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RESEARCH ON TECHNOLOGICAL CLASSIFICATIONS AND APPLICATION AREAS OF SMART WEARABLE CLOTHING

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This study systematically reviews recent literature to categorize the technological classifications and application domains of smart wearable clothing, highlighting its diverse applications in health monitoring, sports assistance, protection, fashion, and rehabilitation. From a design perspective, smart wearable clothing is evolving from a "function-augmentation" model to an "experience-immersion" paradigm. Designers must seamlessly integrate technological modules into the language of fashion through synergistic innovations in technology concealment, naturalized interaction, and aesthetic contextualization, ultimately fostering a seamless symbiosis between humans, clothing, and the environment.

Key words: smart wearable clothing, garment design, user experience, technological classifications, application areas, innovative uses.

INTRODUCTION

Smart wearable clothing refers to the integration of smart technologies into traditional garments, endowing them with additional functions beyond basic purposes such as warmth and coverage. For example, components such as sensors, electronic circuits, and communication modules are embedded into textiles to enable functionalities such as health monitoring, data processing, and wireless transmission. The concept of smart wearable clothing has existed for many years, originating from early 20th-century attempts. With the advancement of microelectronics, sensor technologies, and the Internet of Things, it has gained widespread applications in health monitoring, sports, and entertainment in recent years, accompanied by a notable increase in market demand [1]. Research into smart wearable clothing technologies holds significant academic value and promising application prospects, not only addressing health monitoring needs in the context of an aging population but also driving industry upgrades and positively contributing to the development of a smart society [2].

PURPOSE

The study provides a comprehensive overview of the core technologies, market dynamics, and future development directions of smart wearable clothing. It includes an analysis of the technological classifications and application areas of



smart wearable clothing, explores its real-world applications in fields such as health monitoring, sports and fitness, and interactive entertainment, examines its potential to enhance user experience, meet personalized needs, and drive industry upgrades, and investigates the challenges and emerging trends in the development of smart wearable clothing.

RESULTS AND DISCUSSION

This study utilizes a literature review to analyze recent relevant academic literature on the technical classifications and application areas of smart wearable clothing.

(1) The categories of technology can be divided into sensor-integrated, wireless communication, and dynamic feedback systems.

The sensor-integrated design incorporates various sensors, such as biosensors, environmental sensors, accelerometers, and pressure sensors, to monitor physiological and environmental changes in real-time. Special soft, flexible sensors allow the technology to closely conform to the body, ensuring no restrictions during movement or daily activities, while preserving the garment's softness and wearability. Sensor-based technologies are primarily used to monitor physiological indicators such as heart rate, body temperature, and acceleration, with widespread applications in health monitoring and sports tracking for analyzing and providing feedback on health data [3].

Wireless communication systems are an essential component of smart wearable clothing. By integrating communication technologies like Bluetooth, Wi-Fi, and NFC, smart garments can transmit sensor data to external devices (such as smartphones and cloud platforms), enabling data synchronization, remote monitoring, and control. This allows real-time transmission of users' physiological data to healthcare providers or health platforms for remote diagnostics and management.

Dynamic feedback systems in smart clothing provide real-time feedback to the wearer through modules that alter vibration, thermal control, or pressure. For example, smart massage clothing offers muscle relaxation through vibration or heating functions, while smart running apparel uses vibrations to remind the wearer to adjust posture. Dynamic feedback technologies enhance the user's experience by offering immediate comfort and exercise guidance.

(2) The application areas can be categorized into health monitoring applications, sports assistance applications, protective applications, fashion-oriented applications, and rehabilitation applications.

Health-monitoring smart clothing is primarily used to collect and track the wearer's physiological data, such as heart rate, body temperature, and respiratory rate. Such clothing is commonly applied in elderly care and remote monitoring of chronic disease patients. Through integrated sensors, the wearer's health data can be transmitted in real-time to doctors or health management platforms, enabling personalized health interventions and treatment.

Sports-support smart clothing integrates motion sensors and analysis systems to monitor the wearer's physical activity in real-time. Such clothing can track parameters like exercise intensity, step count, and posture, and offer exercise



recommendations based on data analysis, helping users optimize their performance and minimize injury risks. Typical examples include smart sports T-shirts and smart running shoes.

