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Examination and Evaluation of Design within the Field of Intelligent and Functional Textiles and Garments

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Abstract

The term "smart material" was initially coined in Japan in 1989. The primary example of a material recognized as a smart textile was silk thread. In the past few years, due to technological advancements, market growth, and the introduction of new types of fibers, the garment industry has transitioned from a traditional approach to one of industrialization. Clothes are no longer solely used for protection or concealment. They enhance and enrich one's quality of life. Not only have technological innovations brought about a fresh wave of textile production and consumer habits but have also affected various sectors, including medicine and the military. The innovative fibers and textiles have proven so cost-effective in certain situations that industry experts and owners prefer them over other alternatives. Wearable sensors can offer significant data regarding an individual's well-being, detecting potential risks and exposing dangers within their surroundings. Technology is omnipresent, encompassing our lives and gradually integrating into our existence.

Hence, intelligent garments aim to combine elements of style, technology, user interaction, user satisfaction, data protection, design, and scientific knowledge to create innovative technologies that can predict and fulfill wants and preferences. Presently, the swift merging of textiles and electronics allows for the extensive and seamless integration of sensors into fabrics, and the creation of conductive threads. A new era for the retail industry is anticipated with the possibility of smart fabrics that can interact with smartphones, enabling the processing of various biometric data like heart rate, temperature, breathing, stress, movement, acceleration, and hormone levels. In this study, the primary prerequisites for creating smart garments integrated with the Internet of Things are analyzed, alongside the potential influence of these garments on business models in the future. A worldwide IoT structure is put forward, illustrating the key types and elements of IoT wearables and intelligent garments, examining their primary necessities, and investigating some of the most recent smart clothing applications. This paper studies the historical and current aspects of smart clothing to offer recommendations for upcoming developers who aim to create a network where clothing can be linked similarly to other Internet of Things (IoT) devices. This network is referred to as the Internet of Smart Clothing.

Keywords: Smart clothing; Wearable; Internet of Things; Electronic textiles; Industry. Biometric; Sensors; Block chain.

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1. Introduction

Hence, intelligent garments aim to combine elements of style, technology, user interaction, user satisfaction, data protection, design, and scientific knowledge to create innovative technologies that can predict and fulfil wants and preferences. Presently, the swift merging of textiles and electronics allows for the extensive and seamless integration of sensors into fabrics and the creation of conductive threads. A new era for the retail industry is anticipated with the possibility of smart fabrics that can interact with smartphones, enabling the processing of various biometric data like heart rate, temperature, breathing, stress, movement, acceleration, and hormone levels. In this study, the primary prerequisites for creating smart garments integrated with the Internet of Things are analyzed, alongside the potential influence of these garments on business models in the future. A worldwide IoT structure is put forward, illustrating the key types and elements of IoT wearables and intelligent garments, examining their primary necessities, and investigating some of the most recent smart clothing applications. This paper studies the historical and current aspects of smart clothing to offer recommendations for upcoming developers who aim to create a network where clothing can be linked similarly to other Internet of Things (IoT) devices. This network is referred to as the Internet of Smart Clothing.

The advancement of smart textiles facilitates a deeper level of communication and interaction between humans and between humans and machines. Consequently, smart wearables and smart clothing are pushing the boundaries between the physical and digital realms. When integrated with technologies like smart glasses, they can significantly impact society through widespread adoption. These areas introduce notable changes across various industries and lay the groundwork for the emerging concept known as the "Internet of Smart Clothing," which envisions a future where intelligent garments can interact with each other, their surroundings, and servers. These smart clothes communicate wirelessly over the internet to provide advanced services.

2. Literature Review

The research will be conducted using a descriptive-analytical method to address the problem.

To begin with, this article assumes that designing functional clothing involves two main stages: conducting user-oriented research and identifying their needs. Therefore, the design specifications vary for each design.

The advancements in technology today have revolutionized the alterations made to garments.

Smart clothing and textiles have gained increasing interest from fashion enthusiasts times. The use of digital products, including smart clothes, is rising steadily due to technological advancements. Throughout history, the primary purpose of textiles has been to safeguard the human body against diverse environmental elements like sunlight, wind, rain, etc. Smart and aesthetically pleasing fabrics have been introduced in clothing manufacturing in the current era. These intelligent textiles serve the purpose of safeguarding individuals in harsh weather conditions, and aiding in the prevention, monitoring, and occasionally even treatment of injuries or illnesses.

2.1. What does the term smart textile mean?

E-textiles, known as Electronic Textiles, are fabrics incorporating digital and electronic components like batteries, sensors, circuits, and small lights woven or embedded into the fabric, depending on the specific tool. The unique characteristics of these textiles have made them popular among individuals interested in fashion and technology. Smart textiles can respond to environmental, thermal, mechanical, chemical, biological, and magnetic cues. Additionally, they can establish connections with other smart devices through Wi-Fi or Bluetooth technology. Smart textiles enhance fabrics and clothing with added functionality. These textiles, including fibers, threads, and yarns woven or knitted into fabrics, interact with the environment or the wearer. Integrating electronics creates e-textiles, further advancing smart materials and providing improved benefits for the user.

2.2. Smart fabrics

Smart fabrics are materials that can respond to their surroundings. They are capable of activating digital and electronic components. Pyles-Friedman from the Pratt Institute explains that what sets smart fabrics apart is their capacity to perform tasks that traditional fabrics cannot, such as communication, transformation, energy management, and even growth. Smart textiles are designed to be sensitive and responsive to environmental conditions or specific mechanical, thermal, chemical, and electrical stimuli. To be considered smart textiles, they must consist of three essential components: sensors, actuators, and control units. The introduction of smart textiles has posed numerous challenges across various fields, including medicine, sports, military, and aerospace.

Figure 1. Smart fabric

2.3. Classification of functional clothing

Occupational-situational protection means safeguarding against thermal, chemical, microbial, radioactive, and mechanical risks, electrical, biological, rain/moisture, UV flame, environmental damage (protection injury), and creating a visibility wearer. Firefighter and rescue team attire, miners' clothing, sweepers' workwear, welding jumpsuits, protective gear for working with glass, cutting tools for wood, and a chainsaw. Radio and microbial technology, telemedicine, and QU (perceived quality) are all essential components in healthcare. Monitoring vital signs and providing rehabilitation are crucial for maintaining good health. Additionally, there is a growing need for hospital and emergency workers to have access to anti-protolymphatic and hypertrophy clothing, and Venus X clothing. These advancements also extend to the sports industry, where specialized sports clothes play a vital role.

