# IoT Impact in textiles management

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**Abstract:** Textiles are a sophisticated and ancient technology with many appealing qualities. They are frequently soft and are readily folded, twisted, sliced, or deformed. When under tension, textiles can hold their shape and can even be manufactured to have different degrees of stretchability. Smart wearables and IoT-based clothing have the potential to have a significant impact by balancing functionality and the joy that fashion brings, along with the rise of the Internet of Things (IoT). It is now possible to easily fabricate both soft materials with embedded flexibility and stiff objects with embedded flexibility by combining textiles and 3D printing. In order to reinvent technology that can anticipate wants and desires, smart clothing tries to strike a balance between engineering, cybersecurity, interface, fashion, user experience, design, and science. The increasing merging of textiles and electronics now allows for the seamless and widespread integration of sensors into textiles, and conductive yarns have been developed to make this possible.

**Keywords**: smart textiles, IoT, sensors, e-textiles, 3D printing

## 1. Introduction

Textiles are an extremely advanced technology since construction, manipulation, and modification methods have been perfected over thousands of years. Textiles have several appealing traits, including the ease with which they may be folded, twisted, or distorted. Some textiles can also hold their shape when under tension and keep their functional properties when cut. These qualities, together with others like aesthetic appeal, warmth, and adaptability, have given textiles a long history of useful uses ranging from clothing and adornment to more functional items like furniture and even as structural components of structures.

The only wearable technology that can change to fit our daily routines is clothing. Smart wearable devices can be incorporated into garments to create smart clothing. It has a good chance of succeeding smartphones and other wearable connected gadgets as the future interface between the physical and digital worlds. Smart wearables can be characterised as electronic devices intended to be positioned next to, on, or inside the body to de-liver smart services that can integrate into a broader smart system, thanks to the usage of communication interfaces. Even if there are an increasing number of experts in the field of smart textile design all over the world, the methods and technologies often employed to manufacture a textile with sensing capabilities have not developed or expanded to the same degree. Furthermore, since textiles fit and are largely in close contact with our bodies, their physical characteristics and the power of flexible electronics make them the ideal wearable medium.

In daily life, a resistance-based smart textile sensing circuit is frequently utilised. It is made using sensors that only monitor changes in resistance brought on by the deformation of the textile (such as bending, pressing, or stretching), or it employs conductive yarn to make connections that mimic switches. A capacitive touch sensing smart textile can replace a resistance-based sensor circuit. Because, for example, a stretch and a squeeze have the same impact, interactions based on these inputs are similarly limited and prone to errors. This allows for interactions that don't require direct human-material contact but instead rely on proximity, such as hovering and swiping in addition to more direct types of touching (i.e. tapping, pressing). Although capacitive sensing allows for a wider variety of interactions, technological difficulties are brought about by the technology's sensitivity to ambient electricity and the requirement for a software to compute capacitance. It follows that this makes it difficult to tell if the input is coming from the desired source through a particular interaction or as a consequence of electrical noise from adjacent people, objects, or equipment, or even from mains power.

E-textiles give us the chance to combine clothing and wearable technology in a variety of fascinating ways. According to research, conductive materials can act as conduits for data and electricity through various types of fabric and stitching. Using conductive mate-rials, such as conductive sleeves, has become more common in the classification and measurement of movement. It is anticipated that fashion and garment designers would be able to produce designs that are both aesthetically pleasing and useful by experimenting with new materials. Given these objectives, it is surprising that there hasn't been more interaction between e-textile research, clothing design, and the standard methods for producing and arranging clothing in order to take advantage of these qualities.

## 2. From textiles to smart-textiles

Smart fabrics that snugly fit to the body and can sense the wearer's position and motions can be created using an unique production process. The machine-washable, sensor-embedded clothing can be altered to fit closely against the wearer's body [1, 2]. This kind of sensing might be used to keep tabs on athletes, astronauts, and sick patients who are at home or in the hospital.

Long, flexible strips covered with epoxy and sewn into little channels in the cloth make up the electronic sensors. The sensors can be exposed to the skin through the tiny perforations in these channels. However, since yarn is flexible and soft, as the wearer moves, the layers move and rub against one another. The pressure sensors' accuracy is greatly reduced as a result of the noise and variability this causes. The incorporation of a unique type of plastic yarn and use of heat to partially melt it via a technique called thermoforming might substantially increase the precision of pressure sensors woven into multi-layered knit textiles. A hardware and software system to make "smart" shoes and mats can be constructed using this method [3, 4, 5].

