SMART TEXTILE SYSTEMS. SOLUTIONS FOR DIFFERENT APPLICATIONS

Roxana SCARLET, Roxana DELIU, Liliana Rozemarie MANEA
"Gheorghe Asachi" Technical University, Faculty of Textiles, Leather Engineering and Industrial Management, Iasi, Romania
rscarlet@tex.tuiasi.ro

Abstract:
After technical textiles and functional textiles, intelligent textiles also came into force a few years ago. The term „smart textile systems" covers a broad range. They include textiles that can sense and analyze the sygnals and which respond in an intelligent way. It can be described as textile materials that think and act for themselves.
Smart clothing is already being a part of our daily life; they are a reality of our times. Even if they are still the prerogative of some special social categories such as sportsmen, IT specialists, businessman or researchers, the explosive expansion of the mobile communications and computation technique, will bring them into everybody wardrobe.
This paper discusses some theoretical aspects and the most important applications of smart textile systems.
Keywords: smart systems textiles, sensor, applications, intelligent clothes

1. Introduction

Integrated set of nanoscale smart materials, whose properties are noticeable on a macroscopic scale, are called smart structure unit acting under the influence of external stimuli. An intelligent system is resulted from the assembly of active elements (i.e., attachment or integration of active particles) in a unitary product. Concerns researchers in creating artificial intelligence had as a starting point the desire to facilitate the achievement of adaptive structures that hold the ability to change characteristics depending on environmental claims exposure. The concept of "artificial life" ("a-life") refers to the study, development and implementation of smart materials in various industrial applications [1].
Intelligent systems can be classified as follows [1]:
• passive intelligence systems (passive smart) - have the ability to feel changes in operating environment through: structural changes and position (shape, appearance, position, etc.), changes of mechanical, thermal, electrical characteristics (internal vibration frequency, friction, viscosity, rheological, etc..), emission of visual and/or sound signals in some operating conditions;
• active intelligence systems (active smart) - can perform similar functions of living systems with the capability to not only feel but also programmed to react to stimuli (mechanical, thermal and electrical) and to adjust specific characteristics through the feedback mechanism; these functions can be of control (brain), sensors (nerves) and actuators (muscles).
• very smart systems - can detect environmental changes having the capacity to feel, control, monitor (changes that have generated the respective change), react and adapt; these materials have memory function ("learning" function).

2. Exposition

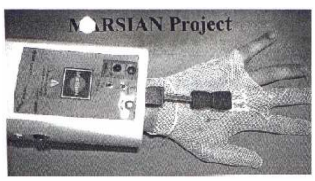
Functions and features (generated by the embedded intelligence) of intelligent systems are simplified in Table 1 [1].

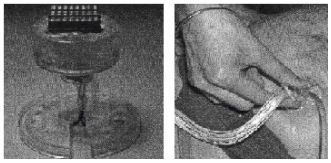
Table 1. Functions of Intelligent Systems

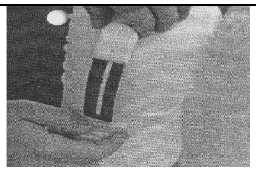
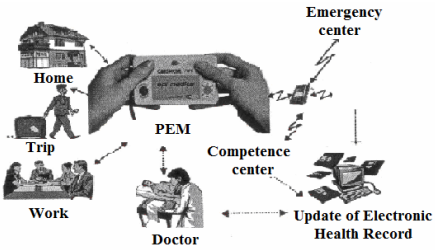
Nr.	Function	Definition / general characteristics
1.	sensors (nerves)	Sensors define the so-called "captive" (sensory materials) and represent detection systems that translate changes detected in the environmental in signals describing the state of structure, namely the material system.
2.	actuators (muscles)	Actuators define so-called "action elements", "reactive" materials or "adaptive" (which are "educated"), are able to carry out actions strictly mechanical, change certain structural-design characteristics (shape, appearance, position, etc.), mechanical (rigidity, vibration frequency, friction, viscosity), in response to different types of changes: heating, electrical, magnetic, damping capacity, etc.).
3.	control (brain)	-define the so-called "neural networks" or transfer devices which fulfilling the role in ensuring the complex communication (signal processing, memory, control of these reactions); - functional architecture incorporated in such a system includes a complex organizational system through a global or local hierarchy, so each information is processed at a level of complexity appropriate to its importance; - to fulfil the following functions: signal processing, ranking of the signals after their importance and/or precision, memory, signal evaluation, control response to the received signal.
4.	learning	- specific to very intelligent systems that have the ability to detect, react, change, control and monitor changes in a parameter and to generate optimal responses to changes in the operation.