The management of temperature, and humidity, and monitoring health and vital signs to protect against shock and injury (such as cut and slash protection).
Enhancing blood circulation and improving aerodynamics.

Apparel designed for various activities including mountaineering, diving, motorcycling, skiing, rugby, hockey, athletics, and specialized clothing for Muslim athletes.

Enhancing the aesthetics of the body through shaping (such as accentuating body shape and size, addressing physical disabilities, and clothing for individuals with hunchbacks).

Adding functionality by combining clothes with other accessories (such as backpacks, umbrellas, and jewelry), promotes social interaction, and increases productivity.

Special needs that may be either temporary or permanent are necessary for various groups such as middle-aged individuals, children, those who are weak or disabled, pregnant and lactating women, as well as patients with diabetes or autism. These needs include protective gear, bulletproof clothing, camouflage attire, and health monitoring devices, specifically designed for special military security missions.

Moreover, there is a requirement to monitor vital signs, environmental conditions, telecommunications, and protection against radiation exposure.

Additionally, there is a need for wearable equipment, suits for the destruction of ammunition, and guards for the police force. Furthermore, there is a need for specialized attire at high altitudes, including astronaut suits, and life jackets for safety purposes (See figure 2.).

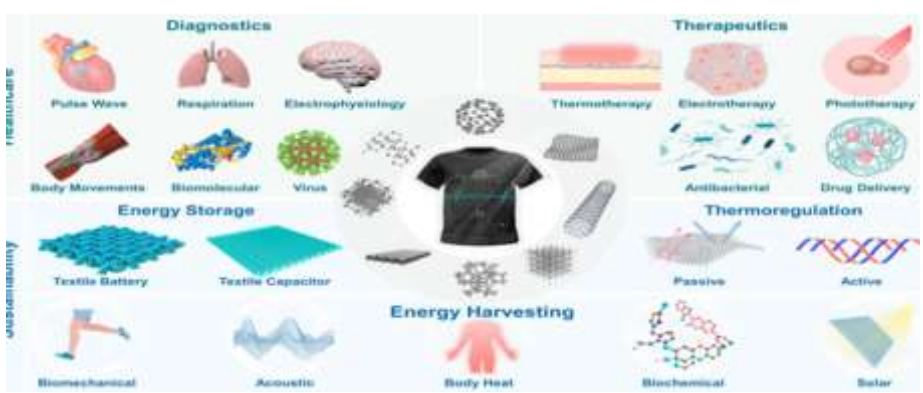

Figure 2. Smart functional textiles and clothing

2.4. All types of intelligent fabrics

1. Passive smart materials: This category comprises materials that solely recognize environmental conditions or stimuli, such as changes in color, shape, thermal properties, or electrical resistance.

Example: A heat-resistant shirt that can monitor body temperature.

2. Active smart materials: can respond to external conditions or stimuli. By incorporating actuators into the passive smart textile component, they transform into active smart fabrics, allowing for a specific response to a given stimulus.

Example: The fabric of a shirt is sensitive to the surrounding temperature. When exposed to high temperatures, the shirt automatically pulls up its sleeves.

3. Smart materials: These materials exhibit a trifecta of functions. Firstly, they possess sensors capable of receiving signals. Secondly, they can react based on the received signals. Finally, they can change in shape, size, color, or action according to the function.

4. Highly materials transfer artificial intelligence to computers, a capability beyond human research. Achieving this requires research and development in textiles and electronics, specifically through smart fabrics or advanced materials that align with computer technology.

2.5. Three categories encompass smart textiles

• Textiles that consist of circuits, batteries, or LEDs.

• Diodes, wires, conductive fibers, and solar cells are directly integrated into the fibers of advanced electrical textiles.

• Smart textiles that combine elements from the types as mentioned earlier.

2.6. Intelligent wearable fabrics

Smart wearable textile products can engage, communicate, and comprehend due to the materials used in their production.

- Metal fibers are utilized.
- Conductive ink is employed.
- Chromic material is incorporated.
- Coating with nanoparticles is applied.
- Organic semiconductors play a role.
- The materials possess both shape and the capability to store memory.
- Optical fibers are included.
- Quantum tunneling composites are utilized.
- Intrinsically conductive polymers are incorporated.

Yarns are predominantly utilized in technical sectors, including apparel, military gear, medical applications, and electronics manufacturing. Conductive materials are combined with metallic or natural fibers to create conductive fibers. Fabric sensors are produced using stainless steel threads, metallic silk, organza net, and special carbon fibers. Moreover,

materials such as metal polymers, conductive polymers, optical fibers, electrical conductivity, quantifiable sensors, and data transmission are employed. These flexible materials are characterized by elasticity, lightness, affordability, and ease of processing.

2.7. What is the difference between electronic textiles and smart textiles?

Nowadays, the world has various interpretations of the term "electronic textile." It can also be referred to as "integrated electronic textiles."

- The concept of electronic textiles involves the fusion of conventional fabrics and fibers with electronic components.
- By utilizing electronic textiles, it becomes possible to transmit various types of data, such as heat, light, motion, and sensory information regarding local conditions.
- Integrated e-textiles are primarily intended for wearable devices, although they can also have other applications.
- Alternative definitions approach the concept differently, stating that e-textiles are electronic threads specifically designed to integrate with a particular textile product.

2.8. Two main types of e-textiles

- Electronic components are integrated into fabrics, creating embedded electronic textiles. This particular product resembles a textile product rather than an electronic one.
- Multi-layer electronic fabrics are applied onto a non-textile material and then affixed or sewn onto the fabric's surface. These products may appear more akin to electronic items rather than textiles.

2.9. Smart textiles

ASTM International distinguishes between "e-textiles" and "smart textiles" by their definitions. Regarding functionality, "e-textiles" possess an electronic component, while "smart textiles" may have a mechanical reaction without an electronic element. A fabric such as thermochromic fabric, which changes color based on temperature, is an example of a smart fabric that does not fall under the "e-textile" definition. Furthermore, a smart fabric composed of suitable materials can modify its structure and regulate airflow, enhancing the comfort of the clothing during movement and in diverse environmental situations.