This fabrication method, which makes use of digital knitting technology, allows for rapid prototyping and is easily expandable for mass production. Numerous uses for the method are possible, particularly in the fields of healthcare and rehabilitation. For in-stance, technology may be used to create socks that monitor pressure on a diabetic patient's foot to avoid the development of ulcers or smart shoes that track the stride of someone learning to walk again after an injury [6].

A computerized knitting machine can weave together layers of fabric using rows of regular and functional yarn to create smart material. You have the option to create your own designs with digital knitting, and you can incorporate sensors into the structure itself to make it seamless and comfy. You can even customize it to fit the contour of your body. The multilayer knit fabric is made out of a piezoresistive knit that changes resistance when squeezed, sandwiched between two layers of conductive yarn knit. The machine stitches this useful yarn in horizontal and vertical rows across the fabric in accordance with a pattern. A pressure sensor is formed where the functional fibers converge [7, 8].

In addition to altering the deformation of the yarn fibers, movement while engaging with the textile form also affects the contact resistance between the conductive parts. Only one resistor and a voltage source are needed to create a voltage divider circuit that converts these changes into a form that an electronics platform can understand. It generates a volt-age output that the electronics platform can read. The smart textile sensors can be connected to a constant, steady voltage in order to use these resistance-based sensors with "direct current." Batteries or the voltage-pins of the electronics platform can be used to power these DC sensors; both options are widely available and only need for a connection to the conductive yarn. As a result, the interaction modifies the resistance, and a readable voltage signal is generated when a constant voltage is applied to the modified resistance [9].

A capacitance sensor can be made and used in a variety of increasingly complex ways, but the most basic capacitance-measuring smart textile sensor is similar to resistance-based sensors in two ways: it uses direct current voltage and a resistor. Electronic platforms can read the voltages produced by such capacitance measurement circuits, and the sensor value is determined by how quickly the voltage on the pin changes. Because it is susceptible to environmental factors, capacitive sensing has been identified as a challenge in the development of smart textiles [10]. Capacitive readings can be used to supplement resistive sensing.

Capacitive and resistive smart textile sensors require DC voltage or complex electronics. The latter has a more limited application in a design setting and is more useful in an electronics lab. The former depends on the voltage being very steady; if these sensors receive their power from a source that fluctuates sporadically, the sensor signal will also fluctuate arbitrarily. It would be impossible to determine if a signal change was brought on by movement, interaction, or any other factor if the voltage was unstable or "noisy" [11]. However, purposely producing an alternating signal might be advantageous because it adds frequency and gives the sensor additional information. In conclusion, it is clear that although capacitance and frequency-based measures are well known, smart textiles do not make good use of them. The standards, which don't mention frequency-based capacitive systems, make this clear. In order to address the more complicated possibilities brought about by the development of active yarns, materials, and the combination of textile-interaction, it is necessary to move beyond utilizing a multimeter and direct cur-rent-based measurements.

## 3. E-textiles

E-textiles, or electronic textiles, have garnered a lot of attention due to their significant role in wearable electronic systems. These wearable electronic devices can be very useful in a variety of fields, including robotics, the monitoring of medical conditions, and sporting activities. Unlike traditional textiles, e-textiles are conductive and may be capable of sensing. E-textiles typically use polymer composites with conductive nano-fillers like graphene, carbon nanotubes, metal nanowires, or metal nanoparticles. The common methods for creating conductive polymer composites include soaking, dip coating, drop casting, brushing, and inkjet printing. However, the nano-fillers produced by these methods often have weak adherence to the polymers and can be removed after rinsing. The composites are therefore not washable. Good washability in e-textiles allows for pro-longed use. This has the potential to be much less expensive, less harmful to human health, and better for the environment [12, 13, 14].

With the rise of 5G technology and the fourth industrial revolution, many new fields of advanced computers and tech are emerging. Things like AI, big data, cloud computing, and the Internet of Things are developing. Behind this boom is a concern for environmentally friendly and sustainable power systems that can harness electricity from multiple sources, such as solar panels, thermoelectric generators, and biofuel cells. Although re-chargeable batteries can provide short-term power, they can’t sustainably meet future needs due to their short lifespan, frequent charging, and safety hazards [15, 16]. However, their reliable operation depends on certain external conditions, such as sunlight, temperature, co-catalysts, etc. Therefore, the development of wearable electronics still requires a more active and less environmentally dependent energy harvesting method.

