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Utilization of Smart Textiles in Healthcare

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Abstract
Healthcare related smart clothes, which are in contact with almost all the surface of the skin, offer huge potential for the location of sensors for non-invasive measurements. The term “Smart Textiles” refers to a broad field of studies and products that extend the functionality and usefulness of common fabrics. In this paper, we discuss the utilization of smart textiles in healthcare.

Keywords: *Smart textiles, E-textile, E-textile for healthcare, Wearable computing*

Introduction

In recent decades, the increases have been observed in the number of elderly people suffering from diseases. For this reason, the health care systems require to eliminate the inefficiencies and to control the reducible costs. The automatic and smart health care services can be seen as important tools for achieving these goals. The previous medical system can be defined as “reactive” that means the system takes action in emergency and/or disease cases. But the present situation of the healthcare system, transformed into a preventive and predictive system, can be defined to be more cost-efficient, more personalized, and welfare-oriented. This transformation has been achieved through new measuring and imaging technologies and new electronic and mathematical equipment. These new tools have also required high amounts of investments. But the resulting healthcare system allows us to become a part of the medical process.

When there is a need for following the users during their daily-live activities such as sitting, running, walking, working, and etc., the textile sensor and communication systems offer a durable solution.

An example utilizing textile sensors is the smart clothes designed for medical care purposes. These clothes have contact with almost entire skin, and thus provide many advantages for non-invasive measurements. As the localization is important for many purposes, in order to capture the signals from the sources at the closest points, the smart-

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cloth options can be exemplified with head band, collar, t-shirts, socks, shoes, pants, and etc. Besides the purpose of capturing important bio-signals, they also offer significant ergonomic features.

In order to reference the researches and the product carrying the functionality and the capabilities of the standard textile products, the term "Smart Textiles" is used. We can identify the "Smart Textiles" as textile products such as fibers and filaments, yarns combined woven, knitted or non-woven structures, and they can contact with the environment/user. The combination of textiles with electronics (e-textiles) results in the development of smart materials. These materials are able to perform many actions that are actually performed by hard and non-flexible electronic devices. Smart Textiles are to be utilized in order to improve the quality of social life, and they are capable of leading to significant decreases on the welfare budget. These products are the products of high intelligence, and we can classify them under 3 classes:

- Passive smart textiles: they are able to sense only the environment/user, and they are sensor-based ones;
- Active smart textiles: they responds to any stimuli coming from the environment, and combine the actuator function with a sensing tool;
- Very smart textiles: they are capable of sensing, responding, and matching their actions with the given circumstances.

A lot research has been done in the field of e-textile, in this paper, we review some of the work done in the area of healthcare based e-textile systems [1-15].

Developed e-textile healthcare applications

SmartShirt

One of the firms operating in this field is the Sansatex company, and they have developed a system named "SmartShirt" (Figures 1 and 2) [3]. Its operation is based on a multi-function on-shirt processor evaluating and processing the signals coming from the sensors on the same shirt. The evaluated results can be seen at displaying component. Moreover, there are some tools on the clothes, which can wirelessly communicate with computers. Again, thanks to these tools, the connection with a remote person can be established through internet, and the vital information about the user of cloth can be received.

Figure 1. *Clothes Detecting Vital Signs (Smart Shirt) [3]*

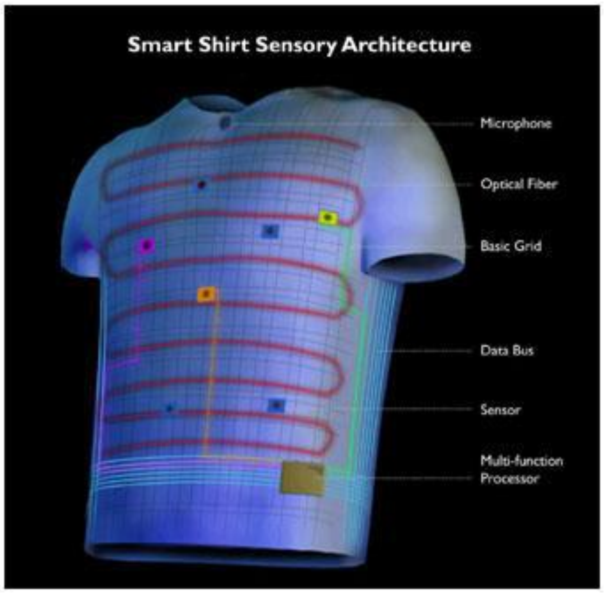

Figure 2. *Clothes Detecting Vital Signs (Smart Shirt) [3]*

At the same time, thanks to this cloth, it is possible to find the people buried in the wreckage in earthquakes, and the people fainted due to the effects of gases.