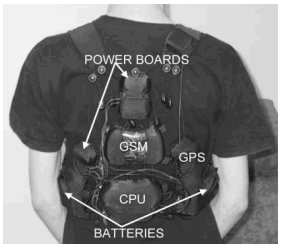
These intelligent systems require a highly specialized, interdisciplinary background covering a range of research aimed at holding up the top technique in various fields. The usage domains of these smart materials and systems are wide, the most interesting and recent applications from the textile industry are presented in Table 2 [1, 2].

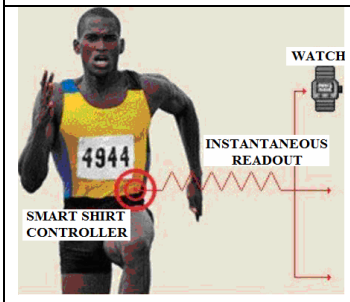
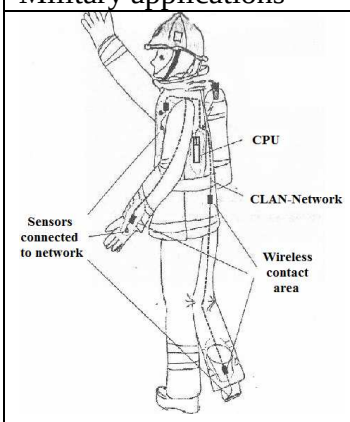
Tabel 2. Smart systems applications in textile industry

Commercial name / company	Observations
Clothing with medical applications Intelligent medical clothing have the potential to substantially change the health care services for example for those who suffer of chronic diseases (such as diabetes, cardiovascular, respiratory disorders) and the elderly with specific needs. When are embedded into the clothing, the technology could monitor the wearer's heart rate, temperature, respiration, blood pressure, perform an ECG and other vital functions, alerting the wearer or physician if there is a problem. Developments in telecommunication and computers are the main technical tools for Telemedicine (Telecare, Telehealth). Telemedicine represents the possibility to stay in contact with their physician or health care provider for some medical advices, to be alerted if something goes wrong with their health. All these are new possibilities for personalized health care.	
	- it is a modular autonomous recorder system for the measurement of the autonomic nervous system activity [3]; - it is a hybrid device associating the advantages and the specificity of the smart clothes and of the wrist devices; - it has 6 hours autonomy at full utilization. - the MARSIAN smart glove has a specific design to ensure

MARSIAN – a modular autonomous recorder system for measurement of autonomic nervous system activity	both a good contact from skin to electrodes whatever the hand motion will be and a correct furtivity of the glove so as not to modify the typical physiology of the hand skin; - it ensures real-time physiological data aquisition, treatment and wireless transmission in a minimum size.
 DEPIC - Early Detection of Cutaneous Infection in Peritoneal Dialysis	- is a portable device, autonomous, usable in hospital, but also at home [6]; the device developed a non-invasive sensor analyzing the cutaneous thermal parameters around the permanent catheter used for peritoneal dialysis and can be handled by the patient at home; - uses a flexible technology for the membrane and 20 sensors for the mapping of the skin thermal parameters; - the device is connected to "DIALETIC" system of telemonitoring of dialysis at home which analyzes the data to detect alarm signals and to prevent aggravations; if an alarm occurs, the system informs the nephrologists, the patient and the treating general practitioner; - allows the diagnosis of an infection before the appearance of complications and can alert the patient and the physician in time.
Mini Fetal Monitor	- a fetal monitoring device that tracks a baby's position and movement in the womb, as well as baby and mother heart rates; the device is capable of collecting data for up to 24 hours and is portable and wearable, about the size of a mobile phone [6]; - five electrodes placed on the mother's belly pick up electrical signals just like an EKG for heart monitoring; the monitor stores the information on a USB device that doctors can read off any computer; the monitor can spot danger signs earlier, giving doctors time to intervene and help save lives.
 MELODIE – a programmable and portable pump	- allows the physician to program the frequency and timing of administration of drugs, in exact accordance with the prescribed regimen; - it ensures all the basic requirements for monitoring treatment by producing two documents for inclusion in the patient's medical records. While the protocol is being set up, a program report is produced which ensures that the infusion can be checked at a later stage. Similarly, at the end of the treatment, an infusion record is produced which documents all events occurring during treatment [3, 5]; - the MELODIE pump offers for the patients the chance of returning home sooner, greater independence in their daily lives and the security of knowing that their treatments are being given according to the established protocol.
VTAMN	- medical equipment integrated into clothing that provide increasing autonomy through telemonitoring and telephone helpline for people with different risk conditions and optimization of medical procedures [7]; - the suit for telemonitoring (Medical Teleassistance Suite) is a complex system with integrated sensors (textile electrodes for