2.10. The objectives of electronic textiles and smart textiles

The main objective of e-textiles and smart textiles is to develop completely new categories of products. Unlike traditional forms, e-textile wearable technology and smart textiles do not need PCBs or other bulky hardware components; instead, sensors and circuits are directly integrated into the clothing. Several e-textiles and smart textiles have the potential to revolutionize clothing and other markets, including products such as a shirt that monitors an athlete's heart rate during exercise and works in conjunction with a smartphone app. • Wearable medical devices that are small, lightweight, and fashionable,

designed to monitor health metrics such as blood oxygen levels and alert the medical team automatically in case of any problems.

• Clothing made of e-textiles that offer guidance on maintaining proper exercise form to athletes based on their speed, posture, and stress levels.

• Children's backpacks are integrated with location tracking and other features for enhanced safety through smart fabric technology.

• Clothing and accessories using smart textiles that can change color or patterns depending on factors like the wearer's condition, external temperature, or the current season.

• A winter jacket with an incorporated heating element in its interior, showcasing smart textile innovation.

These examples demonstrate how e-textiles counteract smart fabrics and fibers. E-textiles possess smart capabilities but rely on the computing power of smartphones or tablets by utilizing connectivity. In contrast, smart fabrics lack this information and instead have a reactive and passive role, only enabling users to activate or deactivate functions. For instance, a jacket with integrated heating does not require a smartphone connection, whereas performance shirts that track hydration and blood oxygen levels need to be connected to a separate device to access and utilize the gathered data.

2.11. The instruments utilized in electro textiles

Smart textiles are created using various tools, including diodes, batteries, circuits, wires, GPS technology, LEDs, and conductive metals.

Use of LED:

Smart textiles often incorporate bright LEDs illuminating in the night darkness leading to a captivating spectacle. This can be observed in the attire of ski athletes, for instance.

Using GPS:

The utilization of GPS in creating intelligent apparel is widely prevalent, as evidenced by clothing accessories that incorporate GPS technology. This technology is employed to locate these devices.

Both types of e-textiles offer numerous benefits:

• E-textiles can render sensors and computers flexible, lightweight, wearable, comfortable, and fashionable.

• Electronic filaments have the potential to be virtually imperceptible, allowing users to experience a high level of sensitivity.

• Recent advancements in fabric technologies concentrate on enhancing resistance to crushing and impact damage and increasing the flexibility and durability of embedded circuits.

2.12. Chemical-optical sensors

Chemical sensors, as per the Cambridge definition, can be defined as miniaturized devices that can provide online information about the presence of ions or specific compounds, even in complex samples.

The main aim of a chemical sensor is to generate measurable signals that correspond to a

particular concentration of a compound in the surrounding environment. Typically, a chemical sensor consists of two components: the sensor or receiving part, and the conversion unit.

Optical sensors work on various principles such as absorption, reflection, radiation, fluorescence, refractive index, thermal-optical effects, and light scattering. Transducers in the sensor segment emit light upon contact with a specific analyte. An examination of the composition and effectiveness of chemical sensors

In general, chemical-optical sensors can be categorized into two main subgroups, namely direct-type sensors and detector-mediated sensors. When it comes to direct optical sensing, the analyte is detected directly based on its inherent optical characteristics like absorption and emission.

2.13. Fiber-optical chemical sensors

Fiber-optical chemical sensors belong to the category of chemical sensors. Typically, they can be classified as either intrinsic or non-intrinsic. In non-intrinsic sensors, optical fibers are commonly employed to transmit electromagnetic radiation to the sensor directly in contact with the sample.

Optical fiber sensors involve altering the optical fiber configuration and utilizing the fiber as an integral component in the sensing process. The optical fiber is a cylindrical cable with a diameter varying from under 1 micrometer to several hundred millimeters. Plastics, glass, and quartz are the predominant materials employed in fiber production. The prevailing sensors are typically non-intrinsic, comprising a chemical detector immobilized at the upper portion of a single or paired optical fiber. Alternatively, a chemical sensor can be affixed at the central region of the optical fiber to form an unsteady field sensor.Optical sensors offer advantages such as inexpensive optical fibers, enabling long-distance signal transmission without added complexity. Their compact size and flexibility also facilitate rapid data acquisition in challenging environments.

Removable sensors can be integrated into textiles using adhesive tape or sewing. Optical fiber sensors can be woven or layered into fabrics, effectively becoming part of the material. For fabrics designed to function as sensors, larger sensor surfaces are crucial. Consequently, chemical-optical sensors are applied via dyeing, printing, or coating. Detection relies on color changes, which can be observed visually, measured spectrophotometrically, or analyzed calorimetrically.

Recent advances have successfully integrated physical sensors for parameters like breath rate, heart rate, and temperature into clothing. Incorporating chemical sensors into fabrics introduces a novel dimension to smart textiles, offering valuable insights into individual health through the use of coated sensors.

2.14. Integration of an optical sensor in fabric

Various functions have been carried out in the textile industry to absorb sweat in clothing.

However, incorporating chemical sensors into textiles is challenging. Therefore, addressing well-known issues related to wearable physical sensors, including physiological, environmental, and motion disturbances. Furthermore, chemical sensors have additional requirements due to their sensing mechanisms. The primary concern with sensor materials such as dyes, polymers, residual solvents, and additives is their potential toxicity. Additionally, when the sensor is directly in contact with the skin, it should not cause any reaction or harm to the skin. Moreover, the sensor should not pose any concerns or risks for users.

2.15. Use of metal fibers

Metal fibers significantly impact the field of E-Textiles and the textile industry. One notable example is Lame fabric, a blend of nylon and metal fibers. The reflective and glossy appearance of Lame fabric is attributed to metal fibers, while its elasticity is due to the presence of nylon.

2.16. Use of conductive metals

Conductive fibers known as Fibertronics are the product of combining metal and textile fibers, enabling them to possess conductivity or semi-conductivity. To achieve this, these fibers are blended. Their versatility allows them to be woven or sewn into the fabric, making them ideal for creating conductive properties in smart textiles. Moreover, Fibertronics are significantly lighter and more pliable compared to metal wires. Among the various applications, one notable use of these fibers is in designing police uniforms that offer protection against electric shocks. The concept of "smart material" was initially coined in Japan in 1989. The first textile material recognized as a smart textile was silk thread.

2.17. Smart clothes

Advancements in both fashion and technology have led to unique opportunities within the fashion industry. The aim of E-Textiles researchers is to create and design intelligent, adaptable, flexible, and comfortable garments similar to everyday clothing. As previously noted, smart fabrics are innovative textiles incorporated with technology. Initially, these fabrics attracted attention in the fashion world due to their ability to change color and lighting. However, over time, there have been significant improvements in these fabrics. Today, these garments feature technologies that allow communication with smartphones and other smart devices.

