HACKTEX VIRTUAL TRAINING MATERIALS

Functional and smart textiles
Learning unit 1
Lesson 2

Applications of smart textiles: In the domain of medical, transport & energy, protection & communication.

Innovative smart textiles & entrepreneurship

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Content

Introduction

Smart textiles are a transformative innovation and represent a significant advancement in the field of textile engineering. This innovative technology enables textiles to exhibit properties such as sensing, actuation, and communication, which were previously unimaginable. Smart textiles have a vast economic impact and potential, as they bring the traditional textile sector to a high technological level. The development of smart textiles has resulted in the production of high-performance and highly-functional textiles, which are of great interest to various sectors. These sectors include healthcare, sports, fashion, military, and aerospace industries. The potential applications of smart textiles are vast and range from monitoring vital signs to environmental sensing. In order to achieve optimum output from smart textiles, a multidisciplinary approach is crucial. The integration of knowledge from different fields, such as intelligent materials, chemistry, and microelectronics, is necessary to develop and optimize the performance of smart textiles. Creation of textiles with enhanced properties, such as increased conductivity and improved durability are essential for the success of smart textiles in various applications. The advancement in smart textiles requires extensive research and development to overcome the technical challenges related to integrating electronics into textiles. The integration of electronics requires the development of new materials, such as conductive polymers and nanomaterials, and the use of emerging technologies, such as 3D printing and nanotechnology.

1. Smart textile applications in medical sector

1.1. Monitoring and sensing devices

Smart textiles for monitoring and sensing devices can be obtained with/without integrating electronics. Several studies explored the smart textile applications in medical sector for monitoring health, revolutionize medical practitioners' operative method and human well-being. Textiles integrated with electronics generally includes digital components and battery to operate. Researchers have explored several textile technologies such as knitting, weaving, and printing to develop electrode integrated garments for electrocardiogram (ECG) measurement (Nigusse et al., 2021).

NUUBO textile electrode (https://www.nuubo.com/en-us) has been designed to obtain optimum ECG measurements with flexible and stretchable conductive tracks. It provides comfort to patient, flexibility and is cost-effective. Similarly, HealthWatch is another company pioneer in harnessing e-textile technology to produce smart-digital garments with interwoven sensors measuring vital signs of hospital-grade quality. The company's first product is a sensor-rich heart sensing textile garment allowing ECG and wider vital signs monitoring such as 12-lead ECG with heart rate detection, skin temperature, respiratory, and body posture.

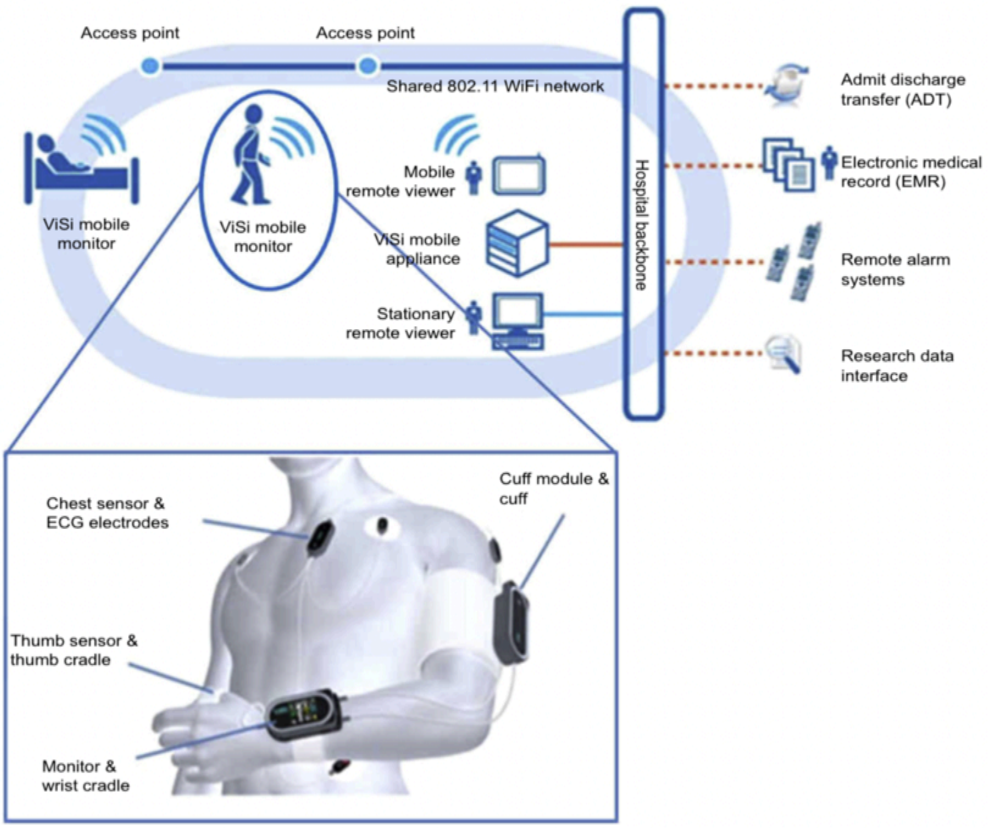

Figure 1. Visi Mobile monitoring system from http://www.visimobile.com/visi-product-info/technical/

In Figure 1, health monitoring and healthcare system has been demonstrated by Sotera´s Visi Mobile. Its body sensor network systems (BSN) imbedded in E-Tex can provide health care services such as medical monitoring of physiological signals and ambulatory communication. Multiple types of body sensors are deployed to collect and communicate a wearer’s health status anytime and anywhere (Kogias et al., 2016) (Younes et al., 2016).

