D. Zavec Pavlinić *

THE POTENTIAL OF WEARABLES RELATED IN SMART TEXTILES

UDK 677.017:614.8
RECEIVED: 2017-02-13
ACCEPTED: 2017-05-08

SUMMARY: Smart textiles are the future. Innovations in the textile and clothing sector (T&C sector) are introducing wearable technologies associated with healthcare, movement and transport. An innovation boom in the wearable textile sector has brought in a range of new products, such as smart gloves with sensors and controls, smart socks with thin blood pressure sensors and smart products that monitor stress and fatigue. Recent technological advances combine apparel technology and textile industry to develop smart wearable devices. These have the capability to interact with the user or the environment, including tracking and communicating data about the user or the environment to other devices through embedded sensors and conductive yarns. The ICT sector has been important for the T&C sector for quite some time and its importance continues to rise. The market for smart textile wearables is expected to grow at a CAGR of 132% between 2016 and 2022.

Key words: *wearable electronics, smart textiles, health, protection, functionality*

INTRODUCTION

The Textile & Clothing (T&C) sector in Europe is a very strong player worldwide. Total European exports of textiles and clothing amounted to 43 billion EUR in 2014 and constantly grows over the years. Manufacturing currently makes 16% of EU GDP, and the EU would like to bring it to 20% by 2020. To strengthen the manufacturing industry is possible with significant funding for research and innovation – around 80 billion EUR for the 2014-2020 periods. R&D, which is one of the key factor, can get a lot of funding for topics related to materials, nanotechnology, biotechnology, ICT, robotics, photonics, etc… *(Future Textiles, p. 38, 2016).*

A new report from technology consultancy Cientifica defines three generations of textile wearable technologies: first generation is where a sensor is attached to apparel; second generation products embed the sensor in the garment; and the third-generation wearables where the garment is the sensor *(Report, 2016).*

Wearables and to textiles connected wearable electronics are changing the business models in the field of T&C sector [Raconteur, The Design Surgery].

Europe is overall well positioned to scope and exploit the potential of smart wearables; spin-off and small companies as well as large companies are very active in the field of electronic textile & garments, wearable electronics, body-worn and personal portable devices. Plenty of opportunities exist in a large number of sectors, particularly

*Daniela Zavec Pavlinić, Ph.D., (daniela@titerad.com), TITERA d.o.o., Obrtna ulica 40, 9000 Murska Sobota, Slovenija.

Figure 1. Wearable technology (relation to clothing items)
Slika 1. Nosive tehnologije (u odjevnim artiklima)

in healthcare and medical, fitness and wellness, sports goods, clothing and technical textiles (including personal protective equipment). The market for wearables using smart textiles is forecast to grow at a CAGR of 132% between 2016 and 2022 representing a $70 billion market *(Report, 2016)*.

According to the Cisco Global Mobile Data Traffic Forecast, there were 97 million wearable devices in the world in 2015. The Figure 2. shows the regional distribution of these devices. The North American and Asia-Pacific regions hold the top two positions and together the 70% of the global market. Europe follows in third place and represents around one fifth of the global wearables market. According to CISCO estimates, there will be 601 million wearable devices globally by 2020.

Europe's share which is currently slightly above 20% of the global market is expected to increase to 30% by 2020. Number of connected wearable devices in Europe, which is some 20 million today, could grow eight-fold to reach some 173 million units in 2020 *(Cisco VNI Mobile Forecast, 2016)*.

The market will be over the next five years dominate by watches and bands, but equally IDC expect that other form factors such as clothing, eyewear and hearables will gain importance. In terms of application areas, the healthcare market for wearables becoming as important as infotainment, followed by fashion and industrial markets (IDC Forecasts, 2016).