2.18. Related articles

Eco print and sustainable fashion
Recent developments in e-textiles
Investing in the new textile machinery industry since...
One of the key advantages of smart garments is their ability to seamlessly integrate into our

daily lives. For instance, consider an elderly individual who might forget to wear their health bracelet but is unlikely to forget their underwear or vest. Smart clothing can monitor vital signs like heart rate and blood pressure, potentially revolutionizing preventive healthcare. Medical smart wear provides valuable real-time health data to the medical community. This includes everything from bedding, clothing, and surgical bandages to more advanced materials like light-emitting fabrics used for photodynamic treatment of stents and composite heart valves. The most cutting-edge advancements in this field feature intricate fabric structures used in medicine. The smart shirt acts as a versatile framework for this innovative clothing.

2.19. There are three groups in which smart clothing can be classified.

- Wearable devices that store data in memory and perform complex calculations
- A garment monitor that tracks an individual's activities or health
- Smart apparel that controls specific factors such as temperature or ventilation

2.20. Washing ability:

When electronic circuits are permanently integrated into the fabric, it is essential to ensure that these circuits are properly protected during the garment's washing or cleaning process. The innovative method of embedding flexible electronics in a polymer like PDMS allows for safe washing. Smart clothing or wearable garments refer to clothing items that utilize technology to provide functionalities beyond those of regular clothes. Some smart clothes are made with advanced fabrics that incorporate circuits. Alternatively, certain types of smart wearables use sensors or additional hardware to achieve intelligent capabilities. While most smart clothes can connect to a secondary device via an app, it is important to note that this wireless connection is not necessary for intelligently interpreting the features of a garment.

2.21. Smart textiles in other industries

Smart textiles have gained popularity across various industries, including fashion, medicine, architecture, and entertainment, because of their unique features and applications. These textiles integrate multiple technologies, such as embedded infrared transmitters and receivers, which allow for wireless communication. Currently, this technology is employed in the military, medical, and architectural sectors.

The In terms of fashion, there are garments that can change color, as well as clothing that features a keyboard and smart screen for sending text messages, reading messages, and playing music. Moreover, fabrics have been developed for use in offices and homes, enabling adjustments in lighting and temperature. Additionally, TV controls are conveniently placed on sofa handles. All these examples highlight the advancements made in the textile industry within this field.

2.22. Smart military clothing

Smart clothing has quickly entered the military sector due to the essential need for enhancing performance. For example, when a soldier wears a specialized smart outfit, any injuries suffered in combat will trigger an immediate transmission of information about the wound and the soldier's condition to a nearby medical team. As a result, this allows the doctor to evaluate the severity of the injury by examining the soldier's heart rate and breathing, enabling them to prioritize and provide the necessary treatment. As technology keeps advancing, innovative products have appeared that equip clothing with smart features without significantly adding to its weight.

In our country, researchers have recently developed advanced military clothing with remarkable capabilities. This clothing includes three components: the dress itself, gloves, and boots, each with distinct features. Specifically designed for climbers, the gloves can keep hands warm in temperatures as low as -40 degrees Celsius. However, their functionality extends beyond temperature regulation. In mountainous terrains with no signal, these gloves can display the soldier's vital signs and geographic coordinates, helping to prevent them from getting lost. Another groundbreaking element of this intelligent Iranian military uniform is its boots, which are equipped with scanners capable of detecting mines and radioactive materials within a 5-meter radius of the ground, promptly alerting the soldier. Furthermore, these boots can scan the ground from depths of 30 to 40 cm.

2.23. Developing intelligent garments to enhance soldiers' ability to withstand fatigue

Engineers at Harvard University's Weiss Institute are currently developing a smart suit that aims to enhance physical endurance, delay fatigue, and potentially improve the body's ability to withstand injuries while carrying heavy loads.

The primary goal of this clothing is to delay the onset of fatigue, thereby allowing individuals to travel greater distances and protecting them from potential injuries caused by heavy equipment.

This lightweight, efficient, and adaptable garment will incorporate wearable supplementary devices that utilize various groundbreaking technologies. One such technology is a stretch sensor that monitors the body's biomechanics without the need for conventional tools that can hinder movement. This system has the potential to detect early signs of fatigue. Additionally, another technology used in this garment helps maintain balance by delivering subtle mechanical vibrations that enhance the body's sensory function. This new smart suit aims to address several limitations commonly associated with existing protective clothing, such as their high force requirements and rigid structure.

Additionally, these advanced technologies have the potential to be used in various applications. For example, similar wearable soft devices could be used to enhance resilience in seniors and improve mobility for individuals with physical disabilities. (See Figure 3)

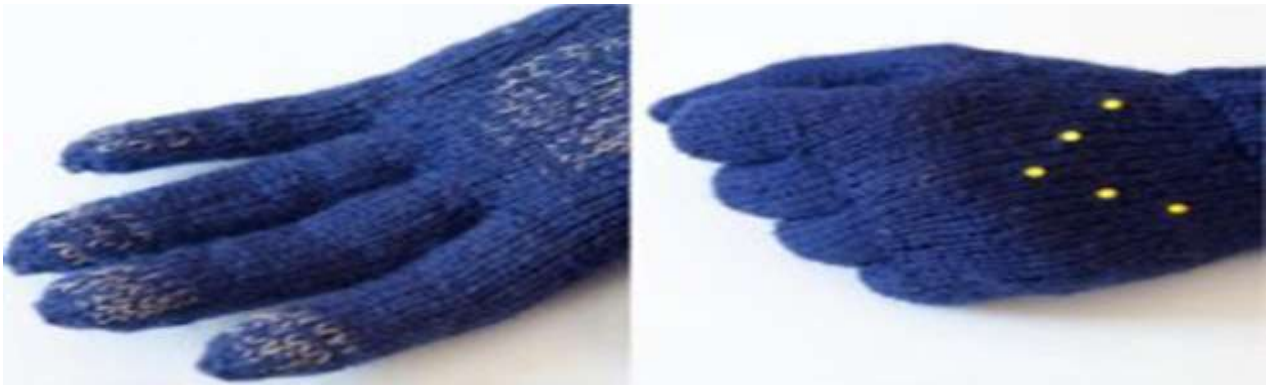

Figure 3. Bicycle gloves at night

2.24. The initial wearable fabric designed to track an individual's well-being

Researchers in the United States developed a dress that can be considered one of the earliest digital garments. Originally designed for military purposes over the past two decades, this attire incorporates optical fibers and sensors into its fabric to measure a person's heart rate and breathing rate. Another significant feature of this intelligent clothing is its ability to indicate the location of a bullet within a wounded soldier's body during combat. By transmitting a light signal from one side of the dress to the other, it can determine if the light beam fails to reach the opposite side, indicating that the soldier has been shot. The reflected light is then used to identify the bullet's position and the resulting hole in the fabric. Furthermore, this uniform can also monitor vital signs such as the soldier's heart rate and breathing rate.