Due to the heat generated during the operation of wearable electronic devices and circuits, thermal management can also be a significant problem for e-textiles in addition to electrical conduction because the human body can only withstand a certain range of temperatures. For the heat to be promptly released into the environment, a high thermal conductivity may be necessary. The typical clothing and materials, however, often have very little thermal conductivity. Due to their extraordinarily high heat conductivity and strong electrical conductivity while having low densities, carbon-based materials are generally very appealing. For instance, graphene has an electrical conductivity of up to 6,000 S/cm and a thermal conductivity of up to 5,000 W/(mK), both of which are higher than CNTs. Additionally, the coexistence of graphene and CNTs can display greater conductivities, structural toughness, or thermal conductivity than either material alone. Due to its capacity for achieving personal cooling and delivering thermal comfort, thermally regulating fabrics have garnered considerable interest [17, 18].

## 4. Internet of Smart Clothing

Healthcare, agriculture, manufacturing, home automation, transportation, energy, emergency management, defense, and public safety are just a few of the sectors that are connected by the Internet of Things (IoT). By employing 5G communication networks that integrate virtual/augmented reality, cyber-physical systems, artificial intelligence (AI), and smart textiles, wearable technology and smart clothes can expand human-to-machine and human-to-human connections. Due to their broad use across a variety of industries, these wearables and clothes exist at the nexus of the physical and digital worlds. They can significantly alter society when used in conjunction with other digital items, like smart eye-wear. In the near future, apparel and wearable technology may be used more widely. To provide them great capabilities, the clothing and wearables would connect with other clothing and wearables, as well as with external items and internet servers [19]. The Internet of Smart Clothing is a concept that is built on the foundation of this domain. In this universe, smart clothing can connect with other pieces of smart clothing, as well as with external objects and distant servers on the internet. For this use, the materials, clothing, and wearables must be adaptable, efficient, and in some situations ideally undetectable. Additionally, they must be able to carry out very complex activities, make use of energy-harvesting technology, and offer sophisticated power management.

The International Electrotechnical Commission's Technical Committee 124 has developed a system for classifying embedded wearable electronics and smart clothes. Wearable electronics for commerce and payment, wearable electronics for personal safety and protection, wearable electronics for social engagement, and wearable electronics for health and fitness, are the four categories [20]:

- Wearable textile/cloth products – they use flexible materials to integrate electronics into textiles.
- Wearable accessories - these are low-power devices that can be worn as accessories, such as smart glasses, fitness trackers or smart watches, because they fit the human body.
- Wearables as patches - they are thin, flexible, and skin-patchable gadgets.
- Wearables as implants - they are small, self-powered devices that pose no health risks when inserted into people.

Although the end-user applications for each of the aforementioned smart wearable kinds may be comparable, each type requires a distinct level of integration, power, and body-tailoring. IEC TC 124 believes that we are currently in the first phase of developing smart wearables, with wearable accessories already in development and widely available in retail [21]. The second step of developing textile/fabric wearables to the same degree of maturity is now being worked on by academics and industry. Additionally, the limits of performance, usability, and usefulness have been significantly pushed through the employment of innovative materials, designs, energy storage, energy harvesting, and production techniques.

In today's world, wearable technology offers multiple options to improve people's lives through data-driven professional services. Due to their embedded intelligence, seamless connectivity, and increasing accessibility, wearables present opportunities for activity and condition monitoring, predictive modeling, workout, location applications, identification, personal contextual alerts, event detection, information display (video/image/audio), and virtual assistance.

Smartwatches and fitness trackers are the most common commercial wearables to-day. But many other products are on the market or are already on the market, including smart jewelry, earphones, exoskeletons, and patches and earphones with built-in sensors (for example, earrings and hearing aids in the form of smart jewelry). sleep quality monitoring). Neither current commercial wearables nor smart clothing initiatives use block-chain or any other distributed ledger technology to receive, verify, store and share collected data to avoid unreliable sources, as most people need to stress that they cannot be seen as supporting IoT [22].

From the perspective of the end-user, several considerations must be made while de-signing smart clothing:

- Technical prerequisites - ruggedized smart clothing and wearables are required to support daily and/or athletic activity. Additionally, the embedded electronics must be able to run on their batteries for the duration of the monitored activity.
- Functional - Because comfortable, elegant clothing must be able to adapt to the hu-man body. Additionally, garments with integrated electronics must be secure and flexible enough to follow the movement of the body. It is also important to consider how the body regulates its body temperature and how it is exposed to bodily fluids.
- Cultural proposals - Much like fashion, it's critical to distinguish between various clothing styles according to the wearer's community and age range. Depending on the user's culture, custom, and dress code, the same goods may or may not be appropriate.
- Aesthetics – This determines whether smart clothes is accepted. As a result, the de-sign must take into account both the material's technical and aesthetic properties.

