel cannot contact the climber through the communication equipment, they can search and rescue the climber according to the location of the wireless locator. Smart fabrics are a new

application of intelligent wearable technology in clothing. These fabrics have electronic components, such as sensors, embedded directly into the fabric itself, allowing for a more seamless integration of technology and clothing. This technology can be used to create clothes that change color or pattern depending on the user's mood or to provide information about the wearer's environment [8].

In the article [13] several main aspects are conducted: functional materials, major fabrication processes of smart textile components, functional devices, system architectures and heterogeneous integration, wearable applications in human and nonhuman-related areas, and the safety and security of Smart textile-integrated microelectronic systems (STIMES). The authors of the article classify such types of textile-integrated nonconventional functional devices: sensors, actuators, displays, antennas, energy harvesters and their hybrids, batteries and supercapacitors, circuit boards, and memory devices.

The universities that initially conducted research on smart clothing were renowned international laboratories, and also those that conducted research on smart clothing later on were also mostly universities with internationally advanced laboratories. They started their research relatively early, with an advanced sense of design and development and cross-aided by multidisciplinary expertise, and also with a certain level of theory, which gives them an advantage over other universities.

For example, in 1994, the US Army Laboratory published a journal in Popular Science on a conceptual model of an Army uniform for the 21st century soldier with GPS positioning and infrared sensitivity; in 1997, the MIT Media Lab published a paper in Digest of Papers.

First International Symposium on Wearable Computers, a conference paper proposing technology for building circuits from fabrics, yarns, fasteners and components, and examining how this could be incorporated into smart clothing; and a journal paper on e-textiles and clothing in the MRS Bulletin,

Cambridge University, 2003, which introduced the concept of I-textile concept and the building blocks to implement it, based on which the design development of the Smart Shirt is proposed, integrating sensing, physiological monitoring and information processing devices, and also discussing the implications of this design paradigm. Research in foreign universities has been conducted in depth mainly in the direction of physiological data monitoring, e-textiles and sensor networks.

**Statement of the problem.** Although intelligent wearable technology has many potential applications in clothing, there are still some challenges and limitations to be considered. On the one hand, the design of clothing is usually not applicable to electronic components, so power supply for these components may require further adjustment and testing. On the other hand, clothing with embedded electronic components may be bulky, uncomfortable to wear, and not have a sense of design, making it not suitable for daily use.

In order to ensure the comfort of clothing and give full play to the maximum advantages of intelligent devices, this paper analyzes the circuit problems of intelligent wearable devices applied to clothing and the comfort and design problems of intelligent clothing from multiple perspectives, so as to minimize the disadvantages of current intelligent clothing and provide new suggestions for the application of intelligent wearable devices in clothing in the future.

**Results of the research.** Due to the progress of technology and the growing demand for smart devices, smart wearable electronic components in clothing have become increasingly important. These components include sensors, processors, batteries and other electronic components that can be seamlessly integrated into clothing and accessories.

In terms of health and fitness, wearable electronic components in clothing can help track vital signs, such as heart rate, blood pressure and body temperature, thus providing valuable insights into a person's health and

fitness level. This allows individuals to monitor their health more closely and take appropriate measures to improve their overall health. In terms of security, smart wearable electronic components in clothing can also provide additional security measures, such as GPS tracking, emergency alarm and personal alarm. This is especially important for individuals who travel alone or engage in high-risk activities. In terms of convenience, wearable electronic components in clothing can also provide additional convenience, such as controlling music, answering calls and monitoring information without touching phones or other devices [9].

For example, in 2015, Google&Levi invented the commuter truck jacket (Fig. 3). The jacket is composed of the jacket itself, the touch area on the sleeve, the rechargeable smart tag and the corresponding mobile application [4].

The Levi's brand has developed a denim smart jacket – Levi's Commuter Trucker Jacket, created by the brand together with the department of innovative developments Advanced Technology and Projects (ATAP), which is part of Google. Google presented a technology for introducing special conductive threads into ordinary fabrics, which turn fabrics into sensitive panels with which the user can interact in the same way as with the screens of smartphones or tablets. A jacket with the function of answering calls, navigation, sending SMS and controlling music on a smartphone, created on the basis of Jasquard – a platform designed by ATAR specifically for "smart" clothing. Such fabric works as a micro-sensor, recognizing gestures. You need to slide your finger over a sensitive area on the cuff in a certain direction or double-tap it, and the electronics sewn directly into the sleeve connect wirelessly with the smartphone's operating system. Levi's Commuter Trucker Jacket is designed primarily for cyclists, city dwellers, photographers, etc. The jacket can be washed by first removing the Bluetooth transmitter. Project participants believe that over time, "smart" sensors can be integrated

into a wide variety of clothing items, reading indicators of the vital activity of a swimmer's or runner's body during training [14].

The application allows you to control the music, answer the phone and view the time of the phone through gesture touch. The tag shows whether the pairing is successful. From the perspective of fashion, intelligent wearable electronic components can be integrated into clothing design to create a unique and innovative fashion statement.