	2015		2020	
	Number of Wearable Devices (K)	Percent of Global	Number of Wearable Devices (K)	Percent of Global
Asia Pacific	30,403	31.4%	194,669	32.4%
Central and Eastern Europe	5,006	5.2%	45,850	7.6%
Latin America	1,828	1.9%	26,083	4.3%
Middle East and Africa	4,087	4.2%	25,416	4.2%
North America	38,645	40.0%	180,963	30.1%
Western Europe	16,748	17.3%	127,644	21.3%
Global	96,717	100.0%	600,625	100.0%

Source: Cisco, 2016

Figure 2. Regional wearables devices share growth forecast
Slika 2. Predviđanje rasta udjela nosivih uređaja u regiji

WEARABLES AND SMART TEXTILES

Most wearables created till today are driven by rapid growth of digital health monitoring. The adoption of health-monitoring devices is likely to be swift as new entrants to the market. However, the researchers stress the need for new entrants to prove their hardware can measure health indicators with the same accuracy as standard medical devices. In addition, the big data collected by such monitoring devices presents significant medium-term opportunity for different IT platforms. It will offer insight into health information and enable efficient decision-making through data analytics. This led to the emergence of wearable technology built into daily clothing too, Figure 3 *(Schumann, A., 2016)*.

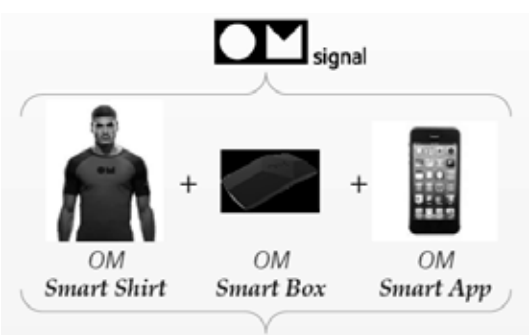

Figure 3. Example of wearable electronics
Slika 3. Primjer nosive elektronike

Wearables offer an unlimited number of opportunities for improving human life.

The products alike will make possible also for healthcare providers to offer personalized plans based on an individual's genetic traits and susceptibility to diseases such as cancer, including treatments that have previously achieved positive results. Thanks to data delivered by wearables, healthcare providers can diagnose health disorders at an early stage, monitor patients and interfere in a timely manner when problems occur. There is already a wide range of wearable devices in the market that track and predict epilepsy seizures or that monitor the glucose level of diabetes patients and support drug delivery *(Austen, 2015)*.

One of the criteria of these products is to be lightweight and can be worn during the day while active, and at night while sleeping. Some of them has built in a tri-axial accelerometer, barometer and software to distinguish the actions of the user, and determine how many calories have been burned.

Smart textiles for human safety, comfort and health

Wearable devices are today mainly used for fitness, well-being and health. Diagnosis at point of care and preventive care are expected to

enable considerable savings in public finances whilst unlocking new opportunities for products and data-driven services. There are clear signs that wearables supported by IoT solutions will soon be utilized on a much larger scale, such as in areas of workplace safety, productivity, security, smart houses, emergency response or banking. Thanks to wearables, conventional businesses in medical or sports equipment can be transformed into service businesses, provide assistance for ambient and healthy living or for tracking, measuring and augmenting the performance of sports professionals. Such transformative effects can reach out too many industries including medical, fashion, sports goods, retail marketing, military and entertainment *(European Commission, 2016, p. 8)*.

Recently a lot of smart textile products have been developed. These innovative products are divided by end functionality of integrated electronic components and turns garments into active motion sensors too.

Smart gloves with sensors can for example enable control of a phone via Bluetooth or wi-fi technology is originally designed for safety applications in the sports sector, like motorcycling and in transportation. With integrated conductive fabric, it allows to wearer to control their device.

Smart socks with integrated thin soft textile pressure sensors that enable runners to monitor their running form and to help to reduce the risk of injuries. They measure cadence (a combination of your weight, height, led and stride length), foot landing (heel or ball striking), foot contact time on the ground, foot impact force, pace and more, and all information can be monitored through a mobile phone. Further such technology can be used for various sensing capability, also to monitor driver posture (pressure against car seat, for self-driving vehicles) and even for driving gloves to monitor stress and fatigue *(Sensoria Inc., US, 2016)*.

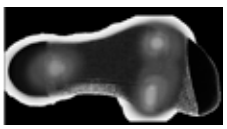

Figure 4. Sensoria smart socks
Slika 4. Pametne čarape Sensoria

Smart footwear *(Under Armour, 2016)* track and store data including time and date, duration, distance and splits, while enabling athletes to run device-free. Further the development integrates the heated insoles and smartphone connectivity. The aim is to design the footwear for casual everyday use with a warming system to eliminate cold feet, sensors to follow and measure its user's fitness activities, an opening and closing system that controls the fit of the shoes, an integrated torch lamp, and shock absorption measurement *(Digitsole, 2016)*.