The sensor subsystem may consist of a number of different kinds of sensors that may monitor a range of environmental phenomena or occurrences. The three most common types of sensors used in smart clothing are motion, gesture, and location sensors. Although some applications employ a barometer to determine altitude, accelerometers and gyroscopes are the most often used sensors. To determine proximity, infrared or ultrasonic sensors are frequently utilized. Additionally, inbuilt Passive Infrared (PIR) sensors can track the movement of nearby people or animals. Other motion sensors include pedometers, vibration sensors, and tilt switches. For the body temperature it is advised using various cutting-edge technologies rather than conventional sensors for measuring body temperature, such as Resistance Temperature Detectors (RTDs). There are sensors for measuring oxygenation, glucose levels, blood pressure, respiration rate, heart rate, electrodermal activity, and galvanic skin response. Additionally, electrocardiograms (ECGs) and electroencephalograms (EEGs) can be obtained using embedded sensors (EEGs). Lastly, sensors for interaction, which typically use mechanical switches to detect contact, but capacitive or resistive touch screens are also an option. Fabric switches, keyboards, and even 2D touchpads are also available [23, 24].

## 5. 3D printing and textiles

We consider 3D printed products may gain a lot from the flexibility, stretchability, and aesthetic features present in many textiles, even though the majority of 3D printing techniques produce stiff objects, often made of plastic and more recently metal. The accuracy and practical qualities of 3D printing, as well as the usage of computer-aided design software, can also increase the usefulness of textiles. The combination of 3D printing with textiles creates a new design area for hard things with integrated flexibility and soft mate-rials with beneficial qualities.

The 3D printing community has recently become fascinated with textiles because they can take use of the aesthetic and other qualities of textiles while requiring less physical effort throughout the creation process. There hasn't been much research done yet on fusing FDM printing with current textiles. The capacity to provide cloth structure and manipulability has long been of interest in the field of textiles, particularly fashion design. However, less attention has been paid to the actual fabrication process and more to the final product. For instance, fashion design has long utilized computer-aided design (CAD) and manufacturing (CAM). Textiles may now be modeled in high detail, in part because to the demands of realism in animation [25].

A long-standing area of interest is the different ways that textiles can be enhanced. Consumers now have easier access to technology-textile hybrids, and both hobbyists and academia are active innovators in this field. Fabric can be selectively stiffened by the addition of plastic, allowing the fabric's ability to flex and stretch to be managed. By using this fundamental primitive, it is possible to create a variety of higher-level primitives, such as mechanically actuated gadgets, interactive, sensor-based objects, and larger-scale fabric-skinned fabrications.

Without hinges, printed plastic typically cannot bend. However, adding hinges to a design frequently necessitates a level of precision that is difficult to accomplish with consumer-grade printers and/or additional assembly stages. Contrarily, the majority of fabrics are typically not stiff at all. There are many methods for making fabric stiffer, such as inserting additional hard materials (such cardboard or plastic whalebone); but adding these materials can be time-consuming and require a great deal of sewing and textile shaping knowledge and expertise. We can selectively stiffen various portions of cloth by printing plastic on it, so regulating the fabric's ability to flex. On top of cloth, we can allow or prohibit bending in the direction perpendicular to the fabric by adjusting the spacing of 3D printed parts [26].

We can control the amount of flexing and stretching in the fabric's plane as well as bending out of it by gluing plastic to the fabric in specific places. By carefully adjusting the places where plastic sticks to the fabric, we may further tailor behaviour. Painter's tape can be used to cover textile regions where plastic has been applied but shouldn't stick to limit adhesion. The hot plastic is then supported by the tape, which prevents it from connecting with the surface below, allowing us to print on and around it. After printing is finished, the cloth may stretch or move while in touch with the plastic but not cling to it. Using textiles with 3D printing has a number of benefits, including the ability to save print time by substituting portion of the printed plastic with fabric because the layers of fabric are prefabricated. However, the cloth may need to be strengthened to prevent bending in order to mimic the hard plastic it replaces [27].

## 5. Conclusions

The components of smart clothing and wearables, as well as their communication architecture and wearable device categories, are diverse. This article discusses the most prominent wearables as well as smart clothing applications. The specific use examples demonstrate the possibilities of IoT smart apparel. As the section explores business op-portunities and possibilities, next-generation smart clothing offers enormous promise. The sections define the essential topics that should be included in the structure of the smart clothing sector, and then offer advice for IoT smart clothing designers and developers. The purpose of this paper is to introduce the concept of the Internet of Smart Clothing to de-signers and developers.

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