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E-Textiles Desinged for Biomedical Applications- A Survey

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Abstract— Electronic textiles, also known as "e-textiles" is one such new field of textile, which is finding its unique applications in various fields such as civilian, medical, military and various other sectors. They are now utilized in numerous industries and applications that are greatly beneficial to the mankind. Special care is essential while dealing with electronic textiles employed in the field of medical sciences or health care applications because it involves direct contact with the human body. This paper presents a overview on e-textile.

Keywords- ***electronic-textiles; biomedical applications, fibers***

I. INTRODUCTION

Electronic textiles or e-textiles are a new emerging interdisciplinary field of research which brings together specialists in information technology, microsystems, materials, and textiles. The focus of this new area is on developing the enabling technologies and fabrication techniques for the economical manufacture of *large-area*, *flexible*, *conformable* information systems that are expected to have unique applications for both consumer electronics and military industry.

E-textiles offer new challenges for designers and CAD tool developers due to their unique requirements, cutting across from the system to the device and technology:

- The need for a new *model of computation* intended to support widely distributed applications, with highly *unreliable* behavior, but with stringent constraints on *longevity* of the system.
- *Reconfigurability and adaptability* with low computational overhead.

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E-textiles rely on simple computing elements embedded into fabric or directly into active yarns. As operating conditions change (environmental, battery lifetime, etc.), the system has to adapt and reconfigure on-the-fly to achieve a better functionality.

Smart or intelligent electronic textiles are a relatively novel area of research within the textile industry with enormous potential within the healthcare industry. These textiles have electronics and interconnections woven into the fabric to make them wearable.

E-textiles may be considered as "living designs" consisting of low-cost, simple components and interconnect. The other versatile features of e-textiles are:

- limited processing, storage; and energy per computational node;
- potential failures for *both* nodes and communication links;
- highly *spatially and temporally correlated* node and/or link failures due to topological placement or due to external events;
- need for scalability and flexibility of resource management, as well as local versus global management tradeoff;
- active or smart links which embed simple logic (passive or active components).

II. E- TEXTILES IN BIOMEDICAL APPLICATIONS

Intelligent medical clothing and textiles have the potential to substantially change the provision of health and healthcare services for large population groups, such as those suffering from chronic diseases, viz. cardiovascular, diabetes, respiratory and neurological disorders; and the elderly with specific needs. Integration of high technology into textiles, such as modern communication or monitoring systems; development of new materials with new functions; Smart sensor system and new approaches to analyze and interpret data together with cost effective telematics approaches can fundamentally change the interface between patient and the healthcare provider. Patients discharged after major surgeries (e.g., heart bypass), mentally ill patients (e.g., those suffering from manic depression), athletes during practice sessions and in competition, injured soldiers, etc. need to be monitored on a regular basis. This helps to gain a better understanding of the relationship between their vital

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signs and their behavioral patterns so that the treatment can be provided immediately or can be suitably modified, if necessary. Moreover, information processing via Internet and other suitable means has opened up a new era in the field of e-textile for its utilization in a better way for medical services.

III. DESIGN ISSUES FOR WEARABLE E-TEXTILES

A major challenge for designing wearable e-textiles is that the design issues span a diverse range of areas including:

- ✓ Physical environment,
- ✓ Sensor behavior,
- ✓ Human body and motion,
- ✓ Motion/draping of clothing,
- ✓ Manufacturability (weave & piecework),
- ✓ Networking,
- ✓ Power consumption,
- ✓ Software execution

