Intelligent Clothing to Improve Safety at Work and Support Production

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1. Theme description

In order to reduce costs, to improve worker productivity, some companies are driving the development of smart wearables and sensors in industrial environments[1].

Currently, the safety on work is guaranteed through PPE (personal protective equipment) like safety eyewear and other. The technology upgrades could make the standard do an even better.[2].

Examples of possible Wearable technology that can greatly improve workplace safety are[3]:

- Smart bands and sensors embedded in clothing and gear that monitor workers' health and wellbeing by tracking factors such as heartrate, heat stress, respiration, fatigue and exposure. The data obtained could be sent to workers when critical levels are reached;
- In case of dangerous environments, machine and environmental sensors that provide contextual information to field workers to help them to know from what they are surrounded and wearable GPS tracking to help to know their spatial position;
- Smart glasses and other HUDs (Head-Up Display) that allow workers to access specific instructions and manuals in the field, in addition to allow remote guidance;
- In the insurance sector, clothing with camera-equipped could be used to document a job or incident for later review.

In the following, a review based on intelligent clothing, with future developments, are reported.

[1] http://www.ehstoday.com/eye-face-head/ppe-and-internet-things
[2] https://blog.safetyglassesusa.com/technology-impacting-workplace-safety/
[3] https://brainxchange.io/3-great-use-cases-wearable-tech-ehs/

2. Components for smart PPE

Smart PPE made up as synergy of different technologies:

- smart materials;
- electronics embedded for smart PPE;
- Network system.

In this paragraph are described before listed technologies, focusing on the functionalities added on PPE.

Smart Materials

Smart materials are materials able to react at environmental stimuli, producing a significant change of their properties for a desired and effective response[4]. This technology has played an essential role in technological progress, allowing the development of new smart PPE applications.

Smart materials are able to act both as sensors and actuators, allowing functionality on PPE that could never be achieved with a use of traditional materials.

Smart materials for smart PPE can be divided in categories:

- Piezoelectric[5]. If this smart material is subject to an electric charge or a variation in voltage, it will undergo to mechanical change (and vice versa). In the first case is called direct effect in the second converse effect;
- Electrostrictive[6]. It is like a piezoelectric material, but the mechanical change is proportional to the square of the electric field. The displacements are always in the same direction;
- Magnetostrictive[7]. This smart material is similar toelectrostrictive material, only that is necessary a magnetic field to produce mechanical strain (and vice versa). Like electrostrictive material, it can be used as sensor and/or actuators.
- Shape Memory Alloys[8]. This smart material is sensible to thermal field, undergoing to a phase transformation that produce shape changes (martensitic in condition of low temperature and austenitic in condition of high temperature). An alloy with this propriety is the Nitinol alloy.

[4] http://www.journal.forces.gc.ca/vo1/no3/doc/25-32-eng.pdf
[5] http://www.nanomotion.com/piezo-ceramic-motor-technology/piezoelectric-effect/
[6] https://aip.scitation.org/doi/full/10.1063/1.4861260
[7] https://www.sciencedirect.com/science/article/pii/S0261306907000027
[8] https://www.sciencedirect.com/science/article/pii/S0261306913011345

- Optical Fibers[9]. Fiber that uses phase, intensity, frequency or polarization of modulation to measure temperature, strain, pressureelectrical/magnetic fields, etc. So, they are largely used like sensors.

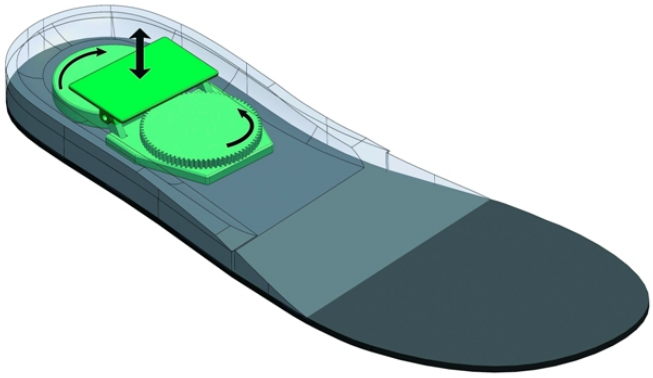

Figure1. Piezoelectricapplication: shoes that produces energy.

Electronics embedded of smart PPE

Wearable electronics are devices that are always attached to a person, being comfortable and easy to use (other its primary function)[10].

Recent advances in miniaturization of ICT (Information and Communication Technologies) allowed to increase the interest for wearable electronics. The result was the development of a range of solutions, used for PPE too, starting from simple device containing sensors and actuators, and ending with highly specialized ESs (embedded systems), incorporated into larger products in order to perform some specific advanced functions[11].

Wearable technology is divided principally in:

- actuators;
- sensors;
- I/O device (analogical or digital).

One of first application of the wearable electronics was for medical and sport purposes: it was development a new monitoring system to study human activity and

[9]http://www.explainthatstuff.com/fiberoptics.html
[10] Tao XM. Introduction. In: Tao XM, editor. Wearable electronics and photonics. Cambridge: Woodhead in association with The Textile Institute; 2005
[11]Marwedel P, editor. Embedded system design. Embedded systems foundations of cyber-physical systems. New York (NY): Springer; 2011

health/physiological status. These systems usually take a lot of sensors (like strain gauges, body temperature sensors, heart rate monitors, ECGsensors, etc.)[12].