The system is mainly capable of measuring and displaying the vital signals (heart rate, blood pressure, temperature, and etc.) of the user, and establishing mutual communication with necessary units. The communication is carried out via radio waves. This system has been developed mainly for military personnel, firemen, healthcare professionals, and policemen [3].

This system consists of various temperature, pressure and etc. sensors, a processor processing the information coming from the sensors, a display component, and the conductive optic fibers ensuring the connections. Thus, the cloth consists of the combination of the electronic equipment and the textile.

Thanks to the system's capability of establishing mutual communication, it eases the access to injured people in emergency cases [3].

LifeShirt

The LifeShirt system developed by Vivometrics, another company carrying out studies on this matter, is capable of recording many of medical information from blood pressure to heart rate, and submitting them for doctor's evaluation [4].

The examples of LifeShirt system developed by Vivometrics Co. are presented in Figure 2.

Figure 3. *Clothes Detecting Vital Signs (LifeShirt) [4], 2005*

Smart Bodysuit for Babies

In order to prevent the sudden baby death syndrome causing to deaths of thousands of sleeping babies every year, the clothes informing the parents when the baby stops breathing or when there is an unexpected change in heart rate or body temperature of the baby (Figure 4). The cloth can communicate with PDA or PC of the mother or father wirelessly. When the baby stops breathing, the cloth transmits a sign.

Figure 4. *Smart Bodysuit for Babies*

Many various e-textile systems have been developed for baby monitoring in recent years [5].

Outlast

The clothes manufactures by utilizing Outlast® technology arrange and reuse the user's body temperature by sometimes absorbing, sometimes distributing and sometimes releasing the temperature [6].

This technology has been developed initially for NASA in order to protect the astronauts from environmental effects of rapid temperature changes occurring in space. But nowadays, it is utilized even in underwear, socks, shoes, sleeping bags, bed clothes, and etc. (Figure 5)

Figure 5. *The utilization of Outlast® Technology*

Research Done on Smart Textiles for Healthcare

Lin, Jium-Ming, Hung-Han Lu, and Cheng-Hung Lin.

In [7], a bio-potential measurement setting has been introduced (Figure 6). The system involves a wireless device that transmits the acupuncture bio-potential information to a remote control station in order for health conditions to be analyzed and monitored. This setting has some key components such as replaceable foam-rubber cushions, double-side conducting tapes, chip and antenna on RFID tag. In order to minimize the contact resistance, these foam-rubber cushions should be sunk into salty water, and then placed onto acupuncture points. There also the double-side conducting tapes placed onto foam-rubber cushions in order to stabilize them. Thus, the cushions and/or tapes can easily be replaced with new ones. The tags can be smoothly placed onto the skin, because they are flexible plastic substrates. Moreover, the amplifier utilizing CMOS technology on

RFID chip can amplify the signals in order to enhance the S/N ratio and impedance matching. By this means, the cloud server can wirelessly display the health conditions. This example indicates that the presented setting can be utilized as a wireless health condition display. In order to analyze the 11 bio-potential for the important acupunctures of eleven meridians on a person's hands and legs, the numerical method and the criteria are given. This information would allow a physician to evaluate the health status of the cloth's user.

Here, there is some information about the operation setting of the introduced system. There are 2 operation modes. These are the

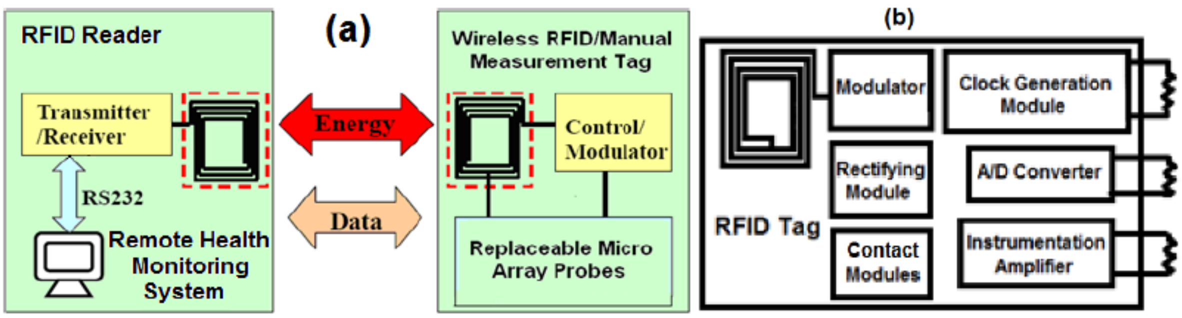

Figure 6. *RFID based system*

measurement of acupuncture bio-impedance and the measurement of the acupuncture bio-potentials. The processor unit located on the RFID tag decodes the command signal transmitted by the RFID reader about analyzing some acupuncture points on the user. The digital signal can be sent by the RFID tag back to the RFID reader. After the FFT (Fast Fourier Transform) and signal conditioning processes, the RFID reader can send the information about the acupuncture impedance to the cloud server. Then further medical evaluations and monitoring can be executed.