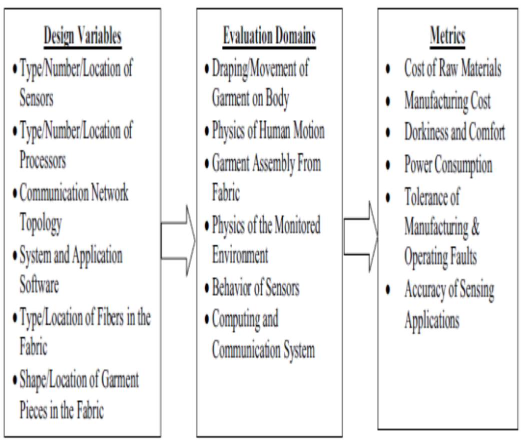


Fig 1. Block diagram for design

In the case of wearable e-textiles, the human body is an important design issue. There are at least two aspects of the human body that must be considered: body size and human motion. Body size is a static (design time) issue, but human motion is a dynamic (run time) one. Size and motion affect sensor placement on a garment; it is expected that many wearable applications will require sensors placed relative to the wearer's body, e.g., on the knee, as opposed to sensors placed a fixed distance from each other. Size will determine initial placement on a garment, while motion will affect which set of sensors is active while the garment is in use. Both aspects must be considered in the design of an e-textile application if it is to be useful in everyday use by a large segment of the population. There are multiple sources of data for body motion/size.

An important category of applications for e-textiles is sensing the user's environment and the user's actions. An e-textile fabric provides an interconnection network for sensors and processing elements at a much lower power cost than using wireless networking. The fabric itself may be capable of sensing depending upon the fibers that are woven into it (e.g., piezoelectric film strips, chemical sensing fibers). Thus a design framework for e-textiles must incorporate the behavior of the physical environment, particularly the stimuli provided to the sensors.

IV. COMPONENTS OF E-TEXTILES

The conductive fibres are of two types, viz. electrical conductive fibres and optical conductive fibres. The following section gives an overview of conductive and responsive materials that are currently most used in wearable computational textiles.

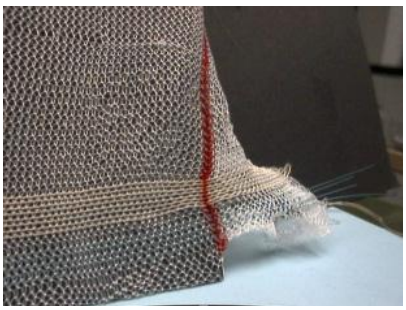
Conductive fabrics and textiles are plated or woven with metallic elements such as silver, nickel, tin, copper, and aluminum. There are many different fabrics with various textures, looks and conductivity, those are: electronylon, electronylon nickel, clearmesh, softmesh, electrolycra and steelcloth. All these textiles show amazing electrical properties, with low surface resistance[15], which can be used for making flexible and soft electrical circuits within garments or other products, pressure and position-sensing systems. They are lightweight, flexible, durable, soft and washable (some) and can be sewn like traditional textiles, which makes them a great replacement for wires in computational garments.

Conductive threads and yarns have a similar purpose to wires and that is to create conductive paths from one point to another. However, unlike wires they are flexible and can be sewn, woven or embroidered onto textile, allowing for soft circuits to be created. They contain metallic elements such as stainless steel or silver, with nylon or polyester as base fiber. Commercially available conductive threads usually vary in the resistance and the thickness of the thread. Figure 5 (middle and right) illustrates few commercially available threads. Since they are conductive when working with them, one has to take all the precautions as when using uncoated electric wire or a metallic surface without insulation. Conductive threads and yarns offer alternative ways of connecting electronics on soft and flexible textiles medium as well offering traditional textile manufacturing techniques for creating computational garments.

Conductive coatings are used to convert traditional textiles into electrically conductive materials. The coatings can be applied to different types of traditional fibers, yarns and fabrics, without changing their flexibility, density and handling.

Conductive ink is an ink that conducts electricity, providing new ways of printing or drawing circuits. This special ink can be applied to textile and other substrates. Since wearable e–textiles require great flexibility, conductive inks are become more interesting for designers and developers in this area. Conductive inks contain powdered metals such as carbon, copper or silver mixed with traditional inks.