Another example of wearable electronics could be the protective gloves for firefighters: this kind of PPE should integrate a wireless system for temperature measurement, a haptic feedback and some gestures in order to help workers in case of warnings messages[13].

A commercial example of wearable technology is the smart watch: a device that incorporates a lot of sensors, with a device of I/O, in normal watch. This product is largely used in different areas: sport, health care, business, organization, etc[14].

Network System

The Internet of Things (IoT) concerns the using of intelligently connected devices and systems to control data gathered by embedded sensors and actuators in machines and other physical objects[15].

Connectivity solutions such as Wi-Fi, mobile networks, Zigbee and Broadband communication are omnipresent and capable of supporting large volumes of IoT connectivity, for a small cost to enterprises and consumers.

IoT presents an excellent opportunity to improve health and safety equipment market[16].

Consumers will receive a better customer experience, while companies can be more competitive, taking advantage by harvesting the masses of data that IoT devices produce.

Furthermore, companies can profit from IoT technology, using it to monitor employees via sensors attached to their clothing and footwear, drawing benefit for the health of workers and the business itself[17].

In conclusion, the Internet of Things can enable the next wave of life-enhancing services across several fundamental sectors of the economy, health, etc.

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[12] Mason A, Wylie S, Korostynska O, et al. Flexible e-textile sensors for real-time health monitoring at microwave frequencies. Int J Smart Sensing Intell Syst. 2014

[13] Mrugala D, Ziegler F, Kostelnik J, et al. Temperature sensor measurement system for firefighter gloves. Procedia Eng. 2012

[14] Wearable technologies: The role of usefulness and visibility in smartwatch adoption, Stephanie Hui-Wen Chuah, Philipp A. Rauschnabel, Nina Krey, Bang Nguyen, ThurasamyRamayah, Shwetak Lade, Computers in Human Behavior 65 (2016)

[15] https://www.gsma.com/iot/wp-content/uploads/2014/08/cl_iot_wp_07_14.pdf

[16] http://www.ehstoday.com/eye-face-head/ppe-and-internet-things

[17] https://digitaldirections.com/wearables-workers-can-improve-efficiency-safety-standards/

3. Products and Future Developments

There are a lot of products or collaboration in development of wearables device for smart PPE, so, below are reported some example of smart PPE and future development to give an idea of the state of art:

- Smartwatch for a factory worker. This has a two-way alarm to notify or warn the operator of dangerous situations at the push of a button. It has sensors that monitor health and environmental risks, such as heart rate and the presence of noxious gases. The watches are being piloted by crane operators at Tata Steel in Jamshedpur, India[18];

- Connected worker. Honeywell Industrial Safety is working with Intel to make wearables. Data from a self-contained breathing apparatus, wrist-worn gesture devices and a clip-on heart rate monitor are displayed remotely on a cloud-based dashboard, so, for example, that fire chiefs can anticipate risky situations;

- Smart Helmet. General Electric's Smart Helmets are directly connected field engineers to more experienced colleagues at headquarters, allowing the former to be guided through complex tasks by audio and video. Engineers are also equipped with two small monitors on the helmet and an iPad. These enable two-way communications, so HQ can monitor what the engineer sees in the field and share information. GE is developing Smart Helmets with the University of Pisa and prototypes have been tested with staff engineers;

- SafeScan. It can be described as a fully immersive virtual reality platform. It uses phonemaker HTC's Vive headset as the basis for safety training for high-risk workers in fields. The technology was on display during May's Exponential Manufacturing conference, run by Singularity University, the think-tank based in Silicon Valley;

- North Star Bluescope Steel is working with IBM on developing a cognitive platform that taps into IBM Watson Internet of Things technology to keep employees safe in dangerous environments. North Star is using the platform to combat heat stress, collecting data from a variety of sensors installed on worker's skin body and humidity of the work environment;

[18] https://www.ft.com/content/d0bfea5c-f820-11e5-96db-fc683b5e52db

- National Grid believes work to use wearables in the workplace, to improve safety, speeding up the process of repairs and reducing costs. The project uses interactive wristbands developed by Microsoft to monitor the health, safety and wellbeing of workers who operate alone or remotely.

Figure 2. Example of smart PPE and wearable devices.

4. Conclusion

Currently, a lot of industries are exploiting the benefits of smart sensors and connected technology for data-driven decision-making. In the United States (for example), more than 33% of manufacturers currently are gathering data via smart sensors, only to improve efficiency on work.

Most of devices include sensors that enable end-users to collect information about their own use. A company that uses wearable and sensor manufacturers can generate a new value for itself, based on the efficiency of the health workers[19].

Smart PPEs does not assure only the safety of the worker, but saves time and improves productivity through connectivity, so it is time to use they and do our best[20].

[19] https://intellinium.io/
[20] http://www.perillon.com/blog/what-is-smart-ppe