Protective smart clothing is primarily used in hazardous work environments, such as those for firefighters and construction workers. These garments incorporate features like temperature monitoring, gas detection, and heart rate monitoring to safeguard the wearer's safety. For instance, smart firefighting suits can monitor both the wearer's physical condition and the surrounding environment in real-time, assisting in emergency decision-making and ensuring the safety of the wearer.

Rehabilitation smart clothing is designed to assist with physical rehabilitation and daily activities, particularly for the elderly. It uses sensors to monitor muscle activity, posture, and other relevant data, helping users engage in effective rehabilitation exercises. Smart rehabilitation garments integrate with external devices to provide real-time feedback, assist with movement guidance, and enable data analysis throughout the rehabilitation process. They are widely applied in fields such as physical therapy and elderly care.

Fashion-oriented smart clothing integrates intelligent functionalities with aesthetic design, addressing both users' functional needs and visual appeal. In the design process, innovative morphological techniques such as asymmetric tailoring, detachable modules, and layered structures are employed to seamlessly embed sensors, interactive modules, and other smart components into the garment's silhouette, achieving a high degree of functional integration. Simultaneously, advanced technologies such as programmable luminous fibers, thermochromic coatings, and photochromic materials enable dynamic changes in the garment's appearance in response to environmental factors or user movements, enhancing its visual expressiveness. Moreover, the deep integration of conductive fibers with flexible circuits allows novel textiles and composite materials to improve both the touch responsiveness and data monitoring capabilities of smart clothing. This integration also creates a distinctive aesthetic effect by juxtaposing metallic luster with the textures of traditional fabrics. By holistically coordinating form, color, material, and interaction modes, fashion-oriented smart clothing harmonizes visual aesthetics with interactive experiences, opening new possibilities for interdisciplinary collaboration between technology and fashion.

The technological and clothing type classifications of smart wearable garments are mutually reinforcing. Technological innovations foster the diverse applications of smart clothing, while various clothing types address users' specific needs in different contexts. Clothing, being in close contact with the body and worn for long durations, is often referred to as the human "second skin," making it an ideal platform for real-time monitoring and human-computer interaction.

CONCLUSIONS

With continuous technological advancements, smart wearable clothing is emerging as an innovative platform for multi-domain applications. This study analyzes recent literature to explore the technological classifications and application domains of smart wearable clothing, revealing its extensive use in health monitoring, sports assistance, protection, fashion, and rehabilitation. The integration



of sensor-based, wireless communication, and dynamic feedback technologies enables these garments to not only collect and transmit real-time data but also provide immediate feedback and guidance to users, significantly enhancing the overall user experience. From a design perspective, the evolution of smart wearable clothing is shifting from a "function-augmentation" model to an "experience-immersion" paradigm. Designers must adopt an interdisciplinary approach to transform electronic functional modules into an organic language of fashion design. Through synergistic innovations in technology concealment, naturalized interaction, and aesthetic scenarization, smart wearable clothing fosters a seamless symbiosis between the user, garment, and environment.

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ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНИХ КЛАСИФІКАЦІЙ ТА СФЕР ЗАСТОСУВАННЯ РОЗУМНОГО ОДЯГУ

У цьому дослідженні систематизовано інформацію та виокремлено сфери застосування розумного одягу, висвітлюючи його різноманітне застосування в моніторингу здоров'я, спортивній допомозі, захисті, моді та реабілітації. З точки зору дизайну, розумний одяг еволюціонує від моделі «доповнення функцій» до парадигми «занурення в досвід». Дизайнери повинні мати можливість безперешкодно інтегрувати технологічні модулі в мову моди за допомогою синергетичних інновацій у приховуванні технологій, натуралізованій взаємодії та естетичній контекстуалізації, що в кінцевому підсумку сприятиме симбіозу між людьми, одягом та навколишнім середовищем.

Ключові слова: розумний одяг, дизайн одягу, користувацький досвід, технологічні класифікації, сфери застосування, інновації використання.