(a)



(b)

Fig. 2: Conductive yarns and fabric for e-textiles

Piezoelectric materials have the ability to generate electrical charge when exposed to mechanical stress (sound, vibration, force or motion). Piezoelectric materials exhibit reversible effect because they can produce electrical charge when subjected to stress and also they can generate stress when an electrical field is applied. Therefore the materials can be used both as sensors and actuators. Piezoelectric materials can serve as excellent environmental sensors, but the number of interesting applications in wearable e-textiles is even greater if they are coupled with other sensors, for ex. solar cells where they can be used to convert light to sound, motion or vibration.

The electrical conductive fibers integrate the latest wicking finishes with high metallic content in textiles that still retain the comfort required for clothing. Naturally conductive fibers or metallic fibers are developed from electrically conductive metals such as ferrous alloys, nickel, stainless steel, titanium, aluminum, copper and carbon. Metal fibers are very thin filaments with diameter ranging from 1 to 80 microns. However, they are very expensive and their brittle characteristics can damage spinning machinery over time. They are also heavier than most textile fibers making homogenous blend difficult to produce. The optical conductive fibers use perfloro polymers, which are most transparent in the near infrared region. They are about 120 microns in diameter and are used in conductive textiles to carry signals in the form of pulse of light. Conductive fibers used for the development of military clothing, motion capturing and in tracking of objects. They are developed by drawing molten glass through bushings, creating a filament. Though optical fibers offer excellent strength and sunlight resistance, they are relatively stiff possessing poor flexibility and abrasion resistance. These fibers can be woven in to fabrics to form radiation shields, optical filters and bar codes.

All these fabrics are easy to cut with scissors and can be sewn with a standard sewing machine. The Knitted super-light conductive fabric can even be welded with a welding iron. Recently micro-encapsulation technique has been utilized fabricating electronically *active and sensor fibres*, which will be the basic building blocks of the next generation 'Smart' fibrous materials. The micro-device encapsulation technology involves encapsulating devices with a flexible hermetic seal for mechanical, thermal and electrical protection.

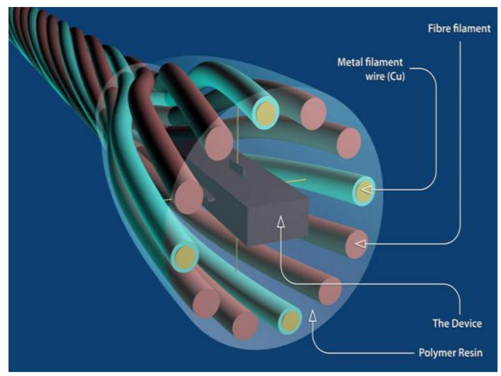


Fig. 3: Conductive yarn containing the device

Electronic Devices

There are many general application sensors and processors used in such medical e-textile systems. Some important sensors (Figure 6) used are accelerometer, magnetometer, light and temperature sensors, pressure and flex sensors and microphones for various applications like motion capturing, beam foaming, etc. For instance, the accelerometer can regulate the results according to the temperature changes to have most accuracy. The temperature sensors are generally used to measure the body temperature or the environment temperature as per the requirement. Also, since one of the most important application in wearable computers and smart textiles is telemedicine, many different kinds of medical sensors, suitable to implant in electronic textiles have been made and used by scientists. Sensors like ECG, respiration electrodes, pulse oximeter, blood pressure and galvanic skin response sensor are just some examples of biomedical ones.

In a general set up, the information gathered by sensors should be sent to an analog-to-digital converter (ADC), then to a micro-controller and finally sent to a personal digital assistant (PDA) by a transceiver. The last stage is the transmission of the information from PDA to the center (which can be a hospital or a central military service) probably through a wireless channel. The ultimate processes and conclusions will be done there.

Two processors are generally used to ensure that the information will not be lost under any circumstances. One of them is used as the main processor, while other one as the redundant. During the failure of the main processor, the redundant processor gets activated and continues the operation as the main processor. Processors which are generally used for different electronic textiles and wearable computer applications are ADSP2188, Atmegal128 AVR, MSP430, etc. Apart from the devices mention above, the transmission of the signals from the e-textiles also requires infrastructural set-up with various facilities, such as cellular tower, internet facility, etc.