2.25. Application of smart fibers in medical science

Smart fibers have various applications in the field of medical science. For instance, a team of researchers recently succeeded in manufacturing synthetic body parts such as lungs using polyester or Teflon fibers. These fibers also have the characteristic of being able to separate viruses like AIDS and hepatitis B without the need for a filter. However, the most significant use of these fibers in medicine is the production of Smart medical clothes. These garments, known as Telemedicine Telemedicine, allow medical treatment remotely. This concept entails the convergence of electronic, medical care, and remote health monitoring, representing one of the latest accomplishments of medical science. It involves the utilization of communication engineering, electronics, and computer sciences. Telemedicine enables continuous monitoring of patient's vital signs, such as blood pressure and heart rate, regardless of location.

Smart medical clothing monitors children with asthma by measuring their breathing rate. Several sensors are placed around the chest to determine muscle activity and respiratory rate, allowing for the detection and diagnosis of asthma attacks.

Concerned parents can buy the Owlet Smart Sock 2 to monitor their baby's health and sleep patterns. Sock 2 contains a sensor measuring heart rate, sleep patterns, and blood oxygen, which accurately evaluates the child's physical condition. Additionally, the Sock can send alerts when the baby's condition is abnormal.

The Owlet package, comfortable for the baby, includes a Wi-Fi connector and a smart sensor. It can send information regarding sleeping habits and oxygen levels to the parents' mobile phones, regardless of location. (See Figure 4)

Figure 4. Sensoria wellness socks

2.26. Sensoria Wellness Socks

Sensoria Wellness Socks use fabric sensors and an ankle device to capture precise gait and ground impact data during walking and running. The sensors wirelessly connect to a mobile app for advanced movement monitoring, analyzing foot temperature, foot strike, contact time, pace, stride, heart rate (with Sensoria HRM or similar), speed, distance, elevation, GPS, and more. Users can also set goals and track progress within the app.

2.27. Monitoring and maintaining optimal heart health through the utilization of a smart vest

One of the most practical digital garments designed so far is the Magic vest, created by a team of Italian researchers. Constructed from conductive fabric, this unique vest can measure an individual's heart and breathing rate, transmitting this vital information to a processing center. Extensive testing of the vest has been conducted in various scenarios, including its use by individuals who were recently hospitalized or have suffered a heart attack. Wearing the vest for several days allowed healthcare professionals to monitor the person's health status enabling the constant transmission of their physical condition during

activity and rest periods to a medical center. Notable features of this intelligent garment include its exceptional comfort, adaptability to different body sizes, and washable nature. Designing smart clothing to prevent bedsores

Bedsores affect immobile, bedridden individuals due to sustained pressure on the skin. Nurses reposition patients to alleviate this. Smart clothing offers a potential solution. Researchers have developed a garment that monitors blood circulation, oxygen, and nutrient levels, and delivers mild shocks via electrodes to improve blood flow, thus reducing the risk of bedsores. (See Figure 5)

Figure 5. Fabric keyboard pant

2.28. Intelligent garments capable of transmitting electronic information

The Smart clothing created by Intelligent Textiles, a British company, incorporates fibers that transmit electricity and electronic data. The company has showcased its innovative garments, including various uniforms, to the public. These Smart garments are equipped with a rechargeable battery, which allows them to generate and transfer electricity as needed.

In addition to their power transmission abilities, these garments can transmit electronic data, functioning as wearable computers. The company has utilized these specialized fibers to produce clothing items such as vests, shirts, safety helmets, backpacks, and gloves.

Currently, Intelligent Textiles Company is developing a fabric keyboard that can be integrated into these garments. (See Figure 6)

Figure 6. LED jacket

2.29. Every time you wash your smart garments, they get recharged

A garment created by a French company received the CES 2014 Health Innovation Award for its extensive functionalities. The dress is constructed using smart textiles containing durable micro-sensors capable of monitoring various bodily functions, such as body temperature, breathing rate, pulse rate, and even movement through GPS technology. Moreover, this fabric can be incorporated into any clothing item, including gloves, pants, and shirts, effectively transforming them into smart garments.

This fabric contains various sensors, a distributed processor, a small transmitter, and a battery that shares information with your smartphone. By receiving this information and using a specialized tool, a person's phone can determine their condition, such as fatigue, anxiety, or the likelihood of a heart attack. Professional athletes and soldiers will benefit from this technology. The price of these intelligent fabrics will likely be 30 to 40% higher than regular fabrics, but they can be washed and ironed as usual. Additional sensors can also be added based on user preferences, such as those that monitor blood oxygen levels, lung airflow, and even blood glucose, providing daily reports. The French company is currently researching charging systems that can harness energy from clothing during the washing process, utilizing the kinetic energy generated by the washing machine to recharge the clothing's batteries. T-shirt for people with epilepsy

Connected T-shirts offer a promising approach to managing epilepsy and reducing hospitalizations.

The Bioserenity T-shirt, developed by designers, engineers, and physicians, monitors and helps prevent seizures in individuals with epilepsy. This approach mirrors the use of connected devices for other chronic conditions, such as blood pressure monitors for hypertension and connected insulin pens for diabetes.

These technologies aim to improve chronic disease management and strengthen the doctor-patient relationship. A French researcher developed a connected T-shirt for epilepsy capable of monitoring and diagnosing the condition.

Epilepsy is a neurological disorder characterized by recurrent seizures, ranging in intensity from subtle to severe. These seizures result from abnormal brain activity. While medication controls up to 70% of cases, consistent sleep, avoiding alcohol and stress, and diligent self-care are also crucial.

Recent studies using these T-shirts demonstrate that seizures often occur predictably, within specific states or environments. Neurologists can now leverage this technology for enhanced disease monitoring.

The Neuronaute de BioSerenity program encompasses a smart suit featuring biometric sensors that continuously record body parameters. Through this program, physicians can monitor seizures and assess the patient's condition remotely, eliminating the need for hospitalization in specialized centers. In the event of an impending seizure, an alarm system integrated into the mobile application notifies the doctor. Additionally, the system allows for data sharing and storage.