Figure 5. The 1st connected heating insole
Slika 5. Prvi grijani ulošci za cipele

Smart fabric undershirt is capable of tracking breathing rate, heart rate and other activity *(Carre Technologies, 2016)*. It supports real-time monitoring using phones and other devices. Originally it is designed for athletes and trainers; however, it could be integrated into the garments for drivers and motorists. The shirt updates you on your vital functions in real time with aim to prevent issues like accidents because of fatigue or medical problems.

Figure 6. Hexoskin smart shirts
Slika 6. Pametne majice Hexoskin

Smart air bag for skiers offers protection from accidents *(In&motion, 2016)*. It is capable to detecting an unavoidable fall and inflating in less than 100 milliseconds to protect the most sensitive areas before the impact with ground. The airbag offers optimal protection to the neck, chest, spine, abdomen and hips. Such embedded technology can revolutionize protection systems for people and equipment.

Figure 7. The smart ski airbag vest
Slika 7. Pametni skijaški airbag prsluk

Smart performance shorts that measure muscle electromyography response. The users receive live feedback on their muscle performance and a detailed analysis to help them reach their maximum potential *(Myontec, 2016)*.

Figure 8. Muscle Monitor
Slika 8. Monitor mišića

Smart textiles for homes and automotive industry

Wearables electronics are presented also in automotive industry with aim to increase the comfort of the driver. Furthermore, wearable devices which interact with emerging digital products, become part of digital systems, such as in the case of the autonomous car *(European Commission, 2016, p. 8)*. Additional features are integrated, like head and neck support, oxygen and water supply fed to the driver through a prototype helmet. In addition, the system could also gather biometric data about its driver.

The innovation in car seats presents also blue light-emitting diodes integrated in the headrest. This light is absorbed by the brain of the driver where it can have a positive effect on his/her wellbeing. In parallel, heating elements are inserted in the upper part of the car seat to replace large-area heating systems, which can usually be found in the seat.

Car seat with feelings can alert drivers if they start to nod off at the wheel. Electrocardiogram (ECG) sensor system is integrated directly into the fabric of car seats *(Nottingham Trent University, 2016)*.

Figure 9. Innovative Car seats
Slika 9. Inovativne autosjedalice

Among the range of smart fabrics presented in wearable garments, the bed monitors sleeping habitats by gathering data to ensure the bed stays comfortable during sleep movements. In addition, the beds senses changes in body pressure and position, and automatically respond to whatever level of comfort you need or desire.

Heating textiles have been developed also for use in plant cultivation. The textiles are placed around the roots of the plant and supply targeted warmth to the area. These high-tech textiles in greenhouse can help save energy as the ambient temperature can be greatly lowered with no reduction in yield. The heating elements can be used to control the vegetative phase accurately to optimize the harvest, and the heating textiles

have also been developed to provide frost protection *(Hohenstein, 2016)*.

Figure 10. High-tech textiles in the greenhouse
Slika 10. Visokotehnološki tekstili u stakleniku

WEARABLES AS A HEART OF PERSONAL PROTECTION

Smart technical textiles and clothing can also be life-savers in harsh working environments by measuring critical indicators such as respiration, heart rate or dangerous gases in the working environment and providing real time feedback to the user.

The PPE market needs a reliable, effective and usable system which fulfils the requirements of the firefighters, beside that provides open solutions and interfaces to boost the development of other manufacturers. The Smart Turnout Gear has been developed and a prototype is produced. It enables to measure, combine, transfer, and monitor and visualize physiological and environment signals collected from and within the firefighter's suit. This innovative turnout gear presents the advantages in fire safety.

Transparent real-time remote monitoring with embedded health and environment sensors becomes a new cost effective paradigm, to protect professionals (firefighters, civil and military special forces, etc) in extreme conditions or in harsh environments. Currently, there is many enabling technologies to measure physiological and environment signals remotely. However, such technologies are less available on the market also in the field of personal protective equipment. Latter needs to provide the protection with built-in protective materials that must be durable and easy to maintain. Therefore, the sensors should be embedded in clothing, in an innovative and user-acceptable manner.