Koski, K., et al.

In [8], some critical electro-textile design parameters about the wearable radio frequency identification (RFID) ultra-high frequency (UHF) patch antennas are introduced (Figure 7). For the antenna ground plane and patch structures, the modeling parameters have been prepared and confirmed. It accounts for the antenna input inductance contributed from the electro-textile. Ideally, such as for highly conductive fabrics and pure conductors, the imaginary part is negligible. Utilizing the proposed design guidelines, a fully wearable and flexible embroidered RFID patch antenna is for the first time realized.

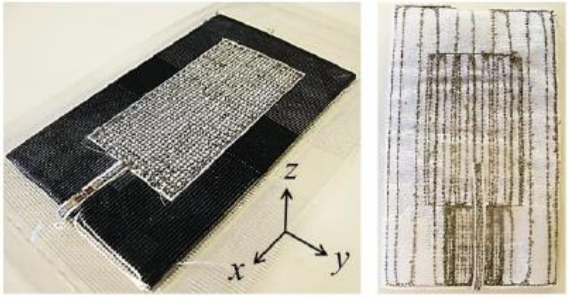

Figure 7. *RFID UHF patch antennas.*

Min, S., Yonghyeon Yun, and Hangsik Shin

In [9], for respiration monitoring purposes, a simplified structural textile capacitive respiration sensor (TCRS) has been introduced. The TCRS consists of the conductive textile and Polyester. Its design is based on the simple layered architecture. The determination of the respiration information is based on the continuous measurements of the distance between the plates, and the calculation of the change. The distances between the plates change during breathing due to the changes in abdominal diameter. The

verification of the accuracy of the TCRS has been made via linearity and comparison tests. In order to test the linearity of change in capacitance by the distance change, the tensile experiments have been made 3 times. The tests indicated that the coefficient of determination (R^2) of designed TCRS was 0.9933. 16 participants have been involved in the comparative experiment. According to the results of it, the proposed respiratory rate detection system involving TCRS has successfully accomplished the respiration measurement when compared with nasal airflow measurement ($R=0.9846$, $p<0.001$). In Bland-Altman analysis, the upper limit agreement is 0.5018 respirations per minute and lower limit of the agreement is -0.5049 respirations per minute. According to these results, we validated the conclusion that the TCRS can be utilized in monitoring the unconscious persons, and in eliminating the discomfort of subjects. The system involving TCRS is capable of providing an accurate respiration rate measurement. Thanks to its lower costs, this setting is capable of enlarging the healthcare applications to home- and mobile-based services.

The respiration measurement based on the BTCRS consists of the textile, analog front end, data acquisition module and the signal processing and analysis algorithm. In order to keep the respiratory activity records, the users wear the BTCRS on their abdominal site, and also the nasal thermocouple of (TSD202A) Biopac System Inc. (USA) is placed onto the user's philtrum as a reference respiration

measurement. An example of this setting involving BTCRS is presented in Figure 8.