1.2. Smart textiles for medical treatment

Modern medical treatments involve various techniques for disease treatment and the advancements in smart textiles have impacted a great deal in today’s healthcare system. Advancement in smart textile structure advancement covers a large range of medical sector needs from surgical clothing, bandages to light-emitting fabrics for photodynamic therapy. The progressive development in integration of electronic embedded systems onto textile support has increased its application use in medical sector. Wearable healthcare is one such emerging market which typically can be categorized into two, ’Diagnostic and monitoring devices’ and ’Therauptic devices’(Kim et al., 2016; Tylcz et al., 2016). Smart ECG monitoring shirt, stretch sensors to detect body movements, piezoresistive fibers are few of the examples for diagnostic and monitoring devices, whereas for pain management, electrical nerve simulation and spinal cord simulation are used as therauptic devices. Optical fiber-based smart textiles are being used for several medical treatments. Light therapy treatments are also explored for skin treatments, as the change in light wavelength modifies the light penetration into human skin tissues (Zaman et al., 2022).

Want to learn more about this topic?

In (Cochrane et al., 2016) , an overview is provided on the current state of the art on smart textiles in healthcare. The focus is on advancement in electrodes for textile sensors and textile-based actuators.

The chapter summarizes working principles of these smart textiles and propose solutions for integration of electronic components to show the current evolution toward ‘embedded everywhere’.

2. Smart textile applications in transport and energy sector

2.1. Transport sector

As per the Mordar Intelligence report, market value for smart textiles in transportation was valued at USD 0.61 billion in 2020 and expected to reach USD 2.46 billion by 2026. Vehicles including cars, trains, aircrafts, and shipping industry are seen to be great consumers of smart materials that can interact, communicate and sense.

Smart textiles have helped the textile industry in its transformation into a competitive knowledge driven industry. These categories of textiles combine knowledge from many disciplines with the specific textile requirements. Sensors/electronic components are integrated as a part of structural material enabling dual functionalities such as actuating and sensing capabilities. Modern aircrafts use composite materials up to 50% by their weight. Its commercial use in military aircrafts for several non-structural and structural parts such as spoilers, horizontal stabilizer, rocket motor castings, landing gear doors, engine cowls, wings, cargo liners, and so on. Carbon fibres dominate the aerospace sector due to their properties of high strength/stiffness and low density. Composite motor cases from carbon fibre/epoxy blend possess high strength and stiffness, thus resulting in substantial weight reductions.

Figure 2. Car seats with smart textiles (https://www.atriainnovation.com/en/smart-textiles/)

As seen in Figure 2, smart textiles are integrated in car seats that can detect occupant´s size, weight, temperature and even mood. Thus, textile sensors can be embedded, and automotive interiors can be modified to offer a wide range of functions due to smart textiles (Drean Emilie and Schacher, 2007). Illumination can be controlled as per the need of passengers to ensure ambient light by incorporating electroluminescent textiles in the car interiors. The other important function ´comfort´ during travel can also be improved using smart textiles.

2.2. Energy harvestment

With increase in population, there is driving demand for multifunctional electronic devices and the electricity needed to power them. As a result, there has been increased attention given to developing energy harvesting techniques that rely on renewable and ambient sources. While materials with unique properties such as photovoltaic, piezoelectric, and triboelectric have been utilized in thin-film structures for some time, their use in textile structures for energy harvesting is a relatively new area of research. Researchers continue to thrive for developments in the field of photovoltaic, piezoelectric, and triboelectric energy-generating textile structures. The fundamentals of these unique properties, production methods, and energy storage capabilities needs to be examined. Thus, it is expected that future trends in the fabrication and application of textile-based energy harvesting and storage will increase (Bayramol Derman Vatansever and Soin, 2017)

Want to learn more about this topic?

In (Wagner, 2013) you will find how smart textiles have become a new topic in vehicle engineering.

In (Dolez, 2021) you will find review of four different energy harvesting mechanisms relevant to smart textiles.

In (El-Zein et al., 2016) you will find fiber-based textile for solar energy harvesting

3. Smart textile applications in protective garments, communication

3.1. Protective and safety clothing

Product development is guided mainly by three trends; the needs of users, global systems, and environmental conditions. Smart materials present solutions to the challenges associated with these trends. In addition to wearable electronics, it can function as sensors for various physiological conditions, temperature, humidity, power, and data transmission, as well as end-of-life indicators, smart materials provide additional ways to address these trends. For instance, barrier membranes with responsive permeability to water vapor can be produced using different materials such as shape memory polymers, polymer gels, superabsorbent polymers, grafted polymer brushes, and polymeric ionic liquids. These membranes can be made self-decontaminating using N-halamines, quaternary ammonium groups, bioengineered enzymes, metals, and metal oxides, nanomaterials, and light-activated compounds. Additionally, phase change materials can improve thermal comfort by providing extra heat or coolness as required. Lastly, shear thickening fluids, which solidify and act as shock absorbers when impacted at high rate, present another example of smart material application in personal protective equipment (Dolez & Mlynarek, 2016).