  Sensors location on the VTAMN suit	temperature and electrocardiogram), miniatural medical equipment (pneumograf, ECG), processors and power sources necessary; the suit incorporates 4 ECG electrodes on the back side and on shoulders; respiration sensor wrap the abdomen region; a GPS / GPRS modulus is connected to the shirt and is used for data transmission; motherboard and transmission modulus are incorporated into a belt and are connected via a VTAMN shirt through a microconnector; sensor records can be immediately transmitted to the center.
  Life Shirt, Southern California	- LifeShirt is an intimate garment without sleeves, made from a comfortable stretch material that uses embedded sensors, PDA to monitor and record continuously for more than 30 physiological signs and with standard monitoring technology; the information is uploaded to a computer through a data card, sent via internet to VivoMetrics, for analysis and interpretation [1, 7] - application areas of "Smart Shirt" are as follows: maintaining a healthy lifestyle, individual athletes/team sports, continuous home monitoring, remote patient examination, infant vital signs monitoring, sleep studies monitoring, vital signs monitoring for mentally ill patients, protecting public safety officers, battlefield combat care solution.
 The Intelligent Knee Sleeve	- the Intelligent Knee Sleeve is a device capable of providing immediate audible feedback to the wearer pertaining to knee flexion angle during human movement [2]; - it can be used by athletes to learn correct landing technique;
 Smart bandages	- although still in a embryonic research stage, smart bandages will be another promising application of smart textiles [7]; - the technology is based on sensors embedded in the fabric bandage and uses porous silicon; when the bandage is placed over an area of infected skin, the bacteria developed on the wound migrates into the porous silicon; - can monitor the patient's condition, can store and transmit accumulated data.
 EPI MEDICS – enhanced personal, intelligent and mobile	- EPI-MEDICS is a new "intelligent" personal ECG monitor used for the early detection and management of cardiac events [3, 4]; - the objective is to design a very affordable, easy-to-use powerful, professional-quality level embedded device that is able to record, store and synthesize standard 12-lead ECG, generate different levels of alarms, and forward without delay, but only if necessary, the alarm messages with the recorded signals and the patient's

system for early detection and interpretation of cardiological syndromes	electronic health record to the relevant health care providers by means of new generation wireless communication techniques (Bluetooth and GSM).
Clothing with smart thermal physiological functions:	
Reima/Finlanda (Tamper University of Technology)	- is a clothing system – bobsleigh equipment that allows protection against cold weather [1] and have the following components: underwear, jacket and trousers; in these components are included: GSM systems, position sensors, motion, temperature, vital functions biomonitoring, two accelerometers; if a collision occurs, the jacket automatically detects and sends a warning message to emergency medical services through messenger services, if the user does not respond, the suit gives the alarm to the center, GPS will enable the transmission of location coordinates, local environmental conditions; the message transmitted the coordinates to the pilot, local environmental conditions and data from device which monitor the heart; the suit is helping in survival, removing the humidity and transferring the heat from the body to the members to avoid freezing.
Smart system for the arctic medium / Finlanda (Tamper University of Technology, Dupont, Nokia)   Supporting structure (back and front) and the settlement of electrical components	- objective: study of different possibilities for using information technology, electronics, textile materials and innovative fibers to achieve intelligent textile systems for arctic environment (special survival suit for snowmobile users to prevent accidents and aid for survival in case of accident) [1]; - the fundamental requirement for computerized system is easy to be worn, i.e. size, low mass and low power consumption; electrical components should withstand to a wide range of temperatures (between -20 °C and 50 °C) and big humidity variations; components integrated into the textile structure can be washed; - the system consists in a set with two parts of underwear, a support structure of components, clothing and self-called Snowmobile pants; clothing is able to provide information about the holder' health, its location and movements; sensors are integrated in the suit (sensors who can monitor the position and user's condition); if the user is injured or is subject to abnormal situations, the suit will inform the emergency center or will activate other pre-selected telephone number via Short Message Service (SMS) or the Global System for Mobile (GSM); - non-electrical equipment - some non-electrical components in order to assist the user in accidents or by increasing the coat's functions, which include: transparent map pocket, pocket for matches, ice spikes, hidden bag to prevent hypothermia, cell phone pocket; - Electrical functionality of intelligent system is divided into four segments: a) communication; b) navigation and positioning; c) environmental monitoring and user's monitoring; d) heating.
Clothing and accessories for sports and leisure	
The Smart Bra,	- it will encourage more women back to sports and in extreme