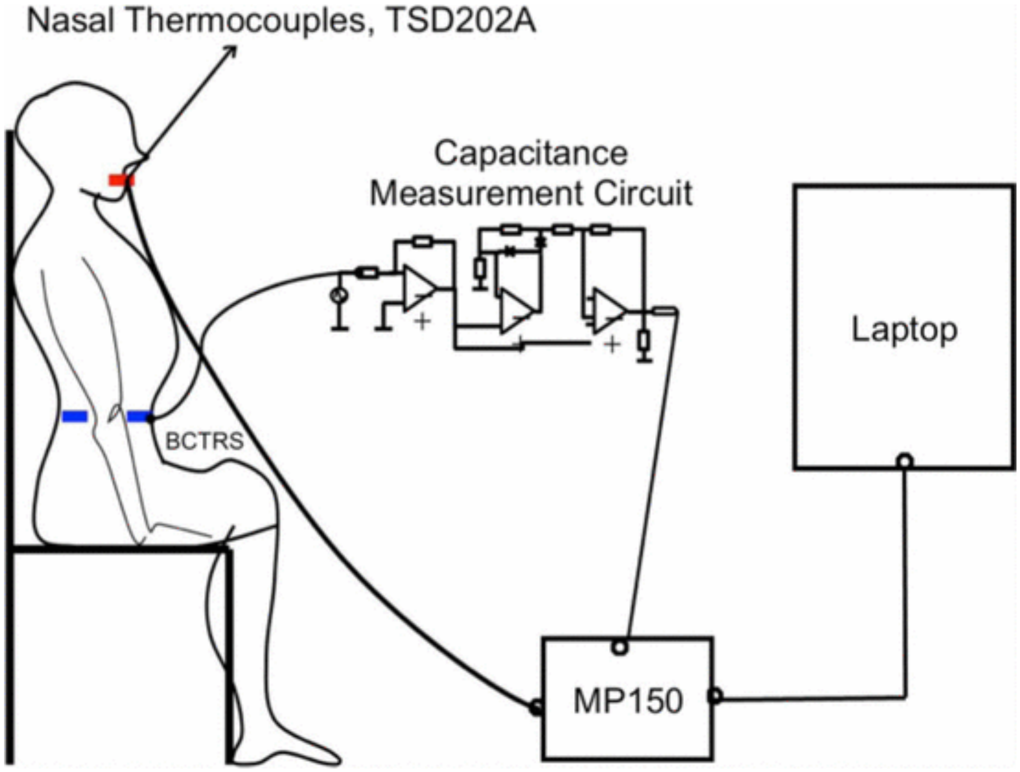

Figure 8. *BTCRS.*

Postolache, O., et al.

In [10], a new smart wheelchair design has been presented (Figure 9). In design of that wheelchair, there are embedded sensors and an acquisition, processing and communication platform. The platform consists of a multifunction I/O module and an embedded PC in order to track the physiological stress parameters and motion activity of the user. The embedded sensors consist of E-textile electrodes placed onto the arms of wheelchair and the 3D MEMS accelerometer for gathering the motion activity information. Besides them, the piezoresistive flexible force sensors are utilized in order to improve the interaction between the ECG and the skin of the user. In order to transmit the digital signals to the client application that is already installed in user's mobile devices, a server application has been developed by LabVIEW and hosted on the embedded computer. This mobile platform involves an interface for -nurses, physiotherapists or physicians besides the wheelchair user or any informal caregivers.

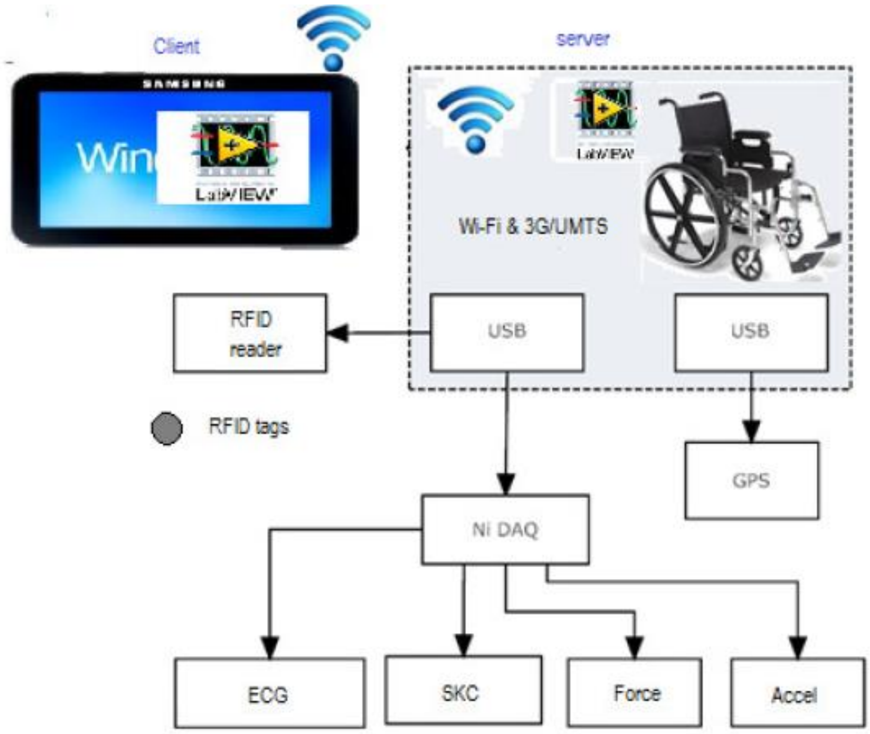

Figure 9. *Smart wheelchair design.*

CONCLUSION

In order to ensure the comfort and higher quality of life of the users, the mentioned settings should involve flexible and smart technologies at the heart of the system. Furthermore, the motivation and consciousness of the system's user must be improved through the system. One of the difficulties experienced during these processes is to obtain the realistic health information under daily life conditions by utilizing the textile materials. The utilization

of such systems aims to minimize the user activity with the sensing system. The fulfillment of the functions is executed by a wearable sensor system combined mounted into the clothes or within the living spaces. Such systems must be capable of tracking the vital signs and activities of the user during

their daily lives. That's because, the utilization of sensing textile materials is of significant and increasing importance.

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