Researchers have access to a variety of data collected from multiple users, which they

can use for in-depth analysis and investigation. This allows for improved identification of disease groups and specific epilepsy syndromes. The Neuronaut system assists in the management, treatment, and regulation of seizures, and also serves as a valuable tool for advancing epilepsy research. Neuronaut aids in seizure management, treatment, and regulation, while also facilitating epilepsy research.

2.30. Analyzing the psychological aspect through virtual clothing.

The expansion of smartphones has facilitated many innovations, including the production of smart clothes. Recently, scientists developed clothing that can recognize and address a person's mental state. This clothing is embedded with tiny sensors that can measure heart rate, body temperature, and skin conductivity, all of which are important indicators for determining one's mental state. The data collected by these sensors is sent to a database through a mobile phone, which then provides an appropriate response based on the person's current situation and general interests. The dress also features a screen with LED lamps displaying uplifting sentences when the person feels sad or upset. Additionally, the dress contains speakers in the hat that can play suitable music, hopeful messages, and even funny jokes.

2.31. Stress monitoring with smart clothes

Omsignal is an innovative type of smart clothing equipped with sensors integrated into the fabric that continuously monitor the wearer's health. These sensors track various metrics, including heart rate, breathing rate, breathing volume, movement (such as steps), movement intensity, heart rate variability, and calories burned. The collected data is stored in a compact black box and transmitted to a software platform, allowing users to assess their performance in real time.

By wearing this advanced clothing, athletes can optimize their training sessions through continuous biometric tracking during physical activities. The OM software translates the wearer's bio-signals into actionable personal insights. Additionally, the OM Fuel software assists with managing stored energy levels, while the OM RPM software offers instant feedback on concentration and physical stress levels.I will present additional instances that demonstrate the functionality of intelligent fibers.

2.32. Gore-Tex

The fabric utilized for outerwear incorporates a carbon membrane to prevent animals from easily detecting human odors. This specific fabric is suitable for both tourists and hunters.

2.33. Coolmax

Coolmax textiles can detect body moisture. Typically, Coolmax is used to produce woven clothing designed for runners and marching. The fabric can absorb and release the

moisture present in the athlete's body. Consequently, the moisture evaporates, and the fabric remains free from any damp sensation.

2.34. Innova

This fabric is composed of an innovative form of polyolefin. Through its ability to whisk away perspiration from the skin, this fabric facilitates its evaporation, resulting in a cool sensation while engaging in physical activities. Furthermore, it provides a comfortable warmth for the body during early morning sports sessions, and the garments made from these fabrics are exceptionally lightweight.

2.35. X-Static

This material utilizes the antibacterial characteristics of silver metal and is employed in medical garments, wound dressings, and athletic apparel. Silver combines with proteins both inside and outside the membrane of bacterial cells, thereby eliminating bacteria. However, it also generates an odor that renders it appropriate for utilization in sports socks.

3. Applications of smart wearable textiles

3.1. Smart ballet shoes

Inspired by ballet dancers' movements, Lesia Trubat recognized the potential of the E-Trac shoe to capture foot pressures and movements via a microcontroller board. These signals could then be transmitted as videos and photos to smart devices like mobile phones.

Smart ballet shoes are equipped with sensors positioned beneath the shoes, enabling dancers to visualize and address any flaws in their dance movements. Furthermore, this innovative technology holds potential for developing various other applications, including educational videos and live television broadcasts. (See Figure 7)

Figure 7. Smart shoes

3.2. Smart shoe design

The human feet are the "second heart" due to their significance in overall health. This is why

careful consideration is given to medical factors during shoe design. However, as different parts of the shoe undergo wear and tear, their effectiveness diminishes, increasing the risk of potential injuries for the wearer. The challenge lies in identifying the hidden areas of the shoe that may have experienced significant wear and tear, as they may not exhibit visible signs of damage. Consequently, even if the shoe appears intact, its structure may no longer provide adequate foot protection and could potentially cause severe harm to the person.

In the meantime, a new kind of shoe has been created with built-in sensors. These sensors are positioned in the shoe's heel or sole and can transmit data regarding the shoe's condition to the person's iOS device. Thus, if there is excessive wear on the heel or sole, the user will be notified about this problem.

Recently, researchers have introduced a new kind of intelligent footwear sending personalized messages to the wearer through speakers in the shoe's tongue. These shoes are fitted with an accelerometer and gyroscope. They have Bluetooth capabilities to connect with a mobile phone. By assessing the wearer's speed and mobility, the shoe selects and broadcasts one of 250 pre-recorded messages to motivate them to persist with their current activity or put aside laziness and pick up the pace.

3.3. Smart Bags

Pieteke Korte, a graduate in fashion design from Design Academi Eindhoven, collaborated with Brandecco to create these bags. The bags are constructed with leather and incorporate heat transfer foils in the fabric. The foils enable the bag to change color based on the temperature. In addition, another version of the bag features laser-engraved geometric patterns on the leather, revealing a secondary color Intelligent Coats or Smart Jackets

Vollebak, an intelligent apparel company established in 2016 by athletes Steve Tidball and his twin brother Nick, has a diverse range of clothing offerings. Among their products is a jacket with remarkable qualities, such as waterproof, stretchable, breathable, soft, and lightweight. The jacket's fabric can be charged by sunlight and artificial light sources. The feature that makes it distinguishable. This innovative garment incorporates a thin membrane composed of phosphorescent materials. These unique materials can absorb light and emit it in darkness, resulting in a glow-in-the-dark effect. (See Figure 8, 9)

Figure 8. Smart jacket

The XO Company and the TwentyFour15 clothing brand collaborated to create these

jackets. These jackets synchronize with your mobile phone and alter the color of the built-in LEDs based on the music played. The result is a technologically advanced jacket that changes color in response to the music.