We have investigated all the possibilities for the re-design of the personal protective turnout gear with aim to equip it with the communication components. Strong collaboration with professional firefighters was established. They have provided the significant knowledge related to firefighting operations, their needs and requirements of harsh environment. Consecutively, the functional design of the ICT vest was made and communication modules have been developed and created *(Kozlovszky, Zavec Pavlinic, 2013)*. Regarding the size and shape of sensor textile belt, communication modules for monitoring, archiving and transmitting the captured data, wiring diagram has been created.

With handheld and PC devices used as data acquisition (DAQ) systems we can collect all kind of information about the person remotely. In our case, we will monitor basic physiological parameters as well the microenvironment temperature. Due to the different - in most cases proprietary and incompatible- sensor technologies and solutions, it is a hard task to create generic, user friendly DAQ systems. Further, this paper focuses on our DAQ solution how to measure, combine, transfer, monitor and visualize physiological and environment signals collected from and within the firefighter's suit.

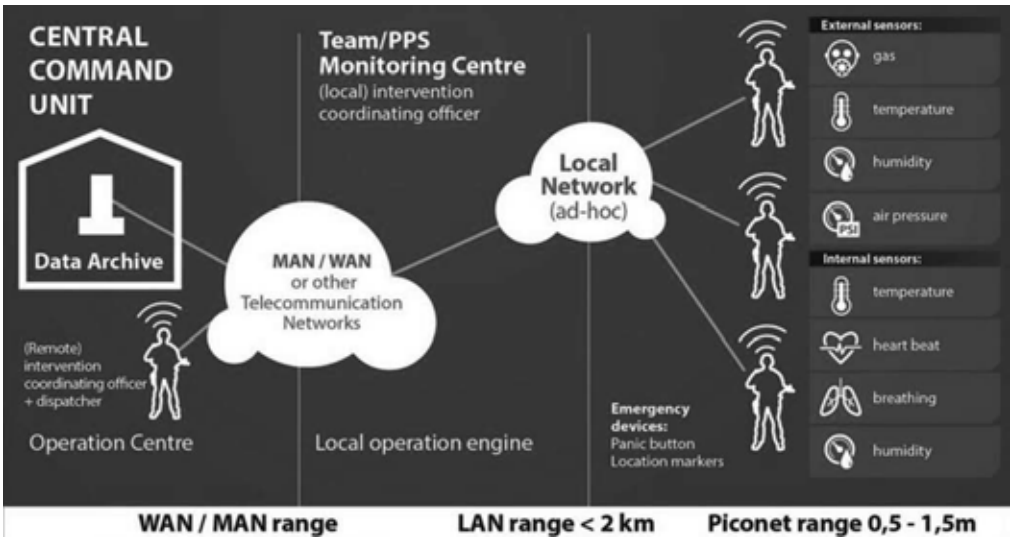

Figure 11. Remote monitoring high-level system overview
Slika 11. Pregled sustava visoke razine za daljinski nadzor

CONCLUSION

Wearable technology is changing the world around us. Not only in daily garments, but also in personal protection equipment, where several different standards must be fulfilled. We have designed and realized a location aware solution using combined multi-modal sensor infrastructure for emergency service personnel. During location sensor fusion, we are converting the data to a common representation format and have created a common coordinate system. The acquired data is processed on different levels, and we evaluate/filter sensor data in real-time. The combination of the sensors can provide better location awareness even in special locations/ extreme environments for the PPS users. The acquired location data can be visualized *(Kozlovszky et al., 2015)* by the PPS user, and can be transmitted towards a remote location to let visualize the emergency service team activities.

Future wearables should be shape able, stretchable and washable/cleanable on-demand, e.g. in the case of textile and clothing (a wearable should indeed look like natural clothing because of comfortability, breathability and wash ability). The driving force behind the development of smart protective equipment is the ongoing technological development by industry. The technology push, the fast-paced continued development of technical capabilities, like constant miniaturisation of components, in combination with the knowledge of involved engineers, makes us possible to transform virtually application into practice and fuels smart PPE's visions. Regarding the given are our main aims and objectives focused into the development of smart PPS for fire fighters work in harsh environmental conditions. In detail, it is about to increase situation awareness, to inform, to prevent and protect humans against environmental impact. To improve rescue protocols and to help saving people's lives.