At the same time, the electronic components and power supply problems of smart clothing are also exposed frequently. One of the most common solutions to power electronic components in wearable technology is to use batteries. They can be rechargeable or disposable, and their size and capacity can vary according to the requirements of the device. However, batteries increase the weight and volume of clothes, which may not be ideal for some applications. Another option is to use solar cells to generate electricity for electronic components. This method can be used in sunny outdoor activities.

For example, the wearable technology designer Pauline van Dongen and the sustainable clothing brand Blue Loop Originals created a solar-powered jacket for the guide [22]. The jacket is installed with three thin-film solar panels and inductive charging system. According to different weather conditions, the smart phone can be charged wirelessly for 1 to 2 hours, and other devices can be charged through USB transmission cable. In addition to its powerful functionality, the solar panel itself has also become the aesthetic feature of the jacket (Fig. 4).

In 2009, the Zegna brand released a limited collection of Zegna Esotesh Solar Jacket jackets – a men's jacket that can be used to charge a phone or tablet [15].

In 2015, designer Ralph Lauren together with the OMSignal company released a collection of "smart" RolloTesh T-shirts for athletes. The material of the t-shirt is a fabric permeated with fine silver fibers connected to a device that is attached to the t-shirt at the level

of the lower left part of the person's chest. The device captures and records various biometric indicators of the user's body, for example, the number of steps taken, heart rate, depth and frequency of breathing, energy consumption, etc. [16].

The Lumis Matrix Smart Helmet has a solar panel that can charge your mobile phone or bicycle computer while riding (Fig. 5) [21]. In terms of electric energy collection, this method includes obtaining energy from the environment, such as body heat, movement or radio waves, to power electronic components. In recent years, energy collection technology has made progress, and it can become a feasible solution for low-power wearable devices.

The latest wireless charging technology can also be used to power electronic components in wearable technology. This method eliminates the need for physical connectors, thus improving the comfort and flexibility of clothing. For example, the BioStamp Research Connect system includes a shirt with a sensor that can wirelessly transmit data to the monitoring device, which can wirelessly charge [20].

The manufacturer of auto racing equipment OMP Racing and the Marelli company in 2020 offered a new development of the "smart" jersey VISM, which can monitor the state of human health [17].

In June 2019, Xiaomi announced the "smart" Zenph Smart Fitness Sportswear T-shirt, aimed at sports fans. The T-shirt performs the same functions as a regular fitness tracker, but at the same time eliminates the discomfort associated with wearing a bracelet during sports [18].

Fashion technology company Wearable X has developed the Nadi X yoga pants, which are equipped with built-in gadgets that gently pulsate at the hips, ankles and knees, encouraging the person doing yoga and exercising to hold a certain position or move [19].

In this way, advances in technology and textiles create the basis for the development of a "reasonable garment". Based on the analysis,

one can see such a variety of "reasonable" clothes:

- products of the "first generation" – those, in which the sensor is attached to the clothes, to beat brandy sportswear brandy Adidas, Nike and Under Armour;
- "second generation" products, if the sensor is worn in the cold. Similar technologies were demonstrated by Samsung, Alphabet, Ralph Lauren and Flex;
- "third generation" – mostly electronic clothing, which is a sensor.

In general, the importance of intelligent wearable electronic components in clothing is that they can provide valuable information, enhance security and convenience, and change fashion design. With the continuous progress of technology, the potential applications of these components may expand, bringing more innovative uses and benefits.

In smart clothing, clothing comfort is crucial because the wearer will wear these clothes for a long time. Comfort is usually achieved by selecting appropriate materials and construction methods, which are easy to move, breathable and hygroscopic [10]. The sense of design is also crucial in smart clothing, because clothing must have visual appeal and conform to the style preferences of the wearer. Designers need to seamlessly integrate this technology into clothing without appearing cumbersome or awkward. The design of clothing must also adapt to technical components without affecting the overall fit or aesthetics.

It is a complex problem to combine intelligent wearable technology with clothing comfort and design, which requires multidisciplinary methods. The following are some potential strategies to deal with this problem:

1. Cooperation with fashion designers: Through cooperation with fashion designers, wearable technology developers can try to integrate their technology into clothing design, making it beautiful and comfortable. Fashion designers have rich experience in creating both practical and fashionable clothing, and their

investment is invaluable in creating both useful and comfortable wearable technology.

2. Conduct extensive user testing: user testing is crucial to ensure the comfort and functionality of wearable technology. By testing wearable technology prototypes of different user groups, developers can find potential design defects and areas for improvement. User feedback can be used to improve the technical design to ensure its comfort and ease of use.

3. Use of flexible and lightweight materials: wearable technology developers can use flexible and lightweight materials in the design to ensure that the technology will not affect the comfort or mobility of the wearer. Spandex, Lycra, polyester and other materials are usually used in sportswear and are ideal for wearable technology applications.

4. The ergonomics of wearable technology is crucial to ensure that the technology is comfortable to wear. Designers should focus on creating wearable technologies that are light, flexible and fit the wearer's body shape. In addition, the placement of the technology should be carefully considered to ensure that it does not interfere with the range of motion of the wearer.