Figure 9. Smart jacket

3.4. Levi's and Google smart coats

Google and Levi's have collaborated to create intelligent jackets that connect to smartphones. This innovative garment enables users to handle phone calls, read and reply to text messages, navigate with Google Maps, and even listen to music, without needing mobile devices. Users can access these various functions, simply by touching the sleeves of the coat. This advanced jacket utilizes built-in sensors that facilitate interaction with the digital realm, eliminating the need for a mobile phone. However, it is worth mentioning that the coat's digital capabilities diminish after undergoing ten rounds of washing. (See Figure 10)

Figure 10. Smart coat

3.5. E-motion

Students of Berlin University of the Arts created the E-motion clothing line. This particular dress showcases the unique capability to express an individual's emotions to others. The E-motion clothing, using image memory technology, alters its form based on our inner sentiments. It is a sophisticated garment that adapts its shape based on the fluctuations in human emotions. (See Figure 11)

Figure 11. Clothing embedded with image retention technology

3.6. Dis.appear

Theresa Lussier has created a jacket that functions as a clever garment. Embedded with an accelerometer, this attire illuminates its LEDs once the wearer initiates movement. Consequently, these LEDs remain lit as long as there is motion while turning off promptly when the person comes to a halt. Hence, these clothes activate the internal LEDs through the wearer's motion**.** (See Figure 12)

Figure 12: LED Jacket with an embedded accelerometer

3.7. Under Armour

The collaboration between Under Armour and Tom Brady, who places great importance on sufficient and high-quality sleep in his training routine, has led to the creation of sleepwear that enhances sleep quality. To achieve this, the clothing incorporates bio ceramic particle technology, which absorbs the body's emitted infrared waves, reflects them

to distant areas, and enhances the sleep experience. (See Figure 13, 14)

Figure 13. Comfortable night dress equipped with bio ceramic particles

Figure 14. Athos Core 20 grams Sensor

3.8. Athos Core 20g sensor

EMG analyzes a person's activity using an electromyography sensor embedded in clothing. The uniqueness of this product is its ability to collect and evaluate the electrical activity produced by muscles to show how strong they are. The complete set of this product includes shorts, a shirt, and an electronic gadget known as the Core. These garments use sensors to measure electromagnetic activity, breathing, and heart rate. The Core has a built-in gyroscope and accelerometer for accurate movement tracking. It can be attached anywhere on the clothing. It is possible to check and follow these activities through the mobile app. (See Figure 15)

Figure 15. Clothing fitted with an internal gyroscope and an accurate motion accelerometer

3.9. Thermotron

UNITIKA Thermotron is a unique material designed to harness sunlight and efficiently convert it into thermal energy, which is stored rather than wasted. One of its key components is zirconium carbide micro-particles, enabling the fabric effectively absorb and filter sunlight. Additionally, the inner layer of the fabric serves to retain the generated heat and prevent its dissipation into the surrounding environment, ultimately benefiting the wearer's well-being. Consequently, this fabric ensures a comfortable and enjoyable experience by offering waterproof and breathable properties in garments**.**

3.10. Stone Island

The stone island jacket indicates the ambient temperature, employing a liquid crystal thermal coating that causes a molecular rotation at 27 degrees Celsius. This rotation alters the path of light, thus causing the color of the garment to transition gradually from a dark shade to a lighter and more see-through hue, which matches the underlying fabric color. If the jacket reverts to its normal temperature, it will regain its primary dark appearance. (See Figure 16.)

Figure 16. Smart Jacket

3.11. Polarseal

This product provides an immediate sensation of warmth at the press of a button. The product offers three levels of heat, ranging from high to moderate to low. It features two heating zones, one at the top and another at the back, ensuring that users stay warm during winter. These techniques have been tested in freezing temperatures at high altitudes, such as alpine environments. These products are characterized by their ease of use and possess notable qualities such as flexibility, lightness, ventilation, and water resistance, making them suitable for outdoor sports activities. These wearables can function as both gloves and shirts. These products can maintain warmth for up to 8 hours with one touch. ZeroI

This is a hat equipped with bone-conducting speakers, allowing sound to be transmitted through the bones. Headphones are unnecessary for listening to music or making phone calls with this hat, as it does not obstruct the ears. Additionally, this wearable is water-resistant, making it suitable for use during rainy seasons. (See Figure 17)

Figure 17. Smart cap

3.12. ORII

Orii is a wearable device that enables voice communication. It is a digital assistant that transforms our finger into a smartphone with a simple touch on the ear. Utilizing the principle of bone conduction, which has been widely employed in medical equipment, the device uses layers of silicone that are durable and hypoallergenic. Through these layers, vibrations are transmitted directly from our finger to the ear, allowing for clear auditory reception. Consequently, it enables us to communicate and listen using only our fingers. The device offers bidirectional sound, allowing communication even in noisy environments by removing the microphone and utilizing bone conduction technology. The functionalities include navigation, alarm setting, translation, SMS composition, weather updates, message sending, call making, timer functions, and map directions. Additionally, it has water resistance capabilities. The information displayed on the device can be personalized, and it is equipped with four LED lights that indicate the type of incoming message.

3.13. Fingers **AIOSleeve**

The sleeve is designed to be worn on a single hand and offers data that requires professional analysis. This wearable enables you to examine your behavior, sleep duration, and sleep quality through your mobile phone. Additionally, this sleeve allows for personalized music playback. It tracks your heart rate, ECG, movements, distance traveled, and calories burned during exercise. Furthermore, the device also measures your stress levels while you work. All of these features can be accessed at any time and from any location through our smartphone. (See Figure 18)

Figure 18. Smart Sleeves

3.14. Arrow smart shirt:

This company has created a seemingly typical shirt with unique, tap-activated functions similar to a tie. By tapping the sleeve, users can display their business card, prepare for work, connect to Bluetooth, and play preferred media. These functions are concentrated in a single sleeve, with an embedded microchip in the cuff button controlled via a dedicated app.

3.15. Mood dress

Scientists have successfully developed and manufactured clothing that can alter color based on the body's shape. This remarkable dress, created by the renowned electronic company Philips, comprises two distinct layers. The internal layer incorporates a biometric sensor that detects an individual's emotional state and effectively showcases it through colors within the external or outer layer. The fluctuations in body temperature and perspiration levels caused by emotions like stress or fear generate light, causing the dress to alter the pattern and hue. For example, anger or nervousness might turn the dress vibrant red, whereas calmness turns the dress into a serene green shade.

3.16. Lumo Run

Self-motivation can prove to be one's greatest advantage, while self-evaluation can present the greatest obstacle for individuals seeking to acquire knowledge independently. Luco run, a motion sensor fastened onto your belt, serves as a valuable tool by collecting data and providing motivation during running. By analyzing your body shape and posture, Luco Run offers insights into your capabilities while safeguarding against potential injuries. The collected data can be conveniently accessed and thoroughly examined through your smartphone, removing the necessity for reliance on Google, smartwatches, or cables.