LITERATURE

Austen, K.: *What could derail the wearables revolution?* 2015. Available from: http://www.nature.com/news/what-could-derail-the-wearables-revolution-1.18263, Accessed: 2017-02-06

Carre Technologies, Canada: Available from http://www.carretechnologies.com, Accessed: 2016-06-27

Cisco VNI Mobile Forecast (2015 – 2020) – Cisco: Available from http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html, Accessed: 2017-02-06

Digitsole: Available from http://www.digitsole.com, Accessed: 2016-06-27

European Commission, 2016. Smart Wearables: Reflection and Orientation Paper: Available from: http://ec.europa.eu/newsroom/document.cfm?doc_id=40542, Accessed: 2017-02-06

Future Textiles: Available from www.wtin.com, Accessed: 2017-02-06

Hohenstein: Available from http://www.hohenstein.de, Accessed: 2016-06-27

IDC Forecasts, 2016: Available from https://www.idc.com/getdoc.jsp?containerId=prUS41100116, Accessed: 2017-02-06

In&motion, France: Available from http://www.inemotion.com, Accessed: 2016-06-27

Kozlovszky, M. & Zavec Pavlinic, D.: Intelligent Firefighter Suite With Real-time Monitoring System, *6th ECPC*, Brugge, Belgium, (2013)

Kozlovszky, M., Zavec Pavlinic, D., Feher, G.: Location awareness using combined multimodal sensor infrastructure for emergency service personnel, *Extrem Physiol Med.*; 4 (Suppl 1): A29, (2015)

Lee, J-Y. et al.: "What do firefighters desire from the next generation of personal protective equipment? Outcomes from an international survey", *Industrial Health,* 53 (5) (2015), pp. 434–444

Myontec, Finnland: Available from http://www.myontec.com, Accessed: 2016-06-27

Nottingham Trent University: Available from http://www.ntu.ac.uk, Accessed: 2016-06-27

Raconteur: WEARABLE TECHNOLOGY, 25/09/14, #0277, Available from http://np.netpublicator.com/netpublication/n74763668, Accessed: 2016-06-29

Report: Smart Textiles Are Fashion's Fourth Industrial Revolution, 2016: Available from http://apparel.edgl.com/news/Report--Smart-Textiles-Are-Fashion-s-Fourth-Industrial-Revolution106982, Accessed: 2017-02-06

Schumann, A.: *Wearables in aller Munde — Internationale Entwicklungen der Smart-Textiles (2016),* Available from http://smarttex-netzwerk.de/images/PDF/5-2016-Workshop/Gherzi.pdf, Accessed: 2016-06-29

Sensoria Inc., US.: Available from http://www.sensoriafitness.com, Accessed: 2016-06-27

Under Armour: Available from http://www.underarmour.com, Accessed: 2016-06-27

POTENCIJALNO NOSIVE ELEKTRONIKE U ODNOSU NA PAMETNI TEKSTIL

SAŽETAK: Pametni tekstili su budućnost. Inovacije u sektoru tekstila i odjeće razvijaju nosive tehnologije povezane s ljudskim zdravljem, micanjem i transportom. Inovacije u sektoru nosivih tekstilnih senzora, kao što su pametne rukavice sa senzorima i kontrolorima, pametne nogavice sa senzorima tlaka, pametni proizvodi za monitoring stresa i napora su u velikom porastu. Napredak u tehnologijama na području odjevnih tehnologija i tekstilnih industrija rezultirao je razvoj novih mogućnosti tekstilnih proizvoda zvanih pametni tekstili. Takvi proizvodi sposobni su za komunikacije između korisnika i okoline, uključujući praćenje i komunikacije korisnika s drugom opremom uz pomoć uključenih senzora i konduktivnih vlakana. U zadnje vrijeme ICT sektor postao je od velikog značenja za tekstilni i odjevni sektor i takva suradnja samo intenzivno raste. Očekuje se da će tržište nosive elektronike koje koristi pametni tekstil narasti između 2016. i 2022. za 132 %.

Ključne riječi: *nosiva elektronika, pametni tekstili, zaštita, funkcionalnost*

Prethodno priopćenje
Primljeno: 13.2.2017.
Prihvaćeno: 8.5.2017.