With the integration of sensors and communication capabilities, devices are now able to comprehend complexity and react quickly. The Internet of Things (IoT) refers to a network of physical objects embedded with electronics, software, sensors, actuators, and network connectivity which can collect and exchange data to obtain a meaningful purpose (Miorandi et al., 2012). This technology can be utilized for complicated tasks that require high-level intelligence, leading us into a new realm. Every year, more and more companies are adopting sensors and connectivity to improve safety and reduce long-term costs by actively preventing health issues and tragic occurrences. This technological trend provides a solid foundation for implementing Personal Protective Equipment (PPE) since its primary objective, beyond regulatory compliance, is to enhance protection by reducing the risk of workplace injuries and even preventing them (Adjiski et al., 2019).

3.2. Communication

Electrochromic textile displays can be used for personal communication. Chromic or luminescent materials can change color or emit light respectively and these materials can alter their optical properties in response to specific stimuli such as optical, thermal, electrical, chemical, or mechanical.

Below figure is the example of electroluminescent flexible device, wherein a polyamide textile substrate is coated with successive layers of electroluminescent material. The uniform textile can display an illuminating text, logo or picture when connected to a battery. It can switch between different intensity levels with respect to the voltage applied.(Moretti et al., 2016)

Figure 3. Electroluminescent flexible (http://fr.zone-secure.net/publications/9534/59271/publication/contents/pdfweb.pdf)

Want to learn more about this topic?

In (Decaens & Vermeersch, 2016) you will find more details about wearable technologies for personal protective equipment

Summary

The main domain of textile applications are health/medical sector, transportation and energy, protection, security, communication and textile electronics. However, with the rise in demand for smart textile products, the global market is expected to witness numerous applications in several industries. Herein, different smart textile application sectors are stated wherein medical sector is a wide domain. Advancement in smart textile structure advancement covers a large range of medical sector needs from surgical clothing, bandages to light-emitting fabrics for photodynamic therapy. The progressive development in integration of electronic embedded systems onto textile support has increased its application use in medical sector. Wearable healthcare is one such emerging market which typically can be categorised into two, ’Diagnostic and monitoring devices’ and ’Therauptic devices’. Smart ECG monitoring shirt, stretch sensors to detect body movements, piezoresistive fibers are few of the examples for diagnostic and monitoring devices, whereas for pain management, electrical nerve simulation and spinal cord simulation are used as therauptic devices. You can see that the applications are broad from transport, energy and communication to textile electronics, and with the advancement and improvement in technologies, the applications will be numerous.

Transport application domain includes automotive, railways and aerospace and this sector is very important for smart textile applications, particularly due to its target in decreasing the vehicle weight which inturn can enhance the performance.

Another such sector is energy and with increase in energy consumption worldwide, it is more important today to focus and provide smart solutions. Thus, smart textiles can facilitate in energy harvesting and production such as flexible photovoltaic cells.

Furthermore, smart and communicative textiles with embedded sensors can be monitored in real time and can alert in case of any problems.

In addition, there is also textile electronics as an exciting area of application, wherein fibrous diodes, flexible sensors, and actuators will be part of clothing and home textiles. The integration of flexible textile-based electronic systems with the database and servers can provide new and effective ways of using textiles.

Advances and challenges in smart textiles:

- Recent developments in the field of smart fabric textiles include the use of nanomaterials and conductive polymers to enhance their properties, such as conductivity and sensing abilities.
- Technological challenges include the need for more durable and washable smart textiles, as well as the development of reliable and accurate sensing technologies.
- Smart textiles with high performance and high functionalities are becoming interestingly evident with its developemt and application use in several sectors as discussed previously. However, for optimum output, it is important to embrace a

multidisciplinary approach and integrate the knowledge of intelligent materials, chemistry and microelectronics.

- The use of nanomaterials and conductive polymers are the recent and ongoing development in the field of smart materials. Enhancing the performance ability in existing smart textile range to develop unique fabric for its use in outer space, space transport system and innovative health/sports wear. The constant search for comfort and light weight with multiple functionalities expectations outcomes can be challenging. For example, during development of military protective garments, drastic climatic condtions and constant or abrupt body movement becomes challenging part. Hence, the need for further research and development in the field of smart textiles, particularly in the areas of durability, comfort, and washability is important.

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Partnership

Project coordinator
TUIASI - Universitatea Tehnica Gheorghe Asachi din Iasi
www.tuiasi.ro

AEI Tèxtils - Agrupació d'Empreses Innovadores Tèxtils
www.textils.cat

CIAPE – Centro pre l'Apprendimento Permanente
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CRE.THI.DEV - Creative Thinking Development
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