University of Wollongong, Australia	cases, stop clavicles snapping from the sudden movement of excessively heavy breasts [9]; - the 'smart bra' will change its properties in response to breast movement, giving better support to active women when they need it most; the ultimate Smart Bra will tighten and loosen its straps, or stiffen and relax its cups, to restrict breast motion, preventing breast pain and sag; - fabric sensors attached to the straps and midriff of a standard bra will monitor breast movement and relay data in real time to a computer via a telemetry system; information gathered from the tests will eventually be stored on a tiny microchip.
 Smart system for sportsmans	- the sport articles have sensors incorporated in the textile materials; these sensors can monitor and show the cardiac activity, the temperature of the body, can monitor the movements through the sensors from the clothing, creating new posibilities to improve the sportsmans activity [9].
Military applications	
 ”Clothing Area Network (CLAN)	- the CLAN project aimed to develop a technical concept and technology needed in enabling both wired and wireless data and power transfer between different intelligent modules (user interfaces, sensors, CPU’s, batteries) integrated into a smart clothing system [9]; - this clothing is able to: a. monitoring the working environment and the wearer’s wellbeing, and b. transmitting the measured data, or any information related to the work itself; it can be especially used when working alone in environments of high risks.

3. Experimental Part

The interest in the development of this topic comes from the concerns of our team. As part of the CEEX 8/2005-2008 project we have made special clothing for low temperatures so that the human body should be better thermally insulated (Fig. 9). The basic functional requirement is to ensure a constant temperature for the body, one of the conditions for keeping the mood and capacity for movement of the bearer. Besides temperature, the characteristics of the materials and of the clothing products have also been chosen according to the weather conditions (air currents, wind, moisture, etc.). The basic vestimentary product has been accomplished with an integrated multi-layer structure so that the humidity should not be stored on the skin surface (Figure 1). Apparel product have as structure face, back, sleeves, hood, pockets, closures and mounting body placed on the line of symmetry of the face, the sleeves ending, the ending product, size and position adjustment of hood. We have made two pads, one of them called hot lining context, a sweatshirt assembled or not by zips to the outer product. Electroconducting panels were attached to the sleeves, back, front and sides of base

garment product (Figure 2). Locations of the heating panels were chosen as indicated in the literature on cases of hypothermia of the human body (areas with heavy blood flow, which subsequently will spread through panels the heat in the whole body) [10].