3.17. Invisible Cloak

A scientist from the University of Tokyo in Japan is investigating a sophisticated cloak that grants invisibility. This cloak uses nanoparticles that reflect light, effectively rendering the wearer unseen. Additionally, the cloak features a camera on its back, enabling the individual to capture and display the motion of objects or activities occurring behind them, further enhancing the illusion of invisibility. Nowadays, an innovative method called the waveguide technique can be employed to produce a fabric-based wearable antenna.

Consequently, various industries such as automotive, retail, military, fashion, and entertainment will benefit from this technology and find specific applications in the future. Using stretchable and flexible sensors enables substantial monitoring capabilities for tracking human movement and physical activity. The electronic fabrics mentioned above, through meticulous analysis of the collected data, can accurately identify human motion. Moreover, this data analysis can be leveraged to measure body dimensions in retail clothing manufacturing businesses or for personal defense objectives. (See Figure 19)

Figure 19. Car cover fitted with advanced wave-guiding technology to form a wearable antenna.

3.18. Smart clothes for babies

Instead of relying on smell, parents can now receive notifications via SMS or email when their baby needs a change of clothes. This technology uses sensor-equipped baby clothes that monitor vital signs and transmit data to phones, computers, or tablets. The washable, discreet sensors track humidity, movement, skin temperature, and heart rate. The clothing connects to the internet via low-power digital radio and is rechargeable. By wirelessly monitoring the baby's condition, the technology sends real-time updates on the baby's vital signs, eliminating the need for constant physical checks. (See Figure 20)

Figure 20. Smart clothes for babies

3.19. Smart clothing helps to identify the reason behind a child's crying.

Scientists have developed smart clothing containing sensors capable of identifying the cause of crying and monitoring the baby's physical well-being. These sensors are embedded within the fabric of the clothing and monitor the baby's body temperature, heart rate, and movements, providing parents with a detailed report of their child's condition. (See Figure 21)

Figure 21. Smart clothing identifies the reason behind a child crying

Detecting the moisture in the baby's clothes, smart clothing can also notify parents when it is time to change the diapers by sending an email or text message. Each item of clothing is equipped with transmitters that can be connected to smartphones and computers. After installing specific software, parents can access and analyze the data gathered about their baby's health status.

By installing software on their smartphones, parents will have access to information regarding the baby's level of physical activity, heart rate, and overall physical condition. This technology can also help identify potential risks such as sleep apnea and sudden infant death syndrome (SIDS) by monitoring vision impairment.

The smart clothing has undergone testing in a children's hospital, and once finalized, it will be available for purchase at $100.

Minimizing infant mortality rates by utilizing intelligent garments embedded with traction circuits to secure their safety.

Researchers have developed a smart suit with flexible orbital plates to reduce the risk of sudden infant death syndrome (SIDS), the exact cause of which is currently unknown. This suit continuously monitors an infant's heart rate and breathing. The orbital plates, made of potentially low-cost polyurethane, are embedded in the chest, abdomen, and back regions to detect cessation of breathing and alert parents. German researchers also plan to use stretchable polyurethane circuit boards in pressure bands and smart adhesives. These adhesives, equipped with a light detector and a blue LED lamp, inject organic fluorescent light into the body for detection, potentially eliminating the need for blood tests. Clinical trials for the adhesive have begun, with commercial availability expected within five years. (See Figure 22)

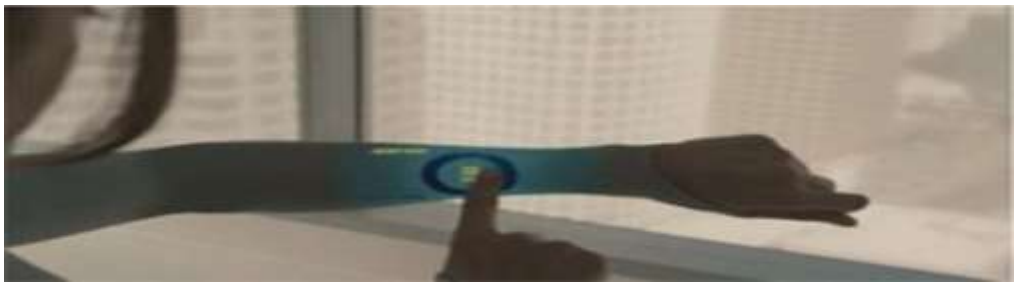

Figure 22. Minimizing infant mortality rate using an intelligent garment embedded with a traction circuit

3.20. Aesthetics and fashion

Functional clothing encompasses aesthetics and fashion, with even color selection taking into account factors like protection and camouflage. However, as clothing is also regarded as a fashion statement, aesthetics should be fused with other human aspects to maintain a balance between functionality and aesthetics. Surprisingly, technology and fashion are not as distant as they may initially appear. For wearable technology to be successful, it must seamlessly integrate with clothing, feeling natural and unobtrusive. The technology should be discreet and unnoticeable, causing the product to be stylish and visually appealing as a clothing accessory. The significance of human response to visual stimuli and positive aesthetics is vital in professional and personal clothing and protective textiles. However, it is worth noting that beauty is subjective and heavily influenced by the wearer's background, social norms, and past experiences. Many functional clothes aim to incorporate visual appeal through technological elegance, featuring clean lines, simple colors, and futuristic designs.

Nevertheless, fashion trends evolve more rapidly than product or technological aesthetics, with the current tendency leaning towards a fusion of nostalgia and sci-fi futurism. It is also crucial to take fashion and trends into account. Fashion plays a vital role in bringing together and intertwining technological elements, thus transforming functional clothing into an interactive relationship. Additionally, some researchers propose simplifying the shape of functional clothing to prolong its lifespan.

4. Conclusion

E-textiles, while offering numerous advantages, contain toxic heavy metals and halogenated chemicals that pose health and environmental risks. Improper disposal via municipal waste or incineration after wash-off can contaminate the environment during recycling. Given the difficulty of recycling e-textiles, future research should focus on developing composite models that allow for easy separation of constituent materials while preserving their electronic properties.

Integrating flexible actuators into textiles during manufacturing as threads or fibers would enhance wearable technologies. Garments like speed-measuring tights could increase consumer appeal. Textiles' ability to mimic biological and mechanical movements

distinguishes them from traditional electronics, offering diverse capabilities. The use of cost-effective smart materials also supports the e-textile industry's sustainability. Addressing emerging market demands requires attention to pricing, production quantity, and scaling. Furthermore, the implementation of these versatile smart products can decrease consumerism, providing a significant advantage as consumers actively seek and invest in sustainable options.

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