5. Use smart textiles: smart textiles are fabrics containing electronic components such as sensors, actuators and conductive fibers. By using smart textiles in wearable technology, designers can create both practical and fashionable clothing.

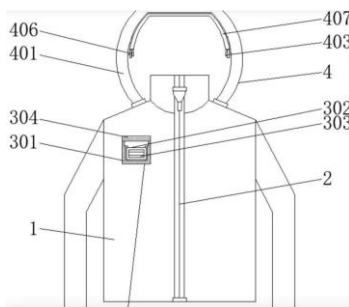
For example, smart textiles can be used to make clothing that can adjust the wearer's body temperature, or can sense when the wearer feels tired and adjust the clothing to provide additional support. For example, Professor Jintu Fan, School of Textiles and Clothing, Hong Kong Polytechnic University, led the research team to develop a clothing that can adjust the temperature adaptively as the temperature changes. The outer surface of the garment is composed of ultra-thin and lightweight strips made of a large number of metals and plastics. When the wearer feels

warm, these strips curl outward, causing the body temperature to drop. On the contrary,

when the wearer feels cold, the band flattens to prevent this heat overflow (Fig. 6).



**Fig. 1.** Smart fitness clothes, Athos, 2012



**Fig. 2.** Functional clothing with positioning function, Zhang Jinfeng, Shen Weihua, Liu Tingting, Chen Li, 2022



**Fig. 3.** Commuter Trucker Jacket, Google&Levis, 2015



**Fig. 4.** Solar powered jacket, Pauline van Dongen, 2019



**Fig. 5.** LUMOS intelligent riding helmet, Jeff Chen and Ding Yuwen, 2015



**Fig. 6.** A garment that can adjust the temperature adaptively as the temperature changes, Fan Jintu, 2022

In general, the application of clothing comfort and design sense in smart clothing is crucial for creating wearable technology, which is not only functional, but also comfortable and visually attractive for the wearer. To solve the problem of combining wearable technology with clothing comfort and design requires cooperation between clothing designers, engineers and user experience experts. Through joint efforts and attention to the needs of users, it is possible to create wearable technology that is both practical and comfortable.

**Conclusions.** The application of intelligent wearable technology in clothing has broad potential and importance. Many studies have shown that intelligent wearable technology can be used to monitor health,

track activities, improve personal safety and increase convenience, and can be combined with fashion to create unique and innovative fashion styles. Although these technologies have many advantages, there are also some challenges and limitations, including the mismatch between electronic components and clothing design, power supply problems, electronic components make clothing cumbersome and uncomfortable. This study analyzes the circuit problems, comfort and design problems of intelligent wearable devices used in clothing, and puts forward some improvement measures to better apply intelligent wearable devices in clothing in the future.

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## ІНТЕЛЕКТУАЛЬНІ ТЕХНОЛОГІЇ В ДИЗАЙНІ ОДЯГУ: СУЧАСНІ НАПРЯМИ ТА СТРАТЕГІЇ РОЗВИТКУ

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**Мета** статті – дослідити застосування «розумних» технологій в дизайні сучасного одягу, які передбачають використання різноманітних вбудованих пристроїв.

**Методологія.** Дослідження зумовлене комплексним вивченням предмета і включає: методи аналізу, синтезу, метод аналізу джерел, порівняльний метод.

**Результати.** У статті проведено аналіз застосування інтелектуальних технологій в одязі та визначено проблеми електронних компонентів і джерел живлення, а також оцінено комфорт і дизайн сучасних моделей «розумного» одягу. До інтелектуальних (smart) технологій належать електронні пристрої і обчислювальні системи, інтегровані в одяг, що надають розширені функції та зручність користувачам. Виявлено, що smart технології можна використовувати для моніторингу здоров'я людини під час спортивних занять, для підвищення її особистої безпеки та зручності користування одягом. Дослідження показало, що інтегровані в одяг електронні пристрої можуть допомагати людям відстежувати основні показники здоров'я та покращувати особисту безпеку, крім того, можуть підвищувати особисту зручність, наприклад, керувати музикою, відповідати на телефонні дзвінки та контролювати інформацію. З погляду моди, інтелектуальні технології можна інтегрувати в дизайн одягу, щоб створити унікальний інноваційний виріб, однак основними труднощами «розумного» одягу залишаються електронні компоненти та блок живлення.

**Наукова новизна.** У статті запропоновано рішення для мінімізації недоліків проектування та використання «розумного» одягу, а також надано пропозиції щодо застосування інтелектуальних технологій, які інтегруються в одяг у вигляді різних пристроїв.

**Практична значущість.** Матеріали статті можуть бути використані при вивченні теми дизайну одягу з використанням сучасних інформаційних технологій та інновацій, а також при написанні наукових робіт.

**Ключові слова:** smart технології; одяг; моніторинг стану здоров'я; особиста безпека; особиста зручність; електронний пристрій, фешн дизайн; проблема з живленням.

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