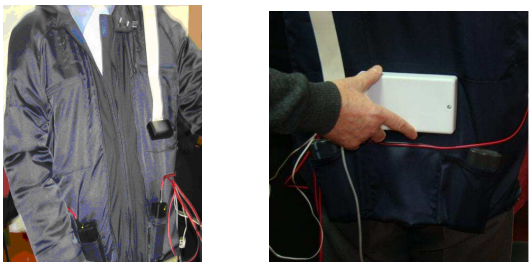


Figure 1. Constructive structure of the product

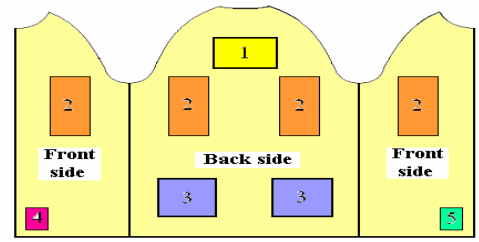


Figure 2. Integration way of the electronic/schematization elements

The notations in Figure 2 are explained in the following:
(1) – pocket for the central unit placed at 15 – 20 cm from the clothing edge in the middle of the shoulders hollow;
(2) – pocket for clamping the electroconductive panels, sewn on one side (seam noted with c), the other sides being fastened with a Velcro band (noted with s); connecting cables between the panels are on the upper and lower sides of the pockets;
(3) – pocket for batteries which are the power unit;
(4) – straps sewn on a side and with a Velcro band on the other one to fasten the large cable;
(5) – connection cable, fastened on the parka and let down on its left sleeve up to the display pocket.
This clothing includes an electrotechnical system for the electric monitoring, for the temperature control and for the humidity detection. The accessing of the electrotechnical system for the electric monitoring, for the temperature control and for the humidity detection is done by means of the block for displaying the results and controls fastened on the left sleeve of the vest with the digital part visible to the user.
This clothing has also a computerized module (embedded wireless networked device – EWND) for controlling through the internet/GMS networks.
This module includes:

- local PC provided with software for the management of the physiological monitoring process and for ensuring of an user interface for setting the specific working conditions;
- embedded-type computer for controlling the physiological monitoring process;
- proper pump and sensors;
- GSM modems and proper software for M2M-type remote control.

The control computer is provided with a special interface accomplished with power triacs with opto-couplers which allow the programmable activation of the ultrasounds generators and of the pump for the water circulation. The control system is in contact with the PC-type base station by an rs 232 wire protocol connection. There also exists a wireless connection variant which uses a Freescale-type communication nucleus with ZigBee protocol.
This is the way in which the remote control of the smart clothing can be possible by firstly proposing a method for the user protection against the negative effects of low temperatures.
The communication in the GSM networks is carried out by the GSM Siemens TC35-type modems. The control data and the information gathered from the sensors are included in the SEM-type messages. This is the way a fiable transmission of the data can be ensured and there can be implemented remote monitoring solutions, especially in emergencies.

4. Conclusions

The potential produced by the combination of the two usage domains such as the textiles technology and that of the information, gives a new importance both to the daily clothing and to the professional one.

Having concrete applications in all activity domains, we can conclude: the clothing constitute the ideal interface between people and environment and a very good support for the integration of modern devices; this new generation of smart clothing needs innovation from the garment industry and provides an immense potential for new business and research domains.

Acknowledgements

This paper was elaborated with the support of BRAIN project Doctoral scholarships as an investment in intelligence, financed by the European Social Found and Romanian Government

5. References

1. Manea L.R., *Intelligent Textile. Materials and intelligent systems,* Ed. Tehnopress, Iasi, 2008, pg. 205, ISBN 978-973-730-702-535-7
2. Deliu R., Scarlet R., Manea L.R., *Theoretical aspects and applications of smart textiles*, International Scientific Conference Unitech 2009, Gabrovo, Bulgaria, Volume II, 20-21 November 2009, pg. 367-373, ISSN 1313-230X
3. Dittmar A., Axisa F., Delhomme G., Gehin C., New concepts and technologies in home care and ambulatory monitoring, *Microcapteurs et Microsystemes Biomedicaux*, INSA Lyon, Bat. Leonard de Vinci, France, pp. 9-35
4. EPI-MEDICS Project. [Online]. Available: http://epi-medics.insa-lyon.fr/epi/
5. MELODIE Pump. [Online]. Available: http://www.aguettant.com/ melodie/index en.html
6. "VTAMN project: *Bioclothes for ambulatory telemonitoring (Vêtement de téléassistance médicale nomade)*, RNTS 2000," French Ministry Res. New Technol., France
7. Weber J.L., Blanc D., Dittmar A., Comet B., Corroy C., Noury N., Baghai R., Vaysse S., Blinowska A., Telemonitoring of vital parameters with newly designed biomedical clothing, *Proc. New Generation Wearable Syst. eHealth, Int. Workshop*, Lucca, Italy, Dec.11–14, 2003, pp. 169–174
8. Munro B.J., Steele J.R., Campbell T.E., Wallace G., Wearable Textile Biofeedback System: are they too intelligent for the wearer?, *Studies in Health Technology and Informatics*, IOS Press, Volume 108/2004, ISSN 0926-9630
9. Meinander H., Honkala M., Potential Applications of smart clothing solutions in health care and personal protection, *Studies in Health Technology and Informatics*, IOS Press, Volume 108/2004, ISSN 0926-9630
10. CEEX 8/2005 project "Intelligent textile structures for communicating clothes".