V. INNOVATIVE APPLICATIONS BIOMEDICAL E-TEXTILES

- **Life-Shirt**: Developed by Southern California-based health information and monitoring company VivoMetrics, the Life-Shirt (Figure 6a) uses embedded sensors and a PDA to monitor and record more than 30 physiological signs and bring standard monitoring technology out of the hospital and into the real-world environment. The information is uploaded to a computer via a datacard and sent over the Internet to VivoMetrics, where it is analyzed and then sent to the physician.

Fig 4 Life Shirt- Smart Biomedical electronic textiles

- Christina von Dorrien (Carmen Systems) et al, started the project *Interactive Pillows* 21 in 2001, which is based on the idea to develop new devices for interpersonal communication with focus on aesthetic, social and emotional aspects. The concept was communication between distant loved ones that involved picking –up and hugging a pair of pillows. When one is hugged, the other will light up and change its aesthetical expression. If the other person hugs theirs back, its pair will warm and start to glow as well. The technical solution is designed using electroluminescent wires, 'hugging sensor' (which basically is two layers of aluminum foil divided with foam, which has inch-size whole, this way when the pillows are squeezed, the two layers of aluminum touch and contact is created, thus the electrical circuit is closed), microprocessor and radio frequency module. The pillows currently are communicating using radio.

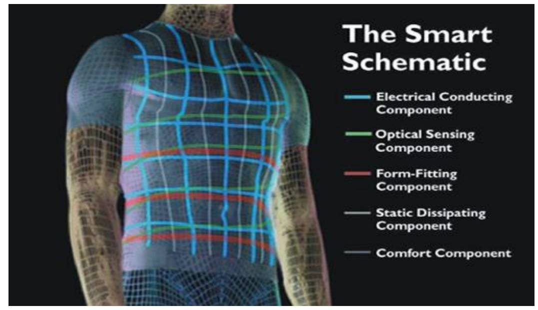


Fig. 5. Smart shirt

Fig.6. Interactive Pillows

- **Mamagoose pyjamas:** The Belgian company Verhaerth Design and Development and the University of Brussels have developed a new type of pyjamas, named Mamagoose baby pyjamas (Figure 7b), that monitors babies during the sleep. It has five special sensors positioned over the chest and stomach, three to monitor the infant's heart beat and two to monitor respiration. This double sensor system guarantees a high level of measuring precision. The special sensors are actually built into the cloth and have no direct contact with the body, thus creating no discomfort for the baby.

Fig 7 Mamagoose pyjamas -Smart Biomedical electronic textiles

- **Smart Socks**: Every year, more than 50,000 Americans with diabetes must undergo foot or leg amputations, which is due to poor blood circulation. Researchers estimate that about three quarters of diabetes-related amputations might be avoided by wearing socks with built-in pressure sensors that would alert the wearer to put his/her feet up for a while.

VI. LIMITATIONS OF BIOMEDICAL E-TEXTILES

There are some limitations encountered with Biomedical e-textiles when they are in use are like they have power consumption limitations as they are not connected to constant power supply. Also, the electronic textile may have physical defects, which may lead to short circuit or open circuit on textile, thereby making the results of the computing components wrong. At the same time the electronic components are prone to damage during washing.

VII. CONCLUSION

An ideal home health care technology should be easy to use, reliable and cost-effective, should blend in with the home environment and should provide accurate medical information to the patient and caregivers. Wearable medical devices should be small, lightweight and simple to attach, while medical devices that are used in the home should be easy to install and permit normal movement about the living space. A patient should be able to go about a daily routine without interference or distraction. Devices that do not have these characteristics will not be widely adopted or effective. In usability studies of health monitoring devices used by the elderly population, participants were apprehensive and lacked confidence in the devices due to the size, non-functionality when moving about and lack of training. An emerging technology, electronic textiles (e-textiles), holds the promise of creating home health care devices that will be more accepted and usable. In this paper, an overview of e-textiles with its applications has been presented.

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